August 20 - 25, 2017

WELCOME

On behalf of the FEL2017 Organizing Committee, we would like to welcome you to the 38th International Free-Electron Laser Conference.

The Scientific Program Committee has created an exciting Conference Program, with both invited and contributed talks and extensive poster presentations. This year's Conference program highlights the impressive advances in Free-Electron Lasers over the past two years, including the first lasing results at the Pohang Accelerator Laboratory X-ray FEL in South Korea, the SwissFEL in Switzerland, the European X-ray FEL in Germany, and the Dalian VUV FEL in China. Sadly, since the last conference the FEL community lost two of its founding members, John Madey and Rodolfo Bonifacio, and a special session has been convened to honor their memories and contributions.

The FEL2017 Conference is held at the Santa Fe Community Convention Center, within walking distance of the Santa Fe Plaza and Historic District. Santa Fe, the capital of New Mexico with a large Spanish and Native American presence, is home to the oldest house in the U.S., with its foundation part of an ancient Indian Pueblo, the famed Cathedral Basilica of St. Francis of Assisi, and the Loretto Chapel with its unusual helical staircase called the "Miraculous Stairs." Santa Fe also boasts a large collection of art galleries, a variety of museums, an outdoor opera and beautiful sunset views of the Sangre de Cristo and Jemez mountains.

The nearby Los Alamos National Laboratory (LANL), located on a mesa 30 miles to the Northwest, plays host to an array of accelerator and scientific facilities such as the Los Alamos Neutron Science Center, the Dual Axis Radiographic Hydrodynamic Test facility, the National High Magnetic Field Laboratory, and the Center for Integrated Nano-Technologies. LANL has also proposed a new facility, Matter and Radiation in Extremes (MaRIE), and will host the Exascale-Class computing to advance materials science through fully characterizing materials during production and dynamic environments to attain the required material performance.

We appreciate the considerable interest from industry to showcase their products at the FEL2017 Conference. We look forward to an exciting Conference with strong participation from China, France, Germany, India, Israel, Italy, Japan, Korea, the Netherlands, Russia, Sweden, Switzerland, the UK, the USA, and other countries. We hope you will enjoy the 38th International Free-Electron Laser Conference and the beautiful city of Santa Fe.

Welcome!

Dinh Nguyen	John Lewellen
Conference Chair	Conference Co-Chair

TABLE OF CONTENTS

GENERAL INFORMATION

CONFERENCE VENUES

Sessions	Reception	Banquet
Santa Fe Convention Center (SFCC)	**Drury Plaza Hotel**	**Eldorado Hotel**
201 W. Marcy St.	828 Paseo de Peralta	309 W San Francisco St
Santa Fe, NM 87501	Santa Fe, NM 87501	Santa Fe, NM 87501
P: 1-800-777-2489	P: 505-424-2175	P: 505.988.4455

CONFERENCE REGISTRATION/INFORMATION DESK

Registration materials (e.g., conference badge, banquet tickets, and companion tickets) will be available at the registration desk located in the main foyer of the Santa Fe Convention Center.

Sunday, August 20	15:00 – 18:00
Monday, August 21	07:00 – 18:00
Tuesday, August 22	07:00 – 18:00
Wednesday, August 23	07:00 – 18:00
Thursday, August 24	07:00 – 12:00

WELCOME RECEPTION - Monday, August 21

You are invited to join us at a Welcome Reception on Monday at the Drury Inn – Rooftop Lounge. Festivities will include live music, drinks and hors d'oeuvres. Flamenco dancers begin a short performance at 19:00. Doors open at 18:00. This event is free for a single companion per registrant.

BREAKS AND LUNCHES

Refreshment breaks will be served each morning and afternoon in Sweeney Ballroom A-D, where our exhibitors/poster sessions will be located. Lunch breaks vary in time so please check your program. There are many great restaurants within the Santa Fe Plaza area. Please feel free to ask the concierge for additional recommendations. Additionally, if you don't wish to roam, there is an option to purchase a hot lunch that will be available in the courtyard each day.

CONFERENCE BANQUET - Thursday August 24

Please join us for the FEL2017 Conference banquet at the Eldorado Hotel Grand Ballrom onThursday night. The program begins with a Mariachi band welcome performance and cocktails at 17:30. Doors open at 18:00 with congratulatory remarks from the Director of Los Alamos Laboratory and the Mayor of Santa Fe. After dinner we will enjoy entertainment to include an award winning Hoop Dancer performance. We will round out the evening with the FEL Prize and Young awards and announcement of the next International FEL Conference plans. Companion tickets can be purchased at the registration area right up to the day of the event.

INTERNET & WIRELESS SERVICE

Arrangements have been made for complimentary WiFi at the internet café, called "The Link", located in the main foyer of the Santa Fe Convention Center. The registration desk can accommodate light printing and other computer needs all through the conference.

COMPANIONS VISITING SANTA FE

In addition to being able to purchase tickets for the meal functions and the Bandelier tour, companions are encouraged to participate in our morning meet and greet, Monday and Tuesday morning at 09:00 in "The Link". This is designed to bring together companions to learn about Santa Fe attractions. A representative will on-hand to show companions all the great activities Santa Fe has to offer, including museums, historical sites, outdoor attractions and places to hang out and relax. This meet and greet will not only introduce them to the city but allow them to meet other companions and possibly plan group trips in various interest areas.

BRADBURY SCIENCE MUSEUM TOUR ON THURSDAY

1230 **Bus transport from SFCCC to Bradbury Science Museum**

Your visit to Bradbury Science Museum will provide you with an opportunity to view the history of Los Alamos National Laboratory, as well as work currently being conducted at LANL. This award-wining museum offers hands-on experience for all ages, while sharing examples of the world-class science and technology at the foundation of our work. A visit to the Bradbury museum does not require badging or other personal information, as the museum is located in our "downtown" historic district of Los Alamos.

1700 **Bradbury Museum tour returns to SFCCC**

LANSCE TOURS ON THURSDAY

Visiting LANSCE requires prior approval. Unless you have signed up for the tour and have been notified of approval at the Conference registration desk, please do not board the bus for the LANSCE tour. **All participants of the LANSCE tour shall meet with LANL security officers on Tuesday** at the SFCC for verification (Non-US Citizens) and badging (US citizens); please bring photo ID and proof of citizenship (e.g. driver's license for US citizens, passport for non-US citizens; note, as per DOE rules, Missouri and Minnesota drivers' licenses are not acceptable and will require additional ID).

No photography is allowed during the LANSCE tour!

Timelines for the LANSCE tours for A) Non-US citizens, and B) US citizens.

A - Non-US citizens

1. Non-US citizens to gather at the Santa Fe Convention Center (SFCC) bus loading location BEFORE noon
2. Load a single bus capable of holding Non-US citizens and two escorts promptly at 12 noon at the SFCC loading location
3. Bus has to depart no later than 12:15 PM from SFCC
4. Bus arrives at TA-3 Otowi Building at 1 PM
5. Non-US citizens are escorted into Otowi bathrooms if needed; others to line up in the Badge Office for badging
6. Badging to complete no later than 1:45 PM; Non-US citizens to board bus in front of Otowi Bldg.
7. Bus to depart Otowi Bldg. at 2 PM and arrive at TA-53 guard gate no later than 2:15 PM
8. Badge checking at TA-53 guard station between 2:15 and 2:30 PM
9. Non-US citizens arrive at TA-53, Building 1 for bathroom and refreshment break
10. LANSCE tour for Non-US citizens to begin at 2:45 PM
11. LANSCE tour for Non-US citizens ends at 4:00 PM; FNs to board bus between 4:00 and 4:15 PM
12. Bus departs LANSCE for SFCC promptly at 4:15 PM.

B - US Citizens

1. US citizens to gather at the SFCC bus loading location between 12:15 and 12:30
2. Load a single bus capable of holding 30 USCs and two escorts at the SFCC loading location
3. Bus has to depart no later than 12:30 PM from SFCC
4. USCs arrive at AT-53, Bldg. 1 at 1:30 PM for bathroom break
5. Tours begin from Bldg. 1 to four different locations at TA-53
6. Tours end at Bldg. 1 at 2:45 PM; USCs gather at Bldg. 1 for refreshments
7. USCs board bus in front of Bldg. 1 at 3 PM
8. Bus transports USCs back to SFCC

1700 **LANSCE tour returns to SFCCC**

INFORMATION FOR SPEAKERS AND PRESENTERS

Proceedings

The Conference Proceedings will be published electronically by JACoW. Oral proceedings can be up to five pages long, and poster proceedings can be up to three pages long. To ensure consistency of the conference proceedings, all papers must meet formal criteria as specified by JACoW. Guidelines, and the required template (in .docx and .tex formats) can be found at www.jacow.org.

The deadline for submitting a proceedings contribution is Friday, August 18, 2017.
Submission is through: https://spms.fnal.gov/pls/fel2017/profile.html

Authors are requested to check the status of their submissions via the status boards located at each end of the Convention Center hallway, or at ***https://spms.fnal.gov/pls/fel2017/profile.html:***

- Green: Submission has been accepted for publication; no additional effort is required.
- Yellow: Significant changes have been made; verification by the author is requested. At the end of the conference, yellow will convert to green, and the submission will be published with the editors' changes.
- Red: Author is required to make significant changes to meet JACoW requirements. An email will contain guidance. Without resubmission by the author that resolved the identified issues, the paper will not be published.

The proceedings office is located in the Nambe Room (across the walkway, second floor).

Oral Sessions

All oral sessions will be in the Sweeney Ballroom. Speakers need to upload their presentation at least 24 hours before their talk, so that Session Chairs have time to download it. ***Submission is through https://spms.fnal.gov/pls/fel2017/profile.html.*** All speakers are encouraged to verify their talk (especially if they include animations, or were developed on a non-Windows platform) in the Speaker Ready Room. Session Chairs will not accommodate individual laptops at the podium.

INSTRUCTIONS FOR POSTER PRESENTERS

Poster Display and Removal

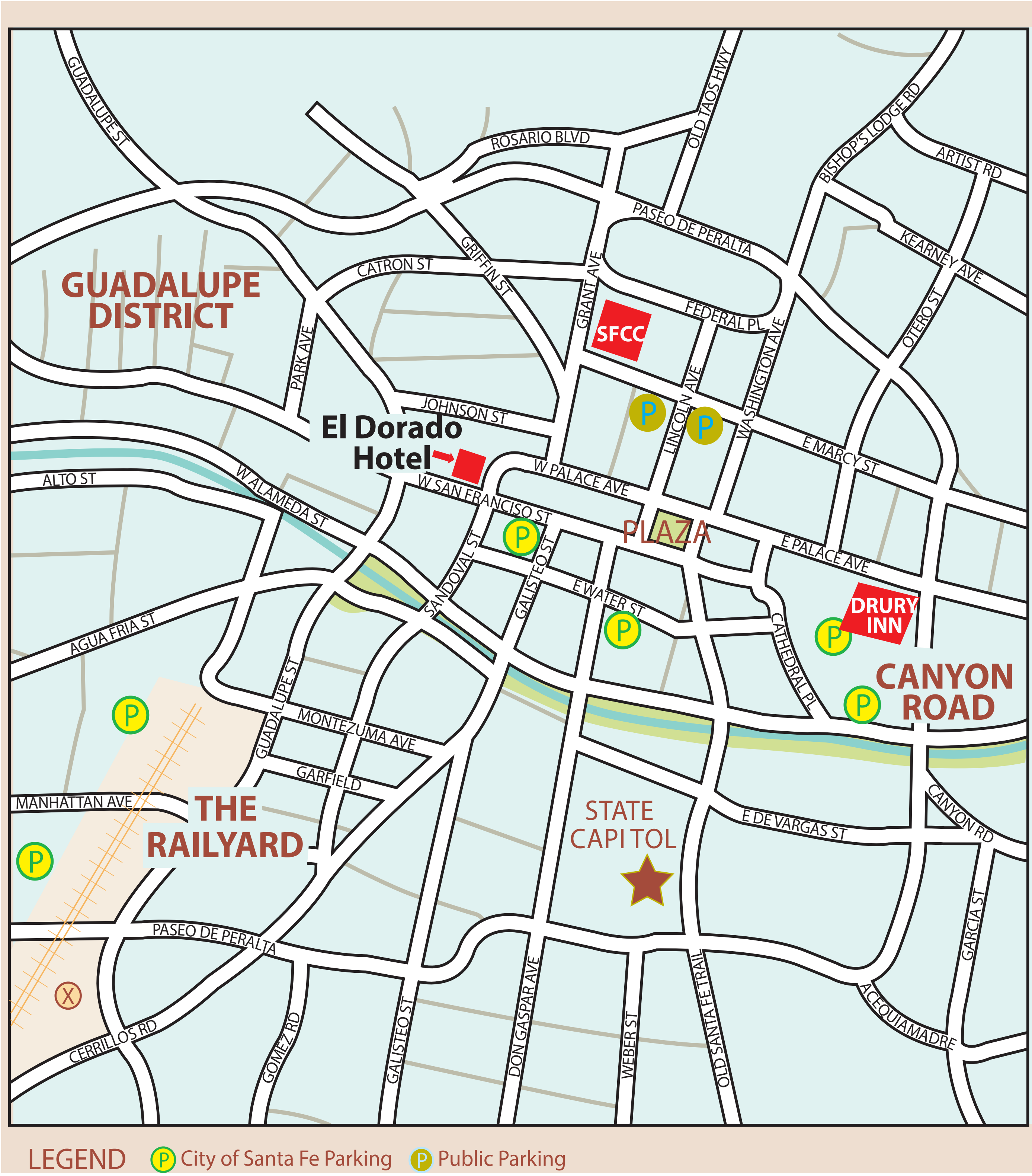
Poster Sessions are Monday through Wednesday afternoons from 15:30 to 17:30, and will take place in the Sweeney Ballroom Exhibit area. Poster presenters may put your poster up any time after 12:00 on the day of your poster session. Please set up your poster before the session begins. A single display board supports two posters. The area available for your poster has width 3.5 feet and height 3.5 feet. Posters must be attended by an author on the day they are presented, according to the following schedule:

- Odd-numbered posters (e.g. MOP301) should be attended from 15:30 to 16:00, and
- Even-numbered posters (e.g. TUP404) should be attended from 16:30 to 17:00.

Posters must be removed promptly when the poster session is over. Any posters left following the session will be discarded.

Posters Published in the Proceedings

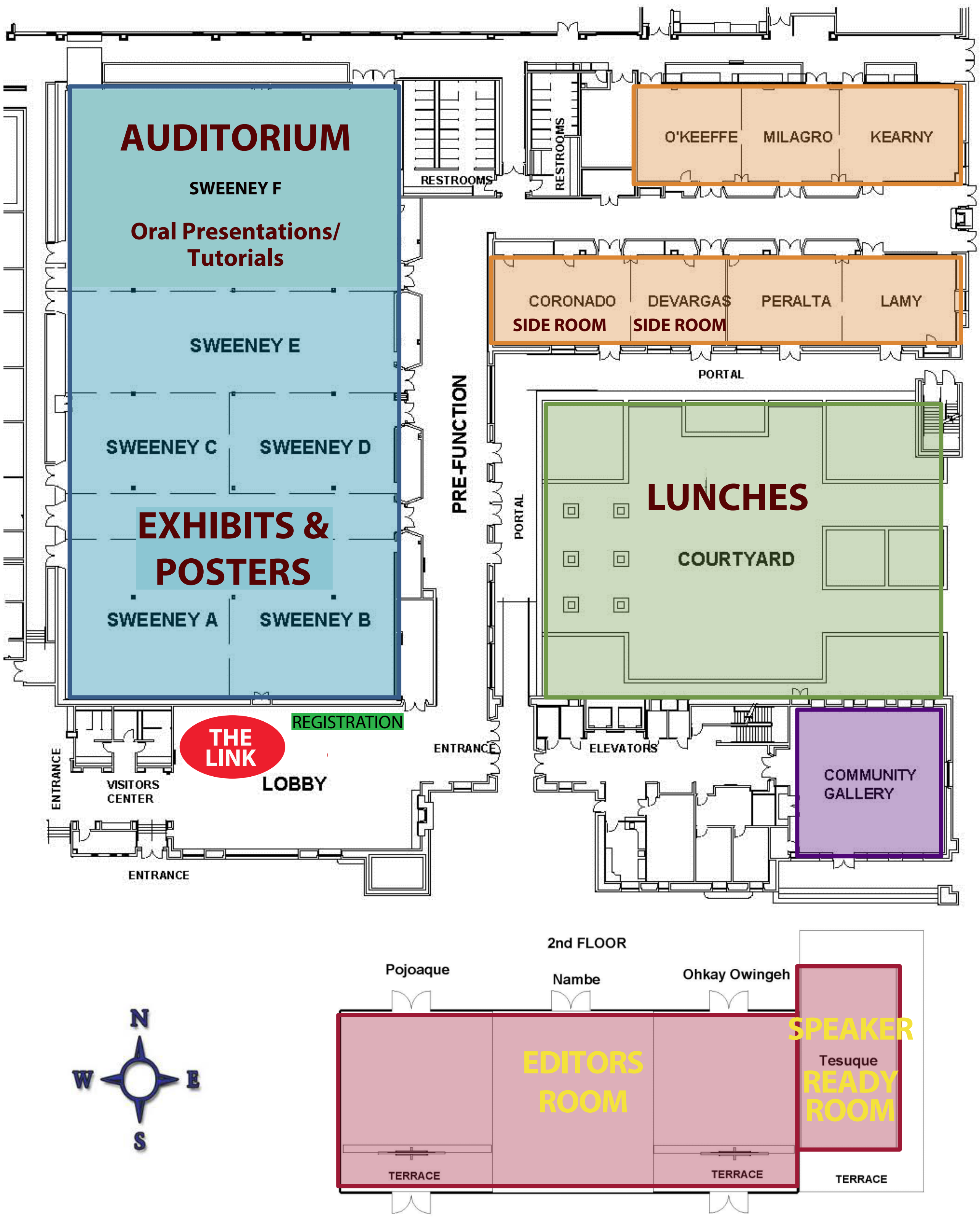
All work properly submitted and presented for FEL2017 will be included in the conference proceedings, which will be published at the JACoW website shortly after the conference. All contributions must be uploaded via SPMS according to the electronic submission guidelines. In accordance with precendent set by prior Conferences, "posters" that are simply printouts of a paper do not satisfy the requirements for publication.



GUADALUPE DISTRICT
El Dorado Hotel
SFCC
PLAZA
DRURY INN
CANYON ROAD
THE RAILYARD
STATE CAPITOL
GUADALUPE ST
ROSARIO BLVD
OLD TAOS HWY
BISHOP'S LODGE RD
ARTIST RD
PASEO DE PERALTA
KEARNEY AVE
CATRON ST
GRIFFIN ST
GRANT AVE
FEDERAL PL
OTERO ST
PARK AVE
WASHINGTON AVE
LINCOLN AVE
JOHNSON ST
E MARCY ST
W PALACE AVE
ALTO ST
W ALAMEDA ST
W SAN FRANCISCO ST
E PALACE AVE
SANDOVAL ST
GALISTEO ST
E WATER ST
AGUA FRIA ST
CATHEDRAL PL
MONTEZUMA AVE
GARFIELD
MANHATTAN AVE
E DE VARGAS ST
CANYON RD
CERRILLOS RD
GOMEZ RD
DON GASPAR AVE
WEBER ST
OLD SANTA FE TRAIL
ACEQUIA MADRE
GARCIA ST
LEGEND
City of Santa Fe Parking
Public Parking

TOURISM SANTA FE

SANTA FE COMMUNITY CONVENTION CENTER



THINGS TO DO IN SANTA FE

Ten Thousand Waves
Among piñons and junipers are beautiful outdoor hot tubs and spa suites, world-class bodywork & skin care, and the amazing Izanami Restaurant. (505) 982-9304
21 Ten Thousand Waves Way, Santa Fe, NM 87501

Meow Wolf
An interactive art experience for children and adults. Hours: 10AM–8PM (505) 395-6369
1352 Rufina Cir, Santa Fe, NM 87507

Food Tour Santa Fe
Visit local restaurants with guides who know and love Santa Fe cuisine.
505-465-9474 www.FoodTourNewMexico.com

Santa Fe Flea Market at Rufina
Tribal Art, Antiques, Folk Art, Books, Textiles, Vintage, Furniture, Fashion and more.
2904 Rufina St, Santa Fe, NM 87507

Museum Hill - World-class Museums in Santa Fe

Museum of International Folk Art
The art of the craftsman is a bond between the peoples of the world. - Florence Dibell...

Museum of Indian Arts and Culture
The Museum of Indian Arts and Culture/ Laboratory of Anthropology is a museum of Native American art and culture

Wheelwright Museum of the American Indian
The Wheelwright Museum of the American Indian is a museum devoted to Native American arts.

Museum of Spanish Colonial Art
Small museum featuring devotional & decorative art, furniture & textiles in Spanish colonial style. Santa Fe, New Mexico offers a central destination for exploring some of the city's finest collections of the Spanish Colonial Period and some of the world's.
Hours: 10AM–5PM
750 Camino Lejo,
Santa Fe, NM 87505

New Mexico Museum of Art
The New Mexico Museum of Art, is the oldest art museum in the state of New Mexico. Hours: 10AM–5PM
107 W Palace Ave, Santa Fe, NM 87501

Santa Fe Opera
Famed opera house features classic pieces & contemporary works in a woodsy, hilltop setting.
301 Opera Dr, Santa Fe, NM 87506
www.santafeopera.org

Santa Fe Architectural and Interior Walking Tour
Explore the architecture of Santa Fe with your local guide on this 3-hour walking tour with up to 8 people. Discover three different style of architecture, including Pueblo, Spanish Territorial, and Norther New Mexico. At the end of your tour, cool off with a refreshing prickly pear cactus ice tea or 'Cota' Indian tea with some homemade biscochitos while relaxing in a traditional inner courtyard.
https://www.viator.com/tours/Santa-Fe/Santa-Fe-Architectural-and-Interior-Walking-Tour/d22369-46992P2?pub=vcps

SANTA FE RESTAURANTS

Santacafe
Upscale New American eatery & bar serving regional fare in an 1850s house with a courtyard.
231 Washington Ave, Santa Fe, NM 87501
Hours: · 11:30AM–2PM, 5:30–10PM
Phone: (505) 984-1788

La Casa Sena
Local ingredients & distinct New Mexican flavors shine at this rustic-yet-elegant adobe restaurant.
125 E Palace Ave, Santa Fe, NM 87501
Hours: · 11AM–10PM
Phone: (505) 988-9232

Geronimo
Eclectic New American fare served amid elegant, minimalist decor in a circa-1756 adobe home.
724 Canyon Rd, Santa Fe, NM 87501
Hours: · 5:30–9:30PM
Phone: (505) 982-1500

Café Pasqual's
Mexican fare from local & organic ingredients along with a community table in a historic adobe.
121 Don Gaspar Ave, Santa Fe, NM 87501
Hours: 8AM–3PM, 5:30–9:30PM
Phone: (505) 983-9340

The Compound
Fine New American dining with Southwestern influences in a cozy adobe home setting.
653 Canyon Rd A, Santa Fe, NM 87501
Hours: 11:30AM–3PM, 5:30–9PM
Phone: (505) 982-4353

Tomasita's
Lively go-to for enchiladas, sopapillas, flautas & more Southwestern favorites amid basic decor.
500 S Guadalupe St, Santa Fe, NM 87501
Hours: 11AM–9PM
Phone: (505) 983-5721

Harry's Roadhouse
Whimsical, colorful cafe serving regional eats & weekend brunch with optional patio seating.
96 Old Las Vegas Hwy, Santa Fe, NM 87505
Hours: 7AM–9:30PM
Phone: (505) 989-4629

Bouche Bistro
French dishes & wine served in a warm, cozy space with an open kitchen, banquettes & covered patio.
451 W Alameda St, Santa Fe, NM 87501
Hours: 5:30–9:30PM
Phone: (505) 982-6297

Arroyo Vino
Relaxed bistro & wine shop serving a refined New American menu sourced from its kitchen garden.
218 Camino La Tierra, Santa Fe, NM 87507
Hours:11AM–9PM
Phone: (505) 983-2100

Coyote Cafe & Rooftop Cantina
Elegant eatery featuring local cuisine with Southwestern flair, cocktails & a rooftop bar.
132 W Water St, Santa Fe, NM 87501
Hours: 11:30AM–9PM
Phone: (505) 983-1615

The Shed
Located in: Sena Plaza
113 E Palace Ave, Santa Fe, NM 87501
Hours: Open today · 11AM–2:30PM, 5–9PM
Phone: (505) 982-9030

OTHER LOCAL INFORMATION

EMERGENCY SERVICES

In general, emergency services (medical, police, fire) can be contacted by dialing 911 from any public phone. Dialing 911 from a cell phone can, in certain circumstances, result in the call being routed to an inappropriate (e.g. non-local) response center. If this happens, the local Santa Fe numbers are:

Santa Fe Police Dispatch	(505) 428-3710
Santa Fe Fire Department	(505) 428-3730
Santa Fe Medical:	contact Police Dispatch and request medical services

CLIMATE, WEATHER AND ALTITUDE

Santa Fe, NM, is at an elevation of 2150 m (7100 ft). Late-August daytime high temperatures average approximately 27 C (80 F), while night-time temperatures can fall to approximately 10 C (50 F). The humidity is generally low. Sunny days with blue sky are generally common in the summer; however, brief but intense rain showers and thunderstorms can happen, especially in the afternoon and evening, and these can cause big temperature change. We recommend dressing in layers to accommodate these temperature swings.

It is very easy for new visitors to the Santa Fe area to become dehydrated, especially when engaged in outdoor activities. We recommend bringing a bottle of water with you on any excursions, and to make a conscious effort to drink more than your usual amount of water while visiting. For those who wear contact lenses, we recommend having a bottle of lubricating eye drops with you at all times.

There are some specific physiological effects a new visitor to high-altitude areas may experience, especially if they usually live at or near sea level; these can include mild shortness of breath with normal exertion (such as brisk walking or jogging), increased heart rates, waking in the morning with headaches that quickly fade, and increased sensitivity to alcohol. (We mention effects these for reference, but emphasize that we are not medical professionals, and urge you to seek medical advice if you have specific concerns.)

SALES TAX

The combined sales tax rate for Santa Fe, New Mexico (total of state, county and city sales taxes) is currently 8.3125% for most non-grocery items. As is customary in the US, this is generally not included in the price displayed in stores, but is added to your bill upon checkout.

FOOD AND DRINK

Santa Fe tap water is safe to drink. (Drink lots – dehydration is unpleasant.)
Food from street vendors in Santa Fe is safe to eat.

As is customary in the US, a gratuity/service charge (or tip) is generally not included in restaurant prices; neither is sales tax. Your bill should contain a summary of the prices for each item you order, the sales tax, and the total. Please note that some restaurants automatically add a gratuity for groups of six or more; if a gratuity has been added it will appear as an itemization on your bill. Gratuities for restaurant service in the US typically range from 10 – 20%, depending upon your judgment of the level of service provided.

RED vs GREEN

Restaurant patrons in New Mexico are frequently asked the question, “Red or Green?” Your waiter is asking whether you would like red or green chile sauce on your dish. Depending on your palate, adventuresomeness, and pain threshold, you may wish to ask your waiter for guidance regarding which is hotter, as this varies by restaurant as well as the season. Answering “Christmas” indicates you want a mixture of red and green chile sauce. If you do not want any chile sauce on your meal, we recommend requesting either red or green, but “on the side.” (As a relatively recent transplant to New Mexico, your Conference Co-Chair has noted that requesting “no chile” appears to be an incomprehensible response to long-term New Mexico residents.)

EXHIBITORS

Agilent Technologies VPD
Contact: Thomas Archuleta
1249 W. Sea Shell Dr.
Gilbert AZ 85233
United States
(505) 386-9139

R&K Company Limited
Contact: Kobayashi Yuya
416-8577
Fuji-City, Shizuoka-Pref. 721-1 MAEDA
Japan
+81 545-31-2609

Amplitude
Contact: Cecile Mukerjee
140 Baytech drive
San Jose CA 95134
United States
(415) 490-7677

RadiaBeam Technologies
Contact: Marcos Ruelas
1717 Stewart Street
Santa Monica CA 90404
United States
(310) 822-5845

Compass Components Inc.
Contact: Joseph Ayala
48133 Warm Springs Blvd
Fremont CA 94539
United States
4086911082

ScandiNova Systems Inc.
Contact: Doug Eaton
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Las Vegas NV 89138
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702-498-9675

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22559 Hamburg
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+49 40 89986538

Spellman High Voltage Electronics Corp
Contact: Loren Skeist
475 Wireless Blvd
Hauppauge NY 11788
United States
(631) 630-3071

Instrumentation Technologies d.d.
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Velika pot 22 VAT-SI6468592
5250 Solkan
Slovenia
+386 5 335 26 00

TDK-Lambda Americas High Power Division
Contact: BONNIE WEST
811 VICTORIA RD
TOMS RIVER NJ 08753
United States
1 732-922-9300

KYMA S.R.L.
Contact: RAFFAELLA GEOMETRANTE
S.S. 14 KM 163,5 IN AREA SCIENCE PARK
snc
34149 TRIESTE (TS) TS
Italy
+39 040 375 8517

Program

21-Aug-17 08:30 – 09:20

08:30 – 09:20 MOA — Madey - Bonifacio Memorials
Session Chair: J.W. Lewellen, LANL (Los Alamos, New Mexico, USA)

MOA01 John Madey: History of My Friend and Colleague
L. Elias (University of Hawaii at Manoa)

MOA02 Rodolfo Bonifacio and the Development of FELs
P. Musumeci (UCLA)

21-Aug-17 09:20 – 10:00

09:20 – 10:00 MOBA — FEL'15 FEL Prize
Session Chair: D.C. Nguyen, LANL (Los Alamos, New Mexico, USA)

MOBA01 Energy Chirp and Undulator Taper in FELs
E. Schneidmiller (DESY)

MOBA02 Coherence Limits of X-ray FEL Radiation
M.V. Yurkov (DESY)

21-Aug-17 10:30 – 11:10

10:30 – 11:10 MOBB — FEL'15 Young Investigator Prize
Session Chair: D.C. Nguyen, LANL (Los Alamos, New Mexico, USA)

MOBB01 Harmonic Lasing & Gain Cascading: More Efficient X-Ray Free Electron Laser Oscillators
H.X. Deng (SINAP)

MOBB02 Temporal and Spatial Shaping of X-Ray Free-Electron Lasers
A. Marinelli (SLAC)

21-Aug-17 11:10 – 12:10

11:10 – 12:10 MOC — New Lasing & Status of Projects I
Session Chair: B.E. Carlsten, LANL (Los Alamos, New Mexico, USA)

MOC01 0.1-nm FEL Lasing of PAL-XFEL
H.-S. Kang (PAL)

MOC02 First Lasing and Commissioning Status of SwissFEL
S. Reiche (PSI)

MOC03 Commissioning and First Lasing of the European XFEL
H. Weise (DESY)

MOC04 Status of Dalian Coherent Light Source
W.Q. Zhang (DICP) S. Chen (SINAP)

21-Aug-17 13:30 – 15:00

13:30 – 15:00 MOD — New Lasing & Status of Projects II
Session Chair: B.E. Carlsten, LANL (Los Alamos, New Mexico, USA)

MOD01 Status of the LCLS-II FEL Project at SLAC
P. Emma (SLAC)

MOD02 Status of the FLASH FEL User Facility at DESY
K. Honkavaara (DESY)

MOD03 Present Status of SACLA
H. Tanaka (RIKEN SPring-8 Center)

MOD04 Status and Perspectives of the FERMI FEL Facility
L. Giannessi (Elettra-Sincrotrone Trieste S.C.p.A.) N.S. Mirian (UVSOR)

MOD05	Status of the SXFEL Facility B. Liu (SINAP)
MOD06	Matter-Radiation Interactions in Extremes (MaRIE) Project Overview R.L. Sheffield (LANL)

21-Aug-17 15:30 – 18:30
15:30 – 18:30 MOP — Poster I

MOP001	Diamond Double-Crystal System for a Forward Bragg Diffraction X-Ray Monochromator of the Self-Seeded PAL XFEL Yu. Shvyd'ko (ANL) V.D. Blank (TISNCM) H.-S. Kang (PAL) P. Vodnala (Northern Illinois University)
MOP002	Design Study of FEL-2 for Dalian Coherent Light Source G.L. Wang (DICP) S. Chen (SINAP)
MOP003	Concept for a Seeded FEL at FLASH2 C. Lechner (DESY) A. Azima (University of Hamburg, Institut für Experimentalphysik) S. Khan (DELTA)
MOP004	Towards the Demonstration of Soft X-Ray Echo-Enabled Harmonic Generation at Fermi E. Allaria (Elettra-Sincrotrone Trieste S.C.p.A.) H.-H. Braun (PSI) G. De Ninno (University of Nova Gorica) B.W. Garcia (SLAC) G. Penn (LBNL) E. Roussel (SOLEIL) A. Zholents (ANL)
MOP005	FEL Pulse Shortening by Superradiance at FERMI N.S. Mirian (Elettra-Sincrotrone Trieste S.C.p.A.) S. Spampinati (Private Address)
MOP006	Characterization of the Polarization of the First and Second Stage of FERMI FEL-2 E. Roussel (Elettra-Sincrotrone Trieste S.C.p.A.) A. Beckmann (XFEL. EU) L. Giannessi (ENEA C.R. Frascati) L. Glaser (DESY) M. Zangrando (IOM-CNR)
MOP007	Study of an External Laser Seeding at the European XFEL T. Tanikawa (European XFEL) G. Geloni (XFEL. EU)
MOP008	Status of the Hard X-ray Self-Seeding Project at the European XFEL G. Geloni (XFEL. EU) V.D. Blank (TISNCM) W. Decking (DESY) X. Dong (European X-Ray Free-Electron Laser Facility GmbH) S. Serkez (European XFEL) D. Shu (ANL)
MOP009	Simulations of the Hard X-ray Self-Seeding Setup at the European XFEL G. Geloni (XFEL. EU) V. Kocharyan (DESY) S. Serkez (European XFEL)
MOP010	Constraints on Pulse Duration Produced by Echo-Enabled Harmonic Generation G. Penn (LBNL) B.W. Garcia (SLAC)
MOP011	Strongly Tapered Undulator Design for High Efficiency and High Gain Amplification at 266 nm Y. Park (UCLA) D.L. Bruhwiler (RadiaBeam) C.C. Hall (RadiaSoft LLC) Y. Sun (ANL)
MOP012	Design of the Self-Seeding Mode for Aramis at SwissFEL A. Rodriguez-Fernandez (PSI)
MOP013	Sub-Terawatt X-Ray Self-Seeded High-Gain Harmonic Generation L. Zeng (PKU) Y. Ding (SLAC)
MOP014	Harmonic Lasing Towards Shorter Wavelengths in Soft X-Ray Self-Seeding FELs L. Zeng (PKU) Y. Ding (SLAC)
MOP015	Demonstration of Harmonic Lasing Self-Seeded Mode for Soft X-Rays Down to 1nm at PAL-XFEL I.H. Nam (PAL)
MOP016	Comparing FEL Codes for Advanced Configurations B.W. Garcia (SLAC) L.T. Campbell (STFC/DL/ASTeC) B.W.J. McNeil (USTRAT/SUPA) S. Reiche (PSI)
MOP017	Echo-Enabled Harmonic Generation Results with Energy Chirp B.W. Garcia (SLAC) D. Xiang (Shanghai Jiao Tong University)
MOP018	Distributed Self-Seeding Scheme for LCLS-II

J. Wu (SLAC) B. Yang (University of Texas at Arlington)

MOP019 Smith-Purcell Seeded FEL
J. Wu (SLAC) W. Liu (USTC/NSRL) B. Yang (University of Texas at Arlington)

MOP020 Sideband Instability in a Tapered Free Electron Laser
J. Wu (SLAC) C.-Y. Tsai (Virginia Polytechnic Institute and State University) M. Yoon (POSTECH) G. Zhou (IHEP)

MOP021 Sideband Suppression in Tapered Free Electron Lasers
J. Wu (SLAC) C.-Y. Tsai (Virginia Polytechnic Institute and State University) M. Yoon (POSTECH) G. Zhou (IHEP)

MOP022 Design Study and Preparations for the Echo-30 Experiment at SXFEL
C. Feng (SINAP)

MOP023 Two-Color Soft X-Ray Generation Based on the EEGH Scheme
Z. Qi (SINAP)

MOP024 Design and Optimization for the Soft X-Ray Self-Seeding at SXFEL
K.Q. Zhang (SINAP)

MOP025 Extending the Photon Energy Coverage of an X-Ray Self-Seeding FEL via the Reverse Taper Enhanced Harmonic Generation Technique
K.Q. Zhang (SINAP)

MOP026 Study of an Echo-Enabled Harmonic Generation Scheme for the French FEL Project LUNEX5
E. Roussel (SOLEIL) C. Evain (PhLAM/CERLA)

MOP027 Seeding of Electron Bunches in Storage Rings
S. Khan (DELTA)

MOP028 Extraction of the Longitudinal Profile of the Transverse Emittance From Single-Shot RF Deflector Measurements at sFLASH
T. Plath (University of Hamburg, Institut für Experimentalphysik) J. Boedewadt (DESY) S. Khan (DELTA)

MOP029 Exploring ESASE For MaRIE
J.E. Williams (CSU) P.M. Anisimov (LANL)

MOP030 Study of the Next Major Flash Upgrade: FLASH2020
B. Faatz (DESY)

MOP031 First Operation of a Harmonic Lasing Self-Seeded FEL
E. Schneidmiller (DESY)

MOP032 Reverse Undulator Tapering for Polarization Control and Background-Free Harmonic Production in XFELs: Results from FLASH
E. Schneidmiller (DESY)

MOP033 Baseline Parameters of the European XFEL
E. Schneidmiller (DESY)

MOP034 XFEL Photon Pulses Database (XPD) at the European XFEL
M. Manetti (European XFEL) L. Samoylova (XFEL. EU) E. Schneidmiller (DESY)

MOP035 Optimum Undulator Tapering of SASE FEL: Theory and Experimental Results From FLASH2
E. Schneidmiller (DESY)

MOP036 Frequency Doubling Mode of Operation of Free Electron Laser FLASH2
M. Kuhlmann (DESY)

MOP037 Opportunities for Two-Color Experiments at the SASE3 Undulator Line of the European XFEL
G. Geloni (XFEL. EU) V. Kocharyan (DESY) S. Serkez (European XFEL)

MOP038 Overview of the Soft X-Ray Line Athos at SwissFEL
R. Ganter (PSI)

MOP039 Possible Methods for the Control of SASE Fluctuations
N. Thompson (STFC/DL/ASTeC) J.A. Clarke (Cockcroft Institute)

MOP040 Design and Status of the Israeli Terahertz FEL Facility

A. Friedman (Ariel University) A. Gover (University of Tel-Aviv, Faculty of Engineering)

MOP041 Commissioning of FEL-Based Coherent Electron Cooling System
V. Litvinenko (BNL)

MOP042 Status of Seeding Development at sFLASH
V. Grattoni (DESY) A. Azima (University of Hamburg, Institut für Experimentalphysik) S. Khan (DELTA)

MOP043 Towards a Beam Driven Plasma Accelerator Free Electron Laser
P. Niknejadi (DESY) A.R. Maier (CFEL) A.R. Maier (University of Hamburg, Institut für Experimentalphysik)

MOP044 Commissioning Status of the European XFEL Photon Beam System
F. Le Pimpec (XFEL. EU)

MOP045 Development of a Compact 14 MeV Linac for a High Power Terahertz Free Electron Laser
T. Hu (HUST) Y.J. Pei (USTC/NSRL) Z.M. Wang (Chinagray)

MOP046 Progress of Delhi Light Source at IUAC, New Delhi
S. Ghosh (IUAC) A. Aryshev (KEK) U. Lehnert (HZDR) V. Naik (VECC) T. Rao (BNL) M. Tischer (DESY)

MOP047 Design Calculation on Beam Dynamics and THz Radiation of Delhi Light Source
V.J. Joshi (IUAC) A. Aryshev (KEK) U. Lehnert (HZDR)

MOP048 A Compact THz FEL at KAERI: the Project and the Status
S.V. Miginsky (KAERI) S. H. Park (Korea University Sejong Campus)

MOP049 Development of Compact THz Coherent Undulator Radiation Source at Kyoto University
S. Krainara (Kyoto University)

MOP050 Present Status of Infrared FEL Facility at Kyoto University
H. Zen (Kyoto University)

MOP051 Polish in Kind Contribution to European X-ray Free Electron Laser (XFEL): Status in Summer 2017
J.A. Lorkiewicz (NCBJ) J. Świerblewski (IFJ-PAN) P.B. Borowiec (Solaris National Synchrotron Radiation Centre, Jagiellonian University) M. Chorowski (WRUT) J. Fydrych (ESS) J. Glowinkowski (Wroclaw Technology Park) P. Grzegory (Kriosystem) J.K. Sekutowicz (DESY)

MOP052 Characterization of Coherent THz Undulator Radiation Driven by Relativistic Ultrashort Electron Pulses
M.C. Chou (NSRRC)

MOP053 High Spectral Density Compton Back-Scattered Gamma-Ray Sources at Fermilab FAST Facility
D. Mihalcea (Northern Illinois University) B.T. Jacobson (RadiaBeam) P. Piot (Fermilab)

MOP054 CLARA Facility Layout and FEL Schemes
D.J. Dunning (STFC/DL/ASTeC)

MOP055 SCLF: An 8-GeV CW SCRF Linac-Based X-Ray FEL Facility in Shanghai
Z.T. Zhao (SINAP)

MOP056 Design of a Diamond Irradiation Endurance Experiment for XFELO Applications
S.P. Kearney (ANL) S. Stoupin (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

MOP057 Diamond Endurance to Irradiation with X-ray Beams of Multi kW/mm^2 Power Densities for XFELO Application
T. Kolodziej (ANL) M. Baldini (High Pressure Synergic Consortium, Advanced Photon Source) V.D. Blank (TISNCM) P. Rigg (Dynamic Compression Sector, Washington State University) S. Stoupin (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

MOP058 High Precision Polarization Diagnostic System for Free-Electron Laser
J. Yan (FEL/Duke University)

MOP059 Synchronized Mid-Infrared Pulses at the Fritz Haber Institute IR-FEL

	R. Kiessling (FHI)
MOP060	Broadband THz FEL Oscillator via Resonant Coherent Diffraction Radiation at ERL Test Accelerator in KEK Y. Honda (KEK)
MOP061	X-ray Regenerative Amplifier Free-Electron Laser Concepts for LCLS-II G. Marcus (SLAC) K.-J. Kim (ANL) D.C. Nguyen (LANL)
MOP062	X-ray FEL Oscillator Seeded Harmonic Amplifier for High Energy Photons W. Qin (SLAC) K.-J. Kim (ANL)
MOP063	Considerations on X-ray FEL Oscillator Operation for the Shanghai Coherent Light Facility K. Li (SINAP)
MOP064	Integration of an XFELO at the European XFEL Facility P. Thiessen (University of Hamburg, Institut für Experimentalphysik) W. Decking (DESY) H. Sinn (XFEL. EU)
MOP065	Analysis of a Free-Electron Lasers Oscillator Based on a Natural Gradient Undualtor Z. Zhao (USTC/NSRL)

22-Aug-17 08:30 – 10:00

08:30 – 10:00	TUA — SASE FELs Session Chair: Z. Huang, SLAC (Menlo Park, California, USA)
TUA01	Recent FEL Experiments at FLASH S. Schreiber (DESY)
TUA02	Design and Modelling of the Baseline Layout for the Soft X-Ray Laser (SXL) at MAX IV Laboratory F. Curbis (MAX IV Laboratory, Lund University)
TUA03	Generation of High Power, Short X-Ray FEL Pulses M.W. Guetg (SLAC)
TUA04	Suppression of the CSR Effects at a Dogleg Beam Transport Using DBA Lattice T. Hara (RIKEN SPring-8 Center) K. Fukami (JASRI/SPring-8) S. Nakazawa (SES)
TUA05	Generating Subfemtosecond Hard X-Ray Pulses with Optimized Nonlinear Bunch Compression S. Huang (PKU) Y. Ding (SLAC)

22-Aug-17 10:30 – 12:00

10:30 – 12:00	TUB — Seeded FELs Session Chair: K.X. Liu, PKU (Beijing, People's Republic of China)
TUB01	Seeding Experiments and Seeding Options for LCLS II E. Hemsing (SLAC)
TUB02	Fresh Slice Self-Seeding and Fresh Slice Harmonic Lasing at LCLS C. Emma (UCLA) J.W. Amann (SLAC) D.C. Nguyen (LANL)
TUB03	ASU Compact XFEL W.S. Graves (Arizona State University) K.-H. Hong (MIT) C. Limborg-Deprey (SLAC)
TUB04	Recent On-Line Taper Optimization on LCLS J. Wu (SLAC) A. Scheinker (LANL)
TUB05	First Demonstration of Fully Coherent Super-Radiant Pulses From a Short-Pulse Seeded FEL X. Yang (BNL) L. Giannessi (Elettra-Sincrotrone Trieste S.C.p.A.)

