INTRODUCTION OF WESTWOOD LINEAR ACCELERATOR TEST FACILITY IN UNIVERSITY OF CALIFORNIA LOS ANGELES

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Abstract

An electron linear accelerator test facility located on UCLA's southwest campus in Westwood, SAMURAI, is presently being constructed. A RF-based accelerator consists of a compact, 3 MeV S-band hybrid gun capable of velocity bunching to bunch lengths in the 100s fs range with 100s pC of charge. This beam is accelerated by an 1.5 m S-band linac with a peak output energy of 30 MeV which can be directed to either a secondary beamline or remain on the main beamline for final acceleration by a SLAC 3 m S-band linac to an energy of 80 MeV. Further acceleration by advanced boosters such as a cryo-cooled C-band structure or numerous optical or wakefield methods is under active investigation. In combination with a 3 TW Ti:Sapphire laser, initial proof of principle experiments will be conducted on topics including the ultra-compact x-ray free-electron laser, advanced dielectric wakefield acceleration, bi-harmonic nonlinear inverse Compton scattering, and various radiation detectors. Furthermore, development of a tertiary beamline based on an ultra low emittance, cryo-cooled gun will eventually enable two-beam experiments, expanding the facility's unique experimental capabilities.

INTRODUCTION

Owing to the establishment of basic beam physics research and experience through the high energy beam experiments, demand for compact lower to medium energy electron linear accelerators has been increased these days in a wide range of communities. Significant interest can be seen for radiation productions in the photon energy of THz, Extreme UltraViolet (EUV), soft X-ray, hard X-ray to the MeV Gamma-ray regime which requires different electron beam parameters depending on the required radiation's characteristics. These are spectral brightness, polarization, coherency, and ultimate discrepancy between each purpose may be total intensity per pulse or average flux. As nature of university laboratory focusing on feasibility studies, including optimization of interaction point, beam manipulation and unique detection system, we are looking for following list of a examples of pulsed photon production and related topics capable by a method of Dielectric WakeField Acceleration (DWFA) [1], Ultra Compact Free Electron Laser (UCFEL) [2], nonlinear Inverse Compton Scattering (ICS) [3] utilizing a University laboratory scale compact electron linac:

- THz-DWA
  ♦Non destructive material, pump probe, imaging of a Molecular - Plasmonics
  ♦Low energy e-beam manipulation
- EUV-UCFEL(Coherent 13.5nm, $\Delta E/E < 10^{-3}$)
  ♦Metrology for such as precision mask manufacturing for lithography (< resolution 5 nm)
  ♦R & D and calibration of multilayer optics
- Soft X-ray-UCFEL (with compact tunable undulator)
  ♦Contrast imaging of a nanoscale structure of biological samples (> 1 μm thickness) through water window (hv = 2.3 - 4.4 nm)
  ♦Photoemission spectroscopy for low Z material
  ♦Polarization sensitive soft x-ray microscopy
- Hard X-ray ICS
  ♦Data collection for photon activation with nano particle
  ♦Energy dependent radiography of high Z material
  ♦Crystal optics R & D including polarization aspect
- Gamma-ray ICS
  ♦Polarization sensitive Nuclear photonics [4]
  ♦High energy gamma detector [5]

In this regard, electron linac based on S-band RF cavities at average energy of 80 MeV is under construction as a basic infrastructure to expand these studies in Westwood, Los Angeles. In addition, initial infrastructure of 3TW Ti: Sapphire laser (Coherent Inc., Model: Astrella, Hydra) allows us to enhance e-beam manipulation studies via Inverse Free Electron Laser(IFEL) [6] or Laser Plasma Wakefield Acceleration covering laboratory astrophysics such as space plasma simulator [7].

In the context of optimization of beam interaction points, realization of high gradient and low emittance cryo-temperature C-band gun is under rigorous investigation. A peak surface field at the cathode 240 MV/m, twice as high as conventional field, could have a potential to lower emittance down to 50 nm rad regime by suppressing beam expansion, due to space charge force, which inversely proportional to beam kinetic energy $\sim 1/\gamma^2$ [8].

OVERVIEW OF THE TEST FACILITY

As shown in the schematic diagram of Fig. 1, the main beam line starts as a Beam Line East (BL-E) from South toward North. A S-band Hybrid gun [9] composed of

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standing wave RF gun section and short traveling wave linac for velocity bunching generate ~3-4 MeV e-beam with charge and emittance as shown in Table 1 based on a GPT (Pulsar Physics, General Particle Tracer code) simulation. As a standard operation, 0.5 nQ charge compresses the beam down to ~ 1 ps with the peak current ~120 A with approximate energy spread $\Delta E/E$~0.3 % at z = 1.5 m from the gun cathode. The hybrid gun is driven by SLAC XK 5 Klystron of RF output ~25 MW with flat top pulse length 4 µs. Majority of RF energy, ~70-90 %, travels from the gun section toward 1.5 m S-band linac (RI Research Instruments GmbH, P95861, 2856 MHz, Shunt impedance > 50 MOhm/m) to accelerate electron energy up to ~30 MeV for downstream beam experiments. During commissioning phase, low energy experiments are under consideration as follows:

