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EXTENSION OF THE PITZ FACILITY FOR A PROOF-OF-PRINCIPLE EXPERIMENT ON THz SASE FEL

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Abstract

The Photo Injector Test Facility at DESY in Zeuthen (PITZ) has been proposed as a suitable facility for research and development of an accelerator-based THz source prototype for pump-probe experiments at the European XFEL. A proof-of-principle experiment to generate THz SASE FEL radiation by using an LCLS-I undulator driven by an electron bunch from the PITZ accelerator has been planned and studied. The undulator is foreseen to be installed downstream from the current PITZ accelerator, and an extension of the accelerator tunnel is necessary. Radiation shielding for the extended tunnel was designed, and construction works are finished. Design of the extended beamline is ongoing, not only for this experiment but also for other possible experiments. Components for the extended beamline, including magnets for beam transport, a chicane bunch compressor, electron beam diagnostics devices, and THz radiation diagnostics devices have been studied. An overview of these works will be presented in this paper.

INTRODUCTION

The European XFEL has planned to perform pump-probe experiments by using its x-ray pulses and THz pulses. To provide the THz pulses, THz generation using laser-based and accelerator-based sources has been considered and studied [1]. For the accelerator-based sources, an interesting idea is to generate THz pulses using a Self-Amplified Spontaneous Emission (SASE) FEL driven by electron bunches from a "PITZ-like" accelerator. Preliminary simulations in [2] show that the SASE FEL can produce pulse energies up to 1 mJ with a spectrum bandwidth of 2-3 % at a wavelength of 100 µm.

Based on the above idea, PITZ has been considered as an ideal machine for the development of such a THz source. Proof-of-principle experiments to generate THz SASE FEL radiation by using an LCLS-I undulator driven by an electron bunch from the PITZ accelerator has been planned and studied. Preliminary Start-to-End (S2E) simulations based on a model beamline were performed [3,4], yielding a THz pulse energy of about 0.5 mJ at a wavelength of 100 µm.

In order to demonstrate such SASE FEL generation experimentally, installation of the LCLS-I undulator downstream from the current PITZ accelerator has been planned. Figure 1 shows a schematic layout of the PITZ facility. There are two tunnels, the main tunnel and the tunnel annex, separated by a concrete wall with a thickness of 1.5 m. The undulator is foreseen to be installed in the tunnel annex. Therefore, an extension of the existing beamline to connect with the undulator is required.

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This paper describes a proposed configuration of the beamline extension and radiation shielding improvement for the tunnel annex. Note that the configuration has not been fully optimized. Studies towards a final design and construction are ongoing.

TUNNEL EXTENSION AND RADIATION SHIELDING IMPROVEMENT

We plan to transport the electron beam from the main tunnel through an aperture inside the wall to the undulator in the tunnel annex, as shown in Fig. 1. Since the electron beam will be blocked by a beam dump in the tunnel annex, the radiation shielding of this tunnel has to be improved.

The FLUKA simulation package [5] was used to calculate produced radiation dose rates and design appropriate radiation shielding for the tunnel annex. The design goal was to limit the dose rates outside the accelerator area to less than 3 μSv/h during beam operations. The radiation protection wall and the movable door made of barite concrete (density of >3.4 t/m^3) were realized as the appropriate shielding. Construction of the radiation shielding was already finished, as shown in Fig 2.

THE EXTENSION BEAMLINE

The layout of the extension beamline is surrounded by the red dashed box in Fig. 1. Main components of the extended beamline are a chicane bunch compressor, collimators, a switchyard, the LCLS-I undulator, and beam dump sections.

The chicane bunch compressor consists of four magnets (D1-D4) with a negative R56 of -0.17 m. Its total length is 3.56 m and it is designed to deflect the electron beam vertically. Design consideration of the chicane is presented in [6].

Vertical and horizontal collimators are used to remove unwanted parts of the beam. Each collimator is a metal sheet with various apertures. The collimator station is located in the main tunnel before the wall. It consists of horizontal and vertical actuators supplied with the collimators. Each collimator can be used individually or simultaneously with the other one.