22-Aug-17 13:30 – 15:00

13:30 – 15:00	TUC — FEL Oscillators Session Chair: Y.K. Wu, FEL/Duke University (Durham, North Carolina, USA)
TUC01	Polarization Control of Storage Ring FELs Using a Cross-Polarized Helical Undulator J. Yan (FEL/Duke University)

TUC02 Thermal and Mechanical Stability of Bragg Reflectors for an XFELO
I. Bahns (University of Hamburg, Institut für Experimentalphysik) W. Decking (DESY) H. Sinn (XFEL. EU)

TUC03 High-Flux, Fully Coherent X-Ray FEL Oscillator
K.-J. Kim (ANL) K.L.F. Bane (SLAC) V.D. Blank (TISNCM) W.M. Fawley (Elettra-Sincrotrone Trieste S.C.p.A.) C. Grizolli (LNLS) W. Qin (PKU) S. Stoupin (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education) J. Zemella (DESY)

TUC04 Enhancement of Radiative Energy Extraction in an FEL Oscillator by Post-Saturation Beam Energy Ramping
H. S. Marks (University of Tel-Aviv, Faculty of Engineering) E. Dyunin (Ariel University)

TUC05 Start-to-End Simulations for an X-Ray FEL Oscillator at the LCLS-II
W. Qin (SLAC) S. Huang (PKU) K.-J. Kim (ANL)

22-Aug-17 15:30 – 17:30
15:30 – 17:30 TUP — Poster II

TUP001 Conceptual Design of Electron Beam Line for `LWFA-Driven' Free-Electron Laser
A.Y. Molodozhentsev (Czech Republic Academy of Sciences, Institute of Physics)

TUP002 Numerical Studies on RF-Induced Trajectory Variations at the European XFEL
T. Hellert (DESY)

TUP003 First Beam Halo Measurements Using Wire Scanners at European XFEL
S. Liu (DESY)

TUP004 Longitudinal phase space optimization for the Hard X-ray Self-seeding
S. Liu (DESY) G. Geloni (XFEL. EU) S. Serkez (European XFEL)

TUP005 Studies of the Transverse Beam Coupling in the European XFEL Injector
M. Scholz (DESY)

TUP006 S2e Simulations with OCELOT for the European XFEL
S.I. Tomin (XFEL. EU) I.V. Agapov (DESY) Y.A. Fomin (NRC)

TUP007 Start-to-End Simulation for a Linac Driving Compact THz FEL Facility at HUST
G. Feng (DESY) T. Hu (HUST)

TUP008 Parmela Code (Re-)Development Update
L.D. Duffy (LANL)

TUP009 The Effect of Transverse Space Charge on Beam Evolution and Longitudinal Coherence in an XFEL
Q.R. Marksteiner (LANL)

TUP010 Double-Bunches for Two-Color Soft X-Ray Free-Electron Laser at the MAX IV Laboratory
J. Björklund Svensson (Lund University) J. Andersson (MAX IV Laboratory, Lund University)

TUP011 Ultra-High Intensity Electron Beam Generation Using a Positive R56 Bunch Compressor
B. Li (USTC/NSRL)

TUP012 Preparation for the Two-Color FEL Experiment at SXFEL
W.Y. Zhang (SINAP)

TUP013 Experience and Initial Measurements of Magnetics Linearization in the MAX IV Linac Bunch Compressors
S. Thorin (MAX IV Laboratory, Lund University)

TUP014 Dynamics of Electron in TEM Wave Field
V.O. Shpagina (NSC/KIPT)

TUP015 Coherent Transition Radiation Observed from Transversely Modulated Electron Beams
A. Halavanau (Northern Illinois University) S.P. Antipov (ANL) A.I. Benediktovitch (BSU) S.N. Galyamin (Saint Petersburg State University)

TUP016 Beam-Dynamics Analysis of Long-Range Wakefield Effects on SCRF Cavities at the FAST Facility

Y.-M. Shin (Northern Illinois University) K. Bishofberger (LANL) A.H. Lumpkin (Fermilab)

TUP017 Beam Manipulation Using Self-Induced Fields in the SwissFEL Linac
S. Bettoni (PSI)

TUP018 High Resolution Method for Uncorrelated Energy Spread Measurement
S. Bettoni (PSI)

TUP019 High Energy Tunable THz Source Based on Wakefield Excitation
S. Bettoni (PSI)

TUP020 Optimization of PAL-XFEL's 3 Bunch Compressor Linac
H.-S. Kang (PAL) D. Khan (SLAC)

TUP021 Simulation Study of Bunch Compressing Optimization with 2 Bunch Compressors in Hard X-Ray Line of PAL-XFEL
H. Yang (PAL)

TUP022 Modeling and Optimization of the APS Photo-Injector Using OPAL for High Efficiency FEL Experiments
C.C. Hall (RadiaSoft LLC) A.Y. Murokh (RadiaBeam) P. Musumeci (UCLA) Y. Sun (ANL)

TUP023 Recent Development and Plans to get Two Bunches with up to 1 Microsecond Separation at LCLS
F.-J. Decker (SLAC)

TUP024 Stochastic Effects from Classical 3D Synchrotron Radiation
B.W. Garcia (SLAC) R.D. Ryne (LBNL)

TUP025 Beam Shaping to Improve the Free-Electron Laser Performance at the Linac Coherent Light Source
Y. Ding (SLAC)

TUP026 Dispersion Based Fresh Slice Scheme
M.W. Guetg (SLAC)

TUP027 Cancellation of Coherent Synchrotron Radiation Kicks at LCLS
D. Khan (SLAC)

TUP028 Approximated Expressions for the Coherent Synchrotron Radiation Energy Spread in Bending Magents
D. Khan (SLAC)

TUP029 Bunch Compressor Study: 5 Bend Chicane
D. Khan (SLAC)

TUP030 An Emittance Preservation Study Of A 5-Bend Chicane for the LCLS-II-HE Beamline
D. Khan (SLAC)

TUP031 Design of a Dog-Leg Chicane Bunch Compressor with Tunable First-Order Longitudinal Dispersion
J. Wu (SLAC) M.C. Chou (NSRRC)

TUP032 Design of the Beam Distribution System for a Soft X-Ray FEL User Facility in Shanghai
S. Chen (SINAP)

TUP033 A Novel Way to Increase the Resolution of an RF Deflecting Cavity
D. Huang (SINAP)

TUP034 Novel Aspects of Beam Dynamics in CeC SRF Gun and SRF Accelerator
I. Petrushina (SUNY SB) T. Hayes (BNL) K. Mihara (Stony Brook University) K. Shih (SBU)

TUP035 CSR Wake Fields and Emittance Growth with a Discontinuous Galerkin Time Domain Method
D. A. Bizzozero (TEMF, TU Darmstadt)

TUP036 Recent Experimental Results on High-Peak-Current Electron Bunch and Bunch Trains with a THz Undulator
X.L. Su (TUB) Y.F. Liang (Tsinghua University)

TUP037 Group and Phase Velocity Matching in THz IFEL interaction
E.J. Curry (UCLA) A. Gover (University of Tel-Aviv, Faculty of Engineering)

TUP038 Experiments in Electron Beam Nanopatterning
C. Zhang (Arizona State University) D.B. Cesar (UCLA) C. Limborg-Deprey (SLAC)

TUP039 Electron Beam Requirements for Coherent Electron Cooling FEL System
G. Wang (BNL) J. Ma (SBU)

TUP040 Intense Tunable X-Rays from Compton Scattering in a Strong Guiding Magnet Field
Z. Li (CAEP/IAE)

TUP041 Investigation of a GW THz Generator Driven by a Pulsed Power Supply
Z. Li (CAEP/IAE)

TUP042 Determination of the Slice Energy Spread of Ultra-Relativistic Electron Beams by Scanning Seeded Coherent Undulator Radiation by Coherent Harmonic Generation
J. Boedewadt (DESY) W. Hillert (University of Hamburg, Institut für Experimentalphysik)

TUP043 Passive Linearization of the Magnetic Bunch Compression Using Self-Induced Field and Without Any Active Higher Harmonic RF Structure
G. Penco (Elettra-Sincrotrone Trieste S.C.p.A.) S. Bettoni (PSI) L. Giannessi (ENEA C.R. Frascati) E. Roussel (SOLEIL)

TUP044 Generation of Sub-fs X-Ray Pulses at the European XFEL
S. Serkez (European XFEL) G. Geloni (XFEL. EU) V. Kocharyan (DESY)

TUP045 Interference-Based Ultrafast Polarization Control at Free Electron Lasers
S. Serkez (European XFEL) G. Geloni (XFEL. EU) E. Saldin (DESY)

TUP046 Ultrafast Electron Diffraction Facility Based on an RF Photogun and Achromatic 90-degree Bends for Sub-100-Femtosecond Timing Jitter
Y.U. Jeong (KAERI) R. Fabian (KAIST) J.H. Han (PAL) H.W. Kim (University of Science and Technology of Korea (UST)) K.W. Kim (Chung Buk National University) S.V. Miginsky (BINP SB RAS) S. H. Park (Korea University Sejong Campus) S. Park (Kyungpook National University)

TUP047 A Linac-Based All-in-One THz-Pump and X-Ray-Probe Sources
S. Setiniyaz (KAERI) N.A. Vinokurov (BINP SB RAS)

TUP048 Automatic Tuning of the Electron Beam Parameters to Enhance LCLS FEL Performance Using ES
P.M. Anisimov (LANL)

TUP049 An Optically Levitated Imaging System for X-Ray Free Electron Lasers
A. Malyzhenkov (LANL)

TUP050 Beam Driven Acceleration and RF Breakdown in Photonic Band Gap Travelling Wave Accelerator Structure
J. Upadhyay (LANL)

TUP051 Reaching High Peak Power X-Ray Radiation in Fels
N.A. Yampolsky (LANL)

TUP052 Demonstration of Cascaded Pre-Bunching for Complete Trapping of a Relativistic Electron Beam in a Strongly Tapered Undulator
N.S. Sudar (UCLA) M. Babzien (BNL)

TUP053 The ACHIP Experimental Chambers at PSI
E. Ferrari (PSI) L. Rivkin (EPFL)

TUP054 Preparations for the Installation of the Double Emittance Exchange Beamline at the Argonne Wakefield Accelerator Facility
G. Ha (PAL) M.E. Conde (ANL)

TUP055 Cascaded Amplification for Terawatt FELs
J.P. MacArthur (SLAC)

TUP056 Generation of Two-Color X-Ray Free-Electron Lasers Using a Matching-Based Fresh-Slice Method
W. Qin (SLAC)

TUP057 Statistical Properties of a Slippage Enhanced SASE
J. Wu (SLAC) C.-Y. Tsai (Virginia Polytechnic Institute and State University) B. Yang (University of Texas at Arlington) M. Yoon (POSTECH) G. Zhou (IHEP)

TUP058 Slippage-Enhanced SASE FEL
J. Wu (SLAC)

TUP059 Alternative Electron Beam Slicing Methods for CLARA and X-ray FELs
D.J. Dunning (STFC/DL/ASTeC)

TUP060 A Complementary Tool to XFEL: 4D Electron Diffraction and Microscopy
D. Xiang (Shanghai Jiao Tong University)

TUP061 Study of the Electron Transport in the COXINEL FEL Beamline Using a Laser-Plasma Accelerated Electron Beam
T. Andre (SOLEIL) S. Bielawski (PhLAM/CERCLA) S. Corde (LOA)

TUP062 Electromagnetic and Mechanical Analysis of a 14 mm 10-period NbTi Superconducting Undulator
F. Trillaud (UNAM) M. Gehlot (Devi Ahilya University)

TUP063 Laser-Plasma Accelerator Based Single-Cycle Attosecond Pulse Generation
Z. Tibai (University of Péece) J.A. Fülöp (MTA-PTE High-Field Terahertz Research Group) A. Sharma (ELI-ALPS)

TUP064 High Harmonic Terahertz Smith-Purcell Free-Electron Laser Based on Two Tandem Planar Gratings
L. Liang (USTC/NSRL)

TUP065 Dielectric Laser Acceleration Setup Design, Grating Manufacturing and Investigations Into Laser Induced RF Cavity Breakdowns
M. Hamberg (Uppsala University) M. Karlsson (Uppsala University, Department of Engineering Sciences) M. Kuittinen (UEF)

TUP066 Luminosity Increase in Laser-Compton Scattering by Crab Crossing
Y. Koshiba (RISE) T. Higashiguchi (Center for Optical Research and Education, Utsunomiya University) K. Sakaue (Waseda University, Waseda Institute for Advanced Study) J. Urakawa (KEK)

TUP067 Study on Cherenkov Laser Oscillator Using Tilted Electron Bunches
K. Sakaue (Waseda University, Waseda Institute for Advanced Study) M. Brameld (Waseda University) R. Kuroda (AIST) J. Urakawa (KEK)

TUP068 Spectral Measurement of the Israeli FEL
A. Friedman (Ariel University) A. Abramovich (Ariel University Center of Samaria, Faculty of Engineering)

TUP069 Using an FEL Amplifier for Coherent Electron Cooling
V. Litvinenko (BNL)

TUP070 Development of Mid-Infrared Photoacoustic Spectroscopy System for Solid Samples at Kyoto University Free Electron Laser Facility
J. Okumura (Kyoto University)

TUP071 Study on Second Harmonic Generation in SiC Using Infrared FEL
S. Tagiri (Kyoto Univeristy) K. Hachiya (Kyoto University Graduate School of Energy Science) T. Kii (Kyoto University) K. Yoshida (Kumamoto University, Department of Applied Chemistry and Biochemistry)

22-Aug-17 17:30 – 18:30
17:30 – 18:30 TUT — Tutorial I

TUT01 On the Science of Seeded FELs
F. Parmigiani (Elettra-Sincrotrone Trieste S.C.p.A.)

23-Aug-17 08:30 – 10:00
08:30 – 10:00 WEA — Electron Guns, RF Lasers, Cathodes
Session Chair: F. Stephan, DESY Zeuthen (Zeuthen, Germany)

WEA01 European XFEL Injector Commissioning Results
B. Beutner (DESY)

WEA02 Model of Photocathode for CW Electron Gun
P.W. Huang (TUB)

WEA03 Simulation Optimization of DC-SRF Photoinjector for Low-Emittance Electron Beam Generation
K.X. Liu (PKU)

WEA04 Novel Concepts of a High Brightness Photoinjector RF Gun
S.V. Kuzikov (IAP/RAS) S.P. Antipov (Euclid Beamlabs LLC) S.P. Antipov (Euclid TechLabs, LLC) S.V. Baryshev (ANL)

WEA05 Higher Fields and Beam Energies in Continuous-Wave Room-Temperature VHF RF Guns
F. Sannibale (LBNL)

23-Aug-17 10:30 – 12:00

10:30 – 12:00 WEB — Electron Diagnostics, Timing, Controls
Session Chair: H.-S. Kang, PAL (Pohang, Kyungbuk, Republic of Korea)

WEB01 Characterization of High-Brightness Electron Beams at the Frontiers of Temporal and Spatial Resolution
R. Tarkeshian (Universität Bern, Institute of Applied Physics) T. Garvey (PSI) P. Krejcik (SLAC) W. Leemans (LBNL)

WEB02 Characterization of Electron Bunches in Ultrafast Electron Diffraction Beamlines at KAERI
H.W. Kim (University of Science and Technology of Korea (UST)) I.H. Baek (KAERI) R. Fabian (KAIST) K.W. Kim (Chung Buk National University) S.V. Miginsky (BINP SB RAS)

WEB03 R&D at SLAC on Nanosecond-Range Multi-MW Systems for Advanced FEL Facilities
A.K. Krasnykh (SLAC)

WEB04 Laser-to-RF Synchronization with Femtosecond Precision
T. Lamb (DESY)

WEB05 ICS Diagnostic of FEL's Electron Beam Based on 6D Wigner Function Approach
A. Malyzhenkov (LANL)

23-Aug-17 13:30 – 15:00

13:30 – 15:00 WEC — Undulators, Photon Diagnostics, Beamline
Session Chair: S.V. Benson, JLab (Newport News, Virginia, USA)

WEC01 Photon Beam Transport and Diagnostics Systems at an EUV FEL Facility: General Considerations, and Specific Challenges, Solutions and Developments at the FERMI Seeded FEL
M. Zangrando (Elettra-Sincrotrone Trieste S.C.p.A.)

WEC02 Optimisation of Superconducting Undulators for Low Repetition Rate FELs
J.A. Clarke (STFC/DL/ASTeC) T.W. Bradshaw (STFC/RAL)

WEC03 Wavefront Preserving Optics for the LCLS Photon Transport System
D. Cocco (SLAC) J. Nicolas (ALBA-CELLS Synchrotron)

WEC04 Progress of PAL-XFEL Undulator Program
D.E. Kim (PAL) I.S. Ko (POSTECH)

WEC05 Radiation-Induced Magnetization Reversal Causing a Large Flux Loss in Undulator Permanent Magnets
R. Kinjo (RIKEN SPring-8 Center) T. Bizen (JASRI/SPring-8)

23-Aug-17 15:30 – 17:30

15:30 – 17:30 WEP — Poster III

WEP001 The Photoinjector and Seed Laser Systems of DCLS
G.R. Wu (DICP)

WEP002 Double Pulse FEL Operation at FLASH
S. Schreiber (DESY)

WEP003 Update on the Lifetime of Cs2Te Photocathodes Operated at FLASH
S. Schreiber (DESY) L. Monaco (INFN/LASA)

WEP004 Calculations of IR/THz FEL and Undulator Radiation Based on the Measured Electron Beam Parameters at PITZ
P. Boonpornprasert (DESY Zeuthen)

WEP005 Coaxial Coupler RF Kick in the PITZ RF Gun
Y. Chen (DESY Zeuthen) W. Ackermann (TEMF, TU Darmstadt) M. Dohlus (DESY) Q.T. Zhao (IMP/CAS)

WEP006 Preliminary On-Table and Photoelectron Results from the PITZ Quasi-Ellipsoidal Photocathode Laser System
J.D. Good (DESY Zeuthen) A.V. Andrianov (IAP/RAS) M. Felber (DESY) E. Syresin (JINR)

WEP007 Electron Beam Asymmetry Compensation with Gun Quadrupoles at PITZ
M. Krasilnikov (DESY Zeuthen) G.A. Amatuni (CANDLE SRI) G. Asova (INRNE) Q.T. Zhao (IMP/CAS)

WEP008 Beam Brightness Improvement by Ellipsoidal Laser Shaping for CW Photoinjectors
H.J. Qian (DESY Zeuthen)

WEP009 A Cryocooled Normal Conducting and Superconducting Hybrid CW Photoinjector
H.J. Qian (DESY Zeuthen)

WEP010 Beam Asymmetry Studies with Quadrupole Field Errors in the PITZ Gun Section
Q.T. Zhao (DESY Zeuthen) G. Asova (INRNE) C. Saisa-ard (Chiang Mai University) Q.T. Zhao (IMP/CAS)

WEP011 High Power Experiments of the ITC RF Gun Applied on the THz-FEL
T. Hu (HUST) Y.J. Pei (USTC/NSRL)

WEP012 A 2.45 GHz Photoinjector Gun for an FEL Driven by Laser Wakefield Accelerated Beam
S.V. Kuzikov (IAP/RAS)

WEP013 Photocathode RF Gun Development at KAERI for Time-Resolving Pump/Prove System
K.H. Jang (KAERI) J.H. Han (PAL) N.A. Vinokurov (BINP SB RAS)

WEP014 Pulse Duration Measurement of Pico-second DUV Photocathode Driving Laser by Autocorrelation Technique Using Two-Photon Absorption in Bulk Material
H. Zen (Kyoto University)

WEP015 Current Experimental Work with Diamond Field-Emitter Array Cathodes
H.L. Andrews (LANL) B.K. Choi (Vanderbilt University)

WEP016 Modeling of Diamond Field-Emitter-Arrays for High Brightness Photocathode Applications
C. Huang (LANL)

WEP017 The Multiphysics Photocathode Growth and Characterization System at LANL
M.A. Hoffbauer (LANL)

WEP018 Electron Beam Heating with the European XFEL Laser Heater
M. Hamberg (Uppsala University) F. Brinker (DESY)

WEP019 High Stable Pulse Modulator for PAL-XFEL
S.S. Park (PAL)

WEP020 Longitudinal Shaping of the Max IV Photocathode Gun Laser Pulses
M. Kotur (MAX IV Laboratory, Lund University)

WEP021 Preliminary Results of the Dark Current Modelling for the Polfel Superconducting Lead Photocathode
K. Szymczyk (NCBJ) J.K. Sekutowicz (DESY)

WEP022 Dark-Current Beam Dynamics in the FAST Injector
P. Piot (Fermilab) D. Mihalcea (Northern Illinois University)

WEP023 Commissioning of the SwissFEL Linac
F. Loehl (PSI)

WEP024 Electromagnetic Design and Optimization of a Micro-Pulse Electron Gun

	D.Y. Yang (PKU) K. Zhou (CAEP/IAE)
WEP025	Emittance Measurements from SRF Gun in CeC Accelerator K. Mihara (Stony Brook University) Y.C. Jing (BNL) I. Petrushina (SUNY SB)
WEP026	Inducing Microbunching in the CLARA FEL Test Facility A.D. Brynes (STFC/DL/ASTeC)
WEP027	Numerical Study of Cherenkov Radiation From Thin Silica Aerogel H. Hama (Tohoku University, Research Center for Electron Photon Science)
WEP028	Diagnostics for the Soft X-ray Laser at MAX IV E. Mansten (MAX IV Laboratory, Lund University)
WEP029	Recent Experimental Results On High-Peak-Current Electron Bunch and Bunch Trains with a THz Undulator L.X. Yan (TUB)
WEP030	Large-Scale Turnkey Timing Distribution System for New Generation Photon Science Facilities K. Shafak (CFEL) A. Berg (Deutsches Elektronen Synchrotron (DESY) and Center for Free Electron Science (CFEL)) A. Berlin (Cycle GmbH)
WEP031	Initial Study in Using a Neural Network Control Policy for FEL Tuning A.L. Edelen (CSU)
WEP032	MicroTCA.4 -Based Control for the Optical Synchronization System at the European XFEL M. Felber (DESY)
WEP033	Generic Optimizer for the European XFEL Commissioning S.I. Tomin (XFEL. EU) I.V. Agapov (DESY)
WEP034	Diagnostics Upgrades for Investigations of HOM Effects in TESLA-type SCRF Cavities A.H. Lumpkin (Fermilab) B.E. Carlsten (LANL)
WEP035	Measurements of Electron Bunch Timing Jitter Using Spectral Decoding Technique for Ultrafast Electron Diffraction Experiments K. Kim (KAERI) N.A. Vinokurov (BINP SB RAS)
WEP036	Adaptive Feedback for Automatic Phase-Space Tuning of Electron Beams in Advanced XFELs A. Scheinker (LANL)
WEP037	Mechanical Engineering of the SXFEL Project L. Yin (SINAP)
WEP038	Sub-Micrometer Resolution, Nanotechnology Based Wire Scanners for Beam Profile Measurements at SwissFEL S. Borrelli (PSI)
WEP039	Saturation of Scintillators in Profile Monitors R. Ischebeck (PSI)
WEP040	Sub-Femtosecond Time-Resolved Measurements Based on a Variable Polarization X-Band Transverse Deflecting Structures for SwissFEL P. Craievich (PSI) R.W. Assmann (DESY) N. Catalan-Lasheras (CERN)
WEP041	HLS to Measure Changes in Real Time in the Ground and Building Floor of PAL-XFEL, Large-Scale Scientific Equipment H. J. Choi (PAL)
WEP042	The Status of LLRF Systems for PAL-XFEL J. Hu (PAL)
WEP043	Tune-Up Simulations for LCLS-II M.W. Guetg (SLAC)
WEP044	Beam Loss Monitor for Undulators in PAL-XFEL H. Yang (PAL)
WEP045	Transition Radiation Beam Profile Diagnostics at EUV Wavelengths A.Y. Murokh (RadiaBeam)
WEP046	Diffusion in Momentum of Ultrarelativistic Electron Beam in an Undulator

	V.V. Ognivenko (NSC/KIPT)
WEP047	The Friction Coefficient for Relativistic Electrons Moving in an Undulator
	V.V. Ognivenko (NSC/KIPT)
WEP048	Coherent Undulator Radiation from an Electron Beam with a Tilted Microbunching
	J.P. MacArthur (SLAC)
WEP049	Stimulated Emission/Absorption of Radiation by a Single Electron Quantum Wavepacket
	A. Gover (University of Tel-Aviv, Faculty of Engineering)
WEP050	An Analysis of Diffraction Effect on Coherent Spontaneous Emission
	Q.K. Jia (USTC/NSRL)
WEP051	Helical Undulators for Coherent Electron Cooling System
	I. Pinayev (BNL) P. Vobly (BINP SB RAS)
WEP052	An Overview of Undulator Developments at Davv
	M. Gehlot (Devi Ahilya University) F. Trillaud (UNAM)
WEP053	Study of a Superconducting THz Undulator at the European XFEL
	T. Tanikawa (European XFEL) V. B. Asgekar (HZDR) S. Casalbuoni (KIT) G. Geloni (XFEL. EU)
WEP054	The Magnetic Field Integral Hysteresis on the European XFEL Gap Movable Undulator Systems
	F. Wolff-Fabris (European XFEL) Y. Li (XFEL. EU)
WEP055	Tapered Flying Radiofrequency Undulator
	S.V. Kuzikov (IAP/RAS) S.P. Antipov (Euclid TechLabs, LLC) C.-J. Jing (ANL) C.-J. Jing (Euclid Beamlabs LLC) A.V. Savilov (UNN)
WEP056	Analysis of Electron-Beam Angle Deviation on the Radiation Power of FEL using TGU
	G. Zhou (IHEP) J. Wu (SLAC)
WEP057	Design of a Compact Hybrid Undulator for the THz Radiation Facility of Delhi Light Source (DLS)
	S. Tripathi (IUAC) M. Tischer (DESY)
WEP058	Development of a Hybrid Electromagnetic Planar Undulator Having Horizontal Focusing Force for a Compact THz FEL
	S. Bae (KAERI) M.Y. Jeon (Chungnam National University)
WEP059	Development of T-Ray-Pumped Ultrafast Electron Diffraction Beamline
	I.H. Baek (KAERI) N.A. Vinokurov (NSU)
WEP060	Streaking Diagnostics for Attosecond X-Ray Pulses at the Linac Coherent Light Source
	S. Li (SLAC) G. Guo (Stanford University)
WEP061	Effect of High-Intensity X-Ray FEL Pulse on Silicon, Germanium, and Diamond
	J. Wu (SLAC) B. Yang (University of Texas at Arlington)
WEP062	Optical Beam-Quality Analysis of the Clara Test Facility Using Second Moment Analysis
	H.M. Castaneda Cortes (STFC/DL/ASTeC)
WEP063	Proposed Two-in-One Type Undulator
	D. Wang (SINAP)
WEP064	Tunable High Gradient Quadrupoles for a Laser-Plasma Acceleration-Based FEL
	A.M. Ghaith (SOLEIL) C. Benabderrahmane (ESRF) O. Cosson (Sigmaphi)
WEP065	Cryogenic Permanent Magnet Undulator for a FEL Application
	A.M. Ghaith (SOLEIL) S. Corde (LOA)
WEP066	A New Structure of PPM Undulator
	L.J. Chen (USTC/NSRL)
WEP067	Off-Axis Con-Focal Transmission Line for Terahertz Radiation
	A. Friedman (Ariel University)
WEP068	Three-Dimensional, Time-Dependent Simulation of Free-Electron Lasers with Planar, Helical, and Elliptical Undulators
	H. Freund (CSU) P. Falgari (Lime BV) D.L.A. Grimminck (ASML) P.J.M. van der Slot (Mesa+)
WEP069	Simulation of a Terawatt X-Ray Free-Electron Laser

	H. Freund (CSU)
WEP070	Distortion of the Spatial Properties of the Radiation from Seeded and SASE FEL Caused by Energy Chirp in the Electron Beam and Undulator Tapering E. Schneidmiller (DESY)
WEP071	Spin Effects in a Free Electron Laser with an Ion Channel Guiding M. Alimohamadi (Farhangian University)
WEP072	Spin Effects in a Free Electron Laser with an Axial Guide Field M. Alimohamadi (Farhangian University)
WEP073	Lie Map Formalism for FEL Simulation K. Hwang (LBNL)
WEP074	Simulations of the Dependence of Harmonic Radiation on Undulator Parameters G. Penn (LBNL)
WEP075	Simulation of Electron Trajectories in Undulator with SCILAB H. Jeevakhan (NITTTR) M. Gehlot (Devi Ahilya University)
WEP076	Effect of Constant Magnetic Field on Intensity of Undulator Radiations with Energy Spread in Electron Beam H. Jeevakhan (NITTTR) M. Gehlot (Devi Ahilya University)
WEP077	Wiggler Problems and Generation of Soft Gamma Rays V.V. Gorev (NRC)
WEP078	Period-Averaged Symplectic Maps for the FEL Hamiltonian S.D. Webb (RadiaSoft LLC)
WEP079	High Gain, High Efficiency Tapered FELs in the Post-Saturation Regime C. Emma (UCLA) C. Pellegrini (SLAC)

23-Aug-17 17:30 – 18:30

17:30 – 18:30	WET — Tutorial II
WET01	Beam-Based Alignment of Undulators for Free-Electron Lasers P. Emma (SLAC)

24-Aug-17 08:30 – 10:00

08:30 – 10:00	THA — FEL Applications Session Chair: A.H. Lumpkin, Fermilab (Batavia, Illinois, USA)
THA01	Observations of Fast Structural Changes with an X-ray FEL: Dynamics Studies on Photoactivated Proteins at SACLA K. Tono (JASRI/SPring-8)
THA02	Four-Wave Mixing Using Extreme Ultraviolet Transient Gratings at FERMI FEL F. Bencivenga (Elettra-Sincrotrone Trieste S.C.p.A.)
THA03	Two-Temperature Equilibration in Warm Dense Hydrogen Measured With X-Ray Scattering from the Linac Coherent Light Source L.B. Fletcher (SLAC)

24-Aug-17 10:30 – 11:45

10:30 – 11:45	THB — Electron-Beam Dynamics Session Chair: S.J. Russell, LANL (Los Alamos, New Mexico, USA)
THB01	Beam Dynamics Optimization in High-Brightness Electron Injectors C.E. Mitchell (LBNL)
THB02	Non-Standard Use of Laser Heater for FEL Control and THz Generation E. Allaria (Elettra-Sincrotrone Trieste S.C.p.A.) E. Roussel (SOLEIL)

THB03 High-Power, Narrow-Bandwidth THz Generation Using Laser-Electron Interaction in a Compact Accelerator
Z. Huang (SLAC) K. Kan (ISIR) Z. Zhang (TUB)

THB04 Two-Color Beam Generation via Wakefield Excitation
S. Bettoni (PSI)

25-Aug-17 08:30 – 10:00

08:30 – 10:00 FRA — Advanced Concepts & Techniques
Session Chair: S. Biedron, Element Aero (Chicago, USA)

FRA01 Fresh-Slice X-Ray Free Electron Laser Schemes for Advanced X-Ray Applications
A.A. Lutman (SLAC) N. Berrah (University of Connecticut) C. Emma (UCLA)

FRA02 Using the Optical-Klystron Effect to Increase and Measure the Intrinsic Beam Energy Spread in Free-Electron Laser Facilities
E. Prat (PSI) E. Ferrari (EPFL)

FRA03 Towards High-Efficiency Industrial FELs
A.Y. Murokh (RadiaBeam) P. Musumeci (UCLA) S. Nagaitsev (Fermilab) S.D. Webb (RadiaSoft LLC) A. Zholents (ANL)

FRA04 Three-Dimensional Manipulation of the Electron Beam Phase Space for Generating Steady State Microbunching in Storage Rings
C. Feng (SINAP) A. Chao (SLAC)

FRA05 European Plasma Accelerator Design Study EuPRAXIA with FEL & HEP User Areas
P.A. Walker (DESY)

25-Aug-17 10:30 – 12:00

10:30 – 12:00 FRB — FEL Theory
Session Chair: A. Gover, University of Tel-Aviv, Faculty of Engineering (Tel-Aviv, Israel)

FRB01 Time-Domain Analysis of Attosecond Pulse Generation in an X-Ray Free-Electron Laser
P. Baxevanis (SLAC)

FRB02 Theory and Simulation of FELs with Planar, Helical, and Elliptical Undulators
H. Freund (CSU) L.T. Campbell (STFC/DL/ASTeC) P. Falgari (Lime BV) D.L.A. Grimminck (ASML) J. Henderson (USTRAT/SUPA) P.J.M. van der Slot (Mesa+)

FRB03 Dynamics of Superradiant Emission by a Prebunched E-Beam and its Spontaneous Emission Self-Interaction
R. Ianconescu (University of Tel-Aviv, Faculty of Engineering) C. Emma (UCLA) A. Friedman (Ariel University) C. Pellegrini (SLAC)

FRB04 Canonical Formulation of 1D FEL Theory Revisited, Quantized and Applied to Electron Evolution
P.M. Anisimov (LANL)

FRB05 Frequency Modulation in the Free Electron Laser
L.T. Campbell (USTRAT/SUPA)

MOA — Madey - Bonifacio Memorials

MOA01

John Madey: History of My Friend and Colleague

L. Elias (University of Hawaii at Manoa)

MOA02

Rodolfo Bonifacio and the Development of FELs

P. Musumeci (UCLA)

Chair: J.W. Lewellen, LANL (Los Alamos, New Mexico, USA)

MOBA — FEL'15 FEL Prize

Energy Chirp and Undulator Taper in FELs

MOBA01

E. Schneidmiller (DESY)

The effects of energy chirp and undulator taper in FELs and applications of these effects in different schemes are discussed. This includes an operation of FEL oscillators with reverse-tapered undulators; energy chirp effects in high-gain, short wavelength FELs like FLASH; compensation of the energy chirp by the undulator taper in high-gain FELs and the application of this effect for generation of attosecond X-ray pulses; reverse taper in high-gain FELs for circular polarization production and for an efficient, background-free harmonic generation. Some new ideas are briefly described such as strongly chirped X-ray pulses, an enhanced X-ray pulse compression, few-cycle hard X-ray pulses etc.

Coherence Limits of X-ray FEL Radiation

MOBA02

M.V. Yurkov (DESY)

The most simple and robust technique for production of short wavelength radiation is Self Amplified Spontaneous Emission (SASE) FEL. Amplification process in SASE FELs develops from the shot noise in the electron beam, and powerful radiation is produced by single pass of the electron beam through the undulator. Serving as a seed, shot noise effects impose fundamental limits on the coherence properties of the radiation (both, temporal and spatial). FEL theory reached mature status allowing elegant description of the shot noise phenomena, and in this report we present relevant overview.

MOBB — FEL'15 Young Investigator Prize

MOBB01

Harmonic Lasing & Gain Cascading: More Efficient X-Ray Free Electron Laser Oscillators

H.X. Deng (SINAP)

In this talk, I will focus on the recent theoretical progresses on X-ray free-electron laser oscillator (XFELO). A simplified one-dimensional theoretical model for fast XFELO optimization, harmonic lasing XFELO scheme which reduces the requiered beam energy for a interested radiation wavelength, and the gain-cascading scheme which may increase the pulse energy and the peak power of XFELO will be presented.

MOBB02

Temporal and Spatial Shaping of X-Ray Free-Electron Lasers

A. Marinelli (SLAC)

The x-ray free-electron laser is the brightest source of x-rays, with a peak brightness ten orders of magnitude higher than conventional synchrotron radiation sources. Much like conventional lasers, XFELs are extremely flexible machines and the properties of the x-rays can be controlled by accurately manipulating the lasing medium, i.e. the electron beam. In my talk I will discuss past and present research on shaping the temporal properties of the x-rays at the Linac Coherent Light Source (LCLS). I will discuss the two-color FEL modes and their applications in user experiments. Finally I will present our results on laser-shaping of x-ray pulses and our plans for attosecond operation in the soft-x-ray regime.

Chair: D.C. Nguyen, LANL (Los Alamos, New Mexico, USA)

MOC — New Lasing & Status of Projects I

0.1-nm FEL Lasing of PAL-XFEL

MOC01

H.-S. Kang, H. Heo, C. Kim, G. Kim, C.-K. Min, H. Yang (PAL)

The hard X-ray free electron laser at Pohang Accelerator Laboratory (PAL-XFEL) achieved saturation of a 0.144-nm free electron laser (FEL) beam on November 27, 2016, making it the third hard X-ray FEL in the world, following LCLS in 2009 and SACLA in 2011. On February 2, 2017, a saturated 1.52-nm FEL beam was also achieved in the soft X-ray FEL line with an electron beam energy of 3.0 GeV. Finally, saturation of a 0.104-nm FEL beam was achieved on March 16, 2017 using an electron beam energy of 9.47 GeV and K = 1.87. In this paper we present the commissioning result of PAL-XFEL as well as the beamline commissioning results.

First Lasing and Commissioning Status of SwissFEL

MOC02

S. Reiche (PSI)

The Swiss FEL commissioning has started in 2016 to achieve lasing in the hard X-ray beamline Aramis with an electron beam energy up to 5.8 GeV. This talk gives a brief status of SwissFEL, first lasing results and the upcoming commissioning tasks in the future, including the second, soft X-ray beamline Athos in 2021.

Commissioning and First Lasing of the European XFEL

MOC03

H. Weise, W. Decking (DESY)

The European X-ray Free-Electron Laser (XFEL) in Hamburg, Northern Germany, aims at producing X-rays in the range from 260 eV to 24 keV out of three undulators that can be operated simultaneously with up to 27,000 pulses per second. The XFEL is driven by a 17.5 GeV superconducting linac. This linac is the worldwide largest installation based on superconducting radio-frequency acceleration. The design is using the so-called TESLA technology which was developed for the superconducting version of an international electron positron linear collider. After eight years of construction the facility is now brought into operation. First lasing was demonstrated in May 2017. Experience with the super-conducting accelerator as well as beam commissioning results will be presented. The path to the first user experiments will be laid down.

Funding: Work supported by the respective funding agencies of the contributing institutes; for details please see http:www.xfel.eu

Status of Dalian Coherent Light Source

MOC04

W.Q. Zhang, D.X. Dai, G.L. Wang, G.R. Wu, X.M. Yang (DICP) S. Chen, C. Feng, D. Wang, M. Zhang, Z.T. Zhao (SINAP)

A Free Electron Laser with high brightness, ultrafast laser pulses in the vacuum ultraviolet (VUV) wavelength region is an ideal light source for excitation of valence electrons and ionization of molecular systems with very high efficiency. it is quite helpful for studies of important dynamic processes in physical, chemical and biological systems. Dalian Coherent Light Source (DCLS) plans to deliver optical beam from 50-150nm in picoseconds or 100 femtoseconds for such research. High gain harmonic generation is the perfect choice in VUV FEL for narrow bandwidth, stable power and low cost due to fewer undulators. After eight months of installation and machine commissioning, a 300-MeV electron beam was achieved with peak current of more than 300A, and the emittance was less than 1.5 mm.mrad. The FEL power for individual pulse at 133nm approached more than 200uJ with 266nm seed laser on Jan. 2017. The gain curve and spectrum of HGHG & SASE FEL was measured, and tapering undulator helps increase the power by almost 100% when the FEL output saturated. The user experiment will start on June 2017. It is open for good proposals from the whole world.

Funding: DCLS is a joint project of Dalian Institute of Chemical Physics (DICP) and Shanghai Institute of Applied Physics (SINAP),CAS. It is supported by National Natural Science Foundation of China (21127902)

MOD — New Lasing & Status of Projects II

MOD01

Status of the LCLS-II FEL Project at SLAC

P. Emma (SLAC)

LCLS-II is a major new Free-Electron Laser (FEL) facility being built at SLAC, with collaborators from other US laboratories at ANL, Cornell, FNAL, LBNL, and TJNAF. This project aims to upgrade the operating LCLS-I facility by building a new 4-GeV superconducting RF (SRF) linac to provide continuous wave (CW) operation of two new FELs at beam rates of up to 1 MHz. The existing fixed-gap FEL undulator will be replaced by two new parallel adjustable-gap undulators providing an FEL spectral tuning range from 0.2 keV to 25 keV with average x-ray power levels approaching 1 kW. The existing 15-GeV copper linac in the last 3rd of the SLAC linac will be maintained as a low-rate, high-energy FEL driver in complementary operations with the new SRF linac. We present a brief status of the project, some of the latest test results, and thoughts on further facility expansion in the long term.