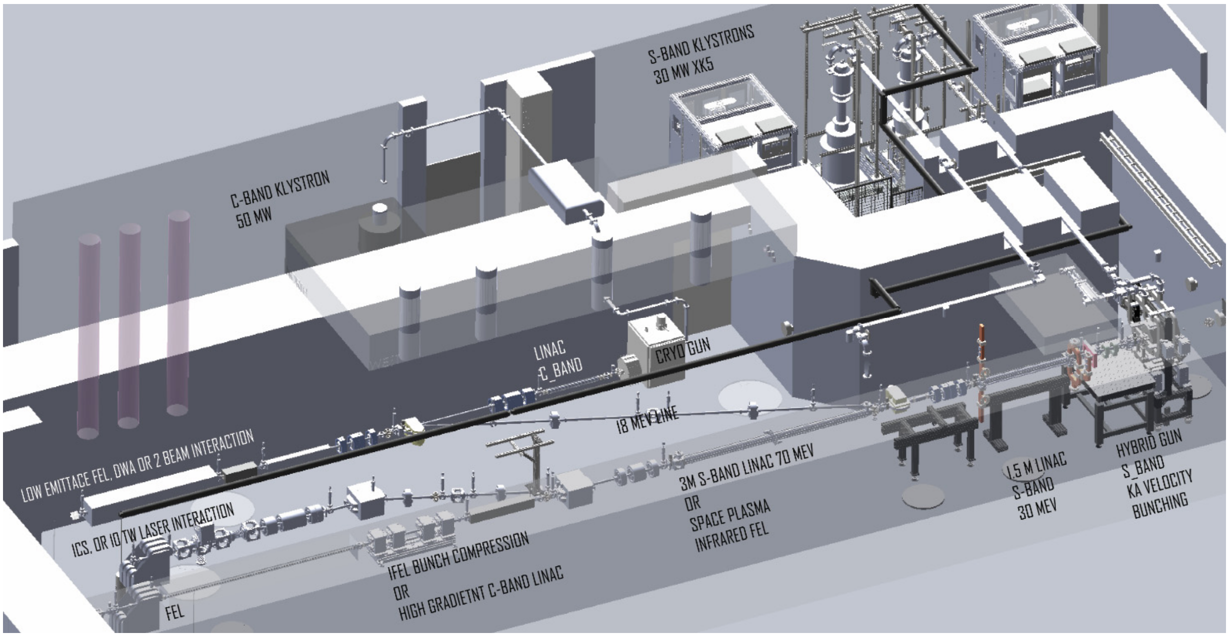


Figure 1: Overview of Westwood Linear Accelerator Test Facility in University of California Los Angeles.

Table 1: S-band Hybrid Gun Output Characteristics at z = 1.5m from Photo Cathode Driven by 25 MW RF Input

Q [nC]	ε [µm rad]	Δx, Δz [µm], z=0 Spot size, length	E_{ave} [MeV], $\Delta E/E$[%]	$\sigma_{x,y}$, σ_z, [µm] z=1.5 m	I_{peak} [A]
0.1	0.6	928, 174	3.871, 0.19	1018, 290	41
0.25	1.1	1260, 236	3.867, 0.26	1407, 394	76
0.5	2.0	1590, 298	3.865, 0.33	1803, 496	121
0.75	2.9	1817, 341	3.865, 0.38	2087, 568	158
1.0	3.8	2000, 375	3.865, 0.42	2318, 626	191
2.0	7.5	2520, 472	3.869, 0.55	2995, 790	303

PHASE I

- Characterization of velocity bunching (3 MeV)
  - ♦Energy-emittance measurement
  - ♦CTR Bunch length measurement
- Higher current far infrared FEL (18 MeV)
  - ♦UCLA-KIAE undulator [10, 11]
- DWA de-chirper [1, 9]
  - ♦Longitudinal phase space optimization for FEL
- Beam energy modulation by PWA (10-30 MeV)
  - ♦For space plasma simulator [7]
- Soft X-ray ICS (30 MeV)
  - ♦3 TW Ti: Sapphire laser interaction
- Compton gamma magnet spectrometer R&D
  - ♦MeV Bremsstrahlung radiation spectrum [5]

Especially, compactness of velocity bunching without bending magnet at low energy operation allows us to to uniquely compress symmetric beam at current I >100s A range. For the high gain UCFEL feasibility studies, as the gain length is proportional to $L_{G0} \sim I^{-1/3}$, interesting electro dynamics will be investigated. In parallel, development of cryo C-band gun will be started in the beam line East (BL-E) area. In order to freeze beams just after the output of the gun at beam energy of < 10 MeV, existing S-band TWT short linac or eventually high gradient C-band linac will be inserted for downstream experiments to appreciate the advantages of the anticipated low emittance e-beam at 100 pC range. In BL-W, the 30 MeV electron propagates through the SLAC 3 meter S-band linac for further acceleration at average energy up to 80 MeV or is branched toward BL-E through a 20 deg dispersive sectio for phase II experiments within couple of years:

PHASE II

- Cryo temperature 1.6 cell gun development (BL-E)
- Bunch compression, CSR study (18 MeV)
  - ♦20 deg dispersion section with Hybrid gun tuning
- 80 MeV e-beam commissioning (BL-W)

Eventually, the 80 MeV e-beam would be further accelerated through an advanced accelerator such as high gradient C-band linac [12] or branched to Beam Line Center (BL-C):

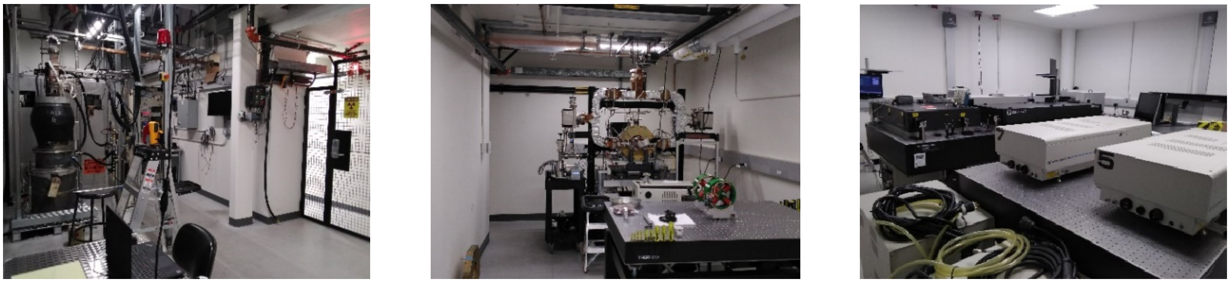
PHASE III

- Ultra low emittance Far infrared FEL (BL-E, 18 MeV)
- Two beam experiments (BL-E&W)
- UCFEL-IFEL compression study (BL-W, 70 MeV)
- Nonlinear ICS (BL-C, 70 MeV, 10 TW laser)
- High gradient C-band linac examination (> 70 MeV)

Ultimately these studies will contribute to the realization of compact EUV UCFEL or Gamma-ray nonlinear ICS light sources eventually.

STATUS UPDATE

Commissioning of the 3 MeV section is underway as indicated in photos of XK 5 Klystron, the Hybrid gun and n Ti: Sapphire laser system in Fig. 2. SLAC XK5 Klystron has been re-evaluated to generate peak power 28 MW with input LLRF power of ~400 W as shown in Figure 3. At this peak power, pulse width of PFN waveform width 5 µs will suffice requirement of Hybrid gun operation at 25 MW RF input. Meanwhile, generation of UV laser pulse at wavelength 266 nm upto 500 µJ per pulse by Ti: Sapphire laser is confirmed which allows flexible parameter space scan for the Hybrid gun characterization associated with pulse length, bandwidth, spatial distribution and polarizations including bunch train formation. In parallel, initial commissioning of the 3TW Ti: Sapphire system has been completed leading to a construction of an additional amplifier for 10 TW laser experiments.



Klystron gallery S-band Hybrid gun section Ti: Sapphire laser room

Figure 2: Status update of Westwood linear accelerator test facility in UCLA.

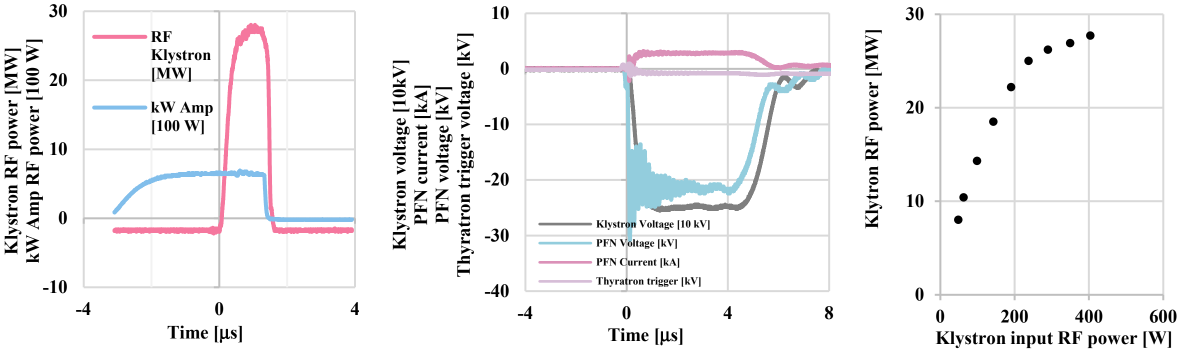


Figure 3: RF characteristics of a SLAC XK5 Klystron for commissioning of the S-band Hybrid gun. Left: Klystron RF output waveform, Center: PFN waveform for Hybrid gun input, Right: LLRF input vs Klystron RF output.

CONCLUSION

As an introduction of the 80 MeV linear accelerator test facility in university laboratory scale, planned experiments of advanced photon science as well as high gradient accelerator studies through commissioning phases are overviewd. Together with a dedicated gun test facility MOTHRA lab in UCLA Hilgard currently aimed for a development of a C-band cryo cooled 0.5 cell gun [13], productive feasibility studies will be initiated. Status updates will continue to be reported in this conference series in coming years.

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