The Switchyard is a dipole magnet located directly after the wall in the tunnel annex. It is used as a horizontal steerer magnet in the current configuration. However, there are possible plans to add other beamlines in the tunnel annex

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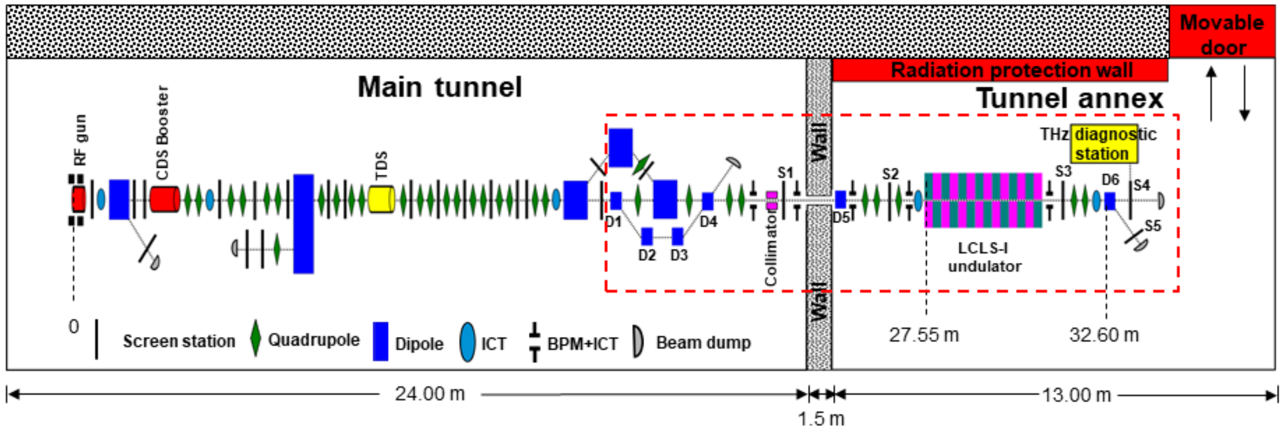

Figure 1: The layout of PITZ beamline including the proposed extension for the THz SASE FEL proof-of-principle experiments (surrounded by a red dashed box).

Figure 2: The radiation protection wall and the movable door in the tunnel annex.

for different experiments, and the switchyard can be used as the first dipole magnet of doglegs.

The LCLS-I undulator is a planar undulator with a fixed gap, so it has a constant K-value of 3.49. The undulator has 112 periods with a period length of 30 mm. More details about the undulator can be found in [7].

Beam dump sections are planned to be installed in three different locations, as shown in Fig. 1. The first beam dump is installed next to D4 in order to dump the beam in the main tunnel. The second beam dump is installed next to the screen S4, and the third beam dump is installed next to the screen S5.

The following is a list of all magnets used in this configuration

- six dipole magnets - four magnets are used for the chicane, one magnet is used for the switchyard, and one magnet is used for the beam dump section in the tunnel annex.
- nine quadrupole magnets.
- At least five steerer magnets - Type and install location of each steerer magnet are under consideration.
- the LCLS-I undulator.

FEL PERFORMANCE

S2E simulations based on the configuration in Fig. 1 are presented in [8]. Electron beams were optimized and transported to the undulator entrance by using the ASTRA code [9]. Then, the optimized beams were used as inputs for Genesis 1.3 [10] for the calculation of THz SASE radiations. Table 1 shows parameters of the optimized beam at the undulator entrance, and the output FEL radiation when a long flattop photocathode laser (FWHM~21.5 ps) was used in the ASTRA code.

Table 1: Parameters of the Optimized Beam at the Undulator Entrance and the Simulated FEL Radiation

Parameter	Value	Unit
Simulated electron beam:		
Bunch charge	4.0	nC
Momentum	17.0	MeV/c
Energy spread	0.4%	
Peak current	180.6	A
Beam emittance	4.3/4.9	mm mrad
Simulated FEL radiation:		
Pulse energy	493.1±108.8	μJ
Pulse power	52.7±11.8	MW
Center wavelength	101.8±0.7	μm
Spectrum width	2.0±0.4	μm

ELECTRON BEAM DIAGNOSTICS

Screen stations with YAG screens are used for transverse beam position and transverse size measurements. We plan to install five screen stations in the extension beamline including:

- S1 is used for observation of the beam after the collimator.
- S2 is used for observation of the beam before the undulator.