Funding: Work supported by the U.S. Department of Energy under Contract No. DE-AC02-76SF00515.

MOD02

Status of the FLASH FEL User Facility at DESY

K. Honkavaara (DESY)

The FLASH facility at DESY (Hamburg, Germany) provides high brilliance FEL radiation at XUV and soft X-ray wavelengths for user experiments. Since April 2016, the second undulator beamline, FLASH2, is in user operation. We summarize the performance of the FLASH facility during the last two years including our experience to deliver FEL radiation to two user experiments simultaneously.

MOD03

Present Status of SACLA

H. Tanaka (RIKEN SPring-8 Center)

According to the increasing demand for XFEL utilization, introduction of pulse-by-pulse multi-FEL operation with full laser performance is a pressing issue, because most of experiments require a short pulse of less than 10 fs. The biggest obstacle is the emittance growth caused by CSR through a dogleg composed of a bend and a bend-back of 3 degrees, which seriously restricts on the operational peak current less than 2.5 kA. In order to solve this problem, we built a dual DBA-based dogleg using a 0.3 MW highly stable pulse power-supply in winter 2016. The full-performance pulse-by-pulse multi-FEL operation was successfully achieved in February 2017. This will be introduced in the user operation as a standard mode after Summer 2017 via the test use scheduled before the summer shutdown. On the other hand, the SXFEL user operation at BL1 has been started since 2016 and now two XFELs (BL2, BL3) and one SXFEL (BL1) beamlines are available simultaneously for user experiments at SACLA. This presentation shows the present status of SACLA focusing on the above topics.

Status and Perspectives of the FERMI FEL Facility

MOD04

L. Giannessi, E. Allaria, L. Badano, F. Bencivenga, C. Callegari, F. Capotondi, F. Cilento, P. Cinquegrana, M. Coreno, I. Cudin, G. D'Auria, M.B. Danailov, R. De Monte, G. De Ninno, P. Delgiusto, A.A. Demidovich, M. Di Fraia, S. Di Mitri, B. Diviacco, A. Fabris, R. Fabris, W.M. Fawley, M. Ferianis, P. Furlan Radivo, G. Gaio, D. Gauthier, F. Gelmetti, F. Iazzourene, S. Krecic, M. Lonza, N. Mahne, M. Malvestuto, C. Masciovecchio, M. Milloch, F. Parmigiani, G. Penco, A. Perucchi, L. Pivetta, O. Plekan, M. Predonzani, E. Principi, L. Raimondi, P. Rebernik Ribic, F. Rossi, E. Roussel, L. Rumiz, C. Scafuri, C. Serpico, P. Sigalotti, S. Spampinati, C. Spezzani, M. Svandrlik, M. Trovo, A. Vascotto, M. Veronese, R. Visintini, D. Zangrando, M. Zangrando (Elettra-Sincrotrone Trieste S.C.p.A.) N.S. Mirian (UVSOR)

FERMI is the seeded Free Electron Laser (FEL) user facility at the Elettra laboratory in Trieste, operating in the VUV to EUV and soft X-rays spectral range; the radiation produced by the seeded FEL is characterised by a number of desirable properties, such as wavelength stability, low temporal jitter and longitudinal coherence. In this paper, after an overview of the FELs performances, we will present the development plans under consideration for the next 3 to 5 years. These include an upgrade of the LINAC and of the existing FEL lines, the possibility to perform multi-pulse experiments in different configurations and an Echo Enabled Harmonic Generation experiment on FEL-2, the FEL line extending to 4 nm (310 eV).

Status of the SXFEL Facility

MOD05

B. Liu, G.P. Fang, M. Gu, Q. Gu, Y.B. Leng, D. Wang, L. Yin, Z.T. Zhentang (SINAP)

The Shanghai Soft X-ray Free-Electron Laser facility (SXFEL) is being developed in two steps, the test facility SXFEL-TF and the user facility SXFEL-UF. The SXFEL-TF, which will generate 8.8 nm FEL radiation with the two-stage cascaded HGHG-HGHG or EEHG-HGHG scheme, is under commissioning at the SSRF campus. In the meantime, The SXFEL-UF, with designed wavelength in the water window region, began construction in November 2016, based on upgrading the linac energy to 1.5 GeV and building a second undulator line and five experimental end-stations. Status and future plan of the SXFEL is presented here.

Matter-Radiation Interactions in Extremes (MaRIE) Project Overview

MOD06

R.L. Sheffield, C.W. Barnes (LANL)

The National Nuclear Security Administration (NNSA) requires the ability to understand and test how material structures, defects and interfaces determine performance in extreme environments. The MaRIE Project will provide the science ability for control of materials and their production for vital national security missions. To meet the mission requirements, MaRIE must be an x-ray source that has high brilliance and with very flexible and fast pulses to observe phenomena at shock-relevant time scales, and with high enough energy to study high-Z materials. This talk will cover the rationale for the machine requirements, a pre-conceptual reference design that can meet those requirements, and preliminary research needed to address the critical high risk technologies.

MOP — Poster I

MOP001

Diamond Double-Crystal System for a Forward Bragg Diffraction X-Ray Monochromator of the Self-Seeded PAL XFEL

Yu. Shvyd'ko, J.W.J. Anton, K.-J. Kim, T. Kolodziej, D. Shu (ANL) V.D. Blank, S. Terentiev (TISNCM) H.-S. Kang, C.-K. Min, B.G. Oh (PAL) P. Vodnala (Northern Illinois University)

An x-ray monochromator for a hard x-ray self-seeding system is planned at PAL XFEL to be used in a 3-keV to 10-keV photon spectral range. The monochromatization in a 5 keV to 7 keV range will be achieved by forward Bragg diffraction (FBD) from a 30-micron-thin diamond crystal in the [110] orientation employing the (220) symmetric Bragg reflection. FBD from the same crystal using the (111) asymmetric Bragg reflection will provide monochromatization in a 3 keV to 5 keV spectral range. In the 7-keV to 10-keV spectral range, a 100-micron crystal in the [100] orientation will be used employing FBD with the (400) symmetric Bragg reflection. Two almost defect-free diamond crystals in the required orientations and thicknesses are mounted in a strain-free mechanically-stable fashion on a common CVD diamond substrate using all-diamond components, ensuring radiation-safe XFEL operations with improved heat transport. We will present results of the optical and engineering designs, manufacturing, and x-ray diffraction topography characterization of the diamond double-crystal system.

MOP002

Design Study of FEL-2 for Dalian Coherent Light Source

G.L. Wang (DICP) S. Chen (SINAP)

Dalian Coherent Light Source (DCLS) is a free electron laser (FEL) user facility working at 50-150 nm, and is now in user operation with its first FEL line, FEL-1. In this paper, we present a design study of the second FEL line, FEL-2, a polarization controllable and femtosecond FEL. The main components including the switchyard and undulator system are considered and a possible schematic of the switchyard is presented to divert the beam and guarantee the beam properties will not be spoiled. The FEL-2 will be based on the principle of High-Gain Harmonic Generation (HGHG), and the radiator system is composed of 2 planer undulators and 3 helical afterburners. With the help of 3D simulation codes, we show the detailed performance of FEL-2 with the realistic parameters of DCLS.

MOP003

Concept for a Seeded FEL at FLASH2

C. Lechner, R.W. Assmann, J. Boedewadt, M. Dohlus, N. Ekanayake, B. Faatz, G. Feng, I. Hartl, T. Laarmann, T. Lang, L. Winkelmann, I. Zagorodnov (DESY) A. Azima, M. Drescher, Th. Maltezopoulos, T. Plath, J. Rossbach, W. Wurth (University of Hamburg, Institut für Experimentalphysik) S. Khan, T. Plath (DELTA)

The free-electron laser (FEL) FLASH is a user facility delivering photon pulses down to 4 nm wavelength. Recently, the second FEL undulator beamline 'FLASH2' was added to the facility. Operating in self-amplified spontaneous emission (SASE) mode, the exponential amplification process is initiated by shot noise of the electron bunch, resulting in photon pulses of limited temporal coherence. In seeded FELs, the FEL process is initiated by coherent seed radiation, improving the longitudinal coherence of the generated photon pulses. The conceptual design of a possible seeding option for the FLASH2 beamline foresees the installation of the hardware needed for high-gain harmonic generation (HGHG) seeding upstream of the already existing undulator system. In this contribution, we present the beamline design, numerical simulations, and tolerance studies of the seeded FEL.

Towards the Demonstration of Soft X-Ray Echo-Enabled Harmonic Generation at Fermi

MOP004

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The echo-enabled harmonic generation seeding scheme is based on an echo mechanism that develops in the electron beam phase-space interacting with two seed lasers before and after a strong dispersive region. It has been proposed for extending the capabilities of externally seeded free electron lasers to reach short wavelengths. After the original proposal, a few experiments have confirmed the capabilities of efficient bunching generation at very high harmonics. However, up to now none of the experiments demonstrated FEL amplification from high harmonic bunching produced at 10 nm wavelengths or shorter. In this work, we report about our plans for performing an EEHG experiment at FERMI. The experiment will be done at the FEL-2 line normally operated in the double stage high-gain harmonic generation configuration in the wavelength range 20-4 nm. After the modification of a few hardware components planned for the first semester of 2018, the FEL-2 layout will be suitable for EEHG at wavelengths down to approximately 6 nm.

FEL Pulse Shortening by Superradiance at FERMI

MOP005

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FERMI is a seeded FEL user facility producing photons from the VUV to the soft X-rays with a high degree of coherence and spectral stability. FERMI has two FEL lines: FEL-1, which covers the wavelength range between 100 and 17 nm and FEL-2 in the range between 17 and 4 nm. The shortest pulses delivered by FEL 1 and FEL 2 have respectively a duration of 30-50 fs and 17-25 fs according to the final wavelength. This short-pulse duration has already been exploited in fast time resolution studies. However, a shorter pulse duration in the femtosecond regime could permit to resolve very fast processes, such as electronic rearrangements, and then would increase the number of potential experiments targeted by FERMI. Explorations of superradiance regime is one of the methods that could be used to reduce the pulse length of the pulses delivered by FERMI. Here we present simulation studies that show the possible application of superradiance to FERMI, leading to a minimum pulse duration of ~10 fs on FEL 1 and ~5 fs on FEL 2 and a peak power exceeding the GW in both cases.

Characterization of the Polarization of the First and Second Stage of FERMI FEL-2

MOP006

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The FERMI free-electron laser (FEL) is nowadays the only user facility equipped with Apple-II type undulators that permit to produce either elliptical, circular or linearly polarized light within the extreme ultraviolet and soft x-ray wavelength range. The FERMI FEL-2 line is based on a two-stage "fresh-bunch" high-gain harmonic generation (HGHG) scheme, where the light emitted by a first HGHG stage seeds a fresh portion of the electron bunch in a second FEL stage. Both FEL lights, from the first and second stages, can be tuned separately to linear horizontal, vertical or circular left and right polarization. We report on a systematic characterization of the polarization state of the two stages of FERMI FEL-2 by using an electron Time-Of-Flight based polarimeter. Our results show a good independent control of the polarization of the two stages, with a high degree of polarization typically higher than 95%*

** E. Roussel et al., Polarization Characterization of Soft X-Ray Radiation at FERMI FEL-2. Photonics 2017, 4, 29.*

MOP007

Study of an External Laser Seeding at the European XFEL

T. Tanikawa, S. Serkez, S.I. Tomin (European XFEL) G. Geloni, S. Karabekyan (XFEL. EU)

Several XFEL facilities are currently in the commissioning or operation phase and have opened new exciting scientific opportunities. In May 2017, the European XFEL successfully achieved a first lasing. Recently, most of the FEL facilities are going to invest (or have already invested) in advanced schemes to increase the longitudinal coherence properties of radiation compared to SASE. As one of the techniques, an external laser seeding is currently applicable at soft X-ray facilities, in a frequency range where external seed pulses are powerful enough to overcome the SASE shot noise. However, these techniques are now also being considered at several hard X-ray FEL facilities and aim for the production of nearly Fourier-limited pulses up to the keV range. At the European XFEL, the challenge of HGHG and EEHG options is the usage of very high electron beam energy. In this presentation, we will report the preliminary simulation results of the external laser seeding feasibility at the European XFEL.

MOP008

Status of the Hard X-ray Self-Seeding Project at the European XFEL

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A Hard X-ray Self-Seeding setup is currently under realization at the European XFEL, and will be ready for installation in 2018. The setup consists of two single-crystal monochromators that will be installed at the SASE2 undulator line. In this contribution, after a short summary of the physical principles and of the design, we will discuss the present status of the project including both electron beam and X-ray optics hardware. We will also briefly discuss the expected performance of the setup, which is expected to produce nearly Fourier-limited pulses of X-ray radiation with increased brightness compared to the baseline of the European XFEL, as well as possible complementary uses of the two electron chicanes.

MOP009

Simulations of the Hard X-ray Self-Seeding Setup at the European XFEL

G. Geloni (XFEL. EU) V. Kocharyan, S. Liu, E. Saldin (DESY) S. Serkez (European XFEL)

In this contribution we will describe simulation work performed for the Hard X-Ray Self-Seeding (HXRSS) setup being built for the European XFEL. The setup, consisting of two single-crystal monochromators, will be ready for installation at the SASE2 undulator line in 2018. Here we will present in detail the expected performance of our setup at several operation points including a study of the output dependence on the electron beam quality. Simulations have been performed using the code Genesis, and partly run using the Ocelot software.

MOP010

Constraints on Pulse Duration Produced by Echo-Enabled Harmonic Generation

G. Penn (LBNL) B.W. Garcia, E. Hemsing, G. Marcus (SLAC)

Echo-enabled harmonic generation (EEHG) is well-suited for producing long, coherent pulses at high harmonics of seeding lasers. There have also been schemes proposed to adapt EEHG to output extremely short, sub-fs pulses by beam manipulations or through extremely short seed lasers, but the photon flux is generally lower than that produced by other schemes. For the standard EEHG layout, it is still interesting to consider different parameter regimes and evaluate how short a pulse can be generated. EEHG at high harmonics uses a large dispersive chicane which can change the relative distance of electrons by substantial distances, even longer than a typical FEL coherence length. We evaluate the ability to produce short pulses (in the femtosecond to 10-fs range) using a combination of theory and simulations.

Funding: This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract Nos. DE-AC02-05CH11231 and DE-AC02-76SF00515.

Strongly Tapered Undulator Design for High Efficiency and High Gain Amplification at 266 nm

MOP011

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Tapering Enhanced Stimulated Superradiant Amplification (TESSA) is a scheme developed at UCLA to increase efficiency of Free Electron Laser (FEL) light from less than 0.1% to greater than 20% using strongly tapered undulators and prebunched electron beams. Initial results validating this method have already been obtained at 10-um wavelength at Brookhaven National Laboratory. In this paper we will discuss the design of an experiment to demonstrate the TESSA scheme at high gain and shorter wavelength (266 nm) using the Linac Extension Area (LEA) beamline at the Advanced Photon Source of Argonne National Laboratory (ANL) to obtain conversion efficiencies between 10-30% depending on the length of the tapered undulator (up to 4m).

Design of the Self-Seeding Mode for Aramis at SwissFEL

MOP012

A. Rodriguez-Fernandez, B. Pedrini, S. Reiche (PSI)

The XFELs rely on the self-amplified spontaneous emission in the hard X-ray regime, and exhibit peak brightness that is many orders of magnitude larger than third-generation synchrotron sources. XFELs open new avenues for investigations of phenomena at the femtosecond time scale. Geloni and co-workers have proposed to exploit these features for self-seeding FELs in the hard X-ray regime. We are interested in a better understanding of space-, time- and frequency-domain aspects of the Forward Bragg Diffraction (FBD) process. The FBD process produces time-delayed beams of well-defined wavelength and reduced bandwidth, which are used to seed the second FEL stage. This self-seeding scheme is foreseen also for the hard X-ray branch (2.0-12.4 keV) of the SwissFEL currently under commissioning at PSI. In this communication, a detailed study of the FBD feature is presented. The base of the simulation work shown is the dynamical diffraction theory model developed by V.A. Bushuev.* The selection of the crystal thickness and reflections to be used for the future self-seeding mode at SwissFEL is discussed for simulation results, which were compared with experimental data collected at SLS.

* *V. A. Bushuev, J. Synchrotron Rad 15 495 (2008).*

Sub-Terawatt X-Ray Self-Seeded High-Gain Harmonic Generation

MOP013

L. Zeng, S. Huang, K.X. Liu, W. Qin, G. Zhao (PKU) Y. Ding, Z. Huang (SLAC)

Self-seeded high-gain harmonic generation is a possible way to extend the wavelength of a soft x-ray free-electron laser (FEL). We have carried out simulation study on harmonic generation within the photon energy range from 2 keV to 4.5 keV, which is difficult to achieve due to a lack of monochromator materials. In this work, we demonstrate the third harmonic FEL with the fundamental wavelength at 1.52 nm. Our results shows that, by using undulator tapering technique, sub-terawatt narrow-bandwidth FEL output can be obtained.

Harmonic Lasing Towards Shorter Wavelengths in Soft X-Ray Self-Seeding FELs

MOP014

L. Zeng, S. Huang, K.X. Liu, W. Qin, G. Zhao (PKU) Y. Ding, Z. Huang (SLAC)

In this paper, we study a simple harmonic lasing scheme to extend the wavelength of X-ray self-seeding FELs. The self-seeding amplifier is comprised of two stages. In the first stage, the fundamental radiation is amplified but well restricted below saturation, and simultaneously harmonic radiation is generated. In the second stage, the fundamental radiation is suppressed while the harmonic radiation is amplified to saturation. We performed a start-to-end simulation to demonstrate third harmonic lasing in a soft x-ray self-seeding FEL at the fundamental wavelength of 1.52 nm. Our simulations show that a stable narrow-band FEL at GW levels can be obtained.

MOP015

Demonstration of Harmonic Lasing Self-Seeded Mode for Soft X-Rays Down to 1nm at PAL-XFEL

I.H. Nam, H. Heo, H.-S. Kang, C. Kim, G. Kim, C.-K. Min, H. Yang (PAL)

Harmonic lasing is a promising way to provide the beams that can be brilliant, stable and narrow-band. We demonstrate the 3rd harmonic lasing operation in the current configuration with gap-tunable planar hybrid type undulators at soft X-ray beam line at PAL-XFEL. In order to suppress the fundamental resonant radiation, we used a set of phase shifters for optimal condition. This new operation mode can improve the spectral brightness compare to Self-Amplified Spontaneous emission (SASE) mode. In this paper, we report the results of these studies of the harmonic lasing mode for soft X-ray in the wavelength down to 1 nm with the electron beam energy of 3 GeV at PAL-XFEL.

MOP016

Comparing FEL Codes for Advanced Configurations

B.W. Garcia, G. Marcus (SLAC) L.T. Campbell (STFC/DL/ASTeC) B.W.J. McNeil (USTRAT/SUPA) S. Reiche (PSI)

Various FEL codes exist which employ different approximations and strategies to model the FEL radiation generation process. Many codes perform averaging procedures over various length scales in order to simplify the underlying dynamics. As FELs are developed in more advanced configurations beyond simple SASE, the assumptions of some codes may be called into question. We compare the unaveraged code Puffin to averaged FEL codes including a new version of GENESIS in a variety of situations. In particular, we study a harmonic lasing setup, a High-Gain Harmonic Generation (HGHG) configuration modeled after the FERMI setup, and a potential Echo-Enabled Harmonic Generation (EEHG) configuration also at FERMI. We find the codes are in good agreement, although small discrepancies do exist.

MOP017

Echo-Enabled Harmonic Generation Results with Energy Chirp

B.W. Garcia, M.P. Dunning, C. Hast, E. Hemsing, T.O. Raubenheimer, G. Stupakov (SLAC) D. Xiang (Shanghai Jiao Tong University)

It has been known since shortly after the discovery of the Echo-Enabled Harmonic Generation (EEHG) process that it is often less sensitive to energy chirp than High-Gain Harmonic Generation (HGHG). We report here on several experimental results from the NLCTA at SLAC involving chirped EEHG beams. We directly observe the sensitivity of the different n EEHG modes to a linear beam chirp. This differential sensitivity results in a multi-color EEHG signal which can be fine-tuned through the EEHG parameters and beam chirp. We also generate a beam which, due to a timing delay between the two seed lasers, contains both regions of EEHG and HGHG bunching. The two regions are clearly separated on the resulting radiation spectrum due to a linear energy chirp, and one can simultaneously monitor their sensitivities.

MOP018

Distributed Self-Seeding Scheme for LCLS-II

J. Wu, T.O. Raubenheimer, C. Yang (SLAC) B. Yang (University of Texas at Arlington)

Self-seeding is a successful approach for generating high-brightness x-ray free electron laser (XFEL). A single-crystal monochromator in-between the undulator sections to generate a coherent seed is adopted in LCLS. However, for a high-repetition rate machine like LCLS-II, the crystal monochromator in current setup cannot sustain the high average power; hence a distributed self-seeding scheme utilizing multi-stages is necessary. Based on the criteria set on the crystal, the maximum allowed x-ray energy deposited in the crystal will determine the machine configuration for such a distributed self-seeding scheme. In this paper, a distributed self-seeding configuration is optimized for LCLS-II type projects in the hard x-ray FEL energy regime. The study is carried out based on numerical simulation.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

Smith-Purcell Seeded FEL

MOP019

J. Wu (SLAC) W. Liu (USTC/NSRL) B. Yang (University of Texas at Arlington)

To generate high-brightness FEL radiation, a coherent seed is a necessary requirement. The existing approaches are mostly based on monochromators: either grating-based for soft x-ray or crystal-based for hard x-ray. In this paper, we study a Smith-Purcell based seeding scheme. The first undulator system will saturate an electron bunch to generate microbunched electron bunch, which will interact with a Smith-Purcell device to produce x-rays. This Smith-Purcell x-ray is then sent into the second undulator system and interacts with a fresh second bunch. The fresh second electron bunch will amplify the Smith-Purcell x-ray to saturation and with additional tapered undulators to reach very high power. The study is carried out with analytical analysis as well as numerical simulation.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

Sideband Instability in a Tapered Free Electron Laser

MOP020

J. Wu (SLAC) C.-Y. Tsai (Virginia Polytechnic Institute and State University) M. Yoon (POSTECH) G. Zhou (IHEP)

For a high-gain tapered free electron laser (FEL), it is known that there is a so-called second saturation point where the FEL power growth stops. Sideband instability is one of the major reasons leading to this second-saturation and thus prevents reaching terawatt-level power output in an X-ray FEL. It is believed that a strong taper can effectively suppress the sideband instability and further improve the efficiency and peak power. In this paper, we give quantitative analysis on the necessary taper gradient to minimize the sideband growth. We also discuss the transverse effects of induced electron de-trapping which is yet another major reason for the occurrence of the second-saturation point even with a strong enough taper. The study is carried out analytically together with numerical simulation. The numerical parameters are taken from LCLS-II type electron bunch and undulator system.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

Sideband Suppression in Tapered Free Electron Lasers

MOP021

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It is known that in a high-gain tapered free electron laser, there is the so-called second saturation point where the FEL power ceases to grow. Sideband instability is one of the major reasons causing this second saturation. Electron synchrotron oscillation coupling to the wideband SASE radiation leads to the appearance of sidebands in the FEL spectrum, and is believed to prevent a self-seeding tapered FEL from reaching very high peak power. A strong seed together with a fresh electron bunch or a fresh slice in conjunction with strong tapering of undulators can effectively suppress the sideband instability. In this paper, we give quantitative analysis on the necessary seed power as well as undulator tapering to minimize the sideband effects. The study is carried out semi-analytically together with numerical simulation. The machine and electron bunch parameters are chosen as those of PAL-XFEL and LCLS-II.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

MOP022

Design Study and Preparations for the Echo-30 Experiment at SXFEL

C. Feng, S. Chen, H.X. Deng, B. Liu, D. Wang, X.T. Wang, Z.T. Zhao (SINAP)

In this work, design study and hardware preparations for the echo-30 experiment at the SXFEL test facility are presented. With the realistic parameters of the SXFEL, start-to-end simulations considering various three-dimensional effects have been carried out, and the simulation results demonstrate that a single-stage EEHG can generate high-power soft x-ray radiation pulses with narrow bandwidth directly from UV seed lasers. We also show the preparations of the seed lasers, undulators and photon beam diagnostics for the echo-30 experiment at the SXFEL.

MOP023

Two-Color Soft X-Ray Generation Based on the EEGH Scheme

Z. Qi, C. Feng, Z.T. Zhao (SINAP)

Two-color FELs with adjustable time-delay and central wavelengths are significant for the pump-probe experiments of coherent anti-Stokes Raman scattering and most other multi-wave techniques. In this paper, we present a technique for the generation of fully-coherent two-color FEL based on the echo-enable harmonic generation (EEHG) scheme.

MOP024

Design and Optimization for the Soft X-Ray Self-Seeding at SXFEL

K.Q. Zhang, C. Feng, D. Wang (SINAP)

The design and optimization studies for the soft x-ray self-seeding experiment at SXFEL have been presented in this paper. Some critical physical problems have been intensively studied to help us obtain a more stable output and a clearer spectrum. The monochromator is optimized considering various unideal conditions such as the reflection and diffraction rate and the roughness of the grating and the mirrors. The calculation and simulation results show that the properties of the self-seeding can be significantly improved by using the optimized design of the whole system.

MOP025

Extending the Photon Energy Coverage of an X-Ray Self-Seeding FEL via the Reverse Taper Enhanced Harmonic Generation Technique

K.Q. Zhang, C. Feng, D. Wang (SINAP)

In this paper, we propose a novel method that combines the reverse undulator taper and harmonic generation techniques to extend the photon energy coverage of a self-seeding FEL. The proposed scheme utilizes a baseline configuration of a self-seeding FEL and does not require the installation of any additional hardware in the undulator system. The proposed technique can be easily implemented at already existing or planned x-ray FEL facilities to generate x-ray radiation pulses with consecutively tuning wavelength from soft x-ray to hard x-ray regions. Theory and simulation is carried out in this paper. The proposed scheme will be a reliable method to extend the wavelength range of the soft x-ray self-seeding scheme.

MOP026

Study of an Echo-Enabled Harmonic Generation Scheme for the French FEL Project LUNEX5

E. Roussel, M.-E. Couprie, A.M. Ghaith, A. Loulergue (SOLEIL) C. Evain (PhLAM/ CERLA)

In the French LUNEX5 project (Laser à électrons libres Utilisant un Nouvel accélérateur pour l'exploitation du rayonnement X de 5ème génération), a compact advanced free-electron laser (FEL) is driven by either a superconducting linac or a laser-plasma accelerator that can deliver a 400-MeV electron beam. LUNEX5 aims to produce FEL radiation in the ultraviolet and extreme ultraviolet (EUV) range. To improve the longitudinal coherence of the FEL pulses and reduce the gain length, it will operate in Echo-Enabled Harmonic Generation (EEHG) seeding configuration.

EEHG is a strongly nonlinear harmonic up-conversion process based on a two-seed laser interaction that enables to reach very high harmonics of the seed laser. Recent experimental demonstration of ECHO-75, starting from an infrared seed laser, was recently achieved at SLAC and is opened the way for EEHG scheme in the EUV and soft x-ray range. Furthermore, FELs are promising candidates for the next generation of lithography technology using EUV light. In this work, we report a preliminary study of EEHG scheme for LUNEX5 in order to reach the target wavelength of 13.5 nm, currently expected for application to lithography.

Seeding of Electron Bunches in Storage Rings

MOP027

S. Khan, B. Büsing, N.M. Lockmann, C. Mai, A. Meyer auf der Heide, R. Niemczyk, B. Riemann, B. Sawadski, M. Suski, P. Ungelenk (DELTA)

Seeding schemes for free-electron lasers (FELs) can be adopted to generate ultra-short radiation pulses in storage rings by creating laser-induced microbunches within a short slice of a long electron bunch giving rise to coherent emission at harmonics of the seed wavelength. In addition, terahertz (THz) radiation is produced over many turns. Even without FEL gain, a storage ring is an excellent testbed to study many aspects of seeding schemes and short-pulse diagnostics, given the high repetition rate and stability of the electron bunches. At DELTA, a storage ring operated by the TU Dortmund University in Germany, coherent harmonic generation (CHG) with single and double 40-fs pulses is performed at seed wavelengths of 800 nm or 400 nm. Seeding with intensity-modulated 10-ps pulses is also studied generating tunable narrowband THz radiation. As a preparation for echo-enabled harmonic generation (EEHG), simultaneous seeding with 800/400-nm pulses in two different undulators is performed and several techniques are employed to ensure optimum timing between the seed pulses. The paper describes these experiments and gives an outlook of future applications of seeding at storage rings.

Funding: Funded by BMBF (05K16PEA), MERCUR (Pr-2014-0047), DFG (INST 212/236-1 FUGG) and the Land NRW.

Extraction of the Longitudinal Profile of the Transverse Emittance From Single-Shot RF Deflector Measurements at sFLASH

MOP028

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The gain length of the free-electron laser (FEL) process strongly depends on the slice energy spread, slice emittance, and current of the electron bunch. At an FEL with only moderately compressed electron bunches, the slice energy spread is mainly determined by the compression process. In this regime, single-shot measurements using a transverse deflecting rf cavity enable the extraction of the longitudinal profile of the transverse emittance. At the free-electron laser FLASH at DESY, this technique was used to determine the slice properties of the electron bunch set up for seeded operation in the sFLASH experiment. Thereby, the performance of the seeded FEL process as a function of laser-electron timing can be predicted from these slice properties with the semi-analytical Ming-Xie model where only confined fractions of the electron bunch are stimulated to lase. The prediction is well in line with the FEL peak power observed during an experimental laser-electron timing scan. The power profiles of the FEL pulses were reconstructed from the longitudinal phase-space measurements of the seeded electron bunch that was measured with the rf deflector.

Exploring ESASE For MaRIE

MOP029

J.E. Williams, S. Biedron, S.V. Milton (CSU) P.M. Anisimov, B.E. Carlsten, Q.R. Marksteiner (LANL)

We are exploring alternative design concepts for the proposed MaRIE XFEL including those involving novel beam phase-space manipulation techniques. Meeting the required beam energy, energy spread, transverse and longitudinal emittances, and peak current at the entrance to the FEL line requires using an extremely low-emittance injector and careful accelerator lattice propagation. Here we propose a shift from originally-presented point designs, moving toward utilizing a C-band injector and linac in conjunction with the novel bunch compression technique

known as enhanced self-amplified spontaneous emission (ESASE) to mitigate some of the emittance degrading collective effects while meeting the required input parameters. This paper shows our initial results on how sharp, intra-bunch current spikes created through ESASE process can help mitigate some of the collective affects such as coherent synchrotron radiation (CSR) induced energy spread, while still producing the desired XFEL output.

Funding: DOE SCGSR

MOP030

Study of the Next Major Flash Upgrade: FLASH2020

B. Faatz (DESY)

The FLASH facility has delivered beam to two experiments simultaneously since Spring 2016. Both users can request a large variety of parameters independently, without interfering with the other experiment and the setup for both users can take place in parallel. For several years, a study has started to plan for the next major upgrade, referred to as FLASH2020. The ultimate goal is a CW version of FLASH with up to 1 million bunches per second which should be able to go down in wavelength to cover the complete water window. In this presentation we will present the different upgrade scenarios that are under discussion. Also we present tests already performed and planned for the near future to optimize the design and maximize the flexibility of the new facility.

MOP031

First Operation of a Harmonic Lasing Self-Seeded FEL

E. Schneidmiller, B. Faatz, M. Kuhlmann, J. Roensch-Schulenburg, S. Schreiber, M. Tischer, M.V. Yurkov (DESY)

Harmonic lasing is a perspective mode of operation of X-ray FEL user facilities that allows it to provide brilliant beams of higher-energy photons for user experiments. Another useful application of harmonic lasing is so called Harmonic Lasing Self-Seeded Free Electron Laser (HLSS FEL), that allows it to improve spectral brightness of these facilities. In the past, harmonic lasing has been demonstrated in the FEL oscillators in infrared and visible wavelength ranges, but not in high-gain FELs and not at short wavelengths. In this paper, we report on the first evidence of the harmonic lasing and the first operation of the HLSS FEL at the soft X-ray FEL user facility FLASH in the wavelength range between 4.5 nm and 15 nm. Spectral brightness was improved in comparison with Self-Amplified Spontaneous emission (SASE) FEL by a factor of six in the exponential gain regime. A better performance of HLSS FEL with respect to SASE FEL in the post-saturation regime with a tapered undulator was observed as well. The first demonstration of harmonic lasing in a high-gain FEL and at a short wavelength paves the way for a variety of applications of this new operation mode in X-ray FELs.

MOP032

Reverse Undulator Tapering for Polarization Control and Background-Free Harmonic Production in XFELs: Results from FLASH

E. Schneidmiller, M.V. Yurkov (DESY)

Baseline design of a typical X-ray FEL undulator assumes a planar configuration which results in a linear polarization of the FEL radiation. However, many experiments at X-ray FEL user facilities would profit from using a circularly polarized radiation. As a cheap upgrade, one can consider an installation of a short helical afterburner, but then one should have an efficient method to suppress powerful linearly polarized background from the main undulator. There is an efficient method for such a suppression: an application of the reverse taper in the main undulator.* In this contribution, we present the results of experiments with reverse taper at FLASH2 where a high contrast between FEL intensities from the afterburner and from the reverse-tapered main undulator was demonstrated. Another important application of the reverse taper is a possibility to produce FEL harmonics in the afterburner (or in the last part of baseline gap-tunable undulator). We present recent results from FLASH2 where the second and the third harmonics were efficiently generated with a low background at the fundamental.

** E.A. Schneidmiller and M.V. Yurkov, Phys. Rev. ST Accel. Beams 13-080702 (2013).*

Baseline Parameters of the European XFEL

MOP033

E. Schneidmiller, M.V. Yurkov (DESY)

We present the latest update of the baseline parameters of the European XFEL. It is planned that the electron linac will operate at four fixed electron energies of 8.5, 12, 14, and 17.5 GeV. Tunable gap undulators provide the possibility to change the radiation wavelength in a wide range. Operation with different bunch charges (0.02, 0.1, 0.25, 0.5 and 1 nC) provides the possibility to operate XFEL with different radiation pulse duration. We also discuss potential extension of the parameter space which does not require new hardware and can be realized at a very early stage of the European XFEL operation.

XFEL Photon Pulses Database (XPD) at the European XFEL

MOP034

M. Manetti (European XFEL) L. Samoylova, H. Sinn, J. Szuba, K. Wrona (XFEL. EU) E. Schneidmiller, M.V. Yurkov (DESY)

The best way to plan user experiments would be performing start-to-end simulations tracing a radiation pulse from its origin (undulator) through a beamline (mirrors, monochromators, etc.) to a target, simulations of physical processes of the radiation interaction with a sample, and simulations of detection processes of related debris (photon, electrons, ions, etc.) by detectors. Modern FEL simulation codes allow prediction of all details of the output radiation pulses from x-ray FEL (3D maps of radiation fields for the fundamental and higher frequency harmonics). We present an XFEL photon pulses simulation database accessible through public web-server that allows access to the data produced by the time-dependent FEL simulation code FAST. A web application allows pick-up of selected photon pulse data in the hdf5 format for any given XFEL operation mode (electron energy, charge/photon pulse duration, active undulator range, etc.) suitable for statistical analysis, including propagation through the optical system, interaction with the sample, etc. The pulse post-processing data, including the gain curve, time structure, source size and far-field angular divergence are also provided.

Optimum Undulator Tapering of SASE FEL: Theory and Experimental Results From FLASH2

MOP035

E. Schneidmiller, M.V. Yurkov (DESY)

Optimization of the amplification process in FEL amplifier with diffraction effects taken into account results in a specific law of the undulator tapering.* It is a smooth function with quadratic behavior in the beginning of the tapering section which transforms to a linear behavior for a long undulator. In practice, an undulator consists of a sequence of modules of fixed length separated with intersections. Two modes of undulator tapering can be implemented: step tapering and smooth tapering. Step tapering uses a step change of the undulator gap from module to module, while smooth tapering assumes additional linear change of the gap along each module. In this report, we simulate the performance of both experimental options and compare with theoretical limit.

** E.A. Schneidmiller and M.V. Yurkov, Optimization of a high efficiency free electron laser amplifier, Phys. Rev. ST Accel. Beams 18-030705 (2015).*

Frequency Doubling Mode of Operation of Free Electron Laser FLASH2

MOP036

M. Kuhlmann, E. Schneidmiller, M.V. Yurkov (DESY)

We report on the results of the first operation of a frequency doubler at free electron laser FLASH2. The scheme uses the feature of the variable-gap undulator. The undulator is divided into two parts. The second part of the undulator is tuned to the double frequency of the first part. The amplification process in the first undulator part is stopped at the onset of the nonlinear regime, such that nonlinear higher-harmonic bunching in the electron beam density becomes pronouncing, but the radiation level is still small to disturb the electron beam significantly. The modulated electron beam enters the second part of the undulator and generates radiation at the second harmonic. A frequency doubler allows operation in a two-color mode and operation at shorter wavelengths with respect to standard SASE scheme. Tuning of the electron beam trajectory, phase shifters and compression allows tuning of intensities of the first and the second harmonic. The shortest wavelength of 3.1 nm (photon energy 400 eV) has been achieved with a frequency doubler scheme, which is significantly below the design value for the standard SASE option.

MOP037

Opportunities for Two-Color Experiments at the SASE3 Undulator Line of the European XFEL

G. Geloni, T. Mazza, M. Meyer (XFEL. EU) V. Kocharyan, E. Saldin (DESY) S. Serkez (European XFEL)

As is well known, the installation of a simple magnetic chicane in the baseline undulator of an XFEL allows for producing two-color FEL pulses. In this work we discuss the possibility of applying this simple and cost-effective method at the SASE3 soft X-ray beamline of the European XFEL. We consider upgrades of this method that include the further installation of a mirror chicane. We also discuss the scientific interest of this upgrade for the Small Quantum Systems (SQS) instrument, in connection with the high-repetition rate of the European XFEL, and we provide start-to-end simulations up to the radiation focus on the sample, proving the feasibility of our concept. Our proposed setup has been recently funded by the Finnish Research Infrastructure (FIRI) and will be built at SASE3 in 2020-2021.

MOP038

Overview of the Soft X-Ray Line Athos at SwissFEL

R. Ganter, S. Bettoni, H.-H. Braun, M. Calvi, P. Craievich, C.H. Gough, F. Loehl, M. Paraliev, L. Patthey, M. Pedrozzi, E. Prat, S. Reiche, T. Schmidt, A.C. Zandonella (PSI)

The Athos line will cover the photon energy range from 250 to 1900 eV and will operate parallel to the hard X-ray line Aramis of SwissFEL. Athos consists of a fast kicker magnet, a dog-leg transfer line, a small linac and 16 APPLE undulators. The Athos undulators follow a new design: the so-called APPLE X design where the 4 magnet arrays can be moved radially in a symmetric way. Besides mechanical advantages of such a symmetric distribution of forces, this design allows for easy photon energy scans at a constant polarization or for the generation of transverse magnetic gradients. Another particularity of the Athos FEL line is the inclusion of a short magnetic chicane between every undulator segment. These chicanes will allow the FEL to operate in optical klystron mode, high-brightness SASE mode, or superradiance mode. A larger delay chicane will split the Athos line into two sections such that two colors can be produced with adjustable delay. Finally a post undulator transverse deflecting cavity will be the key tool for the commissioning of the FEL modes. The paper will present the current status of the project started in 2017 and is expected to be completed by the end of 2020.

MOP039

Possible Methods for the Control of SASE Fluctuations

N. Thompson, J.A. Clarke, D.J. Dunning (STFC/DL/ASTeC) J.A. Clarke, D.J. Dunning (Cockcroft Institute)

It is well known that because the SASE FEL starts up from the intrinsic electron beam shot noise, there are corresponding fluctuations in the useful properties of the output pulses which restrict their usability for many applications. In this paper, we discuss possible new methods for controlling the level of fluctuations in the output pulses.

MOP040

Design and Status of the Israeli Terahertz FEL Facility

A. Friedman, E. Dyunin, Yu. Lurie (Ariel University) A. Gover, A. Nause (University of Tel-Aviv, Faculty of Engineering)

The Israeli FEL is a compact device designed to operate at wavelengths of 1 to 3.5 THz. The device is based on a 6.5 MeV photo cathode electron gun built in collaboration with UCLA and INFN. We expect to see its first electron beam in August 2017, and first lasing in July 2018. The FEL is a super radiance device. We intend to operate it in two modes: a single pulse mode with total charge per pulse of 300 pC, and a bunched pulse with total charge of 1.2 nC. It is anticipated that the device will yield 50 kW peak power in a single pulse and over 1 MW peak power in a

bunched mode. In the future it is intended to build an advanced-concept undulator that will push the frequency into the far infrared regime and will allow higher power emission. The design and simulations of the project will be presented. The status of the project at the time of the conference will also be depicted.

Funding: Funded in part by Israeli Ministry of Science. Funded in part by Israeli Ministry of Defense.

Commissioning of FEL-Based Coherent Electron Cooling System

MOP041

V. Litvinenko (BNL)

In this talk we are presenting the most recent results from the commissioning of unique Coherent Electron Cooling system, which is using an FEL amplifier to facilitate cooling of hadrons by an electron beam. We present achieved results as well as changes we encountered in the process.

Funding: DoE NP office, grant DE-FOA-0000632, NSF grant PHY-1415252

Status of Seeding Development at sFLASH

MOP042

V. Grattoni, R.W. Assmann, J. Boedewadt, I. Hartl, T. Laarmann, C. Lechner, M.M. Mohammad Kazemi, A. Przystawik (DESY) A. Azima, M. Drescher, W. Hillert, L.L. Lazzarino, V. Miltchev, J. Rossbach (University of Hamburg, Institut für Experimentalphysik) S. Khan, N.M. Lockmann, T. Plath (DELTA)

The experimental seeding setup at FLASH has operated now for two years in high-gain harmonic generation mode. Using a transverse deflecting structure downstream of the seeding section allows a temporal characterization of seeded electron bunches. In addition, temporal characterization of the seeded FEL beam can be performed in a dedicated diagnostic hutch. In this contribution, we give an overview of the latest achievements and present an outlook of the planned studies.

Towards a Beam Driven Plasma Accelerator Free Electron Laser

MOP043

P. Niknejadi, R.T.P. D'Arcy, V. Libov, J. Osterhoff (DESY) A.R. Maier (CFEL) A.R. Maier (University of Hamburg, Institut für Experimentalphysik)

FLASHForward is a Future-ORiented Wakefield Accelerator Research and Development project at the DESY free-electron laser (FEL) facility FLASH. It aims to produce high-quality, GeV energy electron beams over a plasma cell of a few centimeters. The plasma is created by means of a 25-TW Ti:Sapphire laser system. The plasma wakefield will be driven by high-current density electron beams extracted from the FLASH accelerator. The project focuses on the advancement of plasma-based particle acceleration technology through the exploration of both external and internal witness beam injection schemes. Multiple conventional and cutting edge diagnostic tools, suitable for diagnosis of short electron beams, are under development. The design of the undulator section will benefit from the result of these aforementioned diagnostics. In this proceeding the status of the project, as well as the progress towards achieving its overarching goal of usable plasma-driven FELs, is discussed.

Commissioning Status of the European XFEL Photon Beam System

MOP044

F. Le Pimpec (XFEL. EU)

The European XFEL located in the Hamburg region in Germany has finished its construction phase and is currently being commissioned. The European XFEL facility aims at producing X-rays in the range from 260~eV up to 24~keV out of three undulators that can be operated simultaneously with up to 27000~pulses/second. The FEL is driven by a 17.5~GeV linear accelerator based on TESLA-type superconducting accelerator modules. The accelerator has finished its first commissioning phase and is currently delivering photon beam to the experimental areas for commissioning in view to the user operation. This paper presents the status of the photon beam system from the undulators to the 3 experimental areas as well as the status of each instruments.

MOP045

Development of a Compact 14 MeV Linac for a High Power Terahertz Free Electron Laser

T. Hu, Q.S. Chen, G. Feng, K.F. Liu, B. Qin, P. Tan, Y.Q. Xiong (HUST) Y.J. Pei (USTC/NSRL) Z.M. Wang (Chinagray)

A high power FEL-based THz radiation source with a quite compact layout has been constructed and commissioned in Huazhong University of Science & Technology since 2014.8. The FEL is driven by a 14 MeV travelling wave Linac with the EC-ITC RF gun as the electron bunch source. After operated for over 2 years, the setup of the Linac and the commissioning of electron beam come to a conclusion, and the measurement results match with the design values. At present, beam commissioning is still ongoing and radiation commissioning is launched. In this paper the operation status with latest testing results of the Linac will be stated, analyzed, and compared with simulation results. Moreover, preliminary performances and upper setup plan for the whole facility will be described and discussed either.

MOP046

Progress of Delhi Light Source at IUAC, New Delhi

S. Ghosh, R.K. Bhandari, G.K. Chaudhari, V.J. Joshi, D. Kabiraj, D. Kanjilal, B. Karmakar, J. Karmakar, N. Kumar, S. Kumar, A. Pandey, P. Patra, G.O. Rodrigues, B.K. Sahu, A. Sharma, A.S. Sthuthikkatt Reghu, S. Tripathi (IUAC) A. Aryshev, M.K. Fukuda, S. Fukuda, N. Terunuma, J. Urakawa (KEK) U. Lehnert, P. Michel (HZDR) V. Naik, A. Roy (VECC) T. Rao (BNL) M. Tischer (DESY)

The first phase of the pre-bunched FEL based on the Photoinjector RF electron gun, known as Delhi Light Source (DLS),* has been planned at Inter University Accelerator Centre (IUAC), New Delhi. The electron gun made from OFHC copper had already been fabricated and tested with low power RF at KEK, Japan. The beam optics calculation by using ASTRA, GPT codes has been performed and radiation produced from the pre-bunched electron bunches are being calculated.** The high power RF systems will be commissioned at IUAC by the beginning of 2018. The design of the laser system is being finalized and assembly/testing of the complete laser system will be started soon at KEK. The initial design of the photocathode deposition mechanism has also been completed and its procurement/development process will start shortly. The first version of the undulator magnet design has been completed and further improvements are underway.*** The initial arrangements of the DLS beam line have been worked out and various beam diagnostics components are being finalised. The production of the electron beam and THz radiation is expected by 2018 and 2019, respectively.

** S. Ghosh et al., NIM-B, (2017) in press. ** V. Joshi et al., Proc. of this conference. *** S. Tripathi et al., Proc. of this conference.*

Funding: This project is jointly supported by Inter University Accelerator Center and Board of Research in Nuclear Science.

MOP047

Design Calculation on Beam Dynamics and THz Radiation of Delhi Light Source

V.J. Joshi, R.K. Bhandari, S. Ghosh, D. Kanjilal, J. Karmakar, N. Kumar, S. Tripathi (IUAC) A. Aryshev, J. Urakawa (KEK) U. Lehnert (HZDR)

The development of a compact light source facility, Delhi Light Source (DLS), based on a pre-bunched free electron laser, has been initiated at Inter University Accelerator Centre (IUAC).* A photocathode-based normal conducting RF gun will generate a low-emittance 'comb' electron beam with a maximum energy of ~8 MeV which when injected into ~ 1.5 metre compact undulator magnet ($\sim 0.4 < K_{\mathrm{rms}} < \sim 2$) will produce intense THz radiation in the frequency range of 0.15 THz to 3.0 THz.** Each microbunch of the electron beam is expected to emit super-radiant radiation, and an enhancement in the overall spectral power can be achieved if the frequency (inverse of the spatial separation) of the electron microbunches coincides with that of the THz radiation being emitted. There will be provisions to vary the spatial separation between the successive microbunches of the 'comb' beam so that by varying the undulator magnetic field and/or electron energy, the THz frequency range can be tuned. The results of the beam optics for the entire range of frequencies mentioned above along with the detailed information of the radiation to be generated from the facility will be presented in the paper.

** S. Ghosh et al., NIMB-2017, in press. ** S.Tripathi et al., Proc. of this conference.*

Funding: This project is jointly supported by Inter University Accelerator Center and Board of Research in Nuclear Science.

A Compact THz FEL at KAERI: the Project and the Status

MOP048

S.V. Miginsky, S. Bae, B.A. Gudkov, K.H. Jang, Y.U. Jeong, K. Lee, J. Mun, S. Setiniyaz (KAERI) S. H. Park (Korea University Sejong Campus)

A new compact THz free electron laser driven by a microtron is being recently developed at KAERI. It uses a hybrid electromagnetic undulator. A novel scheme of injection/extraction/outcoupling is developed. The machine is partially assembled and commissioned. Characteristic features and current state are described in the paper.

Development of Compact THz Coherent Undulator Radiation Source at Kyoto University

MOP049

S. Krainara, T. Kii, H. Ohgaki, S. Suphakul, H. Zen (Kyoto University)

A new THz Coherent Undulator Radiation (CUR) source has been developed to generate intense quasi-monochromatic THz radiation at Institute of Advanced Energy, Kyoto University. The system consists of a photocathode RF gun, bunch compression chicane, quadrupole magnets, and short planar undulator. The total length of this system is around 5 m. At the present, this compact accelerator has successfully started giving the THz CUR in the frequency range of 0.16 - 0.55 THz. In order to increase the undulator radiation intensity, the effects of electron beam energy spread and emittance need to be reduced and optimized for producing more radiation efficiency. The measured results of electron beam characteristics and THz CUR generated by this system will be reported in the paper.

Present Status of Infrared FEL Facility at Kyoto University

MOP050

H. Zen, T. Kii, S. Krainara, K. Masuda, H. Ohgaki, J. Okumura, S. Suphakul, S. Tagiri, K. Torgasin (Kyoto University)

A mid-infrared free electron laser (FEL) named KU-FEL has been developed for promoting energy-related research at the Institute of Advanced Energy, Kyoto University.* KU-FEL can cover the wavelength range from 3.6 to 23 micrometers and is routinely operated for internal and external user experiments. Recently a THz Coherent Undulator Radiation (CUR) source using a photocathode RF gun has been developed as an extension of the facility.* As the result of commissioning the experiment, it was confirmed that the CUR source can cover the frequency range from 160 to 550 GHz. Present status of these infrared light sources will be presented.

* *H. Zen et al., Physics Procedia 84, pp.47-53 (2016).*

Polish in Kind Contribution to European X-ray Free Electron Laser (XFEL): Status in Summer 2017

MOP051

J.A. Lorkiewicz, K. Chmielewski, Z. Go’’biewski, W.C. Grabowski, K. Kosinski, K. Kostrzewa, I.M. Kudla, P. Markowski, K. Meissner, E.P. Plawski, M. Sitek, J. Szewinski, M. Wojciechowski, Z. Wojciechowski, G. Wrochna (NCBJ) J. Świerblewski, M. Duda, M. Jezabek, K. Kasprzak, A. Kotarba, K. Krzysik, M. Stodulski, M. Wiencek (IFJ-PAN) P.B. Borowiec (Solaris National Synchrotron Radiation Centre, Jagiellonian University) M. Chorowski, P. Duda, A. Iluk, K. Malcher, J. Polinski, E. Rusinski (WRUT) J. Fydrych (ESS) J. Glowinkowski, M. Winkowski, P. Wlk (Wroclaw Technology Park) P. Grzegory, G. Michalski (Kriosystem) J.K. Sekutowicz (DESY)

In the years 2010-2017, some of the Polish research institutes took responsibility of production and delivery of certain components or test procedures for the EU-XFEL sc linear electron accelerator and elements of slow control systems for the first six XFEL experimental instruments. The presentation summarizes the output of the work on design and manufacturing of cryogenic transfer lines for supercritical helium transport and two vertical cryostats for low-power acceptance tests of sc cavities. The cryogenic installations were prepared by Wroclaw University of Science and Technology and its subcontractors. A team of Institute of Nuclear Physics in Cracow was in charge of preparation and performance of acceptance tests for XFEL sc cavities, accelerator modules and sc magnets. Two teams of National Centre for Nuclear Research (NCBJ)in Świerk were involved in the project. One of them was responsible for design, manufacturing, testing and delivery of 1648 high-order mode couplers, 824 pick-up antennae and 10^8 beam-line absobers. The other NCBJ group was obliged to deliver 200 modules containing programmable logic controller terminals to be used at the ends of SASE x-ray beam lines.

MOP052

Characterization of Coherent THz Undulator Radiation Driven by Relativistic Ultrashort Electron Pulses

M.C. Chou, K.T. Hsu, S.Y. Hsu, N.Y. Huang, C.-S. Hwang, J.-Y. Hwang, J.C. Jan, C.K. Kuan, W.K. Lau, A.P. Lee, C.C. Liang, G.-H. Luo, I.C. Sheng (NSRRC)

Generation and characterization of coherent undulator radiation in the THz region using the NSRRC S-band photo-injector linac system is achieved. The system consists of a laser photocathode RF gun and one 5.2-m long S-band accelerating linac. Electron bunches in the linac can be accelerated and compressed simultaneously by velocity bunching. In this work, narrow-band tunable fully-coherent THz radiation can be produced from a U100 planar undulator when it is driven by a 100 pC electron bunch with effective bunch length of 90 fs. The experimental setup and the measurement of the power and the frequency spectrum of the coherent THz undulator radiation are reported.

MOP053

High Spectral Density Compton Back-Scattered Gamma-Ray Sources at Fermilab FAST Facility

D. Mihalcea, P. Piot (Northern Illinois University) B.T. Jacobson, A.Y. Murokh (RadiaBeam) P. Piot, J. Ruan (Fermilab)

A ~1 MeV gamma-ray source is planned to be built at Fermilab following the completion of the ~300 MeV superconducting linac. The high-energy photons are back-scattered from the interactions between electrons and high-intensity IR laser pulses. In this contribution, we discuss some of the experiment design challenges and evaluate the performances of the gamma-ray source. We expect the peak brilliance to be of the order of 10^{22} photons/s-(mm-mrad)^2-0.1% BW and the spectral density of the radiation in excess of 3×10^5 photons/s/eV.

MOP054

CLARA Facility Layout and FEL Schemes

D.J. Dunning (STFC/DL/ASTeC)

CLARA is a new FEL test facility being developed at STFC Daresbury Laboratory in the UK. Commissioning has started on the front-end (photo-injector and linac) while the design of the later stages is still being finalised. We present the latest design work, focusing on the layout and specification of components in and around the undulator sections. We give an overview of the design and modelling of the FEL schemes planned to be tested.

MOP055

SCLF: An 8-GeV CW SCRF Linac-Based X-Ray FEL Facility in Shanghai

Z.T. Zhao, D. Wang (SINAP)

The Shanghai Coherent Light Facility (SCLF) is a newly proposed high repetition-rate X-ray FEL facility, based on an 8-GeV CW superconducting RF linac. It will be located at Zhangjiang High-tech Park, close to the SSRF campus in Shanghai, at the depth of ~38m underground and with a total length of 3.1 km. Using 3 phase-I undulators, the SCLF aims at generating X-rays between 0.4 and 25 keV at rates up to 1MHz. This paper describes the design concepts of this hard X-ray user facility.

Design of a Diamond Irradiation Endurance Experiment for XFELO Applications

MOP056

S.P. Kearney, K.-J. Kim, T. Kolodziej, R.R. Lindberg, D. Shu, Yu. Shvyd'ko, D. Walko, J. Wang (ANL) S. Stoupin (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

We have designed a diamond irradiation setup capable of achieving multiple kW/mm2 power density. The setup was installed at the 7-ID-B beamline at the Advanced Photon Source (APS) for a successful irradiation experiment, testing the capability of diamond to endure x-ray free electron laser oscillator (XFELO) levels of irradiation (≥ 10 kW/mm2) without degradation of Bragg reflectivity.* Focused white-beam irradiation (50 μm x 20 μm spot size at 12.5 kW/mm2 power density) of a diamond single crystal was conducted in a vacuum environment of $1\text{x}10^{-8}$ Torr for varying durations of time at different spots on the diamond, and also included one irradiation spot during a spoiled vacuum environment of $4\text{x}10^{-6}$ Torr. Here we present the apparatus used to irradiate the diamond consisting of multiple subassemblies: the fixed masks, focusing optics, gold-coated UHV irradiation chamber, water-cooled diamond holder, chamber positioning stages (with sub-micron resolution) and detector.

** T. Kolodziej et al., Free Electron Laser Conf. 2017.*

Funding: Work supported by the U.S. Department of Energy, Office of Science, under Contract No. DE-AC02-06CH11357.

Diamond Endurance to Irradiation with X-ray Beams of Multi kW/mm^2 Power Densities for XFELO Application

MOP057

T. Kolodziej, T. Gog, S.P. Kearney, K.-J. Kim, W. Liu, A. Said, D. Shu, Yu. Shvyd'ko, D. Walko, J. Wang (ANL) M. Baldini, W. Yang (High Pressure Synergic Consortium, Advanced Photon Source) V.D. Blank, S. Terentiev (TISNCM) P. Rigg (Dynamic Compression Sector, Washington State University) S. Stoupin (Cornell University (CLASSE), Cornell Laboratory for Accelerator-Based Sciences and Education)

X-ray science has recently been considerably shaped by the advent of modern bright and powerful x-ray sources: 3rd generation synchrotron radiation storage rings and XFELs. XFELs in the oscillator configuration (XFELO) are possible future new sources, in which x-ray beams generated by the undulator circulate in an optical x-ray cavity comprised of high-reflectance (close to 100%) diamond crystal mirrors working in Bragg backscattering. XFELOs will produce stable, fully coherent hard x-rays of ultra-high (meV) spectral purity. The average power density of the x-ray beams in the XFELO cavity is however predicted to be unprecedentedly high, about ~15 kW/mm^2. Therefore, the XFELO feasibility relies on the ability of diamond to withstand such a high radiation load and preserve its high reflectivity. We are reporting on endurance studies of the highest-quality, practically flawless synthetic diamond crystals to irradiation with power density close to that expected on the XFELO crystals. Most importantly, we are studying whether the extremely high Bragg reflectivity of meV-monochromatic x-rays from the diamond crystals in backscattering is conserved after the irradiation.

Funding: Work at Argonne National Laboratory was supported by the U.S. Department of Energy, Office of Science, under Contract No. DE-AC02-06CH11357

High Precision Polarization Diagnostic System for Free-Electron Laser

MOP058

J. Yan, H. Hao, S.F. Mikhailov, V. Popov, G. Swift, Y.K. Wu (FEL/Duke University)

In the Duke storage ring FEL facility, an upgrade of the undulator system has created research opportunities to explore novel modes of storage ring FEL operation using as many as four helical undulators simultaneously. Recently, the generation of a linearly polarized FEL beam with the rotatable polarization direction has been realized using two sets of helical undulators of opposite helicities. To study and optimize this new FEL, high-precision polarization diagnostics are being developed to cover a wide range of wavelength from infrared (IR) to visible (VIS) to vacuum ultraviolet (VUV). In this work, we report the development of the first IR-VIS-UV polarization diagnostic system for Duke FEL operations from 1 micron to about 350 nm. This system is capable of measuring the FEL beam Stokes parameters using the extracted FEL beam. High precision measurements of FEL beam polarization have been demonstrated using a set of carefully calibrated optics.

MOP059

Synchronized Mid-Infrared Pulses at the Fritz Haber Institute IR-FEL

R. Kiessling, S. Gewinner, A. Paarmann, W. Schöllkopf, M. Wolf (FHI)

The combined application of FEL radiation and femtosecond table-top lasers for two-color spectroscopy demands an accurate pulse synchronization. In order to employ the Infared FEL at the Fritz Haber Institute for non-linear and time-resolved experiments, an RF-over-fiber-based timing system has been established. Using a balanced optical cross-correlation scheme, we determined an FEL micro-pulse timing jitter of 100-200 fs (rms). The long-term timing drift was found to be well correlated to the energy fluctuations of the accelerated electron bunches. By means of the jitter-corrected cross-correlation signal, we directly measure the FEL pulse shape at different cavity detunings. For large cavity detuning, narrowband IR radiation (~ 0.3 % FWHM) can be generated and utilized for high-resolution non-linear spectroscopy. On the other hand, sub-picosecond pulses are provided at small detuning, which are well-suited for time-resolved measurements. At intermediate detuning values, we observe the build-up and dynamics of multipulses that result in the well-known limit-cycle power oscillations.

MOP060

Broadband THz FEL Oscillator via Resonant Coherent Diffraction Radiation at ERL Test Accelerator in KEK

Y. Honda, A. Aryshev, R. Kato, T. Miyajima, T. Obina, M. Shimada, R. Takai, N. Yamamoto (KEK)

An Energy Recovery Linac can produce a low emittance and short bunch beam at a high-repetition rate. A test accelerator, compact-ERL, has been operating in KEK for development works of technologies related to ERL and CW-Superconducting accelerators. One of the promising applications of such a short bunch beam is a high-power THz radiation source produced by a coherent radiation. When a charged particle beam passes close to a conductive target, a radiation called diffraction radiation is produced. If the target mirrors form an optical cavity whose fundamental frequency matches the repetition frequency of the beam, the radiation resonates in the cavity, resulting in extracting a huge radiation power determined by the loss of the cavity. When the cavity is designed to be zero carrier envelope offset, all the longitudinal modes excite at the same time. This situation can be understood as an undulatory-less broadband FEL oscillator. We plan to perform an experiment of the resonant coherent diffraction mechanism in the return-loop of the compact-ERL. We report the design of the experimental setup to be installed in the summer of 2017.

MOP061

X-ray Regenerative Amplifier Free-Electron Laser Concepts for LCLS-II

G. Marcus, Y. Ding, J.P. Duris, Y. Feng, Z. Huang, J. Krzywinski, T.J. Maxwell, D.F. Ratner, T.O. Raubenheimer (SLAC) K.-J. Kim, R.R. Lindberg, Yu. Shvyd'ko (ANL) D.C. Nguyen (LANL)

High-brightness electron beams that will drive the next generation of high-repetition rate X-ray FELs allow for the possibility of optical cavity-based feedback. One such cavity-based FEL concept is the Regenerative Amplifier Free-Electron Laser (RAFEL). This paper examines the design and performance of possible RAFEL configurations for LCLS-II. The results are primarily based on high-fidelity numerical particle simulations that show the production of high brightness, high average power, fully coherent, and stable X-ray pulses at LCLS-II and the LCLS-II-HE upgrade using both the fundamental and harmonic FEL interactions.

MOP062

X-ray FEL Oscillator Seeded Harmonic Amplifier for High Energy Photons

W. Qin, J. Wu (SLAC) K.-J. Kim, R.R. Lindberg (ANL)

High-power, high-energy X-ray pulses in the range of several tens of keV have important applications for material sciences.* The unique feature of an X-ray FEL Oscillator (XFELO) makes it possible to seed a harmonic amplifier to produce such high energy photons.** In this contribution, we present simulation studies using 14.4-keV output pulses from an XFELO to generate harmonics around 40 keV (3rd harmonic) and

60 keV (4th harmonic). Techniques such as undulator tapering and fresh bunch lasing are considered to improve the amplifier performance.

** MaRIE project: http://www.lanl.gov/science-innovation/science-facilities/marie/. ** K.-J. Kim, XFELO-Seeded Amplifier, talk on MaRIE workshop, 2016.*

Considerations on X-ray FEL Oscillator Operation for the Shanghai Coherent Light Facility

MOP063

K. Li, H.X. Deng (SINAP)

Shanghai Coherent Light Facility (SCLF) is a quasi-CW hard X-ray free electron laser user facility which is recently proposed. Due to the high repetition rate and high quality electron beams, it is straightforward to consider an X-ray free electron laser oscillator (XFELO) operation for SCLF. The main parameters required for the undulator, X-ray cavity and electron beam for XFELO operation are discussed, and the performances of the expected fully coherent X-ray pulses are investigated and optimized by the combination of theoretical analysis and numerical simulation.

Integration of an XFELO at the European XFEL Facility

MOP064

P. Thiessen, I. Bahns, C.P. Maag, J. Rossbach (University of Hamburg, Institut für Experimentalphysik) W. Decking (DESY) H. Sinn (XFEL. EU)

An X-ray free-electron laser oscillator (XFELO) is a fourth generation x-ray source promising radiation with full three-dimensional coherence, nearly constant pulse-to-pulse intensity and an order of magnitude higher peak brilliance compared to SASE FELs. Proposed by Kim et al. in 2008, an XFELO follows the concept of circulating the light in an optical cavity - as known from FEL oscillators in longer wavelength regimes - but uses Bragg reflecting crystals instead of classical mirrors.* With the new European X-ray free-electron laser (XFEL) facility currently under commissioning, the realization of an XFELO with radiation in the Angstrom regime seems feasible. Though, the high thermal load of the radiation on the cavity crystals, the high sensibility of the Bragg-reflection on reflection angle and crystal temperature, as well as the very demanding tolerances of the at least 30-m long optical cavity pose challenges which need to be considered. In this work, the current status regarding the possible integration of an XFELO at the European XFEL facility shall be summarized. Also, first experimental results of the thermal characterization of the Bragg-reflectors shall be presented.

** K.-J. Kim, Y. Shvydko and S. Reiche, Phys. Rev. Lett. 100 (2008), 244802.*

Funding: Funding by BMBF (05K16GU4)

Analysis of a Free-Electron Lasers Oscillator Based on a Natural Gradient Undualtor

MOP065

Z. Zhao, Q.K. Jia, H.T. Li (USTC/NSRL)

Transverse Gradient Undulators (TGU) have been proposed to mitigate the gain degradation in free electron laser (FEL) oscillators driven by beams with a large energy spread. However, a special-designed TGU with a fixed transverse gradient is required to enhance the gain. Therefore, we investigate using a normal planar undulator with the natural field gradient instead of a TGU. In this method, a vertical dispersion on the beam is introduced and then the dispersed beam passes through a normal undulator with a vertical off-axis orbit. The reasonable selection of dispersion strength and vertical field gradient can improve the FEL performance. Comparing with the TGU, using the natural gradient planar undulator has a distinct advantage that the gradient can be conveniently tuned in a quite large range by adjusting the beam orbit offset. This paper presents theoretical analysis and numerical simulations based on parameters of FELiChEM, which is an infrared FEL user facility under construction in Hefei.

TUA — SASE FELs

TUA01

Recent FEL Experiments at FLASH

S. Schreiber, E. Schneidmiller, M.V. Yurkov (DESY)

The FLASH free-electron laser user facility at DESY (Hamburg, Germany) provides high brilliance SASE FEL radiation in the XUV and soft X-ray wavelength range. With the recent installation of a second undulator beamline (FLASH2), variable-gap undulators are now available. They now allow various experiments not possible with the FLASH1 fixed gap undulators. We report on experiments on tapering, harmonic lasing, reverse tapering, frequency doubling at FLASH2 and experiments using double pulses for specific SASE and THz experiments at FLASH1.

TUA02

Design and Modelling of the Baseline Layout for the Soft X-Ray Laser (SXL) at MAX IV Laboratory

F. Curbis, S. Werin (MAX IV Laboratory, Lund University)

The Soft X-ray Laser (SXL) is a project aiming to build a new beamline that will exploit the potential of the MAX IV 3 GeV linac and its Short Pulse Facility (SPF). In fact, this injector, which is routinely used as an electron source for the two rings in the laboratory, is capable of delivering ultra-brilliant electron pulses and possibly driving a Free Electron Laser (FEL). While the necessary technical improvements and features of the linac are described in another contribution, this paper presents the baseline layout of the SXL FEL and point out the features of the photon source that should deliver brilliant pulses between 1 and 5 nm. The baseline design consists of a SASE FEL with variable polarization undulators. However, the plan is to develop a comprehensive system of external sources at various wavelength in order to enable various pump-probe schemes, thereby satisfying the requests of the users community. Moreover the design needs to take into account the possibility of accommodating two-pulse-two-color capability and the production of femtosecond or even attosecond pulses.

TUA03

Generation of High Power, Short X-Ray FEL Pulses

M.W. Guetg (SLAC)

X-ray Free Electron Lasers combine high pulse power, short pulse length, narrow bandwidth and a high degree of transverse coherence. Increasing the photon pulse power, while shortening the pulse length, is of key importance on the way to single molecule imaging. This letter shows experimental results at the Linac Coherent Light Source improving its power to more than 300 GW, while reducing the photon pulse length to 10fs. This was achieved by removing residual transverse-longitudinal centroid beam offsets and correction of dispersion when operating over 6 kA peak current.

TUA04

Suppression of the CSR Effects at a Dogleg Beam Transport Using DBA Lattice

T. Hara, T. Inagaki, C. Kondo, Y. Otake, H. Tanaka, K. Togawa (RIKEN SPring-8 Center) K. Fukami (JASRI/SPring-8) S. Nakazawa (SES)

Multi-beamline, multi-user operation is an important issue of linac-based XFELs to improve usability and efficiency of facilities. At SACLA, the multi-beamline operation had been tested since 2015 using two beamlines (BL2 and BL3). But the CSR effects at a 3-degree dogleg beam transport of BL2 caused a projected emittance growth and instability of the beam orbit due to a high peak current of 10 kA and a short bunch duration of SACLA. Consequently, stable lasing was obtained only for elongated electron bunches with low peak currents below 3 kA. To mitigate the CSR effects, the beam optics of the dogleg was rearranged. The new beam optics are based on two DBA (double bend achromatic) structures and the transverse effects of CSR are cancelled between four bending magnets. To avoid the bunch length change, the electron beam passes an off-center orbit at the quadrupole magnets of DBA. Under the new beam optics, stable lasing has been successfully obtained with 10 kA electron bunches, and the parallel operation of the two beamlines will be started in September 2017 for user experiments.

Generating Subfemtosecond Hard X-Ray Pulses with Optimized Nonlinear Bunch Compression

S. Huang (PKU) Y. Ding, Y. Feng, Z. Huang, J. Krzywinski, A.A. Lutman, A. Marinelli, T.J. Maxwell, D. Zhu (SLAC)

A simple method for generating single-spike hard x-ray pulses in free-electron lasers (FELs) has been developed at the Linac Coherent Light Source (LCLS). By optimizing the electron bunch compression in experiments, we have obtained half of the hard x-ray FEL shots containing single-spike spectrum. At 5.6-keV photon energy, the single-spike shots have a mean pulse energy of about 10 J with 70% intensity fluctuation and the pulse width (full width at half maximum) is evaluated to be at 200-attosecond level.

Funding: This work is supported by the U.S. Department of Energy Contract No. DE-AC02-76SF00515 and the National Key Research and Development Program of China (Grant No. 2016YFA0401904).

TUB — Seeded FELs

TUB01

Seeding Experiments and Seeding Options for LCLS II

E. Hemsing (SLAC)

We discuss the present status of FEL seeding experiments toward the soft x-ray regime and on-going studies on possible seeding options for the high repetition soft x-ray line at LCLS-II. The seeding schemes include self-seeding, cascaded HGHG, EEHG, and possible hybrid methods to reach the 1-2 nm regime with the highest possible brightness and minimal spectral pedestal. We describe relevant figures of merit, performance expectations, and potential issues.

TUB02

Fresh Slice Self-Seeding and Fresh Slice Harmonic Lasing at LCLS

C. Emma, C. Pellegrini (UCLA) J.W. Amann, M.W. Guetg, J. Krzywinski, A.A. Lutman, C. Pellegrini, D.F. Ratner (SLAC) D.C. Nguyen (LANL)

We present results from the successful demonstration of fresh slice self-seeding at the Linac Coherent Light Source (LCLS).* The performance is compared with SASE and regular self-seeding at photon energy of 5.5 keV, resulting in a relative average brightness increase of a factor of 12 and a factor of 2 respectively. Following this proof-of-principle we discuss the forthcoming plans to use the same technique** for fresh slice harmonic lasing in an upcoming experiment. The demonstration of fresh slice harmonic lasing provides an attractive solution for future XFELs aiming to achieve high efficiency, high brightness X-ray pulses at high photon energies (>12 keV).***

** C. Emma et al., Applied Physics Letters, 110:154101, 2017. ** A. A. Lutman et al., Nature Photonics, 10(11):745-750, 2016. *** C. Emma et al., Phys. Rev. Accel. Beams 20:030701, 2017.*

TUB03

ASU Compact XFEL

W.S. Graves, J.P.J. Chen, M.R. Holl, R. Kirian, L.E. Malin, K.E. Schmidt, J. Spence, U. Weierstall, C. Zhang (Arizona State University) K.-H. Hong, D.E. Moncton (MIT) C. Limborg-Deprey, E.A. Nanni (SLAC)

ASU is pursuing a concept for a compact x-ray FEL (CXFEL) that uses nanopatterning of the electron beam via electron diffraction and emittance exchange to enable fully coherent x-ray output from electron beams with an energy of a few tens of MeV. This low energy is enabled by nanobunching and use of a short-pulse laser field as an undulator, resulting in an XFEL with 10 m total length and modest cost. The method of electron bunching is deterministic and flexible, rather than dependent on SASE amplification, so that the x-ray output is coherent in time and frequency. The phase of the x-ray pulse can be controlled and manipulated with this method so that new opportunities for ultrafast x-ray science are enabled using e.g. attosecond pulses, very narrow linewidths, or extremely precise timing among multiple pulses with different colors. These properties may be transferred to large XFELs through seeding with the CXFEL beam. Construction of the CXFEL accelerator and laboratory are underway, along with initial experiments to demonstrate nanopatterning via electron diffraction. An overview of the methods, project, and new science enabled are presented.

Funding: This work was supported by NSF Accelerator Science award 1632780, NSF BioXFEL STC award 1231306 and DOE contract DE-AC02-76SF00515.

TUB04

Recent On-Line Taper Optimization on LCLS

J. Wu, X. Huang, T.O. Raubenheimer (SLAC) A. Scheinker (LANL)

High-brightness XFELs are demanding for many users, in particular for certain types of imaging applications. Self-seeding XFELs can respond to a heavily tapered undulator more effectively, therefore seeded tapered FELs are considered as a path to high-power FELs in the terawatts level. Due to many effects, including the synchrotron motion, the optimization of the taper profile is intrinsically multi-dimensional and computationally expensive. With an operating XFEL, such as LCLS, the on-line optimization becomes more economical than numerical simulation. Here we report recent on-line taper optimization on LCLS taking full advantages of nonlinear optimizers as well as up-to-date development of artificial intelligence: deep machine learning and neural networks.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

First Demonstration of Fully Coherent Super-Radiant Pulses From a Short-Pulse Seeded FEL

X. Yang (BNL) L. Giannessi (Elettra-Sincrotrone Trieste S.C.p.A.)

The generation of a single X-ray isolated spike of radiation with peak power at the GW level and femtosecond temporal duration represents an almost unique opportunity for time-resolved non-linear spectroscopy. Such a condition is met by an FEL operating in superradiance. The resulting pulse has a self-similar shape deriving from the combined dynamics of saturation and slippage of the radiation over fresh electrons. The pulse is followed by a long pedestal, resulting from the complex dynamics occurring in the tail after saturation. This tail consists of a train of pulses with both transverse and longitudinal coherence and decaying amplitudes. We analyze the dynamical conditions on slippage and pulse length leading to the formation of the main pulse and the following tail. We study the correlation of the tail structure with the longitudinal phase space of the e-beam and provide recipes to partially suppress it near the background level leading to the fully coherent super-radiant pulse. Our analytical prediction of the intensity peak of the leading pulse evolving along the undulator before, during, and after becoming a super-radiant pulse agrees well with the simulations.

TUC — FEL Oscillators

TUC01

Polarization Control of Storage Ring FELs Using a Cross-Polarized Helical Undulator

J. Yan, H. Hao, S.F. Mikhailov, V. Popov, Y.K. Wu (FEL/Duke University)

For more than two decades, accelerator researchers have been working to gain control of polarization of synchrotron radiation and FELs using non-optical means. In 2005, the first experimental demonstration of polarization control of an FEL beam was realized with the Duke storage-ring FEL. With the recent upgrade of the undulator system, the Duke FEL can be operated with up to four helical undulators simultaneously. Using two sets of helical undulators with opposite helicities, for the first time, we have demonstrated full polarization control of a storage ring FEL. First, the helicity switch of the FEL beam has been realized with good lasing up to a few Hz. Second, the linearly polarized FEL beam has been generated with a high degree of polarization ($P_{lin} > 0.95$). The FEL polarization direction can be fully controlled using a buncher magnet. Furthermore, the use of non-optical means to control the FEL polarization allows us to extend polarization control to gamma-ray beams generated using Compton scattering. This has been experimentally demonstrated with the production of linearly polarized Compton gamma-ray beams with rotatable polarization direction based upon helical undulators.

TUC02

Thermal and Mechanical Stability of Bragg Reflectors for an XFELO

I. Bahns, C.P. Maag, J. Rossbach, P. Thiessen (University of Hamburg, Institut für Experimentalphysik) W. Decking (DESY) H. Sinn, V. Sleziona (XFEL. EU)

The European XFEL is under commissioning, the first lasing was achieved in May 2017. Soon this facility will deliver up to 27000 photon pulses 1/s, in 600 μs long bunch trains with a repetition rate of 10 Hz*. These conditions give the possibility for the realization of an x-ray free-electron laser oscillator (XFELO)**. With the integration of an XFELO at the XFEL longitudinally full coherent pulses and an increase of the peak brilliance by one order of magnitude should be achievable. However, under these radiation conditions the thermal and mechanical stability of Bragg reflectors, which are necessary for the XFELO, have to be considered in detail. Therefore analytical and numerical calculations of the thermoelastically introduced strain and of the force introduced by radiation pressure by the incoming X-ray radiation on a diamond crystal have been carried out. The results of these calculations give a first impression which temporal changes of the lattice parameter and which deflection of a clamped diamond crystal are expected. An experimental setup for the investigation on thermal/mechanical properties of diamond crystals will be discussed and first results will be presented.

** Altarelli, M. and Mancuso, A. P. (2014). Phil. Trans. R. Soc. B, 369(1647), 20130311 ** Kim, K. J., Shvyd'ko, Y., and Reiche, S. (2008). Physical Review Letters, 100(24), 244802*

Funding: BMBF FKZ 05K16GU4

High-Flux, Fully Coherent X-Ray FEL Oscillator

TUC03

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By optimizing the parameters of the accelerator, undulator, and the optical cavity, an XFELO driven by an 8-GeV superconducting linac is predicted to produce 10^{10} photons per pulse at the important photon energies around 14.4 keV.* This is an order of magnitude larger than that in previous designs.** With a BW of 3 meV (FWHM), rep rate of 1 MHz, and taking into account the full coherence, the spectral brightness is then 2×10^{26} photons per ($mm^2 mr^2 \times 0.1\%$ BW), which is higher than any other source currently operating or anticipated in the future. Experiments at APS beam lines have shown that a high-quality diamond crystal can survive the power density (~15 kW/mm2) expected at the XFELO intra-cavity crystals preserving the high reflectivity.*** The compound refractive lenses can serve as the focusing element. Adding an XFELO to the suite of other FEL sources will, at a minor incremental cost but with a major scientific payoff, significantly expand the scientific capabilities at superconducting linac-based XFEL facilities, such as the European XFEL, the proposed LCLS-II High Energy upgrade and the XFEL project in Shanghai.

** W. Qin et al., this conference. ** R.R. Lindberg et al., Phys. Rev. ST Accel. Beams, vol 14, 403 (2011). *** T. Kolodziej et al., this conference.*

Funding: The ANL part of this work is supported by the U.S. DOE Office of Science under Contract No. DE-AC02-06CH11357 and the SLAC part under contract No. DE-AC02-76SF00515.

Enhancement of Radiative Energy Extraction in an FEL Oscillator by Post-Saturation Beam Energy Ramping

TUC04

H. S. Marks, A. Gover (University of Tel-Aviv, Faculty of Engineering) E. Dyunin, Yu. Lurie (Ariel University)

We present experimental results showing a greater than 50% increase in post-saturation radiation power extraction from a Free Electron Laser oscillator based on an electrostatic accelerator. Electrostatic accelerator free electron laser oscillators have the potential for CW operation. Present day operating oscillators rely on long pulses of electrons, tens of microseconds in duration; they generate correspondingly long radiation pulses, at a single longitudinal mode after a mode competition process. The presented post-saturation power extraction enhancement process is based on temporal tapering (up-ramping) of the beam energy, enabling a large synchrotron oscillation swing of the trapped electron bunches in passage along the interaction length. We further discuss the theoretical limits of the temporal tapering efficiency enhancement process.

Start-to-End Simulations for an X-Ray FEL Oscillator at the LCLS-II

TUC05

W. Qin, K.L.F. Bane, Y. Ding, Z. Huang, G. Marcus, T.J. Maxwell (SLAC) S. Huang, K.X. Liu (PKU) K.-J. Kim, R.R. Lindberg (ANL)

The proposed high repetition-rate electron beam from the LCLS-II and LCLS-II High Energy (LCLS-II-HE) upgrade are promising sources as drivers for an X-ray FEL Oscillator (XFELO) operating at both the harmonic and fundamental frequencies. In this contribution we present start-to-end simulations for a 14.4 keV XFELO operating at the fifth harmonic with 4 GeV LCLS-II beam and at the fundamental with 8 GeV LCLS-II-HE beam. The electron beam longitudinal phase space is optimized by shaping the photoinjector laser and adjusting various machine parameters. The XFELO simulations show that high-flux output radiation pulses with 10^{10} photons and 3 meV (FWHM) spectral bandwidth can be obtained with the 8 GeV configuration.

TUP — Poster II

TUP001

Conceptual Design of Electron Beam Line for `LWFA-Driven' Free-Electron Laser

A.Y. Molodozhentsev, G. Korn, L. Pribyl (Czech Republic Academy of Sciences, Institute of Physics)

Free-electron lasers (FEL) are unique light sources for different applications on the femtosecond scale, including the most basic reaction mechanisms in chemistry, biology and matter physics. Laser wake field acceleration (LWFA) opens a new way to develop compact 'laser-based' FEL. A dedicated electron beam line from a LWFA source to an undulator is required to preserve unique parameters of the electron beam. In the frame of this paper, we discuss the main features of the electron beam line, which should deliver the electron beam to the undulator for the 'FEL-demonstration' experiment. The effects of laser-pointing jitter, 'shot-to-shot' variation of initial beam parameters, the space charge, and the coherent and incoherent synchrotron radiation in a decompressor have been analyzed. The FEL power has been simulated for different strengths of the bending magnets of the decompressor. A successful demonstration of the laser-driven FEL regime would open a new perspective in the development of FEL producing femtosecond photon bunches for a very wide user community.

Funding: This work was supported by the project ELI - Extreme Light Infrastructure - phase 2 (CZ.02.1.01/0.0/0.0/15$_0$08/0000162) from European Regional Development Fund.

TUP002

Numerical Studies on RF-Induced Trajectory Variations at the European XFEL

T. Hellert, B. Beutner, W. Decking, N. Walker (DESY)

At the European X-Ray Free-Electron Laser, superconducting TESLA-type cavities are used for acceleration of the driving electron bunches. Due to the high achievable duty cycle, a long radio frequency (RF) pulse structure can be provided, which allows to operate the machine with long bunch trains. The designated pointing stability of the FEL radiation places stringent restrictions on the acceptable trajectory variations of individual electron bunches. Therefore a transverse intra-bunch-train feedback system (IBFB) is located upstream of the undulator section. However, intra-bunch-train variations of RF parameters and misalignment of RF structures induce significant trajectory variations that may exceed the capability of the IBFB. In this paper we give an estimate of the expected RF-induced intra-bunch-train trajectory variations for different machine realizations and investigate methods for their limitation.

TUP003

First Beam Halo Measurements Using Wire Scanners at European XFEL

S. Liu, W. Decking, L. Froehlich (DESY)

Beam halo measurements and collimation are of great importance at the European XFEL, especially for the operation at high-repetition rates (27,000 pulses/s). First beam halo measurements will be performed during the commissioning using wire scanners installed before and after the ~200 m long post-linac collimation section with different collimation optics. We will present the measurement results and the comparison of beam halo distributions under different collimation conditions.

TUP004

Longitudinal Phase-Space Optimization for the Hard X-ray Self-Seeding

S. Liu, B. Beutner, W. Decking, M. Dohlus, G. Feng, V. Kocharyan, M. Scholz, I. Zagorodnov (DESY) G. Geloni (XFEL. EU) S. Serkez (European XFEL)

For the demonstration of Hard X-ray Self-Seeding (HXRSS) at European XFEL, short electron beam bunches ($\leq$ 50 fs) are preferred to mitigate spatio-temperal coupling effect and to fit to the seeding bump width. Therefore, operations with low charges ($\leq$ 250 pC) are preferred. Longitudinal phase space optimization have been performed and will be measured for the 100 pC case during the commissioning of the European XFEL. We will present the S2E simulations with HXRSS as well as the longitudinal phase space measurements results for the 100 pC case.