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- S3 is used for observation of the beam after the undulator and is equipped with a THz mirror to deflect the THz radiation to the THz diagnostic station. Since the electron beam impinges on the THz mirror, transition radiation is generated. Therefore, the radiation that transport to the THz diagnostic station is a mixture between the radiation from the undulator and the transition radiation.

- S4 has a similar purpose to S3. It is used for observation of the beam and is also equipped with a THz mirror to deflect the THz radiation to the THz diagnostic station. Since the electron beam is already deflected away by D6 and therefore no transition radiation generated from the THz mirror.

- S5 is used for observation of the beam before the beam dump.

Beam Position Monitors (BPMs) are used for beam transverse position measurements. They can be used to measure and correct the beam trajectories. At least five BPMs are planned to be installed in the extension beamline.

Integrating current transformers (ICTs) used for charge measurements are planned to be installed at two locations, before the undulator, and before D6.

THz RADIATION DIAGNOSTICS

The THz radiation diagnostics system will be setup on a trolley. Therefore, it is convenient to move and use at both screen stations, S3 and S4. There are two THz radiation detectors foreseen to be used in the diagnostic system, a pyroelectric detector used for measurements of the radiation pulse energy and a THz camera used for measurements of the transverse distribution.

With different optical configurations, this diagnostics system can be used to measure various properties of the THz radiation including total pulse energy, polarization, transverse distribution, and spectral distribution.

CONCLUSIONS

Extension of the PITZ beamline into the tunnel annex for the THz SASE FEL proof-of-principle experiment is under study. Radiation shielding of the tunnel annex was improved by adding a radiation protection wall and a movable door. A preliminary layout of the extended PITZ beamline is proposed and described. S2E simulations of SASE FEL using this layout were performed and reported in [8]. Further research on the design configuration of the beamline and construction plan is ongoing.

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REFERENCES

[1] P. Zalden *et al.*, "Terahertz Science at European XFEL", European XFEL, Schenefeld, Germany, Rep. XFEL.EU TN-2018-001-01.0, 2018.

[2] E. Schneidmiller, M. Yurkov, M. Krasilnikov, and F. Stephan, "Tunable IR/THz source for pump probe experiment at Eu-ropean XFEL", in *Proc. 34th Int. Free-Electron Laser Conf.(FEL'12)*, Nara, Japan, Aug. 2012, paper WEPD55, pp. 503-506.

[3] M.Krasilnikov *et al.*, "Start-to-End Simulations of THz SASE FEL Proof-of-Principle Experiment at PITZ", in *Proc. 13th Int. Computational Accelerator Physics Conf. (ICAP'18)*, Key West, FL, USA, Oct. 2018, paper TUPAF23, pp. 246-252. doi:10.18429/JACoW-ICAP2018-TUPAF23

[4] X.K. Li *et al.*, "Design Studies of a Proof-of-Principle Experiment on SASE FEL at PITZ", in *Proc. 10th Int. Particle Accelerator Conf. (IPAC'19)*, Melbourne, Australia, May 2019, paper TUPRB018, pp. 1713-1716. doi:10.18429/JACoW-IPAC2019-TUPRB018

[5] T.T. Böhlen *et al.*, "The FLUKA Code: Developments and Challenges for High Energy and Medical Applications", *Nuclear Data Sheets*, vol. 120, pp. 211-214, 2014.

[6] H. Shaker *et al.*, "Design of a Magnetic Bunch Compressor for the THz SASE FEL Proof-of-Principle Experiment at PITZ", presented at the 39th Int. Free-Electron Laser Conf. (FEL'19), Hamburg, Germany, Aug. 2019, paper TUP003, this conference.

[7] J. Arthur *et al.*, "Linac Coherent Light Source (LCLS) Conceptual Design Report", SLAC, Menlo Park, CA, USA, Rep. SLAC-R-593, 2002.

[8] X.K. Li *et al.*, "Progress in Preparing a Proof-of-Principle Experiment for THz SASE FEL at PITZ", presented at the 39th Int. Free-Electron Laser Conf. (FEL'19), Hamburg, Germany, Aug. 2019, paper TUP002, this conference.

[9] K. Flöttmann, ASTRA particle tracking code, http://www.desy.de/~mpyflo

[10] S. Reiche, GENESIS 1.3 code, http://genesis.web.psi.ch