Studies of the Transverse Beam Coupling in the European XFEL Injector

TUP005

M. Scholz, B. Beutner (DESY)

Coupling of the transverse plains leads to increased emittances. The coupling between plains can be studied with dedicated scans of several quadrupole magnets while the x-y correlation is observed on a screen. In this paper we show the results from coupling studies in the European XFEL injector and in the diagnostic sections downstream the two bunch compressors.

S2e Simulations with OCELOT for the European XFEL

TUP006

S.I. Tomin, G. Geloni (XFEL. EU) I.V. Agapov, M. Dohlus, S. Liu, I. Zagorodnov (DESY) Y.A. Fomin (NRC)

OCELOT is an open source toolkit for beam dynamics and free electron laser simulations written in Python. Recently, the main collective effects (space charge, coherent synchrotron radiation, wakefield) were implemented in OCELOT and the code was cross-checked with existing codes. In this work, we will present the results of simulations of the European XFEL obtained with OCELOT. The code was used for optimization of the electron beam parameters.

Start-to-End Simulation for a Linac Driving Compact THz FEL Facility at HUST

TUP007

G. Feng (DESY) , T. Hu (HUST)

A compact THz FEL facility has been installed in HuaZhong University of Science and Technology (HUST). This machine consists of an independently tunable RF gun, a traveling-wave linac that works in S band, and a beam transport line with an arc section and an FEL oscillator. The FEL oscillator includes an undulator section and an optical resonator. From the FEL system, THz radiation with wavelengths from 30 micrometers to 120 micrometers will be generated. In the paper, a start-to-end simulation for this machine is presented, which includes beam dynamics simulation as well as radiation simulation. In the simulation, collective effects, such as space charge and coherent synchrotron radiation, have been taken into account. At present, the linac commissioning is ongoing. An electron beam with good properties has been obtained as expected. The results of beam diagnostics are in good agreement with the beam dynamics simulation results. As what we planned before, radiation commissioning will be started in the next months.

Parmela Code (Re-)Development Update

TUP008

L.D. Duffy, B.E. Carlsten, F.L. Krawczyk, X. Pang, L. Rybarcyk (LANL)

The design of modern accelerator systems for free-electron lasers and colliders requires high-fidelity beam dynamics simulations. The Parmela code has long been a tool for accelerator beamline design, but was written before modern computing capabilities, such as multi-core processors and graphics processing units, were available. At LANL, we are now in the process of modernizing the Parmela code. The first step is to transfer the code to a modern form in C++, with the end goal of parallelizing the code to fully utilize multi-core desktop computers. We report here on progress on the initial version of Parmela in C++.

The Effect of Transverse Space Charge on Beam Evolution and Longitudinal Coherence in an XFEL

TUP009

Q.R. Marksteiner (LANL)

An electron beam experiences a transverse electric field which tends to act like a defocusing force on the electron beam. This defocusing force will act with different strengths at different locations in the electron beam because the current varies along the beam. A simple, quasi-analytic method is presented to calculate the impact of this force on beam projected emittance. In addition, estimates are made regarding the degree to which this could degrade the transverse coherence of x-rays in an XFEL.

TUP010

Double-Bunches for Two-Color Soft X-Ray Free-Electron Laser at the MAX IV Laboratory

J. Björklund Svensson, O. Lundh (Lund University) J. Andersson, F. Curbis, M. Kotur, F. Lindau, E. Mansten, S. Thorin, S. Werin (MAX IV Laboratory, Lund University)

The ability to generate two-color free-electron laser (FEL) radiation enables a wider range of user experiments than just single-color FEL radiation. There are different schemes for generating the two colors, the original being to use a single bunch and two sets of undulators with different K-parameters. A development of the scheme has recently been shown, where two separate bunches in the same RF bucket are used for lasing at different wavelengths. We here investigate the feasibility of accelerating and compressing a double-bunch time structure generated in the photocathode electron gun for subsequent use in a soft X-ray FEL at the MAX IV Laboratory.

TUP011

Ultra-High Intensity Electron Beam Generation Using a Positive R56 Bunch Compressor

B. Li (USTC/NSRL)

Because of the space charge effects in the section of photoinjector, the output electron beam has a negative energy chirp. In order to compress such a beam to the sub-picosecond range directly, we design a positive R56 bunch compressor with several quadrupoles inserted in the four-dipole chicane. We apply Elegant to carry out the multi-objective optimization procedure of the whole scheme. IMPACT-T and CSRtrack are applied to consider the space charge and CSR effects. The simulation results show that ultra-short (~155 fs RMS) with 0.8 nC charge, ultra-high brightness (~5000 A peak current)) can be obtained.

TUP012

Preparation for the Two-Color FEL Experiment at SXFEL

W.Y. Zhang, C. Feng, B. Liu, Z. Qi (SINAP)

Generation of double ultra-short radiation pulses with different carrier wavelengths in the x-ray regime is of remarkable interest in the FEL user community. Applications exist over a broad range of wavelengths involving pump-probe experiments. This paper presents the design studies for the two-color FEL experiment at the Shanghai soft x-ray FEL test facility. An optical system has been built to produce the double pulse two-color seed laser. We show the design and measurement results of this seed laser system.

TUP013

Experience and Initial Measurements of Magnetics Linearization in the MAX IV Linac Bunch Compressors

S. Thorin (MAX IV Laboratory, Lund University)

The MAX IV Linac is now in routine operation for injection into two storage rings, and as a high-brightness driver for a Short Pulse Facility (SPF). In short-pulse mode the electron bunch is created in a photo cathode gun and compressed in two double achromat bunch compressors that also linearize longitudinal phase space with the second order transfer matrix element T566. T566 in the compressors can be tweaked with weak sextupoles located at high dispersion. In this paper we present the current experience from operating the bunch compressors at MAX IV and results from initial measurements of longitudinal phase space using the zero-crossing method.

Dynamics of Electron in TEM Wave Field

TUP014

V.O. Shpagina (NSC/KIPT)

Large amounts of works deal with solutions of differential equations associated with electron motion in electromagnetic field, using methods of classical electrodynamics. The proposed work differs in that, when getting the solution of an equation of electron motion in TEM wave in a laboratory coordinate system, the theory of almost periodic functions is used. This gives an opportunity to get precise formulas of electron coordinates and rates in a form of explicit functions of time. The received formulas are suitable for analyses of electron dynamics in the fields of both low- and high-field intensity. In the present work, the formulas are given for electron rate projections on coordinate axis in TEM wave field, which are the functions of the wave generalized phase, and were received as a result of integration of a dynamics differential equation.

Coherent Transition Radiation Observed from Transversely Modulated Electron Beams

TUP015

A. Halavanau (Northern Illinois University) S.P. Antipov (ANL) A.I. Benediktovitch (BSU) S.N. Galyamin, A.V. Tyukhtin (Saint Petersburg State University)

Transverse laser-shaping optical setup using microlens arrays (MLAs), previously developed and employed at Argonne Wakefield Accelerator (AWA), allows formation of both highly uniform and modulated (patterned) beams. In the latter case, transverse modulation is imposed in the sub-millimeter scale. In the present study we report the measurement of coherent transition radiation (CTR) emitted from such a transversely modulated beam. We compare the case of a uniform round beam against different transverse modulation wavelengths, by generating CTR on an aluminum target and measuring the autocorrelation function of the resulting radiation with an interferometer. We particularly focus on the difference between round and patterned beam distributions and discuss possible future applications of this setup in THz radiation generation.

Beam-Dynamics Analysis of Long-Range Wakefield Effects on SCRF Cavities at the FAST Facility

TUP016

Y.-M. Shin (Northern Illinois University) K. Bishofberger, B.E. Carlsten, F.L. Krawczyk (LANL) A.H. Lumpkin, J. Ruan, R.M. Thurman-Keup (Fermilab)

Long-range wakefields in SCRF cavities create complicated effects on beam dynamics in SCRF-based FEL beamlines. The driving bunch excites effectively an infinite number of structure modes (including HOMs) which oscillate within the SCRF cavity. Couplers with loads are used to damp the HOMs; however, these HOMs can persist for long periods of time in superconducting structures, which leads to long-range wakefields. Clear understanding of the long-range wakefield effects is a critical element for risk mitigation of future superconducting accelerators such as XFEL at DESY, LCLS-II XFEL, and MaRIE XFEL. We are currently developing a numerical tool for simulating long-range wakefields in SCRF accelerators and plan to experimentally verify the tool by measuring these wakefields at the FAST facility. The particle-in-cell (PIC) simulation model designed with the FAST 50 MeV beamline indicates strong bunch-by-bunch variations of beam parameters with the operating conditions of 1, 3, 4.5, and 9 MHz bunch rep-rates along a macro-pulse and 500 pC, 1 nC, and 2 nC per bunch. The simulation results will be presented in comparison with experimental data to be measured at the 50 MeV beamline.

Beam Manipulation Using Self-Induced Fields in the SwissFEL Linac

TUP017

S. Bettoni, P. Craievich, R. Ganter, P. Heimgartner, H. Joehri, F. Marcellini, S. Reiche (PSI)

Several possibilities of manipulating the electron beam using sources of wakefield are being explored. Longitudinal wakefield has been successfully used to remove the energy chirp residual from the magnetic compression (dechirper) and to generate more bunches to produce two-color free electron laser beams or to produce beams suitable for

THz generation. Transverse wakefield has been used to passively streak the beam as an alternative way to diagnose the beam longitudinal profile. At SwissFEL, we plan to install at the injector a 2-m long system to accommodate sources of wakefield with different periodicities. We plan to test a geometry corresponding to the design of the dechirper for SwissFEL, continue the activities of passive streaking the beam using the transverse wakefield, and generate two bunches to produce two-color mode for SwissFEL and wakefield acceleration using a second source of wakefield installed downstream of the machine. In this paper we summarize the design of the system and the planned activities.

TUP018

High Resolution Method for Uncorrelated Energy Spread Measurement

S. Bettoni, S. Reiche (PSI)

The beam uncorrelated energy spread is a key quantity to characterize the electron bunch, especially in FEL facilities. This quantity is expected to be between 1 and 3 keV at the end of a typical photo-injector. A method based on the analysis of a streaked beam in a dispersive section does not typically reach the necessary resolution. A different approach, based on the coherent harmonic generation, demonstrated the capability of reaching a resolution in the range of a few keV. Following this idea, we propose to use the laser of the laser heater to generate a time-energy modulation on the beam and to measure the bunching downstream of a compressor as a function of the dispersion to determine the uncorrelated energy spread. We discuss here the validation of the method, after applying the reconstruction technique to the simulations of the measurements. We determine a discrepancy between the assumed and the reconstructed uncorrelated energy spread, which is below the order of 0.5 keV.

TUP019

High Energy Tunable THz Source Based on Wakefield Excitation

S. Bettoni, P. Craievich, F. Marcellini, S. Reiche, V. Schlott (PSI)

We plan to use the interaction of a beam optimized for the generation of FEL radiation with a dielectric waveguide as a pump source for pump and probe experiments in FEL facilities. This scheme provides several advantages to fulfill the user requirements for a radiation source, in particular synchronization with the hard x-ray pulses, tunability throughout the THz frequency range of interest and energy level. We present the optimization of this scheme for SwissFEL, where optimized beam optics matches into a small aperture dielectric waveguide allowing for the highest THz radiation energy. We also propose a method to further increase the THz radiation energy at higher frequencies by shaping the electron bunch.

TUP020

Optimization of PAL-XFEL's 3 Bunch Compressor Linac

H.-S. Kang, H. Heo, C. Kim, C.-K. Min, H. Yang (PAL) D. Khan, T.O. Raubenheimer, J. Wu (SLAC)

The Pohang Accelerator Laboratory X-Ray Free Electron Laser (PAL-XFEL) consists of a 10 GeV normal-conducting linac delivering an electron bunch to two undulator beamlines and FEL radiation between 0.1 nm (Hard XRay) and 4.5 nm (Soft X-Ray). To provide high quality FEL lasing, it is paramount to optimize the linac settings under the consideration of the collective effects a beam may experience during transport to the undulator. The PAL-XFEL linac consists of four S-band linac sections, an X-band harmonic linearizer proceeding the first linac section, and a three chicane bunch compression system (the very first of its kind in operation). The addition of the third bunch compressor opens the possibility of heightened mitigation of CSR during compression and an increased flexibility of system configuration. In this paper, we outline a procedure to optimize the PAL-XFEL linac under several compression configurations using the particle tracking code Elegant and present its results.

Simulation Study of Bunch Compressing Optimization with 2 Bunch Compressors in Hard X-Ray Line of PAL-XFEL

TUP021

H. Yang (PAL)

PAL-XFEL consists of the hard x-ray (HX) line with 4-10 GeV electron beam and the soft x-ray (SX) line with 3-3.5 GeV electron beam. The HX linac consists of four sections of S-band accelerating columns, three bunch compressors, an X-band linearizer, and a dog-leg line. The HX line generates 0.1 nm FEL with 9.6-GeV and 140-pC electron beam. The electron bunch is compressed to 2.5 kA with 2 bunch compressors. We conduct electron and FEL simulations for optimizing the bunch compressing with the operation condition. The e-beam parameters at the undulator entrance are obtained with various bunching angles and RF phases which produce the target beam current and energy spread by ELEGANT code. The results of ELEGANT are converted to the GENSIS input parameters for simulation of the FEL generation. In this paper, we present the details of the simulation procedure and optimized condition of the bunch compressing.

Funding: This work is supported by MSIP, Korea.

Modeling and Optimization of the APS Photo-Injector Using OPAL for High-Efficiency FEL Experiments

TUP022

C.C. Hall, D.L. Bruhwiler, S.D. Webb (RadiaSoft LLC) A.Y. Murokh (RadiaBeam) P. Musumeci, Y. Park (UCLA) Y. Sun, A. Zholents (ANL)

The Linac Extension Area (LEA) is a new beamline planned as an extension of Argonne's APS linac. An S-band 1.6-cell copper photo-cathode (PC) RF gun has been installed and commissioned at the APS linac front end. The PC gun will provide a beam to the LEA for accelerator technology development and beam physics experiments, in interleaving with a thermionic RF gun which provides a beam for APS storage ring operations. Recently an experiment was proposed to demonstrate the TESSA high-efficiency concept at LEA. In support of this experiment, we have begun simulating the photo-injector using the code OPAL (Object-oriented Particle Accelerator Library). In this paper, we first benchmark OPAL simulations with the established APS photo-injector optimization using ASTRA and ELEGANT. Key beam parameters required for a successful high-efficiency TESSA demonstration are explored, and we report the optimization results for the photo-injector and the APS linac to achieve the high peak current, high brightness electron beam needed for the TESSA at 375-MeV beam energy.

Funding: This work was carried out with support for the United State Department of Energy, Office of Scientific Research, under SBIR contract number DE-SC0017161.

Recent Development and Plans to get Two Bunches with up to 1-Microsecond Separation at LCLS

TUP023

F.-J. Decker, K.L.F. Bane, W.S. Colocho, A.A. Lutman, J.C. Sheppard (SLAC)

To get two electron bunches with a separation of up to 1 microsecond at the Linac Coherent Light Source (LCLS) is important for LCLS-II developments. Two lasing bunches up to 220 ns have been demonstrated. Many issues have to be solved to get that separation increased by a factor of 5. The typical design and setup for one single bunch has to be questioned for many devices: RF pulse widths have to be widened, BPMs diagnostic can see only one bunch or a vector average, feedbacks have to be doubled up, the main Linac RF needs to run probably un-SLEDed, and special considerations have to be done for the Gun and L1X RF.

Funding: Work supported by U.S. Department of Energy, Contract DE-AC02-76SF00515.

TUP024

Stochastic Effects from Classical 3D Synchrotron Radiation

B.W. Garcia, T.O. Raubenheimer (SLAC) R.D. Ryne (LBNL)

In most cases, the one-dimensional coherent synchrotron radiation wakefield gives an excellent approximation to the total coherent effect due to classical synchrotron radiation in bend magnets. However, full particle Liénard-Wiechert simulations have revealed that there is non-numerical, stochastic noise which generates fluctuations about the approximate 1D solution. We present a model for this stochastic term in which this noise is due to long-range interaction with a discrete number of synchrotron radiation cones. The nature of this noise and how it depends on the 3D dimensions of the beam are explored.

TUP025

Beam Shaping to Improve the Free-Electron Laser Performance at the Linac Coherent Light Source

Y. Ding, K.L.F. Bane, W.S. Colocho, F.-J. Decker, P. Emma, J.C. Frisch, M.W. Guetg, Z. Huang, R.H. Iverson, J. Krzywinski, H. Loos, A.A. Lutman, T.J. Maxwell, H.-D. Nuhn, D.F. Ratner, J.L. Turner, J.J. Welch, F. Zhou (SLAC)

A new operating mode has been developed for the Linac Coherent Light Source (LCLS) in which we shape the longitudinal phase space of the electron beam. This mode of operation is realized using a horizontal collimator located in the middle of the first bunch compressor to truncate the head and tail of the beam. With this method, the electron beam longitudinal phase space and current profile are re-shaped, and improvement in lasing performance can be realized. We present experimental studies at the LCLS of the beam shaping effects on the free electron laser performance.

TUP026

Dispersion Based Fresh Slice Scheme

M.W. Guetg (SLAC)

This paper presents experimental studies of the dispersion based fresh slice scheme at LCLS. This scheme lead to pulse shortening resulting in pulse lengths below 10 fs. Careful orbit control allowed generating two colors with individual delay control and color separation of more than 3%. Unlike the dechirper based fresh slice scheme, the dispersion based fresh slice scheme does not require additional hardware. Another key benefit of this scheme is a strong spectral stability making the photon pulse energy independent of the electron energy jitter.

TUP027

Cancellation of Coherent Synchrotron Radiation Kicks at LCLS

D. Khan, T.O. Raubenheimer (SLAC)

In this paper, we look at the cancellation of Coherent Synchrotron Radiation (CSR) induced emittance growth using a phase-advance manipulation technique pioneered by R. Hajima, and extended in the Courant-Snyder formalism by S. Di Mitri. Bending systems in a linear accelerator are essential for beam transport and bunch compression. With the ever-growing demands of high-energy, short wavelength free electron laser (FEL) drivers, the CSR effect has emerged to be a detrimental factor in emittance stability. Under linear approximation, it is showed that the CSR driven dispersive kicks in successive bending magnet systems can, with proper balancing of the linac optics, cancel each other to nullify transverse emittance growth. This technique of optics balancing in the constant bunch length regime is the focus of this paper. We will present our findings for the emittance measurements generated in Elegant simulations for the current LCLS-I dogleg system.

Approximated Expressions for the Coherent Synchrotron Radiation Energy Spread in Bending Magents

TUP028

D. Khan, T.O. Raubenheimer (SLAC)

In this paper, we describe the development of simplified analytic expressions for the Coherent Synchrotron Radiation's (CSR) root-mean-square induced energy spread, typically found in the bending magnets of short bunch-length charged particle accelerators. The expressions are derived for a Gaussian longitudinal bunch distribution and compared with the full-rigor CSR wakefield integral expressions while entering, traversing and exiting a bending magnet. The validity of the expressions are then tested against ELEGANT with the simulation of an unchirped beam traveling across a bending magnet into a drift section, and the second stage bunch compressor (BC2) of the proposed LCLS-II beamline.

Bunch Compressor Study: 5 Bend Chicane

TUP029

D. Khan, T.O. Raubenheimer (SLAC)

In this paper, we present a schematic for a bunch compressor consisting of 5-bend magnets that is designed to compensate for the transverse emittance growth due to Coherent Synchrotron Radiation (CSR). The 5-bend chicane performance is explained using a simple linear dispersive kick model. A specific implementation for the second bunch compressor in the LCLS-I and LCLS-II is demonstrated with the 5-bend chicane and its performance compared with that of the industry-standard 4-bend chicane. The design for each case is initially optimized using the particle tracking code ELEGANT, which implements a 1-D analytical model to calculate the CSR wakefield. We further test the 5-bend chicane performance using the particle tracking code CSRTrack, which implements a 2.5-D analytical model to calculate the CSR wakefield.

An Emittance Preservation Study Of A 5-Bend Chicane for the LCLS-II-HE Beamline

TUP030

D. Khan, T.O. Raubenheimer (SLAC)

The Linac Coherent Light Source II (LCLS-II) is an upgrade intended to advance the great success of its predecessor, LCLS-I, to maintain its position at the forefront of X-ray science. The introduction of a niobium-metal superconducting linac for LCLS-II not only increases the repetition rate to the MHz level (from 120 Hz), but also boasts an average brightness many orders higher (~10,000) than that of LCLS-I. Though, these improvements do not come without a price: the peak brightness suffers by a factor of 10, owing its degradation to the impact of Coherent Synchrotron Radiation (CSR) diminishing the peak current of the beam in the second bunch compressor (BC2). In this paper, we discuss the impact of implementing a plug-compatible 5-bend chicane for BC2 on the beam's emittance dilution for a high-energy, low-emittance configuration of LCLS-II (LCLS-II-HE). The results are compared with that of a standard 4-bend chicane under various settings in Elegant and CSRTrack.

Design of a Dog-Leg Chicane Bunch Compressor with Tunable First-Order Longitudinal Dispersion

TUP031

J. Wu (SLAC) M.C. Chou, N.Y. Huang, W.K. Lau, A.P. Lee (NSRRC)

A nonlinear bunch compressor has been designed for the NSRRC VUV FEL facility. It is a double dog-leg configuration with anti-symmetric dispersion function. A quadrupole pair is therefore necessary to flip the horizontal beam position about the point of anti-symmetry in the chicane. However, quadrupoles always increase the second-order longitudinal dispersion. Sextupoles can be added to correct this second-order effect. In this study, a analytic model of this dog-leg chicane has been developed. Expressions for the first- and second-order longitudinal dispersion have been derived. We also considered the tunability of first-order longitudinal dispersion in the system to adapt possible deviation of operation energy from its nominal values.

TUP032

Design of the Beam Distribution System for a Soft X-Ray FEL User Facility in Shanghai

S. Chen, H.X. Deng, C. Feng, B. Liu, D. Wang (SINAP)

A soft X-ray user facility will be upgraded from an existing soft X-ray test facility in Shanghai. One or more extended FEL undulator lines will be constructed parallel to the previous undulator line. For simultaneous operation of several undulator lines, a beam distribution system is required for spreading the electron bunches from linac to each undulator lines. In this work, the physics design of such a beam distribution system will be described.

TUP033

A Novel Way to Increase the Resolution of an RF Deflecting Cavity

D. Huang, C. Feng, Q. Gu (SINAP)

The RF deflecting cavity is a very useful instrument to measure and observe the longitudinal current and phase-space profile of an electron beam in a free electron laser (FEL) facility. Its resolution is limited by a number of factors such as the RF power, frequency and the distance of the screen, etc. Most of them have very high requirements in manufacturing and material processing. In this article, a simple way is proposed to raise the resolution of an RF deflecting cavity with low cost, which is assumed to be very useful in an FEL facility.

TUP034

Novel Aspects of Beam Dynamics in CeC SRF Gun and SRF Accelerator

I. Petrushina (SUNY SB) T. Hayes, Y.C. Jing, D. Kayran, V. Litvinenko, G. Narayan, I. Pinayev, F. Severino, K.S. Smith, G. Wang (BNL) K. Mihara (Stony Brook University) K. Shih (SBU)

A 15 MeV CW SRF accelerator had been commissioned at Brookhaven National Laboratory to test the coherent electron cooling concept. The accelerator consists of an SRF 113-MHz photoemission gun, two 500 MHz bunching cavities and a 704-MHz 5-cell SRF linac. In this paper we describe our experience with this system with focus on unusual phenomena, such as multipacting in the SRF gun. We also discuss issues of wakefields in the CeC accelerator.

Funding: DoE NP office, grant DE-FOA-0000632, NSF grant PHY-1415252.

TUP035

CSR Wake Fields and Emittance Growth with a Discontinuous Galerkin Time-Domain Method

D. A. Bizzozero (TEMF, TU Darmstadt)

Coherent synchrotron radiation is an essential consideration in modern accelerators and related electromagnetic structures. We present a new method to examine CSR in the time domain using an unstructured Discontinuous Galerkin (DG). The method uses a 2D spatial discretization in the longitudinal and transverse coordinates (z,x) with a Fourier series decomposition in the transverse coordinate y and computes the fields modally; after summation over modes, this treatment describes all electromagnetic field components at each space-time coordinate (z,x,y,t). Additionally, by alignment of mesh-element interfaces along a source reference orbit, DG methods can naturally handle discontinuous or thin sources in the transverse x direction. We present an overview of the method, illustrate it by calculating wake potentials for a bunch compressor, and compute longitudinal emittance growth from the wake potentials.

Funding: Work supported by DESY.

Recent Experimental Results on High-Peak-Current Electron Bunch and Bunch Trains with a THz Undulator

TUP036

X.L. Su, Y.-C. Du, W.-H. Huang, L. Niu, C.-X. Tang, Q.L. Tian, D. Wang, L.X. Yan (TUB) Y.F. Liang (Tsinghua University)

In this paper, experimental results based on a THz undulator with a widely tunable gap installed at Tsinghua Thomson scattering X-ray (TTX) beamline are introduced. This is a planar permanent magnetic device with 8 regular periods, each 10 cm long. The undulator parameter varies from 9.24-1.39 by changing the magnetic gap from 23 mm to 75 mm. The coherent undulator radiation can be used as a narrow-band THz source with central frequency ranging from 0.4 THz to 10 THz. The bunch length was figured out from the radiation intensity at a different undulator gap, which agrees well with simulations. For a 100-MeV ultrashort Gaussian bunch, the resolution of this method can be as high as 1 fs. Furthermore, slice-energy modulation has been directly observed when high-peak-current bunch trains based on nonlinear longitudinal space charge oscillation pass through the undulator. The demonstrated experiment in THz regime provides a significant scaled tool for FEL mechanism exploration owing to the simplicity of bunch modulation and diagnostics in this range.

Group and Phase Velocity Matching in THz IFEL interaction

TUP037

E.J. Curry, S.S. Fabbri, P. Musumeci (UCLA) A. Gover (University of Tel-Aviv, Faculty of Engineering)

We review results from the recent guided-THz IFEL experiment at the UCLA PEGASUS facility. Using a parallel plate waveguide, the group velocity of a near-single cycle THz pulse was reduced to match electron beam propagation in an undulator, resulting in a ponderomotive interaction sustained for 30 cm. With a 1-uJ THz pulse obtained by optical rectification in a LN source, the projected beam energy distribution increased from a full peak width of 30 keV to more than 100 keV. When using a long (multi-ps) electron beam, longitudinal phase-space measurements reveal the snake-like energy modulation from the ps-scale THz pulse. Using a short beam configuration, we also measure bunch compression, limited by the available drift length to a factor of two. Finally, we explore the application of this technique to amplification of the THz seed using the 1-D multi-frequency simulation code we have developed for this novel zero-slippage interaction scheme.

Funding: Work supported by DOE grant DE-FG02-92ER40693 and NSF grant PHY-1415583.

Experiments in Electron Beam Nanopatterning

TUP038

C. Zhang, W.S. Graves, L.E. Malin, J. Spence (Arizona State University) D.B. Cesar, J.M. Maxson, P. Musumeci, A. Urbanowicz (UCLA) C. Limborg-Deprey, E.A. Nanni (SLAC)

We report on experiments in nanopatterning electron beams from a photoinjector as a first step toward a compact XFEL (CXFEL). The nanopatterning is produced by Bragg diffraction of relativistic electron beams through a patterned Si crystal consisting of alternating thick and thin strips to produce nanometer-scale electron density modulations. Multi-slice simulations show that the target can be oriented for a two-beam condition where nearly 100% of the electron beam is diffracted into the 022 Bragg peak. Plans are underway to carry out experiments in UCLA's ultrafast electron microscopy lab showing this effect with 3.5 MeV electrons. We will select either the diffracted beam or the primary beam with an aperture in the diffraction plane of a magnetic lens and record either the dark or bright field magnified image of the strips, respectively. The goals of the experiments are to observe the nanopatterned beam, and to investigate various grating periods, crystal thicknesses, and sample orientations to maximize the contrast in the pattern and explore tuning the period of the modulation. The design of the experiments will be presented along with measurement results.

Funding: This work was supported by NSF Accelerator Science awards 1632780 and 1415583, NSF BioXFEL STC award 1231306, and DOE contracts DE-AC02-76SF00515 and DE-SC0009914.

TUP039

Electron Beam Requirements for Coherent Electron Cooling FEL System

G. Wang, Y.C. Jing, V. Litvinenko (BNL) J. Ma (SBU)

In this paper, we present results of our studies in amplification of density modulation induced by co-propagating ions in the FEL section of a Coherent Electron Cooling system, as well its interaction with hadrons. We present a set of requirements for electron beam parameters to satisfy for necessary amplification of the density modulation, while preventing loss of the phase information and saturation.

Funding: DoE NP office, grant DE-FOA-0000632, NSF grant PHY-1415252.

TUP040

Intense Tunable X-Rays from Compton Scattering in a Strong Guiding Magnet Field

Z. Li (CAEP/IAE)

We report the generation of intense tunable X-rays from Compton scattering in a strong guiding magnet field. A small rf linac (50MeV) combined with a rf photoinjector is installed inside a superconducting magnet, and the electron's radial movement is guided by the guiding magnet field. Being of small length (∼5m), the facility produces an electron beam with radius of ∼0.2mm and current of kAs to make X-ray photo number (in ∼10ps) from the collision between a YAG laser and electron beam more close to that of an X-ray Free electron laser (XFEL) facility (whose photon number is from to in ∼100fs) than that of other facilities (such as synchrotron X-ray sources, laser-driven Compton light sources, and etc.). Moreover the photon energy can be tuned from 7keV to 50keV between pulses with electron energy adjusted from 20MeV to 50MeV in the facility as described in this paper.

TUP041

Investigation of a GW THz Generator Driven by a Pulsed Power Supply

Z. Li (CAEP/IAE)

We report the generation of intense tunable THz from THz FEL in a strong guiding magnet field. A field-emission cathode (driven by the LTD pulse generator) is installed inside a superconducting magnet, and the electrons' radial movement is guided by the guiding magnet field. The small system, ∼1.5-m in length, generates an electron beam with radius of ∼1.0mm and current of kAs, enabling a SASE THz FEL within a electric wiggler. The electric wiggler, which is made of electric electrode, can be installed inside a superconducting magnet. Driven by the LTD pulse generator, the electrons are accelerated by the electric field between the cathode and the anode. Thus, GW THz (0.37-1.04THz) radiation can be generated with the aid of the strong guiding magnet field.

TUP042

Determination of the Slice Energy Spread of Ultra-Relativistic Electron Beams by Scanning Seeded Coherent Undulator Radiation by Coherent Harmonic Generation

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Modern high-gain free-electron lasers make use of high-brightness ultra-relativistic electron beams. The uncorrelated energy spread of these beams is upon creation of the beam in the sub-permille range and below the resolution of state-of-the-art diagnostics. One method to determine the slice energy spread is to use an external seed laser to imprint a coherent microbunching structure that gives rise to coherent radiation processes, different radiation sources such as transition radiation, synchrotron radiation, or undulator radiation and others. Here, we present a method and show measurements to determine the slice energy spread using an external seed laser with 266 nm wavelength to produce coherent undulator radiation at higher harmonics. The distribution of these harmonics allows retrieval of the electron beam slice energy spread with high precision.

Passive Linearization of the Magnetic Bunch Compression Using Self-Induced Field and Without Any Active Higher Harmonic RF Structure

TUP043

G. Penco, E. Allaria, I. Cudin, S. Di Mitri, D. Gauthier, L. Giannessi, E. Roussel, S. Spampinati, M. Trovo (Elettra-Sincrotrone Trieste S.C.p.A.) S. Bettoni, P. Craievich, E. Ferrari (PSI) L. Giannessi (ENEA C.R. Frascati) E. Roussel (SOLEIL)

In linac-driven free-electron lasers, colliders and energy recovery linacs, a common way to compress the electron bunch to kA level is based upon the implementation of a magnetic dispersive element that converts the bunch energy deviation in path-length difference. The non-linearities of such a process are usually compensated by enabling a high harmonic rf structure properly tuned in amplitude and phase. This approach is however not straightforward for foreseen C and X-band linacs. In this work we report the experiment performed on the FERMI linac that has demonstrated the possibility to exploit the longitudinal self-induced field excited by the electron beam itself to passively linearize the compression process without any active higher harmonic rf structure. In this novel configuration, the FERMI electron bunch was compressed up to 700 A as in the nominal case and driven along the FERMI FEL-1 undulators, generating intense extreme-ultraviolet pulses that were provided to users for experiments.

Generation of Sub-fs X-Ray Pulses at the European XFEL

TUP044

S. Serkez (European XFEL) G. Geloni, S.I. Tomin (XFEL. EU) V. Kocharyan, E. Saldin (DESY)

Time-resolved studies of free electron lasers are of a great importance. The resulting temporal resolution of the user measurements is determined by FEL pulse duration. Here we investigate possibilities to obtain sub-fs-long pulses at the European XFEL. Installation of the drive laser, modulator and magnetic chicane before the baseline undulator is required.

Interference-Based Ultrafast Polarization Control at Free Electron Lasers

TUP045

S. Serkez (European XFEL) G. Geloni (XFEL. EU) E. Saldin (DESY)

We present a scheme to generate two distinct FEL pulses with different polarization properties and down to 50 fs-order temporal separation. The scheme is based on installation of two consecutive helical undulators, a corrugated structure and emittance spoiler on top of a baseline variable gap undulator, and is exemplified on the SASE3 beamline of the European XFEL. Good temporal coherence by either self or external seeding is preferable. Our schemes can be used for pump-probe experiments and in combination with the "twin-bunch" technique.

Ultrafast Electron Diffraction Facility Based on an RF Photogun and Achromatic 90-degree Bends for Sub-100-Femtosecond Timing Jitter

TUP046

Y.U. Jeong, S. Bae, I.H. Baek, B.A. Gudkov, B. Han, K.H. Jang, H.W. Kim, M.H. Kim, Y.-C. Kim, K. Lee, S.V. Miginsky, J. Mun, J.H. Nam, S. Park, S. Setiniyaz (KAERI) R. Fabian, H. Ihee, J. Kim, K.Y. Oang, H. Yang (KAIST) J.H. Han (PAL) H.W. Kim (University of Science and Technology of Korea (UST)) K.W. Kim (Chung Buk National University) S.V. Miginsky, N.A. Vinokurov (BINP SB RAS) S. H. Park (Korea University Sejong Campus) S. Park (Kyungpook National University)

We have developed a laboratory-scale ultrashort electron accelerator for investigating femtosecond dynamics of atoms or molecules with pump-probe experiments. This system includes an S-band radio-frequency (RF) photogun and four achromatic bends for compressing electron bunches. Two of them are for ultrafast electron diffraction (UED) experiments on solid and gas samples. The electron bunch duration at the UED beamlines was designed to be ~30 fs in rms. Our target value of the timing jitter between the pumping laser pulse and probing electron bunch is approximately 10 fs. The synchronization between the pumping laser oscillator and a master oscillator of the RF system was successfully performed with the extremely low timing fluctuation of ~10 fs during 24-hour operation*. We developed a high-intense terahertz pumping source with field strength of more than 0.5 MV/cm for THz-pump and electron-probe experiments. We are conducting three independent application experiments with superconducting and strongly-correlated materials and gas samples for ultrafast molecular dynamics.

* *H. Yang et al., "10-fs-level synchronization of photocathode laser with RF-oscillator for ultrafast electron and X-ray sources," Scientific Reports, 7, 39966, 2017.*

TUP047

A Linac-Based All-in-One THz-Pump and X-Ray-Probe Sources

S. Setiniyaz, I.H. Baek, K.H. Jang, Y.U. Jeong, H.W. Kim, K. Lee, S. H. Park (KAERI) N.A. Vinokurov (BINP SB RAS)

We describe a compact THz-pump and X-ray-probe beamline, based on an electron linac, for ultrafast time-resolved diffraction applications. Two high-energy electron (γ >50) bunches, 5 ns apart, impinge upon a single-foil or a multifoil radiator and generate THz radiation and X-rays simultaneously. The THz pulse from the first bunch is synchronized to the X-ray beam of the second bunch by using an adjustable optical delay of THz pulse. The peak power of THz radiation from the multifoil radiator is estimated to be 0.18 GW for a 200 pC well-optimized electron bunch. The optimization of radiator for X-ray generation, performed by using GEANT4, shows that carbon foils, with a total thickness of 0.5 - 1.0 mm, has the highest yield of 10 - 20 keV hard X-rays for a 25 MeV beam, which is approximately a few 10^3 photons/(pC electrons) within a few degrees of the polar angle. A carbon multifoil radiator with 35 foils (25 μm thick each) can generate close to 10^3 hard X-rays/(keV energy bin)/(pC electrons) within a 2^o acceptance angle. The longitudinal time profile of X-ray pulse ranges from a few tens to hundreds of fs depending on the acceptance angle.

TUP048

Automatic Tuning of the Electron Beam Parameters to Enhance LCLS FEL Performance Using ES

P.M. Anisimov, A. Malyzhenkov, A. Scheinker (LANL)

We report on the design of the new automatic fine tuning system for the electron beam parameters using extremum seeking (ES) to enhance LCLS FEL performance. ES is the fastest multidimensional optimization algorithm for finding extremum. First, we demonstrate ES capability to find optimum Twiss parameters of the electron beam and FODO lattice delivering maximum radiation power in Genesis simulations. Then, we use ES for taper optimization and compare the optimum performance with no taper configuration but optimum Twiss parameters. Moreover, we combine these two techniques together for fine tuning to enhance FEL performance even further. Finally, we propose applying ES for fine tuning at LCLS experimentally: Once FEL is tuned to operate at desirable user parameters, electron beam parameters are changed to maximize radiation power, while the last one remains above the lowest border specified by user during each step of the optimization.

TUP049

An Optically Levitated Imaging System for X-Ray Free Electron Lasers

A. Malyzhenkov, J.H. Bartlett, A. Castro, V. Lebedev (LANL)

We propose an optically levitated imaging system for X-ray Free Electron Lasers. First, we report on the design of an in-vacuo optical levitation trap compatible with X-ray Free Electron Laser vacuum requirements and other technical conditions at the existing Free Electron laser facilities (LCLS, Spring-8, European XFEL, etc). Second, we propose to use this trap for holding a nano/micro particle which will serve as a lens for focusing the X-ray beam on a target. Such a lens can be accurately positioned with respect to the target and, moreover, the relative distance can be varied in time by the user to change optical properties of the X-ray beam on the sample. In particular, we discuss potential materials that can serve as an x-ray propagation media effectively yet also be trapped by optical tweezers. Finally, we discuss the possibility of holding the target in a separate optical trap which would allow target manipulation (position and orientation in space) relative to the X-ray beam and an X-ray detector.

Beam Driven Acceleration and RF Breakdown in Photonic Band Gap Travelling Wave Accelerator Structure

TUP050

J. Upadhyay, E.I. Simakov (LANL)

We report the results of an experiment to demonstrate excitation of wakefields and wakefield acceleration in a photonic band gap (PBG) accelerating structure. The experiment was conducted at the Argonne Wakefield Accelerator (AWA) facility. For modern X-ray free electron lasers (FELs), preservation of the electron beam quality during the beam acceleration is of crucial importance. Therefore, new accelerating structures must be designed with careful attention paid to the suppression of wakefields. PBG structures are widely studied due to their ability to exclude higher order modes. A 16-cell travelling-wave normal conducting PBG structure operating at 11.700 GHz is installed at the AWA beam line. We passed a high-charge single bunch or multiple bunch train through the structure that generated wakefields and evaluated the effect of these wakefields on a low-charge witness beam. We also passed high-charge multiple bunch trains through the structure that generated up to 100 MV/m accelerating gradient and studied the RF breakdown.

Reaching High Peak Power X-Ray Radiation in FELs

TUP051

N.A. Yampolsky, D.C. Nguyen (LANL)

The output power in free electron lasers (FELs) such as MaRIE can be achieved through temporal compression of the output pulse. Such a compression can be achieved with conventional gratings in soft x-ray regime or Bragg crystals in hard x-ray regime. Currently, the use of compressing optics is limited due to high radiation fluences and the damage it causes to the grating. We investigate the possibility of reducing the local x-ray fluence at the grating through streaking the pulse transversely and designing optics which compress the streaked pulse. The streaking of the optical pulse can be achieved through streaking of the driving electron beam with a set of transverse deflecting cavities. The optical pulse shape mirrors the shape of the electron beam resulting in the streaked x-ray beam.

Funding: This work has been supported by LANL LDRD Programm.

Demonstration of Cascaded Pre-Bunching for Complete Trapping of a Relativistic Electron Beam in a Strongly Tapered Undulator

TUP052

N.S. Sudar, I.I. Gadjev, P. Musumeci, Y. Sakai (UCLA) M. Babzien, M.G. Fedurin, M.A. Palmer, I. Pogorelsky, M.N. Polyanskiy, C. Swinson (BNL)

We present results of an experiment recently performed at the Brookhaven National Lab's Accelerator Test Facility showing the first successful demonstration of a cascaded pre-bunching scheme. Two modulator-chicane pre-bunchers arranged in series and a high-power CO2 laser seed manipulate the longitudinal phase space of a 52-MeV electron beam, increasing the fraction of electrons initially trapped in the stable accelerating potential of a seeded, strongly tapered undulator interaction from 25% to 95%, accelerating up to 80% of the particles to the final design energy. These results represent an important step in the development of high efficiency tapered undulator interactions, both as advanced accelerators and as high peak and average power coherent radiation sources.

Funding: US DOE Office of High Energy Physics DE-SC0009914 US Dept. of Homeland Security Grant 2014-DN-077-ARI084-01 US DOE Office of Science SCGSR Graduate Student Research Fellowship

TUP053

The ACHIP Experimental Chambers at PSI

E. Ferrari, S. Bettoni, S. Borrelli, H.-H. Braun, M. Calvi, M.M. Dehler, F. Frei, T. Garvey, N. Hiller, R. Ischebeck, C. Ozkan Loch, E. Prat, S. Reiche, L. Rivkin, A. Romann, V. Schlott (PSI) L. Rivkin (EPFL)

ACHIP is an international collaboration, funded by the Gordon and Betty Moore Foundation, whose goal is to demonstrate that a laser-driven accelerator on a chip can be integrated to fully build an accelerator based on dielectric structures. PSI will provide access to the high brightness electron beam of SwissFEL to test structures, approaches and methods towards achieving the final goal of the project. In this contribution, we will describe the two interaction chambers installed on SwissFEL to perform the proof-of-principle experiments. In particular, we will present the positioning system for the samples, the magnets needed to focus the beam to sub-micrometer dimensions and the diagnostics to measure beam properties at the interaction point.

Funding: Gordon and Betty Moore Foundation

TUP054

Preparations for the Installation of the Double Emittance Exchange Beamline at the Argonne Wakefield Accelerator Facility

G. Ha (PAL) M.E. Conde, D.S. Doran, W. Gai, J.G. Power (ANL)

Preparations to upgrade the single EEX beamline at the Argonne Wakefield Accelerator (AWA) facility to a double EEX beamline are underway. The single EEX beamline recently demonstrated exchange-based longitudinal bunch shaping (LBS) which has numerous applications including high-energy physics linear colliders, x-ray FELs, and intense radiation sources. The exchange-based method can generate arbitrary LBS in the ideal case but has limitations in the real case. The double EEX beamline was proposed as a means to overcome the limitations of single EEX due to transverse jitter and large horizontal emittance. In this paper, we present the current status of beamline design and installation and simulation results for the planned experiments: collinear wakefield acceleration with tailored beams and tunable bunch compression without the double-horn feature.

Funding: This work is supported by Department of Energy, Office of Science, under Contract No. DE-AC02-06CH11357.

TUP055

Cascaded Amplification for Terawatt FELs

J.P. MacArthur (SLAC)

The peak power of an x-ray pulse from the LCLS is limited by saturation effects to a few tens of gigawatts. However, users looking at two-photon processes that scale with the square of the power need higher power photon pulses. We investigate a multistage cascaded amplification scheme for the LCLS. This scheme can be used in conjunction with enhanced SASE to produce half TW pulses. The recently developed fresh-slice scheme can be added to reach TW powers. We discuss these results in the context of FEL superradiance.

TUP056

Generation of Two-Color X-Ray Free-Electron Lasers Using a Matching-Based Fresh-Slice Method

W. Qin, Y.-C. Chao, Y. Ding, A.A. Lutman (SLAC)

Two-color high intensity X-ray free-electron lasers (FELs) provide powerful tools for probing ultrafast dynamic systems. A novel concept of realizing fresh-slice two-color lasing through slice-dependent transverse mismatch has been proposed by one of the authors.* In this paper we present a feasible example following this concept based on the Linac Coherent Light Source parameters. Time-dependent mismatch along the bunch is generated by a passive dechirper module and controlled by downstream matching sections, enabling FEL lasing at different wavelengths with a split undulator configuration. Simulations for soft X-ray FELs show that tens of gigawatts pulses with femtosecond duration can be generated.

** Y. Chao, SLAC Report No. SLAC-PUB-16935, 2016.*

Statistical Properties of a Slippage Enhanced SASE

J. Wu, T.O. Raubenheimer (SLAC) C.-Y. Tsai (Virginia Polytechnic Institute and State University) B. Yang (University of Texas at Arlington) M. Yoon (POSTECH) G. Zhou (IHEP)

TUP057

Slippage-Enhance SASE (SeSASE) is a demonstrated approach for generating high-brightness x-ray free electron laser (XFEL). With an enhanced slippage, the FEL spikes get stronger phase and amplitude mix, thus lengthening the cooperation length and improving the temporal coherence. Since SeSASE starts from shot-noise from the electron bunch in the same way as SASE does, statistical properties of a SeSASE FEL are important to characterize and will be reported in this paper. Besides analytical analysis to elucidate the underlying physics, numerical simulation is also carried out for realistic electron bunch of LCLS-II type. The results reported are based on the LCLS-II project machine configuration and parameters.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

Slippage-Enhanced SASE FEL

J. Wu, C. Pellegrini, T.O. Raubenheimer (SLAC)

TUP058

High-brightness XFEL is demanding for many users, in particular for certain types of imaging applications. Seeded FELs including self-seeding XFELs were successfully demonstrated. Alternative approaches by enhancing slippage between the x-ray pulse and the electron bunch were also demonstrated. This class of Slippage-enhanced SASE (SeSASE) schemes can be unique for FEL spectral range between 1.5 keV to 4 keV where neither grating-based soft x-ray self-seeding nor crystal-based hard x-ray self-seeding can easily access. SeSASE can provide high-brightness XFEL for high repetition rate machines not suffering from heat load on the crystal monochromator. We report start-to-end simulation results for LCLS-II project and PAL-XFEL project with study on tolerance. Performance comparison between SaSASE FEL and self-seeding FEL in the overlapping frequency range is also presented.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

Alternative Electron Beam Slicing Methods for CLARA and X-ray FELs

D.J. Dunning (STFC/DL/ASTeC)

TUP059

Methods to generate ultra-short radiation pulses from X-ray FELs commonly slice a relatively long electron bunch to feature one (or more) short regions of higher beam quality which then lase preferentially. The slotted foil approach spoils the emittance of all but a short region, while laser-based alternatives modulate the electron beam energy, improving potential synchronisation to external sources. The CLARA FEL test facility under development in the UK will operate at 100-400 nm, aiming to demonstrate FEL schemes applicable at X-ray wavelengths. We present new laser-based slicing schemes which may better suit the wavelength range of CLARA and provide options for X-ray facilities.

A Complementary Tool to XFEL: 4D Electron Diffraction and Microscopy

D. Xiang (Shanghai Jiao Tong University)

TUP060

Historically particle accelerators are instrumental for high energy and nuclear physics (accelerator based colliders) and photon science (accelerator based synchrotron light sources and free electron lasers). Now there is growing interest in applying accelerator technology to solve the grand challenge in probing matter at ultrafast temporal and ultrasmall spatial scales. Here we discuss how one can use near-relativistic electrons produced in accelerators (e.g. photocathode rf guns) to study ultrafast dynamics at atomic scale through ultrafast electron diffraction (UED) and microscopy (UEM) techniques. In general the 4D electron diffraction and microscopy technique is complementary to X-ray free electron lasers, yet with greatly reduced size and cost. We will also describe the current status of the UED/UEM facility at Shanghai Jiao Tong University (SJTU). Several pump-probe experiments have been performed to test the temporal and spatial resolution of the facility. This center is expected to provide access to new sciences by producing kHz rep-rate ultrafast and ultrabright electron beams that will allow researchers to examine the fundamental nature of matter with high resolution.

Funding: This work was supported by the National Natural Science Foundation of China (Grant No. 11327902).

TUP061

Study of the Electron Transport in the COXINEL FEL Beamline Using a Laser-Plasma Accelerated Electron Beam

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The ERC Advanced Grant COXINEL aims at demonstrating the free electron laser (FEL) at 200 nm, based on a laser-plasma accelerator (LPA). To achieve the FEL amplification a transport line was designed to manipulate the beam properties. The 10-m long COXINEL line starts with a triplet of permanent-magnet variable-gradient quadrupoles (QUAPEVA), which handles the large divergence of LPA electrons. The slice energy spread is reduced by a magnetic chicane. A set of electromagnetic quadrupoles provides chromatic focusing in a 2-m undulator. Electrons were transported through the line for the LPA with ionization-assisted self-injection (broad energy spectra up to ~220 MeV, few-milliradian divergence), and with shock injection, where energy spread is much smaller (few percents). Beam position and dispersion are controlled precisely thanks to a specific beam-based alignment method using displacement of the QUAPEVA magnetic center. The transported energy range was also controlled using a slit inserted in the chicane. Experimental results and numerical simulations are in good agreement. Preliminary results on undulator radiation are also reported.

TUP062

Electromagnetic and Mechanical Analysis of a 14 mm 10-period NbTi Superconducting Undulator

F. Trillaud, G.A. Barraza Montiel (UNAM) M. Gehlot, G. Mishra (Devi Ahilya University)

A 14 mm 10-period NbTi superconducting undulator for the next generation of free electron laser has been studied.* The optimum electromagnetic pre-design was carried out using RADIA, an extension module of the commercial software Mathematica.** For this study, a variable gap was considered and figures of merits were derived. Additionally, a basic thermo-mechanical study of the one half of the superconducting undulator was conducted which relied on a thermal and mechanical contact modelling.***. The goal was to determine the minimum coil pre-loading necessary to ensure the desired operation of the undulator. The cooling speed as well as the definition of the contact were taken into account to infer the best cooling scheme. Numerical results are presented for both studies.

** M. Gehlot et al., Nucl. Inst. and Meth. in Phys. Res., Sec. A, Vol. 846, p. 13-17, 2017. ** B.J.A. Shepherd et al., Proceedings of IPAC2014, WEPRI095, 2014. *** J. Grimmer, R. Kmak, PAC 2005.*

Funding: DGAPA of UNAM, fund PAPIIT TA100617

TUP063

Laser-Plasma Accelerator Based Single-Cycle Attosecond Pulse Generation

Z. Tibai, G. Almasi, J. Hebling, M.I. Mechler, A. Nagyvaradi (University of Péece) J.A. Fülöp, Gy. Tóth (MTA-PTE High-Field Terahertz Research Group) A. Sharma (ELI-ALPS)

A carrier-envelope-phase controlled single-cycle attosecond pulse source was proposed by us relying on a conventional linear accelerator.* Here, we demonstrate the feasibility of a related scheme, where a laser-plasma accelerator, rather than a LINAC is used. Pulses from a TW/PW-power laser are focused into a gas jet to generate a relativistic electron beam, which is then sent through a first quadrupole triplet to reduce its divergence. The reduction of the slice energy spread can be accomplished by a first chicane. The electron beam passes through a modulator undulator along with a TW laser beam (ELI-ALPS SYLOS).** Here, the interaction between the electrons, the magnetic field of the undulator, and the electromagnetic field of the laser introduces a periodic energy modulation.

The electrons propagate through a second chicane which leads to the formation of a train of nanobunches. The nanobunched electron beam then moves through the radiator undulator consisting of a few periods and creates CEP-stable attosecond pulses According to our calculations, at 60 nm (100 nm) wavelength CEP stable pulses with 13 nJ (22 nJ) energy and 240 as (400 as) duration can be achieved at $K = 0.8$.

** Z. Tibai et al., Phys. Rev. Lett. 113, 104801 (2014). ** online at http://www.eli-alps.hu for ELI-ALPS (The Scientific Case of ELI-ALPS (2015)).*

High Harmonic Terahertz Smith-Purcell Free-Electron Laser Based on Two Tandem Planar Gratings

TUP064

L. Liang, Q.K. Jia, W. Liu, Y. Lu, L. Wang (USTC/NSRL)

The terahertz wave is an attractive topic due to its promising applications in many fields, while a compact and efficient terahertz radiation source is expected. In this paper, we propose a novel terahertz Smith-Purcell free-electron laser (SP-FEL) based on two tandem planar gratings. The preset grating with larger size is used to pre-bunch the initial continuous electron beam, and the second grating with smaller size works as the main radiator. Compared with traditional SP-FEL operating at the second harmonic of the beam's bunching frequency, the present scheme operates at much higher harmonics. The radiation frequency is remarkably increased consequently, and the radiation power is also significantly enhanced. It could be developed as an efficient terahertz source with frequency up to 0.5 THz in practice.

Funding: Natural Science Foundation of China (61471332, 51627901, U1632150); Anhui Provincial Natural Science Foundation (1508085QF113).

Dielectric Laser Acceleration Setup Design, Grating Manufacturing and Investigations Into Laser Induced RF Cavity Breakdowns

TUP065

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Dielectric laser acceleration (DLA) is the technique utilizing strong electric fields in lasers to accelerate electrons in the proximity of nanoscaled dielectric gratings. The concept was recently demonstrated in experimental studies. Here we describe the experimental DLA investigation setup design including laser system and scanning electron microscope (SEM). We also present the grating manufacturing methods as well investigations into vacuum breakdowns occurring at RF accelerating structures.

Funding: Work supported by Stockholm-Uppsala Centre for Free Electron Research.

Luminosity Increase in Laser-Compton Scattering by Crab Crossing

TUP066

Y. Koshiba, S. Ota, T. Takahashi, M. Washio (RISE) T. Higashiguchi (Center for Optical Research and Education, Utsunomiya University) K. Sakaue (Waseda University, Waseda Institute for Advanced Study) J. Urakawa (KEK)

Laser-Compton Scattering X-ray (LCS-X) sources have been expected as compact and powerful sources, beyond X-ray tubes. They will enable laboratories and companies, opening new X-ray science. It is well known that luminosity depends on the collision angle of a laser and electron beam. Head-on collision is ideal in the point of maximizing the luminosity, though it is difficult to create such a system especially with an optical enhancement cavity for a laser. In collider experiments, however, crab crossing is a promising way to increase the luminosity. We are planning to apply crab crossing to LCS to achieve a higher luminosity leading to a more intense X-ray source. Electron beams will be tilted to half of the collision angle using an RF-deflector. Although crab crossing in Laser-Compton scattering has been already proposed, it has not been demonstrated yet anywhere.* The goal of this study is to experimentally prove the luminosity increase by adopting crab crossing. In this conference, we will report about our compact accelerator system at Waseda University, laser system favorable for crab crossing LCS, and expected results of crab crossing LCS.

** V. Alessandro, et al., "Luminosity optimization schemes in Compton experiments based on Fabry-Perot optical resonators." Physical Review Special Topics-Accelerators and Beams 14.3 (2011): 031001.*

Funding: Research Fellow of Japan Society for the Promotion of Science

TUP067

Study on Cherenkov Laser Oscillator Using Tilted Electron Bunches

K. Sakaue (Waseda University, Waseda Institute for Advanced Study) M. Brameld, M. Washio, R. Yanagisawa (Waseda University) R. Kuroda, Y. Taira (AIST) J. Urakawa (KEK)

We have been studying a coherent Cherenkov radiation by using tilted electron bunches. Bunch tilting can enhance the radiation power about 10 times due to the wavefront matching of radiations. Recently, we investigated that this technique can produce high peak power THz pulses with sufficient pulse energy. Resulting pulse energy was more than 30 nJ/pulse and peak power was about 10 kW. Introducing the oscillator cavity with two concave mirrors, it would be possible to achieve lasing using tilted electron bunches. In the calculation, 1 uJ/micro-pulse and 100 uJ/macro-pulse broadband THz pulses are expected to be achieved, which are powerful THz sources compared with the existing THz FELs. In this conference, we will report the experimental results of coherent Cherenkov radiation, calculated results toward lasing and future prospectives.

Funding: This work was supported by a research granted from The Murata Science Foundation and JSPS KAKENHI 26286083.

TUP068

Spectral Measurement of the Israeli FEL

A. Friedman (Ariel University) A. Abramovich (Ariel University Center of Samaria, Faculty of Engineering)

The field of terahertz time-domain spectroscopy (THz-TDS) has not yet achieved its full potential. This is a very promising utility for a wide range of applications. The purpose of this work is to build a THz-TDS system based on a nonlinear process by nonlinear crystal. It is motivated by the need for a detailed analysis of the Israeli FEL output. Before the FEL is ready, the THz generation process occurs via optical rectification in a <110> ZnTe. Optical rectification is a difference frequency mixing and occurs in media with large second-order susceptibility, χ^2. THz detection uses the linear electro-optic (EO) effect, also called the Pockels Effect. A variable delay line (VDL) serves to retard the probe's pulse in time with respect to the THz pulse. The step-length of the VDL sets the temporal resolution. This is the classical way for THz spectroscopy.

TUP069

Using an FEL Amplifier for Coherent Electron Cooling

V. Litvinenko (BNL)

In this paper we present our experiment with using an FEL as amplifier of interactions between electrons and hadrons in Coherent electron Cooling system. We present results of commissioning the system and challenges we met during this process.

Funding: DoE NP office, grant DE-FOA-0000632, NSF grant PHY-1415252.

TUP070

Development of Mid-Infrared Photoacoustic Spectroscopy System for Solid Samples at Kyoto University Free Electron Laser Facility

J. Okumura, T. Kii, H. Ohgaki, H. Zen (Kyoto University)

Photoacoustic Spectroscopy (PAS) enables IR absorption spectrum measurements of solid samples without preprocessing of samples. Its sensitivity and resolution depend on the intensity and spectral width of the infrared light, respectively. Mid-infrared free electron laser (MIR-FEL) is an intense, quasi-monochromatic and tunable laser in MIR region, so the method of PAS with FEL (FEL-PAS) was proposed.*,** However, the resolution was not so good since they used the direct FEL beam which has the spectral width of 1%. We considered that the resolution can be significantly increased by inserting a high-resolution grating monochromator before the PAS cell. Based on this consideration, a PAS system using an MIR-FEL with the monochromator is under development. We have already conducted preliminary experiments using a PAS cell which has been used in previous studies and successfully measured quite high PAS signals with this setup.*,** A

demonstration of experiments to check the spectral resolution will be conducted soon. In this presentation, the progress of the development including the result of demonstration experiments will be reported.

** M. Yasumoto et al., Proceedings of the 2004 FEL Conference, 703-705 (2004). ** M. Yasumoto et al., Eur. Phys. J. Special Topics, 153, 37-40 (2008).*

Study on Second Harmonic Generation in SiC Using Infrared FEL

S. Tagiri (Kyoto Univeristy) K. Hachiya (Kyoto University Graduate School of Energy Science) T. Kii, H. Ohgaki, H. Zen (Kyoto University) K. Yoshida (Kumamoto University, Department of Applied Chemistry and Biochemistry)

Mode-selective phonon excitation (MSPE) is an attractive method for studying the lattice dynamics (e.g. electron-phonon interaction and phonon-phonon interaction). In addition, MSPE can control electronic, magnetic, and structural phases of materials. In 2013, we directly demonstrated MSPE of a bulk material (sample: 6H-SiC) with MIR-FEL (KU-FEL) by anti-Stokes Raman scattering spectroscopy.* Recently, we have certified that the sum frequency generation (SFG) also occurs with anti-Stokes Raman scattering.** For distinguishing between the anti-Stokes Raman scattering photons and SFG photons, we need to know the nonlinear susceptibility and the transmittance. The coefficients can be measured by the second harmonic generation (SHG) spectrometry which was applied to 4H-SiC and 3C-SiC.*** In our case, 6H-SiC has been measured. In this conference, the outline of the measurement system and the experimental results will be presented.

** K.Yoshida, et al., Appl. Phys. Lett., 103, 182103 (2013). ** T.Katsurayama, IRMMW-THz2016, T5P.25.05 (2016). ** *A.Paarmann, et al., Appl. Phys. Lett., 107, 081101 (2015).*

TUT — Tutorial I

TUT01

On the Science of Seeded FELs

F. Parmigiani (Elettra-Sincrotrone Trieste S.C.p.A.)

Tuesday tutorial: 17:30–18:30

WEA — Electron Guns, RF Lasers, Cathodes

European XFEL Injector Commissioning Results

WEA01

B. Beutner (DESY)

In the first commissioning phase of the European XFEL SASE FEL driver linac, we demonstrated the design goals for the injector section. These goals include reliable operation of sub-systems and feasible beam parameters like emittance and bunch length of the beam produced by the RF gun. Of particular interest is the operation of long bunch trains with up to 2700 bunches with a 4.5 MHz repetition rate. In this presentation we will provide an overview of our experiences from the injector commissioning run including beam dynamics studies, diagnostics, and system performance.

Model of Photocathode for CW Electron Gun

WEA02

P.W. Huang, W.-H. Huang, C.-X. Tang (TUB)

Most of the proposed CW guns for free electron lasers use semiconductors as the photocathode due to their high quantum efficiency and potentially low thermal emittance. We manage to establish a model to explain the photoemission of semiconductors with incident photon energy above or below the theoretical threshold and derive the expression for quantum efficiency and thermal emittance. For the incident photon energy near or below the threshold of the cathode, things will be subtle and we should be careful to consider the details we used to neglect. The results of quantum efficiency and thermal emittance agree well with the published work. We also focus on the degradation of the semiconductors and propose a model to examine the development of the thermal emittance. We mainly consider the effect brought by the surface reactions with poisoning gases. The variation of quantum efficiency with time is well-consistent with experiment data. We also present the calculated results of thermal emittance, showing a decline with time. Similar results are presented with typical value of electric field in DC gun and RF gun.

Simulation Optimization of DC-SRF Photoinjector for Low-Emittance Electron Beam Generation

WEA03

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A DC and superconducting rf (SRF) combined photoinjector, DC-SRF photoinjector, has been developed at Peking University to generate high repetition-rate electron bunches. At present stable operation of the DC-SRF photoinjector has been realized and the electron beam has been delivered to a SRF linac with two 9-cell TESLA-type cavities for further acceleration and experiments. Here we will present our latest progress on the DC-SRF photoinjector. We will also present our recent simulation work to decrease the emittance. The purpose is to build an upgraded DC-SRF photoinjector capable of driving CW X-ray free-electron lasers.

Novel Concepts of a High Brightness Photoinjector RF Gun

WEA04

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We propose here a program to design and manufacture a high performance, advanced source of electrons having high beam brightness (>10^{16} A/m^2) and high bunch charge (~100 pC). Three innovations are being considered: 1) the use of a high peak cathode field, short-pulse RF gun; 2) the use of multi-layered diamond photocathode at low temperature; and 3) the utilization of THz ultrafast field emission gating. High peak cathode field is necessary to achieve a high brightness (low emittance) beam to be accelerated to relativistic energies before space-charge effects lengthen the bunch. The multilayered diamond photocathode is needed to obtain high QE with long wavelength laser in the first doped layer, beam cooling in the next layer, and negative electron affinity at the emission layer. High field single cycle THz pulses, produced by means of laser light rectification in a nonlinear crystal, allow to avoid a UV laser, provide high field emission charge (up to nC) and ~1 GV/m pre-acceleration of subpicosecond bunches.

WEA05

Higher Fields and Beam Energies in Continuous-Wave Room-Temperature VHF RF Guns

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The development in the last decade of MHz-class repetition rate free electron lasers (FELs), and ultrafast electron diffraction and microscopy (UED/UEM) applications, required new gun schemes capable of generating high-brightness beams at such high rates. The VHF-Gun, a 186 MHz room-temperature continuous-wave RF photo-gun developed at the Lawrence Berkeley Lab (LBNL) was an answer to that need. The VHF-Gun was constructed and tested in the APEX facility at LBNL successfully demonstrating all design parameters and the generation of FEL-quality electron beams. A close version of the APEX gun is in the final phase of fabrication at LBNL to operate as the electron source for the LCLS-II, the new SLAC X-ray FEL. The recently approved upgrade of the LCLS-II towards higher energies (LCLS-II HE) and the brightness-dependent UED and UEM applications would greatly benefit from an increased brightness of the electron source. Such performance upgrade can be obtained by increasing the electric field at the cathode and the beam energy at the gun exit. In this paper, we present and discuss possible upgrade options that would allow us to extend the VHF-Gun technology towards these new goals.

Funding: Work supported by the Director of the Office of Science of the US Department of Energy under Contract no. DEAC02-05CH11231

WEB — Electron Diagnostics, Timing, Controls

Characterization of High-Brightness Electron Beams at the Frontiers of Temporal and Spatial Resolution

WEB01

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We present two novel diagnostics to characterize high-brightness electron beams. The first technique, based on the tunnel ionization of a neutral gas by the intense (GV/m) self-field of the electron beam, can be used to measure the volumetric charge density of the beam, for example to reconstruct pulse durations shorter than few femtoseconds or to measure transverse beam sizes below the micron level. Experiments with sub-femtosecond unipolar self-field of electron beam, that approach the through-the-barrier tunneling times, could further deepen our understanding of quantum tunneling process. The second method can be used to streak electron beams with single cycle THz radiation concentrated in a micrometer gap of a resonant antenna, creating an enhanced electric near-field distribution. With this diagnostic one can measure with sub-femtosecond resolution the longitudinal duration, the slice emittance and energy spread of beams with energies up to tens of MeV. We show the validity of both methods with analytical calculations and particle-in-cell code simulations. We finally present practical implementation of both diagnostics at LCLS, in the XLEAP* experiment, and BELLA.

* *X-Ray Laser Enhanced Altosecond Pulse Generation (XLEAP) For LCLS.*

Characterization of Electron Bunches in Ultrafast Electron Diffraction Beamlines at KAERI

WEB02

H.W. Kim, I.H. Baek, K.H. Jang, Y.U. Jeong, K. Lee, J.H. Nam, N.A. Vinokurov (University of Science and Technology of Korea (UST)) I.H. Baek, B.A. Gudkov, B. Han, K.H. Jang, Y.U. Jeong, **H.W. Kim**, Y.-C. Kim, K. Lee, S.V. Miginsky, J.H. Nam, S. Park, S. Setiniyaz (KAERI) R. Fabian, H. Ihee, J. Kim, K.Y. Oang, H. Yang (KAIST) K.W. Kim (Chung Buk National University) S.V. Miginsky, N.A. Vinokurov (BINP SB RAS)

Ultrashort electron bunches from ultrafast electron diffraction (UED) beamlines at the Korea Atomic Energy Research Institute (KAERI) has been characterized for sub-100-femtosecond-accuracy time-resolved diffraction experiments. The UED beamlines are designed to deliver electron bunches of 30 fs (rms) duration and 10 fs (rms) timing fluctuation with pumping laser pulses. We have two UED beamlines for solid and gas-phase samples. The energy of the electron beam is ~3 MeV and the bunch charge is more than 1 pC. We measured single-shot and multi-shot electron diffraction patterns of single-crystalline-silicon and poly-crystalline-gold films to confirm the electron beam quality. The temporal characteristics of the electron bunches are investigated by using laser-induced ponderomotive deflecting and spectral decoding of coherent transition radiation from the electron bunch by pumping IR pulse.

R&D at SLAC on Nanosecond-Range Multi-MW Systems for Advanced FEL Facilities

WEB03

A.K. Krasnykh, A.L. Benwell, T.G. Beukers, D.F. Ratner (SLAC)

A nanosecond-range, multi-MW system containing TEM mode electrodynamic structures fed by controllable pulsers are needed for (1) fast injection systems in multi-bend achromat upgraded (MBA-U) storage rings and for (2) arrays of FEL beamlines powered by a superconducting linear accelerators operating with MHz-bunch repetition rate. The R&D effort covers both type (1) and (2) layouts. This report discuss the experimental results of several concepts for a generation of the nanosecond range multi MW pulsers. Compression of the initially formed electromagnetic (EM) power is employed for a generation of the nanosecond pulses in all concepts discussed here. A solid-state nonlinear media assists the EM compression. Features of the materials and components used in the design will be presented. The results will be included in the design of the kicker systems for advanced FEL facilities. For example, in the LCLS-II, the nanosecond range pulse allows for distributing closely spaced bunches to multiple undulators allowing experimenters to take advantage of combining different colored x-rays.

Funding: Work supported by US Department of Energy contract DE-AC02-76SF00515

WEB04

Laser-to-RF Synchronization with Femtosecond Precision

T. Lamb, L. Butkowski, E.P. Felber, M. Felber, M. Fenner, S. Jablonski, T. Kozak, J.M. Mueller, P. Predki, H. Schlarb, C. Sydlo, M. Titberidze, F. Zummack (DESY)

Optical synchronization systems are already in regular operation in many FELs, or they will eventually be implemented in the future. In FLASH and the European XFEL, phase-stable optical reference signals are provided by a pulsed optical synchronization system in order to achieve low timing jitter FEL performance. The generation of phase-stable RF signals from a pulsed optical synchronization system is still a field of active research. The optical reference module (REFM-OPT), designed at DESY for operation in both FELs, employs a laser-to-RF phase detector, based on an integrated Mach-Zehnder interferometer. The phase drift of the 1.3 GHz RF reference signals with respect to the optical pulses is measured and actively corrected within the REFM-OPT at multiple locations in the accelerator. Therefore the REFM-OPT provides phase stable 1.3 GHz RF reference signals at these locations. The short-term and long-term performance in the accelerator tunnel of the European XFEL is presented and carefully reviewed.

WEB05

ICS Diagnostic of FEL's Electron Beam Based on 6D Wigner Function Approach

A. Malyzhenkov, N.A. Yampolsky (LANL)

We report on the design of the Inverse Compton Scattering (ICS) based diagnostic system for the electron beam in the free electron laser. Novel 6D Wigner function ICS theory analytically relates the phase space of emitted radiation to the phase space of the electron beam at the interaction point. Based on this theory, we find signatures of the electron beam phase space features in the emitted ICS radiation. Then, we analyze which of these signatures can be measured in the existing experimental setups and compare reconstructed electron beam phase space features to simulation results from the beam tracking codes. Finally, we inverse the 6D Wigner function ICS theory to find the electron phase space distribution dependence on characteristics of emitted radiation and propose the design of the new diagnostic system to reconstruct desirable 2D projections of the 6D electron phase space.

WEC — Undulators, Photon Diagnostics, Beamline

Photon Beam Transport and Diagnostics Systems at an EUV FEL Facility: General Considerations, and Specific Challenges, Solutions and Developments at the FERMI Seeded FEL

WEC01

M. Zangrando (Elettra-Sincrotrone Trieste S.C.p.A.)

After the start of FLASH user operations in 2005, the possibility of performing user experiments at an EUV free electron laser source became reality. This kind of opportunity was extended in 2012 when the Italian FERMI seeded-FEL user facility started its user program. As a consequence, for such light sources new photon transport and diagnostic solutions were designed, developed, and implemented. A brief general overview about these issues will be introduced, together with a more detailed presentation of challenges faced and solutions found at the FERMI FEL. In particular, different instruments were developed in order to meet machine and endstation users' requirements concerning online non-invasive spectral content determination, pulse length and intensity characterization/control, active modification of the focusing properties, etc. Some examples and results will be presented, possibly comparing them to what was done elsewhere. Possible future implementations in photon-beam manipulation and characterisation will also be discussed.

Optimisation of Superconducting Undulators for Low Repetition Rate FELs

WEC02

J. A. Clarke, K. B. Marinov (STFC/DL/ASTeC) T. W. Bradshaw, M. J. D. Courthold (STFC/RAL)

Superconducting undulators (SCUs) optimised for storage rings and MHz-level FELs require an intermediate beam screen to intercept the power deposited by the electron beam, due to resistive wall wakefields, to prevent magnet quenching. This beam screen increases the magnet gap by around 2 mm which is a significant increase when compared to the typical electron beam aperture of around 5 mm. However, low-repetition rate FELs (up to 1 kHz) only deposit on the order of mW/m, so the beam screen is no longer needed resulting in a significant reduction in undulator magnet gap. We have investigated the impact of this reduced magnet gap and found that the magnetic field level increases greatly. For example, an SCU with a 15 mm period and 5 mm aperture optimised for a low-repetition rate FEL instead of a storage ring will generate a field of 2.1 T compared to 1.4 T. Such a major increase in undulator performance could have a significant impact on the optimisation of low repetition rate FELs. This paper describes how an SCU optimised for application in a low-repetition rate FEL will be able to generate magnetic field levels far beyond those currently foreseen for any other magnet technology.

Wavefront Preserving Optics for the LCLS Photon Transport System

WEC03

D. Cocco, C.L. Hardin, D.S. Morton, P. Stefan (SLAC) J. Nicolas (ALBA-CELLS Synchrotron)

The Linac Coherent Light Source (LCLS) is upgrading to a High Repetition Rate mode and to a higher quality of the wavefront. This poses extreme challenges to the optical components. A new approach to beamline design is needed, starting from a new way to assess the effect of slope and shape errors, to taking into account any potential source of distortion. Among the technical novelties the LCLS optics team is introducing, the most important are: a novel cooling scheme to maintain the mirror shape within 0.5 nm rms under heat load, the study of the effect of the cooling interface to the mirror surface, and new diagnostic systems. Ultra-flat mirrors with novel holder mechanisms have been recently installed. First results, showing the improvement of the beam quality, are expected in mid-June 2017. A controlled cleaning process to remove, in situ, carbonaceous contamination from carbon-based coatings will also be presented. It has been successfully implemented in the SXR mirrors. All the above tests and studies will be presented, as well as the effect seen on a six-year old mirror exposed to FEL for its entire lifetime.

Chair: S.V. Benson, JLab (Newport News, Virginia, USA)

WEC04

Progress of PAL-XFEL Undulator Program

D.E. Kim, H.-S. Kang, K.-H. Park (PAL) I.S. Ko (POSTECH)

Pohang Accelerator Laboratory (PAL) recently commissioned and started early user service of 0.1 nm SASE-based FEL based on the 10 GeV S-band linear accelerator named PAL-XFEL. One of the key components of the PAL-XFEL is the undulator system which consists of 20 units of Hard X-ray undulators, and 7 units Soft X-ray FELs. The basic design concept is based on the EU-XFEL undulator, but it also requires modification reflecting PAL-XFEL requirements. In this report, PAL efforts to modify, re-design, manufacture, take measurements, tune, install, and commission the undulator system will be summarized.

WEC05

Radiation-Induced Magnetization Reversal Causing a Large Flux Loss in Undulator Permanent Magnets

R. Kinjo, Y. Asano, T. Hara, T. Hasegawa, Y. Kida, T. Tanaka (RIKEN SPring-8 Center) T. Bizen, T. Itoga, A. Kagamihata, T. Seike, T. Watanabe (JASRI/SPring-8)

A large degradation of undulator field up to 35 percent was observed at the entrance of the in-vacuum undulators in SACLA; although this may be because of the radiation-induced demagnetization, it is much larger than what is expected from the former irradiation experiments. From the measurement of the surface field profile of individual permanent magnets (PMs) and the numerical calculations, we found that not the demagnetization but the magnetization reversal in small areas of the magnets is the reason of the large degradation of the undulator field. Numerical and experimental studies suggest that the magnetization reversal is a highly nonlinear process with respect to the reverse field in the PM, which is applied to the PM in the hybrid array. The experimental study also shows that a 10-cm stainless steel block placed just in front of the PMs significantly impedes the progress of the magnetization reversal, which suggests a simple and effective method to improve the lifetime of in-vacuum undulators.*

** T. Bizen et al., Scientific Reports 6, 37937 (2016).*

WEP — Poster III

The Photoinjector and Seed Laser Systems of DCLS

G.R. Wu, D.X. Dai, G.L. Wang, X.M. Yang, W.Q. Zhang (DICP)

WEP001

DCLS is free electron laser user facility based on HGHG concept. Two ultrafast laser systems are involved: the photoinjector laser system (PIL) and seed laser system (SL). Both laser systems have been installed and taken part in the commissioning of DCLS since September, 2016. Both laser systems are based on an all-CW-diode-pumped Ti:Sapphire amplifier system. PIL includes a delay-line type third harmonic generation scheme, a direct 3D shaping setup, and an imaging-relay transportation system. SL has two operation modes: 1 ps and 100 fs. It can be switched between these two modes. For the 100 fs mode, a delay-line based THG box is installed which delivers either 400 or 267 nm laser pulse as the seed. As for the 1 ps mode, a ps-OPA is used to deliver seed laser pulse with a wavelength between 240 and 360 nm. In this paper, we report the detailed design and the current status of these two laser systems.

Double Pulse FEL Operation at FLASH

S. Schreiber, K. Klose (DESY)

WEP002

The free-electron laser facility FLASH at DESY (Hamburg, Germany) has been a user facility since 2005 providing high-brilliance XUV and soft X-ray pulses. The facility runs 10-Hz bursts of hundreds of electron bunches, where the bunch distance in the burst is 1 microsecond or more. Some experiments ask for operation modes, with bunches as close as a few ps, ns or hundreds of ns. We report on operation of FLASH with these kind of double pulses for experiments using double soft X-rays and/or THz radiation pulses.

Update on the Lifetime of Cs2Te Photocathodes Operated at FLASH

S. Schreiber, S. Lederer (DESY) L. Monaco (INFN/LASA)

WEP003

The photoinjector of the free-electron laser facility FLASH at DESY (Hamburg, Germany) uses Cs2Te photocathodes. We report on an update of the lifetime and quantum efficiency of cathodes operated at FLASH during the last years.

Calculations of IR/THz FEL and Undulator Radiation Based on the Measured Electron Beam Parameters at PITZ

P. Boonpornprasert, M. Krasilnikov, F. Stephan, Q.T. Zhao (DESY Zeuthen)

WEP004

The Photo Injector Test facility at DESY, Zeuthen site (PITZ), develops high-brightness electron sources for modern linac-based free electron lasers (FELs). The PITZ accelerator can also be considered as a suitable machine for the development of an IR/THz-source prototype for pump-probe experiments at the European XFEL. The photocathode laser systems at PITZ are able to produce various temporal pulse shapes such as Gaussian, flat-top and comb-like. Generation of electron beams with corresponding bunch profiles was demonstrated experimentally. In this contribution, calculations of IR/THz radiation by means of FEL and undulator radiation based on the measured beam parameters will be presented and discussed.

WEP005

Coaxial Coupler RF Kick in the PITZ RF Gun

Y. Chen, P. Boonpornprasert, J.D. Good, I.I. Isaev, M. Krasilnikov, A. Oppelt, H.J. Qian, F. Stephan (DESY Zeuthen) W. Ackermann (TEMF, TU Darmstadt) M. Dohlus (DESY) Q.T. Zhao (IMP/CAS)

We investigate a transverse RF kick induced by the transition between a rectangular waveguide and the coaxial line of the RF coupler in the 1.6-cell normal conducting RF gun at the Photo Injector Test Facility at DESY, Zeuthen site (PITZ). A three-dimensional electromagnetic simulation shows the disturbed RF-field distributions in the fundamental mode. Based on the 3D RF field map, an electron-beam-based quantification of the coaxial RF coupler kick in the PITZ gun is simulated. The results of the investigations are presented.

WEP006

Preliminary On-Table and Photoelectron Results from the PITZ Quasi-Ellipsoidal Photocathode Laser System

J.D. Good, P. Boonpornprasert, Y. Chen, M. Gross, H. Huck, I.I. Isaev, D.K. Kalantaryan, M. Krasilnikov, X. Li, O. Lishilin, D. Melkumyan, A. Oppelt, H.J. Qian, Y. Renier, T. Rublack, F. Stephan (DESY Zeuthen) A.V. Andrianov, E. Gacheva, E. Khazanov, S. Mironov, A. Poteomkin, V. Zelenogorsky (IAP/RAS) M. Felber, T. Kozak (DESY) E. Syresin (JINR)

The optimization of photoinjectors is crucial for the successful operation of linac-based free electron lasers, and beam dynamics simulations have shown that ellipsoidal photocathode laser pulses result in significantly lower electron beam emittance than that of conventional cylindrical pulses. Therefore, in collaboration with the Institute of Applied Physics (Nizhny Novgorod, Russia) and the Joint Institute of Nuclear Research (Dubna, Russia), a laser system capable of generating quasi-ellipsoidal laser pulses has been developed and installed at the Photo Injector Test facility at DESY, Zeuthen site (PITZ). The pulse shaping has been realized using the spatial light modulator technique, characterized by cross-correlation and spectrographic measurements, and is demonstrated with electron beam measurements. In this contribution the overall setup, operating principles, and results of first regular electron beam measurements will be presented together with corresponding beam dynamics simulations. Furthermore, the numerous improvements of the simplified re-design currently under construction shall be detailed.

WEP007

Electron Beam Asymmetry Compensation with Gun Quadrupoles at PITZ

M. Krasilnikov, P. Boonpornprasert, Y. Chen, J.D. Good, H. Huck, I.I. Isaev, D.K. Kalantaryan, X. Li, O. Lishilin, G. Loisch, D. Melkumyan, A. Oppelt, H.J. Qian, Y. Renier, F. Stephan, Q.T. Zhao (DESY Zeuthen) G.A. Amatuni, B. Grigoryan (CANDLE SRI) G. Asova (INRNE) Q.T. Zhao (IMP/CAS)

The electron beam asymmetry observed at the Photo Injector Test Facility at DESY in Zeuthen (PITZ) was traced back to multipole kicks in the gun section, namely around the location of the coaxial power coupler and the main solenoid. Several dedicated studies have been performed to quantify the kick location and strength. Based on these studies, two designs of correction quadrupole coils were proposed. The coils were fabricated and tested with an electron beam. The second updated design implies a two quadrupole setup on the same frame installed around the gun coaxial coupler close to the main solenoid center location. Skew and normal quadrupole magnets are powered independently, enabling the flexibility in electron beam manipulations. By means of this setup, a more symmetric beam was obtained at several screens. This led also to more equal measured horizontal and vertical phase spaces and to even smaller overall emittance values. Some details of the gun quadrupole designs, magnetic measurements, and results of electron beam measurements including emittance optimization will be reported.

WEP008

Beam Brightness Improvement by Ellipsoidal Laser Shaping for CW Photoinjectors

H.J. Qian, M. Krasilnikov, F. Stephan (DESY Zeuthen)

High-brightness photoinjectors operating in a continuous wave (CW) mode are required for many advanced applications, such as CW X-ray FEL, ERL light source, electron coolers for hadron beams and electron-ion colliders and so on. Now, three types of CW electron guns are available: DC gun, SRF gun and normal conducting RF gun, which are under intense development in different institutes based on local

expertise and application demands. Compared to pulsed guns, both beam energy and brightness from CW guns are compromised due to a lower acceleration gradient. Flattop laser shaping has been applied in both pulsed and CW guns to improve beam emittance. In this paper, ellipsoidal laser shaping is applied in CW photoinjectors to improve beam brightness, and preliminary ASTRA simulations are presented.

A Cryocooled Normal Conducting and Superconducting Hybrid CW Photoinjector

WEP009

H.J. Qian, M. Krasilnikov, F. Stephan (DESY Zeuthen)

Continuous wave (CW) photoinjectors have seen great progress in the last decades, such as DC gun, SRF gun and normal conducting VHF-band RF gun. New developments of CW guns are aiming higher acceleration gradient and beam energy for higher-beam brightness. One of the technical challenges for CW SRF guns is the compatibility of normal-conducting high QE cathodes and superconducting cavity. In this paper, a high gradient cryocooled CW normal-conducting gun is proposed to house the high QE cathode, and a SRF cavity nearby gives further energy acceleration. Preliminary ASTRA simulations of such a hybrid photoinjector are presented.

Beam Asymmetry Studies with Quadrupole Field Errors in the PITZ Gun Section

WEP010

Q.T. Zhao, G. Asova, P. Boonpornprasert, Y. Chen, J.D. Good, M. Gross, H. Huck, I.I. Isaev, D.K. Kalantaryan, M. Krasilnikov, X. Li, O. Lishilin, G. Loisch, D. Melkumyan, A. Oppelt, H.J. Qian, Y. Renier, T. Rublack, C. Saisa-ard, F. Stephan (DESY Zeuthen) G. Asova (INRNE) C. Saisa-ard (Chiang Mai University) **Q.T. Zhao** (IMP/CAS)

The Photo Injector Test Facility at DESY in Zeuthen (PITZ) was built to test and optimize high-brightness electron sources for free electron lasers (FELs) like FLASH and European XFEL. Although the beam emittance has been optimized and experimentally demonstrated to meet the requirements of FLASH and XFEL, transverse beam asymmetries, such as wing structures and beam tilts, were observed during many years of operation with different generations of guns. These cannot be explained by simulations with the rotationally symmetric gun cavities and symmetric solenoid fields. Based on previous RF coupler kick, solenoid field imperfection studies and coupling beam dynamics, the beam asymmetries most probably stem from rotated quadrupole field error in the gun section. A thin-lens static quadrupole model is applied in the RF gun section simulations to fit the position and intensity of quadrupole field errors by comparing the beam asymmetry directions in experiments and ASTRA simulations. Furthermore, by measuring the laser position movement at the photo cathode and the corresponding beam movement at downstream screens, the integrated quadrupole field strength can also be extracted.

High Power Experiments of the ITC RF Gun Applied on the THz-FEL

WEP011

T. Hu, G. Feng (HUST) Y.J. Pei (USTC/NSRL)

A novel thermionic RF gun with two independent tunable cavities(ITC) has been adopted to generate high-quality electron beams for an FEL-based THz radiation in Huazhong University of Science and Technology. Based on precise modifications and numerous improvements, the gun has been designed and fabricated, then installed on the HUST THz-FEL and operated for over 2 years. This study aims to explain the development and preliminary experiments for the gun, with special attention to the progress of the gun developed after 2014. A test platform of the FEL injector based on the ITC RF gun as well as a beamline with a measuring scheme will be introduced in detail. After experimental setup and adequate conditioning, high power experiments are performed and preliminary testing results are obtained, then compared to the design results.

WEP012

A 2.45 GHz Photoinjector Gun for an FEL Driven by Laser Wakefield Accelerated Beam

S.V. Kuzikov, E. Gacheva, E.V. Ilyakov, S. Mironov, A.A. Vikharev (IAP/RAS)

The photoinjector of short electron bunches is a key element of investigations aimed on particle acceleration by pulses of the subpetawatt laser PEARL (10 J, 50-70 fs). The projected parameters of the photoinjector are an electron energy level of 5 MeV, a charge > 0.1 nC, a bunch length of about 3 mm, a transversal emittance no worse than 1 mm*mrad, and an energy spread no more than ~0.1%. The photoinjector is based on klystron KIU-111 at frequency 2.45 GHz, produced by company Toriy (output power ~ 5 MW, pulse length ~ 7 mcs, efficiency ~ 44%, power gain ~ 50 dB). It is proposed to use this klystron in order to feed the accelerating resonator of the classical design consisted of 1.5 cells in which the photocathode is inserted. On a base of third harmonics of a Ti:Sa laser, we plan to produce picosecond pulses of no less than 100 mcJ in energy. The photocathode is planned to be made of CVD diamond film which is not critical to vacuum degree and surface contamination, has high QE, a long lifetime, and is capable of being used with cheap, long wavelength optical lasers.

Funding: This work was supported by the Russian Scientific Foundation (grant #16-19-10448).

WEP013

Photocathode RF Gun Development at KAERI for Time-Resolving Pump/Prove System

K.H. Jang, Y.U. Jeong, H.W. Kim (KAERI) J.H. Han (PAL) N.A. Vinokurov (BINP SB RAS)

A photocathode RF gun-based pump/prove system has been developed at KAERI. The facility is mainly composed of a 1.6 cell S-band RF gun, a travelling wave-type linac and 90 degree achromatic magnetic-bends. Actually, it has four beam lines. The front two beam lines of the facility are designed for time-resolving UV & THz pump/electron beam prove experiments, and the last two beam lines are for THz pump/X-ray prove experiments. The photocathode RF gun installed in the system was designed to have a coaxial cylindrical coupler to be able to operate at high repetition rate by emitting the heat quickly with symmetrically water-cooling channels surrounding the RF cavity, and also to position gun solenoid at an optimum location. In the conference, we will present not only the design and fabrication of the gun itself but also the electron emission test results.

WEP014

Pulse Duration Measurement of Pico-second DUV Photocathode Driving Laser by Autocorrelation Technique Using Two-Photon Absorption in Bulk Material

H. Zen, T. Kii, K. Masuda, T. Nakajima, H. Ohgaki (Kyoto University)

A multi-bunch, pico-second DUV photocathode drive laser system has been developed for photocathode operation of mid-infrared free electron laser facility, KU-FEL.* By using the laser, KU-FEL has already succeeded in first lasing under the photocathode operation.** The pulse duration of the photocathode driving laser is a quite important parameter because it determines the initial electron pulse duration on the cathode surface. However, the pulse duration of the photocathode driving laser had not been characterized. A very convenient pulse duration measurement method utilizing two-photon absorption in bulk material, which can be used for DUV laser pulses, has been proposed and demonstrated so far.*** In this study, a DUV nonlinear autocorrelator based on the proposed method was developed to measure the pulse duration of the DUV photocathode driving laser. As the result of measurement, the pulse duration was evaluated as 5.8$\pm$0.2 ps (FWHM). The principle of this method, experimental setup and measured results will be presented.

** H. Zen et al., Proc. of FEL2014, pp.828-831 (2015). ** H. Zen et al., Proc. of IPAC2016, pp.754-756 (2016). *** C. Homann et al., Applied Physics B 104, 783 (2011).*

Current Experimental Work with Diamond Field-Emitter Array Cathodes

WEP015

H.L. Andrews, R.L. Fleming, J.W. Lewellen, K.E. Nichols, D.Y. Shchegolkov, E.I. Simakov (LANL) B.K. Choi (Vanderbilt University)

Diamond Field-Emitter Array (DFEA) cathodes are arrays of micron-scale diamond pyramids with nanometer-scale tips, thereby providing high emission currents with small emittance and energy spread. To date they have been demonstrated in a close-diode configuration, spaced only a few hundred microns from a solid anode, and have shown very promising results in terms of emittance, energy spread, and per-tip emission currents. We present recent results investigating DFEA performance in a large-gap configuration, such that the cathodes are a few millimeters from a solid anode, and show that performance is the same or better as the close-diode geometry previously studied. However, array performance is still limited by anode damage. We are redesigning our cathode test stand to overcome the inherent limitations of a solid anode, allow for transport of the emitted beam, and further explore real-world DFEA performance.

Funding: We gratefully acknowledge the support of the U.S. Department of Energy through the LANL/LDRD Program for this work.

Modeling of Diamond Field-Emitter-Arrays for High Brightness Photocathode Applications

WEP016

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We propose to employ Diamond Field-Emitter-Arrays (DFEAs) as high-current, ultra-low-emittance photocathodes for compact laser-driven dielectric accelerators. It is recognized that an X-ray free-electron laser (FEL) driven by a GeV dielectric laser accelerator is capable of generating higher output powers than the Linac Coherent Light Source while having a size 1-2 orders of magnitude smaller. We develop a semi-classical Monte-Carlo photoemission model for DFEAs that includes the effects of carriers' photoexcitation, their transport to the emitter surface, and tunneling through the surface. The model accounts for the electronic structure size quantization affecting the transport and tunneling process within the sharp diamond tips. Using our model as an input, we perform first principle beam physics simulations of the photoemission quantum yield and the properties of the emitted electron beam. Details of the theoretical model and progress in the model implementation, including the validation against preliminary experimental data, will be presented.

Funding: Work performed under the auspices of the U.S. DOE by the LANS, LLC, Los Alamos National Laboratory (LANL) under Contract No. DE-AC52-06NA25396. Work supported by the LDRD program at LANL.

The Multiphysics Photocathode Growth and Characterization System at LANL

WEP017

M.A. Hoffbauer, J.W. Lewellen, N.A. Moody, V.N. Pavlenko (LANL)

A versatile multiphysics photocathode growth and characterization system is being commissioned by the Applied Cathode Enhancement and Robustness Technology (ACERT) team at LANL. The multiphysics system brings together state-of-the-art surface-science capabilities and leverages unique LANL capabilities to provide an integrated system consisting of (i) bi-alkali antimonide and nitride semiconductor thin-film growth, (ii) advanced surface-science characterization tools, and (iii) incorporation of photocathodes into an operational electron-gun cathode assembly for quantitative beam emittance measurements. Our goal is to provide a modular integrated UHV platform for advancing photocathode performance to the levels needed for the next generation of advanced FELs and accelerators.

Funding: We gratefully acknowledge the support of the U.S. Department of Energy through the LANL/LDRD Program for this work.

WEP018

Electron Beam Heating with the European XFEL Laser Heater

M. Hamberg (Uppsala University) F. Brinker, M. Scholz, L. Winkelmann (DESY)

The commissioning of the European XFEL is ongoing. To reduce unwanted longitudinal micro-bunching effects, a laser heater is implemented. Here we present the first heating steps and commissioning of the laser heater at the injector section.

Funding: Work supported by Swedish Research council, Sweden, Olle Engkvist foundation and DESY, Hamburg, Germany.

WEP019

High Stable Pulse Modulator for PAL-XFEL

S.S. Park, H.-S. Kang, S.H. Kim, H.-S. Lee (PAL)

The XFEL of Pohang Accelerator Laboratory (PAL) commissioned the 10 GeV PAL-XFEL project in 2015. The PAL-XFEL needs a highly-stable electron beam. The very stable beam voltage of a klystron-modulator is essential to provide the stable acceleration field for an electron beam. Thus, the modulator system for the XFEL requires less than 50 ppm PFN voltage stability. To get this high stability on the modulator system, the HVPS of inverter type is an important component. The modulator also needs lower noise and more smart. In this paper, we will discuss the design and the test results of the high-stability pulse modulator system.

Funding: This work is supported by Ministry of Science, ICT(Information/Communication Technology) and Future Planning.

WEP020

Longitudinal Shaping of the Max IV Photocathode Gun Laser Pulses

M. Kotur, J. Andersson, F. Curbis, F. Lindau, S. Thorin, S. Werin (MAX IV Laboratory, Lund University)

The longitudinal shape of the driver laser pulse plays an important role in producing a low-emittance beam in a photocathode electron gun. Here we present a Fourier-domain pulse shaping setup, which is being developed with the goal of being able to achieve arbitrary shapes of the UV laser pulse. Comparisons of the preliminary results with the standard pulse stacking scheme are discussed.

WEP021

Preliminary Results of the Dark Current Modelling for the Polfel Superconducting Lead Photocathode

K. Szymczyk, J.A. Lorkiewicz, R. Nietubyc (NCBJ) J.K. Sekutowicz (DESY)

Preparation for the construction of Polish Free Electron Laser (POLFEL) will begin shortly at National Centre for Nuclear Research (NCBJ) in Warsaw. POLFEL is planned as a fourth-generation light source driven by a superconducting (sc) electron accelerator. The concept includes an all-superconducting injector with a thin-film lead sc photocathode, dedicated to continuous wave or long-pulse linac operation. One of the issues which emerges in connection with operation of high-gradient electron guns furnished with dismountable photocathode plugs is the dark current emitted from the cathode surface inhomogeneities. The dark current usually degrades accelerator performance. The purpose of this paper is to present preliminary investigation results of the dark current generation in the electron gun with a thin lead layer deposited on a niobium plug. Specific features of geometric configuration like rounded plug edges, a gap between the plug and the back gun wall as well as cathode surface roughness have been taken into account for the electron field emission and RF field calculations.

WEP022

Dark-Current Beam Dynamics in the FAST Injector

P. Piot (Fermilab) , D. Mihalcea (Northern Illinois University)

Dark current produced in high-gradient accelerating structure can be transported to high energy along an accelerator beam line and lead to unwanted side effects including the production of X- and gamma-ray background. Such a side effect hindered a recent attempt to detect X-ray radiation produced via channeling radiation at the FAST 50-MeV photoinjector. This paper reviews the dark-current properties,

transport and associated losses along the FAST-injector beamline and explores a possible mitigation mechanism. Numerical simulation of the beam dynamics of the dark current together with measurement is discussed.

Sponsored by the DNDO award 2015-DN-077-ARI094 to Northern Illinois University. Fermilab is operated by Fermi Research Alliance, LLC. for the DOE under contract DE-AC02-07CH11359.

Commissioning of the SwissFEL Linac

WEP023

F. Loehl (PSI)

Since summer 2016, the C-band linear accelerator of SwissFEL has been progressively commissioned. This paper will summarize the first commissioning experience of the first C-band modules and will give an outlook for the planned activities for the remainder of this year.

Electromagnetic Design and Optimization of a Micro-Pulse Electron Gun

WEP024

D.Y. Yang, B.T. Li, X.Y. Lu, W.W. Tan, L. Xiao, Y. Yang, Z.Q. Yang, J. Zhao (PKU) K. Zhou (CAEP/IAE)

Micro-pulse electron gun (MPG) is a novel electron source which can produce narrow-pulse, high-repetition rate electron current. Theoretical and experiment work have been done to study physical properties and steady operating conditions of MPG. Proof-of-principle work has been finished and the next work is to research the parameters of the MPG electron beam and master the MPG work property deeply. Thus, a high voltage accelerating platform which can supply 100 kV direct voltage was designed. Furthermore, electromagnetic and mechanism designs were operated to adapt the high voltage platform and measure beam parameters.

Emittance Measurements from SRF Gun in CeC Accelerator

WEP025

K. Mihara (Stony Brook University) Y.C. Jing, V. Litvinenko, I. Pinayev, G. Wang (BNL) I. Petrushina (SUNY SB)

In this paper we report on extremely good performance of 113 MHz SRF CW gun. This gun is a part of the system built to test coherent electron cooling concept and was aimed to generate trains of 78 kHz pulses with large 1 nC to 5 nC charge per bunch. While it was not built for attaining record low emittances, the machine can achieve very low normalized emittances ~ 0.3 mm mrad with 0.5 nC charge per bunch using CsK2Sb photocathode. In addition to excellent performance, this gun provides for very long lifetime of these high QE photocathodes, with a typical using time of 2 months.

Funding: DoE NP office, grant DE-FOA-0000632 and NSF grant PHY-1415252

Inducing Microbunching in the CLARA FEL Test Facility

WEP026

A.D. Brynes (STFC/DL/ASTeC)

We present simulation studies of the induced microbunching instability in the CLARA FEL test facility. The instability, which manifests itself as correlated energy or density modulations in an electron bunch, can degrade the performance of an FEL. However, if the instability can be controlled, the electron bunch profile can be manipulated, yielding novel applications for the FEL, or for generation of THz radiation. Through modifying the intensity profile of the photocathode laser on the CLARA FEL, we show that it is possible to control the instability.

WEP027

Numerical Study of Cherenkov Radiation From Thin Silica Aerogel

H. Hama, K. Nanbu, H. Saito, Y. Saito (Tohoku University, Research Center for Electron Photon Science)

Cherenkov radiation (CR) emitted from low-refractive index material such as silica-aerogel is a useful tool for electron beam diagnostics because the opening angle (Cherenkov angle) is small and the CR can be transported onto a detector located far from the radiator. We have prepared a thin (1-mm thick) hydrophobic silica-aerogel with a refractive index of 1.05 that has been developed at Chiba University.* Since the intensity of CR is much stronger than that of optical transition radiation, the CR is a better light source for low-intensity beam diagnostics. In order to apply the CR to measurements of a bunch length of electron beams, we have investigated sources of finite time resolution by a numerical simulation study using the Liénard-Wiechert potentials. We will report results of simulations such as pulse duration of CR and discuss what deteriorates the time resolution.

** M. Tabata et al., Nucl. Instr. and Meth. A 668 (2012) 64.*

Funding: This work was supported by JSPS KAKENHI Grant Numbers JP15K13394 and JP17H01070.

WEP028

Diagnostics for the Soft X-ray Laser at MAX IV

E. Mansten (MAX IV Laboratory, Lund University)

We present the diagnostics for the Soft X-ray laser at MAX IV.

WEP029

Recent Experimental Results On High-Peak-Current Electron Bunch and Bunch Trains with a THz Undulator

L.X. Yan, Y. C. Du, W. Gai, W.-H. Huang, Y.F. Liang, X.L. Su, C.-X. Tang, D. Wang (TUB)

In this paper, experimental results based on THz undulator with widely tunable gap at Tsinghua Thomson scattering X-ray (TTX) beamline are introduced. This is a planar permanent magnetic undulator with 8 regular periods, each 10 cm long. The parameter K varies from 9.24-1.39 by changing the magnetic gap from 23mm to 75mm. The coherent undulator radiation can be used as a narrow-band THz source with central frequency ranging from 0.4 THz to 10 THz. The bunch length was figured out from the radiation intensity at different undulator gap, which agrees well with simulations. For 100 MeV ultrashort Gaussian bunch, the resolution of this method can be as high as 1 fs. Furthermore, slice energy modulation has been directly observed when high-peak-current bunch trains based on nonlinear longitudinal space charge oscillation pass through the undulator. The demonstrated experiment in THz regime provides a significant scaled tool for FEL mechanism exploration owing to the simplicity of bunch modulation and diagnostics in this range.

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Funding: supported by the National Natural Science Foundation of China (NSFC Grants No. 11475097) and National Key Scientific Instrument and Equipment Development Project of China (Grants No. 2013YQ12034504).

Large-Scale Turnkey Timing Distribution System for New Generation Photon Science Facilities

WEP030

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Rapidly-emerging new-generation light sources such as X-ray free-electron lasers and attoscience centers show the highest demand in synchronization, on the order of few femtoseconds or below. These generate ultrashort X-ray pulses enabling 4D-microscopy with attosecond-temporal and subatomic-spatial resolution.*,** One of the biggest obstacles preventing this long-standing scientific dream from coming true is a high-precision timing distribution system synchronizing various optical and microwave sources across multi-km distances which is required for seeded FELs and sub-fs pump-probe experiments. Recently, it has been shown that the pulsed-optical timing distribution system can deliver sub-fs timing precision between remotely synchronized lasers and microwave sources in laboratory environments.*** Here, we transform this experimental system into a large-scale turnkey timing distribution system that is able to serve 15 remote optical and microwave sources via timing-stabilized fiber links. The system exhibits less than 1-fs RMS timing jitter at the outputs of the fiber links over 2.5 days of operation.

** http://www.xfel.eu/news/2017/european_xfel_generates_its_first_laser_light. ** G. Mourou and T. Tajima, Science, 331, pp. 41-42, 2011. *** M. Xin et al., Light Sci. Appl., 6, e16187, 2017.*

Initial Study in Using a Neural Network Control Policy for FEL Tuning

WEP031

A.L. Edelen, S. Biedron, S.V. Milton (CSU)

FEL user facilities must often accommodate requests for a variety of beam parameters. Here we present a preliminary investigation into using a neural network control policy for rapid switching between beam parameters (and the resultant FEL wavelength). To investigate this concept, we used PARMELA simulations of the planned 3 - 6 MeV Colorado State University accelerator from the gun up to the entrance of the undulator and measurements from the FEL when it was at University of Twente.

MicroTCA.4 -Based Control for the Optical Synchronization System at the European XFEL

WEP032

M. Felber, E.P. Felber, M. Fenner, C. Gerth, M. Heuer, T. Kozak, T. Lamb, J.M. Mueller, K.P. Przygoda, H. Schlarb, C. Sydlo, F. Zummack (DESY)

The optical synchronization system at the European XFEL will serve as femtosecond-stable reference throughout the 3.5 km long facility. Its operation and performance is essential for the success of pump-probe experiments, first by enabling the LLRF system to stabilize the electron bunch arrival time and thereby the FEL X-ray pulse timing, and second by synchronizing the experimental laser with fs precision. The electronic hardware is realized in various MicroTCA.4 modules. Most of them are specially designed for this application but yet commercially available on the market due to licensing agreements between DESY and industry partners. In this paper we present the applied modules, the topology of the new systems and review the first operational experience.

Generic Optimizer for the European XFEL Commissioning

WEP033

S.I. Tomin (XFEL. EU) I.V. Agapov, W. Decking, G. Geloni, I. Zagorodnov (DESY)

A beam-based optimization project in the framework of OCELOT toolkit development was started in 2015 and was used for SASE pulse energy optimization at FLASH and later at LCLS. Additionally, the online optimization successfully demonstrated efficiency maximization in the Siberia-1 storage ring for the electron beam injection. The diversity of these two applications shows the flexibility of the approach used in the code. For the European XFEL commissioning purposes, a special graphical user interface was developed and the code was modified to allow the users to change the objective function online. In this work, we will present several applications of the OCELOT generic optimizer for commissioning purposes.

WEP034

Diagnostics Upgrades for Investigations of HOM Effects in TESLA-type SCRF Cavities

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We describe the upgrades to diagnostic capabilities on the Fermilab Accelerator Science and Technology (FAST) electron linear accelerator that will allow investigations of the effects of high-order modes (HOMs) in SCRF cavities on macropulse-average beam quality. We focus here on the dipole modes in the first pass-band generally observed in the 1.6-1.9 GHz regime in TESLA-type SCRF cavities due to uniform transverse beam offsets of the electron beam. Such cavities are the basis of the accelerator for the European XFEL and the proposed MaRIE XFEL facility. Initial HOM data indicate that the mode intensities oscillate for about 10 microseconds after the micropulse enters the cavity, resulting in centroid shifts throughout the train. This results in a blurring of the averaged beam image size. The upgrades will include optimizing the HOM detectors' bandpass filters and adding a 1.3-GHz notch filter, converting the BPM electronics to bunch-by-bunch processing, and using the C5680 streak camera in a framing mode for bunch-by-bunch spatial information at the <20-micron level. The preliminary HOM detector data, prototype BPM test data, and first framing camera OTR data will be presented.

Funding: Work at FNAL supported by Fermi Research Alliance,LLC under Contract No. DE-AC02-07CH11359 with the U.S. DoE. Work at LANL supported by U.S. DoE through the LANL/LDRD Program.

WEP035

Measurements of Electron Bunch Timing Jitter Using Spectral Decoding Technique for Ultrafast Electron Diffraction Experiments

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Ultrafast electron diffraction (UED) experiments have been performed to study the ultrafast carrier dynamics of gas and solid targets at Korea Atomic Energy Research Institute (KAERI). For this pump-probe experiment with femtosecond (fs) temporal resolution, each pulse length of a laser beam (pump) and electron beam (probe) should be as short as a few fs, and moreover, the arrival time of each beam is accurately synchronized in the target within a few fs. Therefore, a timing jitter between two beams should be precisely characterized and modified for ultrafast science. Herein we present timing jitter measurements using spectral-decoding method, where coherent transition radiation (CTR) in the terahertz (THz) regime and chirped laser beam are used. The decoding pulse is stretched from 100 fs to 1.2 ps by a grating-pair optical stretcher. The polarization of this laser beam is changed with THz beam by inducing the birefringence of an electro-optic crystal. The polarization modulation can be converted to intensity modulation through the following optics, and the profile and timing jitter of electron bunches can be obtained using a spectrometer.

WEP036

Adaptive Feedback for Automatic Phase-Space Tuning of Electron Beams in Advanced XFELs

A. Scheinker (LANL)

Particle accelerators are extremely complex having thousands of coupled, nonlinear components which include magnets, laser sources, and radio frequency (RF) accelerating cavities. Many of these components are time-varying. One example is the RF systems which experience unpredictable temperature-based perturbations resulting in frequency and phase shifts. In order to provide users with their desired beam and thereby light properties, LCLS sometimes requires up to 6 hours of manual, experience-based hand tuning of parameters by operators and beam physicists, during a total of 12 hours of beam time provided for the user. Even standard operational changes can require hours to switch between user setups. The main goal of this work is to study model-independent feedback control approaches which can work together with physics-based controls to make overall machine performance more robust, enable faster tuning (seconds to minutes instead of hours), and optimize performance in real time in response to un-modeled time variation and disturbances.

Mechanical Engineering of the SXFEL Project

WEP037

L. Yin, F. Gao, X. Hu, Z. Jiang, S. Sun, L. Wang, Y.M. Wen (SINAP)

Shanghai X-ray Free-Electron Laser (SXFEL), a soft X-ray FEL test facility based on an 840-MeV linac and 2-stage radiator undulators, is presently under commissioning. Strong piles were set under a thick concrete slab to suppress ground vibrations. The accelerator components and their spatial relations are considered in detail to ensure successful engineering design and operation. A series of analyses and prototype tests, including the moveable chicane in the Linac and the high precise quadrupole support in radiator section, were carried out to simulate and optimize the mechanical designs. The design, construction and performance of the machine are described in this paper.

Sub-Micrometer Resolution, Nanotechnology Based Wire Scanners for Beam Profile Measurements at SwissFEL

WEP038

S. Borrelli, M. Bednarzik, Ch. David, E. Ferrari, A. Gobbo, V. Guzenko, N. Hiller, R. Ischebeck, G.L. Orlandi, C. Ozkan Loch, B. Rippstein, V. Schlott (PSI)

SwissFEL Wire scanners (WSCs) measure electron beam transverse profile and emittance with high-resolution in a minimally-invasive way. They consist of a wire fork equipped with two 5 micrometer W wires, for high-resolution measurements, and two 12.5 micrometer Al(99):Si(1) wires, to measure the beam profile during FEL operation. Although the SwissFEL WSCs resolution is sufficient for many purposes, for some machine operations and experimental applications it is necessary to improve it under micrometer scale. The WSC spatial resolution is limited by the wire width which is constrained to few micrometers by the conventional manufacturing technique of stretching a metallic wire onto a wire-fork. In this work, we propose to overcome this limitation using the nanofabrication of sub-micrometer metallic stripes on a membrane by means of e-beam lithography. This presentation focuses in the design, construction and characterization of a high-resolution WSC prototype consisting of a silicon nitride membrane onto which two gold or nickel wires, widths ranging from 2 micrometers to 0.4 micrometers, are electroplated. We will also present the preliminary electron beam tests of our prototype.

Saturation of Scintillators in Profile Monitors

WEP039

R. Ischebeck, E. Ferrari, F. Frei, N. Hiller, G.L. Orlandi, C. Ozkan Loch, V. Schlott (PSI)

SwissFEL uses scintillating screens to measure the transverse profile of the electron beam. These screens, in combination with quadrupole magnets and a transverse deflecting RF structure, are used to measure projected and slice emittance, as well as bunch length. Scintillating screens have been chosen over optical transition radiators because of the coherent transition radiation emitted by the compressed bunches. It is therefore instrumental to characterize the linearity of these monitors in order to ensure reliable measurements. We are presenting here a measurement of saturation effects due to the high charge density in SwissFEL, and describe the results with a numerical model of the process.

Sub-Femtosecond Time-Resolved Measurements Based on a Variable Polarization X-Band Transverse Deflecting Structures for SwissFEL

WEP040

P. Craievich, M. Bopp, H.-H. Braun, R. Ganter, M. Pedrozzi, E. Prat, S. Reiche, R. Zennaro (PSI) R.W. Assmann, F. Christie, R.T.P. D'Arcy, B. Marchetti, D. Marx (DESY) N. Catalan-Lasheras, A. Grudiev, G. McMonagle, W. Wuensch (CERN)

The SwissFEL project, under commissioning at the Paul Scherrer Institut (PSI), will produce FEL radiation for soft and hard X-rays with pulse durations ranging from a few to several tens of femtoseconds. A collaboration between DESY, PSI and CERN has been established with the aim of developing and building an advanced X-Band transverse deflector structure (TDS) with the new feature of providing variable polarization of the deflecting force. As this innovative CERN design requires very high manufacturing precision to guarantee highest azimuthal symmetry of the structure to avoid the deterioration of the polarization of the streaking field, the high-precision tuning-free assembly procedures developed at PSI for the SwissFEL C-band accelerating structures will be used for the manufacturing. Such a TDS will be installed downstream of the undulators of the soft X-ray beamline of SwissFEL and thanks to the variable polarization of the TDS, it will be possible to perform a complete characterization of the 6D phase-space. We summarize in this work the status of the project and its main technical parameters.

WEP041

HLS to Measure Changes in Real Time in the Ground and Building Floor of PAL-XFEL, Large-Scale Scientific Equipment

H. J. Choi, S.Y. Baek, H.-S. Kang, S.H. Kim, H.-G. Lee, S.B. Lee (PAL)

A variety of parts that comprise large-scale scientific equipment should be installed and operated at accurate three-dimensional location coordinates (X, Y, Z) through survey and alignment in order to ensure optimal performance. However, uplift or subsidence of the ground occurs over time, and consequently causes the deformation of building floors. The deformation of the ground and buildings cause changes in the location of installed parts, eventually leading to alignment errors (ΔX, ΔY, ΔZ) of components. As a result, the parameters of the system change and the performance of large-scale scientific equipment is degraded. Alignment errors that result from changes in building floor height can be predicted by real-time measurement of changes in building floors. This produces the advantage of reducing survey and alignment time by selecting the region where great changes in building floor height are shown and re-aligning components in the region in a short time. To do so, HLS (hydrostatic leveling sensor) with a resolution of 0.2 micrometers and a waterpipe of 1 km are installed at the PAL-XFEL building. This paper introduces the installation and operation status of HLS.

WEP042

The Status of LLRF Systems for PAL-XFEL

J. Hu (PAL)

PAL-XFEL was constructed for the generation of hard X-ray and soft X-ray. The construction and installation of the machine were completed in late 2015, and the commissioning works were done sequentially including the acceleration of an e-beam up to 10 GeV, 0.1 nm lasing, and the saturation of lasing intensity. The many works required for user services are still ongoing. The digital LLRF systems to support the operation of PAL-XFEL have been in reliable operation for about 1.5 years. The architecture of LLRF systems is described, and the current status of LLRF systems is presented.

WEP043

Tune-Up Simulations for LCLS-II

M.W. Guetg (SLAC)

The planned superconducting LCLS-II linac poses new operational constraints with respect to the existing copper linac currently operated for LCLS. We present the results of exhaustive accelerator simulations, including realistic machine errors and exploring beam tune-up strategies. The results are used to pin-point the required beam diagnostics and the key correction elements. Specifically, these simulations concentrate on longitudinal and transverse beam matching as well as orbit and dispersion control through the new linac and up to the hard x-ray FEL. Dispersion control is achieved by a novel method presented within this paper.

WEP044

Beam Loss Monitor for Undulators in PAL-XFEL

H. Yang, D.C. Shin (PAL)

PAL-XFEL consists of the hard x-ray line with a 4-10 GeV electron beam and the soft x-ray line with a 3-3.5 GeV electron beam. The HX line consists of 20 undulators and the SX line consists of 7 undulators. The permanent magnets in an undulator should be protected from the radiation-induced demagnetization. We develop a beam loss monitor (BLM) for undulators of PAL-XFEL. It consists of a detector part (head)

and an ADC part. The BLM head consists of two fused quartz rods, two photo-multiplier tube (PMT) modules, and an LED bulb. It is based on the Cherenkov radiator: two fused quartz rods are used for radiators. 2 sets of the radiator and PMT module are installed up and down the beam tube. An LED bulb is between the radiators for the heartbeat signal. The ADC part digitizes the output signal of the PMT module. It measures and calculates the beam loss, background, and heartbeat. One ADC processes the signal from 6-8 heads. The BLM system generates interlock to the machine interlock system for over-threshold beam loss. The 28 BLM heads are installed downstream of each undulator. Those are calibrated by the heartbeat signal and operated in the transmission of a 150-pC electron beam.

Funding: This work is supported by MSIP, Korea.

Transition Radiation Beam Profile Diagnostics at EUV Wavelengths

WEP045

A.Y. Murokh, M. Ruelas, H.L. To (RadiaBeam)

We propose a method of measuring transverse profile of high quality photo-injector generated electron beams, using a backscattered transition radiation from multilayer mirrors at the extreme ultraviolet (EUV) spectral region. The motivation for such a short wavelength is twofold: to mitigate coherent effects (COTR) detrimental to beam profile measurements at longer wavelengths; and to achieve sub-micron resolution for high precision applications such as those requiring electron beam matching into photonic structures. The specific wavelength of 13.5 nm was selected to take advantage of high quality optics availability. We discuss anticipated EUV TR signal amplitude and detection methods, analyze strengths and challenges of the proposed system in comparison with more conventional diagnostic methods, and provide a status report on the prototype system development and planned installation and testing at LCLS.

Diffusion in Momentum of Ultrarelativistic Electron Beam in an Undulator

WEP046

V.V. Ognivenko (NSC/KIPT)

We consider diffusion processes in momentum space of a relativistic electron beam moving in the spatially periodic magnetic field of an undulator. Basing directly on the dynamics of individual particles motion under action of the pair interaction forces due to incoherent electromagnetic field of spontaneous undulator radiation of electrons longitudinal (along undulator axis) diffusion coefficient is derived. We obtain the expressions for rms momentum of electrons for both the initial monoenergetic electron beam,* and at the kinetic stage of beam relaxation, when initial momentum spread of electrons is taken into account. It is shown that for the initial spread in momentum of electrons which correspond to high-gain SASE process, the incoherent electromagnetic field can lead to an increase in the momentum spread of electrons. The conditions for the high-gain self-amplification of spontaneous radiation in ultrashort-wavelength FELs have been discussed.

** V.V. Ognivenko, J. Exp. Theor. Phys. 115, 938 (2012)*

The Friction Coefficient for Relativistic Electrons Moving in an Undulator

WEP047

V.V. Ognivenko (NSC/KIPT)

The motion of the relativistic electron beam in an undulator has been considered, taking into account the effect of the incoherent field of the spontaneous undulator radiation on the motion of the electrons. The friction coefficient is derived on the bases of the dynamics of individual particle motion under the action of the pair interaction forces from each of them. The change in the mean value of momentum of relativistic electrons is considered. The expression for the friction force describing the average change of electrons momentum per a time unit, both in the case of motion of initially monoenergetic electrons, and at the kinetic stage motion of electrons, is derived. The relationship between the mean-square spread in momenta of electrons and the frictional force is analyzed.

WEP048

Coherent Undulator Radiation from an Electron Beam with a Tilted Microbunching

J.P. MacArthur (SLAC)

We calculate the coherent undulator radiation from an electron beam with tilted microbunching due to a transverse kick from an upstream corrector. The power suppression in the limit of a thin beam and a wide beam are discussed, as well as the amount of the frequency shift. We then discuss the connection of this model with the recent observations at the LCLS DELTA undulator experiments.

WEP049

Stimulated Emission/Absorption of Radiation by a Single-Electron Quantum Wavepacket

A. Gover, Y. Pan (University of Tel-Aviv, Faculty of Engineering)

We analyze the stimulated (emission/absorption) interaction of a single electron quantum wavepacket with coherent radiation, using perturbation theory and numerical solution. The analysis applies to a wide class of free electron radiative-interaction schemes, and is exemplified for Smith-Purcell radiation. Contrary to spontaneous emission, stimulated radiative interaction depends on the wavepacket characteristics in a certain quantum range. If the electron drifts beyond a critical length, then dimension-dependent acceleration of the wavepacket is fundamentally impossible because of the wavepacket spread. Below this range, such acceleration is possible, approaching the limit of classical 'point particle' linear acceleration, at the conditions of small wavepacket dimensions relative to the radiation wavelength and multi-photon exchange. Our analysis emulates the FEL gain in the limit of negligible recoil, and the quantum momentum recoil sidebands characteristics of PINEM - when recoil effect is significant. We use the platform for discussing the fundamental physics question of measurability of the quantum wavepacket size and the limitation of the classical 'white' shot-noise model.

Funding: Partial support by Deutsche-Israelische Projektkooperation (DIP) and US-Israel Binational Science Foundation (BSF).

WEP050

An Analysis of Diffraction Effect on Coherent Spontaneous Emission

Q.K. Jia (USTC/NSRL)

The coherent spontaneous emission is an important operation mode for the intense narrow-band THz sources. From FEL equations we analyze the coherent spontaneous emission and the influence of the diffraction effect on it. For a resonant electron beam with a radial Gaussian distribution and the radiation on axis, the diffraction correction factor of the emission power is given.

WEP051

Helical Undulators for Coherent Electron Cooling System

I. Pinayev, Y.C. Jing, V. Litvinenko, G. Wang (BNL) P. Vobly (BINP SB RAS)

In this paper we present the description and results of the magnetic measurements and tuning of helical undulators for the Coherent electron Cooling system (CeC). The FEL section of the CeC comprises three 2.5-m long undulators separated by 40-cm drift sections, where BPMs and phase-adjusting 3-pole wigglers are located. We present design, tuning techniques and achieved parameters of this system.

Funding: DoE NP office, grant DE-FOA-0000632

An Overview of Undulator Developments at Davv

WEP052

M. Gehlot, R. Khullar, G. Mishra (Devi Ahilya University) F. Trillaud (UNAM)

Undulators require strict tolerances on the magnetic field quality for high-radiation-quality free electron lasers. This demands development of field measurement and alignments systems to design low field integral undulators for their compliance to the required specifications. In this paper we will review undulator development activities of the laboratory. The laboratory has developed pulsed-wire magnetic measurement systems* and used it effectively to characterize a six-period 300-mm length NdFeB-based PPM undulator. Twenty-five period 500-mm length hybrid undulator has been designed and characterized in a Hall probe bench.** A laser micrometer*** built in house is used for magnet size and gap measurements. Recently a one-meter length PPM undulator with twenty periods has been designed and fabricated. A new girder support system and a stretched wire magnetic measurement system for the one-meter length PPM undulator is ready for measurement. A straightness interferometer has been developed and will be used for undulator gap alignment studies. A prototype superconducting undulator has been proposed for magnetic measurement studies and technology development.****

** G. Sharma et al. Measurement 82, 2016. ** G. Mishra et al. Trans. on Magnet. 53, 2017. *** R. Khullar et al. Opti. and Lasers Eng 68, 2015. **** G. Mishra et al. Jour. of Syn. Radia. 24, 2017.*

Funding: This work is supported by SERB-DST grant EMR/2014/00120 and financial support from UGC[No.F.15-1/2014-15/PDFWM-2014-15-GE-MAD-26801(SA-II)],Delhi and DGAPA of UNAM, fund PAPIIT TA100617.

Study of a Superconducting THz Undulator at the European XFEL

WEP053

T. Tanikawa (European XFEL) V. B. Asgekar, M. Gensch (HZDR) S. Casalbuoni (KIT) G. Geloni, S. Karabekyan (XFEL. EU)

The European XFEL has successfully achieved a first lasing in May 2017. Meanwhile, a THz radiation for pump-probe experiments etc. is under consideration at the European XFEL using laser-based and/or accelerator-based techniques. A superconducting THz undulator as an afterburner is one option, but a challenge to this approach is the usage of very high electron-beam energy up to 17.5 GeV and the requirement of a high magnetic field. In this presentation, we will report the preliminary study of the THz undulator design and the radiation properties at the European XFEL.

The Magnetic Field Integral Hysteresis on the European XFEL Gap Movable Undulator Systems

WEP054

F. Wolff-Fabris (European XFEL) Y. Li, J. Pflueger (XFEL. EU)

The European XFEL GmbH is a new X-ray FEL facility expected to be lasing to users at the end of 2017. Three gap-movable SASE Undulator Systems are designed to produce FELs with tunable wavelengths from 0.05 to 5.2nm.*,** A total of 91 5m long undulator segments and phase shifters were magnetically tuned respecting tight specifications. Magnetic field hysteresis effects due to the gap shift of the Undulator System while changing the FEL radiation wavelength may impact the machine's operational mode. We report on these effects by either opening or closing the gap while performing field integrals measurements with moving wire technique. The undulator segments show negligible magnetic hysteresis and are expected to be operated with no influence to the FEL and beam trajectories in either feed forward or feed backward mode. The phase shifters show first field integrals hysteretic behavior of few G.cm which is comparable in magnitude to the allowed total field integrals and can be associated to the magnetization of the yoke structure. Phase shifters are magnetically tuned for that the feed forward mode (opening gap) fully satisfies the XFEL. EU magnetic specifications for beam operation.

** M. Altarelli et al., Technical Design Rep. DESY 2006-097, July 2007. ** E. Schneidmiller et al., European XFEL Technical Rep. TR-2011-006, Sep. 2011.*

WEP055

Tapered Flying Radiofrequency Undulator

S.V. Kuzikov, A.V. Savilov, A.A. Vikharev (IAP/RAS) S.P. Antipov, C.-J. Jing (Euclid TechLabs, LLC) C.-J. Jing, C.-J. Jing (ANL) C.-J. Jing (Euclid Beamlabs LLC) A.V. Savilov (UNN)

We propose an efficient XFEL consisting of sequential RF undulator sections using: 1) tapered flying RF undulators, 2) short pulse, high peak-power RF and 3) driving undulator sections by spent electron beam. In a flying RF undulator, an electron bunch propagates through a high-power, nanosecond, co-propagating RF pulse. Helical waveguide corrugation supports a space harmonic with a negative propagation constant, providing a large Doppler up-shift. The undulator tapering technique improves FEL efficiency by 1-2 orders of magnitude in comparison with other facilities by decreasing the undulator period so that particles are trapped in the combined field of the incident x-ray and undulator field. We develop a so-called non-resonant trapping regime not requiring phase locking for feeding RF sources. Simulations show that by decreasing the corrugation periodicity one can vary an equivalent undulator period by 15%. The spent electron beam can be used to produce wakefields that will drive the RF undulator sections for interaction with the following beam. We have already manufactured and tested the 30 GHz simplified version of the 50 cm long undulator section for cold measurements.

Funding: This project is supported by DoE Small Business Innovative Research phase I grant #DE-SC0017145.

WEP056

Analysis of Electron-Beam Angle Deviation on the Radiation Power of FEL using TGU

G. Zhou, Y. Jiao, J.Q. Wang (IHEP) J. Wu (SLAC)

Recent study shows that electron beams with constant dispersion together with the transverse-gradient undulator (TGU) can reduce the sensitivity to energy spread for free-electron laser (FEL). By inducing dispersion function, electrons with different energy are placed at different positions corresponding to proper magnetic fields. Thus, FEL resonant condition can be kept for electrons with different energy. In this paper, we mainly studied: 1. The influence of electron beam angle deviation at the entrance of the TGU on the radiation power. 2. The utility of a kicker between two TGU sections to generate a deviation of electron beam angle to improve the FEL radiation power.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

WEP057

Design of a Compact Hybrid Undulator for the THz Radiation Facility of Delhi Light Source (DLS)

S. Tripathi, R.K. Bhandari, S. Ghosh, D. Kanjilal (IUAC) M. Tischer (DESY)

A compact Free Electron Laser (FEL) facility to produce coherent THz radiation is in the development stage at Inter-University Accelerator Centre (IUAC), New Delhi, India.*,** The name of this facility is Delhi Light Source (DLS) in which a low-emittance electron beam from a photocathode RF gun with a maximum energy of 8 MeV will be injected into a compact undulator magnet to generate THz radiation. To produce the THz radiation in the range of 0.15 to 3.0 THz, the electron beam energy and the undulator gap need to be varied from 4 to 8 MeV and 20 to 45 mm, respectively. The variable gap undulator of 1.5-m length will consist of NdFeB magnets with vanadium permendur poles. The magnet design and dimensions are optimised by using code 3D RADIA.*** The detailed design of the compact hybrid undulator will be presented in this paper.

** S.Ghosh et al., presented at this conference. ** S.Ghosh et al., NIMB-2017 (in press). *** RADIA. Available at http://www.esrf.eu/Accelerators/ groups/ Insertion Devices/ Software/ Radia.*

Funding: One author, Sumit Tripathi (PH/16-17/0029), would like to acknowledge University Grant Commission (UGC), New Delhi, India for financial support as D.S.Kothari Postdoctoral fellowship.

Development of a Hybrid Electromagnetic Planar Undulator Having Horizontal Focusing Force for a Compact THz FEL

WEP058

S. Bae, B.A. Gudkov, K.H. Jang, Y.U. Jeong, K. Lee, S.V. Miginsky, J. Mun, S. Park (KAERI) M.Y. Jeon (Chungnam National University)

A THz table-top FEL is under development at KAERI for security applications. We developed a compact microtron to accelerate electrons up to 5 MeV with an energy spread of about 0.4%. A hybrid electromagnetic planar undulator was designed and fabricated to cover the FEL's lasing wavelength range of 400~600 μm. The magnetic field strength in the gap of the undulator is changeable from 0.76 to 1.14 T by varying the coil current of the undulator from 1.5 to 2.5 kA. The undulator provides a horizontal focusing force to keep the low energy electrons passing a specially-designed narrow waveguide. The undulator field error of 1st and 2nd integrals, which is 3.61 x 10^{-4} T·m and 5.75 x 10^{-5} T·m2, respectively, was minimized to reduce the deflection angle and trajectory offset of electron beam to pass through the waveguide having a width of 10 mm.

Development of T-Ray-Pumped Ultrafast Electron Diffraction Beamline

WEP059

I.H. Baek, B. Han, K.H. Jang, Y.U. Jeong, H.W. Kim, M.H. Kim, Y.-C. Kim, K. Lee, J.H. Nam, S. Park (KAERI) N.A. Vinokurov (NSU)

Ultrashort electron diffraction (UED) technique has triggered numerous fundamental studies and technological applications. For a resonant control of materials, the intense T-ray has been regarded as a crucial tool because its low photon energy can excite an extremely low energy level of atomic or molecular system selectively. In this work, we present the ultrafast T-ray-pump/electron-probe crystallography system for observing the structural dynamics of temperature-controlled materials. T-ray with energies of few microjoule is generated from the nonlinear optical crystal lithium niobate and utilized as a pumping source. Three-MeV electron bunches are produced by the RF-photogun with 2.856 GHz and utilized as a diffraction tool. The isochronous bending structure compresses an electron bunch length to ~30 femtoseconds. We believe that our system can guide the way to understand fundamental phenomena in nature.

Streaking Diagnostics for Attosecond X-Ray Pulses at the Linac Coherent Light Source

WEP060

S. Li, R.N. Coffee, J. Cryan, K.H. Hegazy, A. Marinelli, A. Natan, T. Osipov, D. Ray (SLAC) G. Guo (Stanford University)

The development of sub-fs X-ray capabilities at the Linac Coherent Light Source requires the implementation of time-domain diagnostics with attosecond time resolution. Photoelectrons created by attosecond duration X-ray pulses in the presence of a strong-laser field are known to suffer an energy spread which depends on the relative phase of the strong-laser field at the time of ionization. This phenomenon can be exploited to measure the duration of these ultrashort X-ray pulses. We present an implementation which employs a circularly polarized infrared laser pulse and novel velocity map imaging (VMI) design which maps the phase dependent momentum of the photoelectron onto a 2-D detector. In this paper, we discuss specific details of the VMI design and the reconstruction algorithm, and its application to attosecond X-ray free-electron lasers within the XLEAP project at the Linac Coherent Light Source.

Effect of High-Intensity X-Ray FEL Pulse on Silicon, Germanium, and Diamond

WEP061

J. Wu (SLAC) B. Yang (University of Texas at Arlington)

For x-ray FELs, silicon, diamond, germanium, and other crystals are frequently used not only for diagnostics, but also for temporal and spectral manipulation. For examples, self-seeding with a single-crystal diamond monochromator is a successful approach for generating high brightness from an x-ray free electron laser (XFEL), and bent silicon-crystal is used as FEL spectrometer. In this paper, numerical analyses of stress waves and heat loads due to intense XFEL pulses at various powers and repetition rates are carried for a thin silicon and diamond crystal. The results are used to suggest an optimized distributed self-seeding configuration with diamond crystal monochromator and also the accompanying silicon and/or germanium spectrometers for LCLS-II type projects in the hard x-ray FEL energy regime.

Funding: The work was supported by the US Department of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early Career Research Program grant FWP-2013-SLAC-100164.

WEP062

Optical Beam-Quality Analysis of the Clara Test Facility Using Second Moment Analysis

H.M. Castaneda Cortes, D.J. Dunning, M.D. Roper, N. Thompson (STFC/DL/ASTeC)

We studied and characterised the FEL optical radiation in simulations of the CLARA FEL test facility under development at Daresbury Laboratory in the UK. In particular, we determined the optical beam quality coefficient, waist position and other source properties corresponding to different potential FEL operating modes via wavefront propagation in free space using OPC (Optical Propagation Code) and Second Moment Analysis. We were able to find the operation mode and undulator design for which the optical beam has the optimum quality at highest brightness. Furthermore, we studied the way that different properties of the electron bunches (emittance, peak current, bunch length) affect the optical beam. We are now able to understand how the optical beam will propagate from the end of the undulator and through the photon transport system to the experimental stations. This knowledge is necessary for the correct design of the photon transport and diagnostic systems.

WEP063

Proposed Two-in-One Type Undulator

D. Wang (SINAP)

The typical X-ray free electron lasers have long tunnels to accommodate high energy electron linear accelerator and long undulator line to produce intense coherent radiations at very short wavelengths. The number of undulator lines is limited by the available space in the tunnel. This is especially true for those facilities that adopt underground tunnels or utilize the existing tunnels originally built for other purpose. This work explored the possibility to better use the tunnel space for accommodating more FEL undulator lines by designing a new type of undulator structure.

Funding: This work is supported by the Ministry of Science and Technology of China.

WEP064

Tunable High Gradient Quadrupoles for a Laser-Plasma Acceleration-Based FEL

A.M. Ghaith, F. Blache, M.-E. Couprie, F. Marteau, P. N'gotta, M. Valléau, J. Vétéran (SOLEIL) C. Benabderrahmane (ESRF) O. Cosson, F. Forest, P. Jivkov, J.L. Lancelot (Sigmaphi)

The magnetic design and characterization of tunable high gradient permanent magnet based quadrupole, are presented. To achieve a high gradient field with a compact structure, permanent magnets are chosen rather than usual electro-magnets due to their small aperture. The quadrupole structure consists of two quadrupoles superimposed capable of generating a gradient of 210 T/m. The first quadrupole is composed of permanent magnets following a Halbach configuration shaped as a ring attaining a constant gradient of 160T/m, and the second of four permanent magnet cylinders surrounding the ring and capable of rotating around their axis to achieve a gradient tunability of $\pm$50 T/m. Each tuning magnet is connected to a motor and is controlled independently, enabling the gradient to be tuned with a rather good magnetic center stability ($\pm$20 μm) and without any field asymmetry. Seven quadrupoles have been built with different magnetic lengths in order to fulfil the integrated gradient required. A set of QUAPEVA triplet are now in use, to focus a high divergent electron beam with large energy spread generated by a laser plasma acceleration source for a free electron laser application.

Cryogenic Permanent Magnet Undulator for a FEL Application

WEP065

A.M. Ghaith, T. Andre, I.A. Andriyash, P. Berteaud, F. Briquez, N. Béchu, M.-E. Couprie, C. Herbeaux, M. Labat, O. Marcouillé, F. Marteau, E. Roussel, K.T. Tavakoli, M. Tilmont, M. Valléau (SOLEIL) S. Corde, J. Gautier, G. Lambert, B. Mahieu, V. Malka, C. Thaury (LOA)

A Cryogenic Permanent Magnet Undulator (CMPU) is capable of achieving high brightness radiation at short wavelengths, by taking advantage of the permanent magnets' enhanced performance at low temperature. A CPMU of period 18 mm (U18) that has been built at Synchrotron SOLEIL is used for the COXINEL project to demonstrate Free Electron Laser (FEL) at 200 nm using a laser plasma acceleration source. Another undulator of period 15 mm (U15) is currently being built to replace U18 undulator for FEL demonstration at 40 nm. A new method is also introduced, using SRWE code, to compute the spectra of the large energy spread beam (few percent) taking into account the variation of the Twiss parameters for each energy slice. The construction of U18 undulator and the magnetic measurements needed for optimization, as well as the mechanical design of U15, are presented. The commissioning of U18 and measurements of the beam transverse shape captured with a charge coupled device camera are reported and compared to the simulations.

A New Structure of PPM Undulator

WEP066

L.J. Chen (USTC/NSRL)

A new structure of pure permanent magnet (PPM) undulator is proposed to improve the peak magnet field. The poles are cut into two blocks, with the magnetization directions tilted and the peak magnet field is obviously higher than that of normal PPM undulator. Several methods have been proposed to solve the issue of short good field region.

Off-Axis Con-Focal Transmission Line for Terahertz Radiation

WEP067

A. Friedman, E. Dyunin (Ariel University)

FEL radiation has typical properties, such as high-peak power, multimode, wide spectrum, and phase coherent radiation. Therefore, it is impossible to use a waveguide approach or the quasi-optical methods alone. The design and construction of high-power transmission lines for a terahertz radiation with such properties requires a more careful treatment in order to accurately describe resulting beam properties and trajectory. Wigner distribution is used for the transformation of the electromagnetic field, described from Maxwell's equations, to optical beams. A typical beam is characterized by the position in space, phase, polarization and energy. We replace numerical Ray Tracing with analytical methods. That allows a calculation to be performed on the reflected beam from a mirror, with an accuracy of more than 6th order of the wavelength. We use the mean root square method to calculate a Transition Matrix of 3rd order. This method is very useful to estimate the accuracy of the analytical results such as linear transition and aberration, and to correct reflecting surface shape if needed. Adding the phase analysis reveals interference processes occurring in the transmission line.

Three-Dimensional, Time-Dependent Simulation of Free-Electron Lasers with Planar, Helical, and Elliptical Undulators

WEP068

H. Freund (CSU) P. Falgari (Lime BV) D.L.A. Grimminck, I. Setya (ASML) P.J.M. van der Slot (Mesa+)

Free-electron lasers have been built ranging from long-wavelength oscillators through ultraviolet to hard x-ray that are either seeded or SASE. In addition, FELs that produce different polarizations ranging from linear through elliptic are currently under study. In this paper, we develop a 3D, time-dependent formulation that is capable of modeling this large variety of FEL configurations including different polarizations.* We employ a modal expansion for the optical field, i.e., a Gaussian expansion with variable polarization for free-space propagation. The formulation uses the Lorentz force equations to track particles. Arbitrary 3D representations for different undulators are

implemented, including planar, helical, and elliptical. To model oscillators and allow propagation outside the undulator and interaction with optical elements, we link the FEL simulation with the optical propagation code OPC. We present detailed comparisons with experiments including (1) the LCLS, (2) the SPARC SASE FEL experiment at ENEA Frascati, (3) a seeded-tapered amplifier experiment at Brookhaven National Laboratory, and (4) the 10-kW Upgrade Oscillator experiment at Jefferson Laboratory.

** H.P. Freund, P.J.M. van der Slot, D.L.A.G. Grimminck, I.D. Setya, and P. Falgari, New J. Phys. 19, 023020 (2017).*

WEP069

Simulation of a Terawatt X-Ray Free-Electron Laser

H. Freund (CSU)

The possibility of constructing terawatt x-ray free-electron lasers (FELs) has been discussed using novel superconducting helical undulators.* In this paper, we consider the conditions necessary for achieving powers in excess of 1 TW in a 1.5 FEL using the MINERVA simulation code.** Steady-state simulations have been conducted using a variety of undulator and focusing configurations. In particular, strong focusing using FODO lattices is compared with the natural, weak focusing inherent in helical undulators. It is found that the most important requirement to reach TW powers is extreme transverse compression of the electron beam in a strong FODO lattice.

** C. Emma, K. Fang, J. Wu, and C. Pellegrini, Phys. Rev. Accel. Beams, 19, 020705 (2016). ** H. Freund, P. van der Slot, D. Grimminck, I. Setya, and P. Falgari, New J. Phys. 19, 023020 (2017).*

WEP070

Distortion of the Spatial Properties of the Radiation from Seeded and SASE FEL Caused by Energy Chirp in the Electron Beam and Undulator Tapering

E. Schneidmiller, M.V. Yurkov (DESY)

Knowledge of the spatial properties of the radiation properties is a key issue for the users of x-ray FEL facilities. In this report, we present a detailed analysis of the spatial properties of the radiation from an FEL amplifier. Two configurations, seeded FEL amplifier, and SASE FEL, are under consideration. Dependence of the spatial distributions on the electron beam properties is studied, and their evolution along the undulator is traced. It is shown that spatial properties of the radiation may be significantly affected by the effect of energy chirp in the electron beam and undulator tapering.

WEP071

Spin Effects in a Free Electron Laser with an Ion Channel Guiding

M. Alimohamadi (Farhangian University)

The spin effects of the quantum free electron lasers (QFELs) with an ion channel guiding and helical wiggler are considered. The quantum Hamiltonian of single particle has been derived in the Bambini-Renieri (BR) frame. Time-dependent wave functions and the motion constants are obtained.

WEP072

Spin Effects in a Free Electron Laser with an Axial Guide Field

M. Alimohamadi (Farhangian University)

The spin effects of the quantum free-electron lasers (QFELs) with an axial guide field and helical wiggler are considered. The quantum Hamiltonian of a single particle has been derived in the Bambini-Renieri (BR) frame. Time-dependent wave functions and the motion constants are obtained.

Lie Map Formalism for FEL Simulation

WEP073

K. Hwang, J. Qiang (LBNL)

The integration step size in FEL simulation needs to resolve the wiggling motion of the electron beam. In order to increase the step size, the averaged equation of electron motion has been widely used. We present an alternative formalism using Lie map that also allows an increase of the step size for electron motion. In addition, we propose a modified the field equation to improve the accuracy of modeling higher harmonics radiation.

Funding: U.S. Department of Energy under Contract No. DE-AC02-05CH11231

Simulations of the Dependence of Harmonic Radiation on Undulator Parameters

WEP074

G. Penn (LBNL)

The flux and bandwidth of radiation produced at harmonics of the fundamental are very sensitive to the undulator parameter, and thus the beam energy or undulator period. We look at high-energy XFELs with parameters relevant to the MaRIE FEL design. Both SASE and seeded FELs are considered.

Funding: This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Simulation of Electron Trajectories in Undulator with SCILAB

WEP075

H. Jeevakhan, kumar, S. Kumar (NITTTR) M. Gehlot (Devi Ahilya University)

Model-based simulation has been used to analytically simulate the trajectories of an electron traversing through an undulator. Open source software SCILAB's Xcos tool boxes have been employed to design a model for electron beam trajectory. The trajectory analysis given by SCILAB in the present paper is compared with the previous analysis done in Fortran.

Effect of Constant Magnetic Field on Intensity of Undulator Radiations with Energy Spread in Electron Beam

WEP076

H. Jeevakhan (NITTTR) M. Gehlot, G. Mishra (Devi Ahilya University)

Undulator radiations for an undulator with a constant component of magnetic field along the direction perpendicular to the direction of the undulator field have been analyzed. The effect of a constant magnetic field component on undulator radiations with an electron beam having a homogeneous spread has been worked out with the help of generalized Bessel function and semi-numerical analysis.

Wiggler Problems and Generation of Soft Gamma Rays

WEP077

V.V. Gorev (NRC)

In this report we will discuss clues and stubborn problems of soft gamma-ray generation by different types of wigglers (classic and novel). These issues are especially relevant to gamma-ray generation for giant resonance investigation and any others. Directions of this critical research and limitations of the principles will also be discussed.

Period-Averaged Symplectic Maps for the FEL Hamiltonian

WEP078

S.D. Webb (RadiaSoft LLC)

Conventional treatments of synchrotron radiation in electron beams treat the radiation as a non-Hamiltonian aspect to the beam dynamics. However, the radiation can be modeled with an electromagnetic Hamiltonian. We present a period-averaged treatment of the FEL problem which includes the Hamiltonian aspects of the coupled electron-radiation dynamics. This approach is then applied to two problems: a 3D split-operator symplectic integrator, and a 1D single-mode FEL treated using Hamiltonian perturbation theory.

Funding: This work was carried out with support for the United State Department of Energy, Office of Scientific Research, under SBIR contract number DE-SC0017161.

WEP079

High Gain, High Efficiency Tapered FELs in the Post-Saturation Regime

C. Emma, P. Musumeci, C. Pellegrini, N.S. Sudar, A. Urbanowicz (UCLA) C. Pellegrini (SLAC)

We study the 1-D physics of high gain, high efficiency tapered FELs in the post-saturation regime.*,** We derive a basic scaling formula for the FEL output power as a function of the beam current, the seed power and the trapping fraction assuming a constant resonant phase. We examine this analytic scaling using 1-D simulations for a seeded FEL starting from a large seed with a small energy spread electron beam (fresh bunch) with/without pre-bunching. We show that the efficiency improves substantially when the electron beam is suitably pre-bunched compared to the unbunched case. Finally, we study the sideband instability growth via 1-D time-dependent simulations. We confirm the inverse proportionality of the sideband power to the resonant phase as discussed in KMR. We also propose a method of sideband suppression via gain-modulation of the FEL using a modulated taper profile.***

** N. M. Kroll, P. L. Morton, and M. Rosenbluth. Quantum Electronics, IEEE Journal of 17(8): 1436-1468, August 1981. ** R. Iaconescu, in this conference. *** Marinelli et al., PRL 111,134801 (2015).*

WET — Tutorial II

Beam-Based Alignment of Undulators for Free-Electron Lasers

Wednesday tutorial: 17:30–18:30

P. Emma (SLAC)

THA — FEL Applications

THA01

Observations of Fast Structural Changes with an X-ray FEL: Dynamics Studies on Photoactivated Proteins at SACLA

K. Tono (JASRI/SPring-8)

X-ray FELs (XFELs) paved the way for exploring ultrafast structural dynamics in a biological macromolecule. Time-resolved protein crystallography with an XFEL now can reach a resolution of the order of femtosecond. One of the most promising techniques for time-resolved measurement is serial femtosecond crystallography (SFX). We have developed an experimental system for time-resolved SFX at SACLA*. This system has been applied for visualizing structural changes in a photoactivated macromolecule such as bacteriorhodopsin (bR)** or photosystem II (PSII)***. In the application to bR, diffraction measurements cover a wide range of timescales from nanoseconds to milliseconds to fully access the structural transitions in the photocycle. The structural data at more than ten time points provided a cascade of structural changes after photoactivation of the retinal chromophore. This 'movie' clearly shows how bR transports protons through a cell membrane against a chemical-potential gradient. This paper gives an overview of the experimental instruments and techniques for studying ultrafast protein dynamics with XFEL, and recent applications at SACLA.

** K. Tono et al., J. Synchrotron Rad. 22, 532 (2015). ** E. Nango et al., Science 354, 1552 (2016). *** M. Suga et al., Nature 543, 131 (2017).*

THA02

Four-Wave Mixing Using Extreme Ultraviolet Transient Gratings at FERMI FEL

F. Bencivenga, F. Capotondi, R. Cucini, L. Foglia, C. Masciovecchio, R. Mincigrucci, E. Pedersoli, E. Principi, A. Simoncig (Elettra-Sincrotrone Trieste S.C.p.A.)

Four-wave mixing (FWM) processes are exploited in the optical domain in a large array of scientific and technological applications. The extension of this approach to the XUV and X-ray range was theoretically conceived,* but not experimentally pursued because of the lack of photon sources with enough brightness and coherence. This situation has changed with the advent of FELs, in particular those stabilized by seeding processes. In this context, the XUV pulses delivered by FERMI have been used to experimentally demonstrate the FWM response stimulated by XUV transient gratings.** More recently the 'twin-seed' double-colour FEL mode of FERMI has been employed in a two-colour XUV FWM experiment.*** These results provide grounds to build up the sophisticated experiments envisioned by theoreticians,* which could provide access to high energy/high-wavevector excitations, with elemental selectivity and nano to atomic spatial resolution. Capabilities that can be exploited in different fields, ranging from thermal transport dynamics in nanoelectronic devices to charge transfer processes in molecules.

** S. Tanaka and S. Mukamel, Phys. Rev. Lett., 2002, 89, 043001 ** F. Bencivenga et al., Nature, 2015, 520, 205 *** F. Bencivenga et al., Faraday Discuss., 2014, 171, 487*

THA03

Two-Temperature Equilibration in Warm Dense Hydrogen Measured With X-Ray Scattering from the Linac Coherent Light Source

L.B. Fletcher (SLAC)

Understanding the properties of warm dense hydrogen plasmas is critical for modeling stellar and planetary interiors, as well as for inertial confinement fusion (ICF) experiments. Knowledge of thermodynamic properties of hydrogen in a fusion environment furthers our ability to accurately model complex systems essential to ICF. Of central importance are the electron-ion collision and equilibration times that determine the microscopic properties in a high energy-density state. Spectrally and angularly resolved X-ray scattering measurements from fs-laser heated hydrogen have resolved the picosecond evolution and energy relaxation from a two-temperature plasma towards thermodynamic equilibrium in the warm dense matter regime.

The interaction of rapidly heated cryogenic hydrogen irradiated by a 400-nm, 5x10^{17}-W/cm^2, 70-fs laser is visualized with ultra-bright 5.5-keV x-ray pulses from the Linac Coherent Light Source (LCLS) in a 1-Hz repetition-rate pump probe setting. We demonstrate that the energy relaxation is faster than many classical binary collision theories that use ad hoc cutoff parameters used in the Landau-Spitzer determination of the Coulomb logarithm.

Funding: This work was supported by the DOE/SC/FES under contract No. SF00515 and supported under FWP 100182 and DOE/SC/BES, Materials Sciences and Engineering Division, contract DE-AC02-76SF00515.

THB — Electron-Beam Dynamics

THB01

Beam Dynamics Optimization in High-Brightness Electron Injectors

C.E. Mitchell, J. Qiang, F. Sannibale (LBNL)

The next generation of X-ray free electron lasers requires beams with increasingly high peak current and low emittances at ~MHz repetition rates, placing increased demands on the performance of high-brightness electron photoinjector sources. To explore the high-dimensional parameter space associated with photoinjector design, global multiobjective optimization methods based on genetic algorithms or similar tools are playing an increasingly critical role. We review our experience with applying these tools both to understand and to optimize simulated injector beam performance for projects such as LCLS-II (at SLAC) and the Advanced Photoinjector EXperiment (at LBNL), including both challenges and successes.

Funding: This work was supported by the Office of Science of the U.S. Department of Energy under Contract Numbers DE-AC02-76SF00515, DE-AC02-05CH11231, and the LCLS-II project.

THB02

Non-Standard Use of Laser Heater for FEL Control and THz Generation

E. Allaria, L. Badano, M.B. Danailov, A.A. Demidovich, S. Di Mitri, D. Gauthier, L. Giannessi, G. Penco, E. Roussel, P. Sigalotti, S. Spampinati, M. Trovo, M. Veronese (Elettra-Sincrotrone Trieste S.C.p.A.) E. Roussel (SOLEIL)

The laser heater system is currently used at various FEL facilities for an accurate control of the electron beam energy spread in order to suppress the micro-bunching instabilities that can develop in high-brightness electron beams. More recently, studies and experiments have shown that laser-electron interaction developing in the laser heater can open new possibilities for tailoring the electron beam properties to meet special requirements. A suitable time-shaping of the laser heater pulse opened the door to the generation of (tens of) femtosecond-long FEL pulses. Using standard laser techniques it was also possible to imprint onto the electron bunch, energy and density modulations in the THz frequency range that, properly sustained through the accelerator, were exploited for generation of coherent THz radiation at GeV beam energies. Such recent results at the FERMI FEL are here reported, together with near-future plans.

THB03

High-Power, Narrow-Bandwidth THz Generation Using Laser-Electron Interaction in a Compact Accelerator

Z. Huang, G. Marcus (SLAC) K. Kan (ISIR) Z. Zhang (TUB)

We propose a method based on the slice energy-spread modulation to generate strong subpicosecond density bunching in high-intensity relativistic electron beams.* A laser pulse with periodic intensity envelope is used to modulate the slice energy spread of the electron beam, which can then be converted into density modulation after a dispersive section. In this paper, we study this method in a compact accelerator with electron energy on the order of 50 MeV. To interact with an infra-red laser, the modulation undulator is resonant with the laser at a harmonic frequency. We show the flexibility of this method to generate powerful, narrow-bandwidth radiation between 1-20 THz. The THz radiation can be generated at a very high-repetition rate that matches a high-repetition rate X-ray free-electron laser for pump-probe studies of novel materials.

* *Z. Zhang et al., Phys. Rev. Accel. Beams 20, 050701 (2017).*

THB04

Two-Color Beam Generation via Wakefield Excitation

S. Bettoni, E. Prat, S. Reiche (PSI)

Several beam manipulation methods have been studied and experimentally tested to generate two-color photon beams in free electron laser facilities to accommodate the user requests. We propose to use the interaction of the beam with an oscillating longitudinal wakefield source to obtain a suitable electron beam structure. The bunch generates two sub-pulses with different energies and delays in time passing through

a magnetic chicane after its longitudinal phase space has been modulated by the wakefield source. According to this approach, the power of the emitted radiation is not degraded compared to the monochromatic beam, and the set-up in the machine is quite simple because the bunch is manipulated only in the high energy section where the beam is more rigid. We present the design applied to SwissFEL. We identified the parameters and the corresponding range of tunability of the time and energy separation among the two sub-bunches.

FRA — Advanced Concepts & Techniques

FRA01

Fresh-Slice X-Ray Free Electron Laser Schemes for Advanced X-Ray Applications

A.A. Lutman, R.N. Coffee, Y. Ding, J.P. Duris, M.W. Guetg, Z. Huang, J. Krzywinski, J.P. MacArthur, A. Marinelli, T.J. Maxwell, S.P. Moeller, J. Zemella (SLAC) N. Berrah (University of Connecticut) C. Emma (UCLA)

The novel fresh-slice XFEL scheme grants control on the temporal slice of the electron bunch lasing in each undulator section. The technique relies on a time-dependent electron bunch trajectory impressed by the transverse wakefield of a corrugated structure and subsequent orbit manipulation in the undulator section. Fully saturated double pulses are produced in two different undulator sections. The wavelength of each pulse is controlled by the undulator magnetic strength and the delay between the pulses can be scanned from a few femtosecond advance of the pulse generated on the bunch head in the second section to a picosecond delay provided by the magnetic chicane. Three-color saturated pulses are demonstrated by using three undulator sections and the polarization of the pulse generated in the last section can be controlled by the variable polarization Delta undulator. In this work we also show the early results for the first multi-stage amplification scheme, producing ultra-short single-pulses with a 100-GW power level in the soft X-rays. The multi-stage amplification is also demonstrated to improve the performance in power and pulse duration control for the two-color FEL scheme.

Funding: This work was supported by Department of Energy contract nos DE-AC02-76SF00515 and DE-SC0012376

FRA02

Using the Optical-Klystron Effect to Increase and Measure the Intrinsic Beam Energy Spread in Free-Electron Laser Facilities

E. Prat, S. Reiche, T. Schietinger (PSI) E. Ferrari (EPFL)

We present a setup based on the optical klystron concept consisting of two undulator modules separated by a magnetic chicane, that addresses two issues in free-electron laser (FEL) facilities. On the one hand, it allows an increase of the intrinsic energy spread of the beam at the source, which is useful to counteract the harmful microbunching instability. This represents an alternative method to the more conventional laser heater with the main advantage that no laser system is required. On the other hand, the setup can be used to reconstruct the initial beam energy spread, whose typical values in FEL injectors around 1 keV are very difficult to measure with standard procedures.

FRA03

Towards High-Efficiency Industrial FELs

A.Y. Murokh (RadiaBeam) P. Musumeci (UCLA) S. Nagaitsev (Fermilab) S.D. Webb (RadiaSoft LLC) A. Zholents (ANL)

Free Electron Lasers have achieved prominence as the X-ray light source technology for research applications, but their industrial potential remains largely unexplored, even though FELs could reach wavelength coverage and powers unattainable by active media sources. In response to this challenge, we developed the TESSA (tapering-enhanced stimulated superradiant amplifier) FEL scheme, which enables as much as 50% single-pass beam-to-light energy-conversion efficiency. With strongly tapered helical undulator and stimulated rapid deceleration, TESSA offers an order-of-magnitude improvement over all existing high-efficiency FEL paradigms and beyond the limit of many conventional lasers. The proof-of-concept was recently demonstrated by UCLA in a pilot experiment at 10-μm wavelength, where 35% deceleration efficiency has been achieved in a 50-cm wiggler. The next steps discussed herein, include: the ongoing development of the TESSA high gain amplifier at UV wavelength; a planned transition to SCRF linac driven TESSA oscillator to reach high average powers; and eventually a development of the EUV TESSA oscillator for industrial applications in the semiconductor industry.

Funding: DOE Grant No. DE-SC0017102

Three-Dimensional Manipulation of the Electron Beam Phase Space for Generating Steady State Microbunching in Storage Rings

FRA04

C. Feng, Z.T. Zhao (SINAP) A. Chao (SLAC)

Several methods have been developed in the last decade to improve the temporal properties of a storage ring based light source. Most of these methods employ external lasers to manipulate the longitudinal phase space of the electron beam to precisely tailor the properties of the radiation pulses. In this work, we show the possibility of the realization of steady state microbunching and generating fully coherent intense EUV and x-ray radiation pulses via three-dimensional manipulation of the electron beam phase space in storage rings. Theoretical analysis and numerical simulations show that this technique can be used for the generation of megawatt-scale level, fully-temporal coherent EUV and soft x-ray radiation pulses at a storage ring light source.

European Plasma Accelerator Design Study EuPRAXIA with FEL & HEP User Areas

FRA05

P.A. Walker (DESY)

The Horizon 2020 Project EuPRAXIA (European Plasma Research Accelerator with eXcellence In Applications) aims at producing a design report of a highly compact and cost-effective European facility with a 5 GeV electron beam using plasma as the acceleration medium. The accelerator facility will be based on a laser and/or a beam-driven plasma acceleration approach and will have user areas for FEL user experiments as well as high-energy physics (HEP) detector tests. Other applications such as a compact X-ray source for medical imaging will also be included. EuPRAXIA started in November 2015 and will deliver the design report in October 2019. The contribution will introduce the work up to date, the underlying physics of compact plasma accelerators, and its 16 European partner laboratories and further 22 international associated partners.

Funding: Horizon 2020 Programme from European Union

FRB — FEL Theory

FRB01

Time-Domain Analysis of Attosecond Pulse Generation in an X-Ray Free-Electron Laser

P. Baxevanis, Z. Huang, A. Marinelli (SLAC)

The method of enhanced self-amplified spontaneous emission (eSASE) is one of the strongest candidates for the generation of sub-femtosecond X-ray pulses in a free-electron laser. The optimization of an eSASE experiment involves many independent parameters, which makes the exploration of the parameter space with 3-D simulations computationally intensive. Therefore, a robust theoretical analysis of this problem is extremely desirable. We provide a self-consistent, analytical treatment of such a configuration using a one-dimensional, time-dependent FEL model that includes the key effects of linear e-beam chirp and linear undulator taper. Verified via comparison with numerical simulation, our formalism is also utilized in parameter studies that seek to determine the optimum setup of the FEL.

FRB02

Theory and Simulation of FELs with Planar, Helical, and Elliptical Undulators

H. Freund (CSU) L.T. Campbell (STFC/DL/ASTeC) P. Falgari (Lime BV) D.L.A. Grimminck, I. Setya (ASML) J. Henderson, B.W.J. McNeil (USTRAT/SUPA) P.J.M. van der Slot (Mesa+)

Free-electron lasers (FELs) that produce different polarizations of the output radiation ranging from linear through elliptic to circular polarization are currently under study. In particular, elliptic polarizations are undergoing increased interest. In this paper, we develop an analytic model of the resonant wavelength and JJ-factor for an elliptic undulator as well as both one- and three-dimensional, time-dependent formulations that are capable of simulating elliptic undulators using the PUFFIN and MINERVA simulation codes.*,** We present an analytic model of an APPLE-II undulator that is capable of modeling arbitrary elliptic polarizations, and discuss examples of simulation results.

** J. Henderson, L. Campbell, H. Freund, and B. McNeil, New J. Phys. 18, 062003 (2016). ** H. Freund, P. van der Slot, D. Grimminck, I. Setya, and P. Falgari, New J. Phys. 19, 023020 (2017).*

FRB03

Dynamics of Superradiant Emission by a Prebunched E-Beam and its Spontaneous Emission Self-Interaction

R. Ianconescu, A. Gover (University of Tel-Aviv, Faculty of Engineering) C. Emma, P. Musumeci (UCLA) A. Friedman (Ariel University) C. Pellegrini (SLAC)

In the context of radiation emission from an electron beam, Dicke's superradiance (SR) is the enhanced coherent spontaneous radiation emission from a prebunched beam, and Stimulated-Superradiance (ST-SR) is the further enhanced emission of the bunched beam in the presence of a phase-matched radiation wave.* These processes are analyzed for undulator radiation in the framework of radiation field mode-excitation theory. In the nonlinear saturation regime the synchronicity of the bunched beam and an injected radiation wave may be sustained by wiggler tapering: Tapering-Enhanced Superradiance (TES) and Tapering-Enhanced Stimulated Superradiance Amplification (TESSA).** Identifying these processes is useful for understanding the enhancement of radiative emission in the tapered wiggler section of seeded FELs.***,**** The nonlinear formulation of the energy transfer dynamics between the radiation wave and the bunched beam fully conserves energy. This includes conservation of energy without radiation reaction terms in the interesting case of spontaneous self-interaction (no input radiation).

** A. Gover, Phys. Rev. ST-AB 8, 030701 (2005). ** J. Duris et al., New J.Phys. 17 063036 (2015). *** E. A. Schneidmiller et al., PRST-AB 18, 03070 (2015). **** C. Emma et al., this conference.*

Funding: Partial support by US-Israel Binational Science Foundation (BSF) and by Deutsche-Israelische Projektkooperation (DIP).

Canonical Formulation of 1D FEL Theory Revisited, Quantized and Applied to Electron Evolution

FRB04

P.M. Anisimov (LANL)

An original FEL theory relied on quantum analysis of photon generation by relativistic electrons in alternating magnetic field.* In most cases, however, the system of pendulum equations for non-canonical variables and the theory of classical electromagnetism proved to be adequate. As XFELs advance to higher energy photons, quantum effects of electron recoil and shot noise has to be considered. This work presents quantization procedure based on the Hamiltonian formulation of an XFEL interaction in 1D case. The procedure relates the conventional variables to canonical coordinates and momenta and does not require the transformation to the Bambini-Renieri frame.** The relation of a field operator to a photon annihilation operator reveals the meaning of the quantum FEL parameter, introduced by Bonifacio, as a number of photons emitted by a single electron before the saturation takes place.*** The quantum description is then applied to study how quantum nature of electrons affects the startup of XFEL and how quantum electrons become indistinguishable from a classical ensemble of electrons due to their interaction with a ponderomotive potential of an XFEL.

** Madey JMJ 1971 J. Appl. Phys. 42 1906 13. ** Bambini A and Renieri A 1978 Lett. Nuovo Cimento 21 399-404. *** Bonifacio R, Piovella N, Robb G R M and Schiavi A 2006 PRSTAB 9 090701.*

Frequency Modulation in the Free Electron Laser

FRB05

L.T. Campbell, B.W.J. McNeil (USTRAT/SUPA)

The resonant frequency of a free electron laser may be modulated via the undulator or electron beam parameters. This modulation may generate sidebands which can subsequently undergo amplification, analogous to frequency modulation in a conventional cavity laser. However, due to the relative slippage of the light through the relativistic electron beam, the FM-FEL system has a more complex behavior than its conventional laser counterpart. The system may be described in the linear regime by a summation over exponential gain modes, allowing the amplification of multiple light frequencies simultaneously. It is found that, with only small, few percent variations of the FEL parameters, one may generate and amplify multiple modes within a frequency bandwidth which greatly exceeds that of normal FEL operation.

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Time of day	Monday August 21, 2017	Tuesday August 22, 2017	Wednesday August 23, 2017	Thursday August 24, 2017	Friday August 25, 2017
8:00 - 8:15					
8:15 - 8:30	Principal Associate Director's Welcome				
8:30 - 8:45	MOA01 John Madey: History (Elias)	TUA01 Recent FEL experiments at FLASH (Schreiber)	WEA01 European XFEL injector commissioning (Buetner)	THA01 Observation of fast structural changes with an XFEL (Tono)	FRA01 Fresh slice X-ray FEL schemes for advanced x-ray applications (Lutman)
8:45 - 9:00					
9:00 - 9:15	MOA02 Rodolfo Bonifacio (Musumeci)	TUA02 Design & modeling of SXL (Curbis)	WEA02 Model of photocathode (Huang)	THA02 Four-wave mixing using EUV transient gratings (Bencivenga)	FRA02 Using optical klystron effects (Pratt)
9:15 - 9:30	MOBA01 Energy chirp (Schneidmiller)	TUA03 Generation of high-power (Gruetg)	WEA03 Simulation optimization (Liu)		FRA03 Toward high efficiency (Murokh)
9:30 - 9:45	MOBA02 Coherence limit (Yurkov)	TUA04 Suppresion of CSR effects (Hara)	WEA04 Novel concepts of high (Kuzikov)	THA03 Two-temperature equilibration in warm dense hydrogen (Fletcher)	FRA04 Three-dim. manipulation (Feng)
9:45 - 10:00		TUA05 Generation of sub-fs hard X-ray (Huang)	WEA05 Higher field and energy (Sanibale)		FRA05 European plasma accelerator (Walker)
10:00 - 10:15	Break	Break	Break	Break	Break
10:15 - 10:30					
10:30 - 10:45	MOBB01 Harmonic lasing & gain (Deng)	TUB01 Seeding experiments (Hemsing)	WEB01 Characterization of high-brightness electron beams (Tarkeshian)	THB01 Beam dynamics optimization in high-brightness electron injectors (Mitchell)	FRB01 Time-domain analysis of attosecond pulse generation (Baxivanis)
10:45 - 11:00	MOBB02 Temporal & spatial (Marinelli)				
11:00 - 11:15		TUB02 Fresh-slice self seeding (Emma)	WEB02 Characterization of e- bunches (Kim)	THB02 Non-standard use of laser (Allaria)	FRB02 Theory and simulation (Freund)
11:15 - 11:30	MOC01 0.1-nm FEL lasing of PAL (Kang)	TUB03 ASU compact XFEL (Graves)	WEB03 R&D at SLAC on ns (Krashnykh)	THB03 High-power narrow-bw THz (Huang)	FRB03 Dynamics of superradiant (Ianconescu)
11:30 - 11:45	MOC02 First lasing of SwissFEL (Reiche)	TUB04 Recent online taper (Wu)	WEB04 Laser-to-RF synchronization (Lamb)	THB04 Two-color beam generation (Bettoni)	FRB04 Canonical formulation (Anisimov)
11:45 - Noon	MOC03 First lasing of Euro XFEL(Weise)	TUB05 First demonstration (Yang)	WEB05 ICS diagnostics of FEL (Alizhenkov)		FRB05 Frequency modulation (Campbell)
Noon-12:15	MOC04 Status of Dalian (Zhang)	Conference Group Photo (SFCC courtyard)		Bus loading at SFCC	Closing remarks
12:15 - 12:30	Lunch	Lunch (Scientific Program Committee lunch at Eldorado Hotel, Presidential Suite)	Lunch		
12:30 - 12:45				Bus ride to LANSCE & BSM	
12:45 - 1:00					
1:00 - 1:15					
1:15 - 1:30					
1:30 - 1:45	MOD01 Status of LCLS-II (Emma)	TUC01 Polarization control of storage ring FELs (Yan)	WEC01 Photon beam transport & diagnostics systems at EUV FEL (Zangrando)	LANSCE and BSM Tours	
1:45 - 2:00	MOD02 Status of FLASH (Honkavaara)				
2:00 - 2:15	MOD03 Status of SACLA (Tanaka)	TUC02 Thermal & mechanical stability (Bahns)	WEC02 Optimmization of SCUs (Clarke)		
2:15 - 2:30	MOD04 Status of FERMI (Giannessi)	TUC03 High-flux, fully coherent XFELO (Kim)	WEC03 Wavefront preserving optics (Cocco)		
2:30 - 2:45	MOD05 Status of SXFEL (Liu)	TUC04 Enhancement of radiative (Marks)	WEC04 Progress of PAL XFEL undulator (Kim)		
2:45 - 3:00	MOD06 MaRIE Overview (Sheffield)	TUC05 Start-to-end simulations (Qin)	WEC05 Radiation-induced reversal (Kinjo)		
3:00 - 3:15	Break	Break	Break		
3:15 - 3:30					
3:30 - 3:45	MOP Poster Session SASE, Seeded FEL, Oscillators	TUP Poster Session FEL Applications, Electron Beam Dynamics, Advanced Concepts	WEP Poster Session FEL Theory, FEL Technologies		
3:45 - 4:00					
4:00 - 4:15					
4:15 - 4:30				Bus ride back to SFCC	
4:30 - 4:45					
4:45 - 5:00					
5:00 - 5:15					
5:15 - 5:30					
5:30 - 5:45		Tutorial 1 - On the science of seeded FELs (Parmigiani)	Tutorial 2 - Beam-based alignment for undulators for FEL (Emma)	Mariachi Band (Eldorado Hotel)	
5:45 - 6:00					
6:00 - 6:15	Reception (Drury Rooftop) Flamenco Dancers			Banquet (Eldorado Grand Ballroom) Indian Hoop Dancers	
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6:30 - 6:45		IEC Meeting (SFCC Coronado Room)			
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8:15 - 8:30					
8:30 - 8:45		IEC Dinner (La Plazuela at La Fonda)			
8:45 - 9:00					
9:00 - 9:15					
9:15 - 9:30					
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