ISBN: 978-3-95450-227-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2022-TUPOPT016

STATUS OF THE THz@PITZ PROJECT – THE PROOF-OF-PRINCIPLE EXPERIMENT ON A THz SASE FEL AT THE PITZ FACILITY*

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Abstract

In order to allow THz pump–X-ray probe experiments at full bunch repetition rate for users at the European XFEL, the Photo Injector Test Facility at DESY in Zeuthen (PITZ) is building a prototype of an accelerator-based THz source. The goal is to generate THz SASE FEL radiation with a mJ energy level per bunch using an LCLS-I undulator driven by the electron beam from PITZ. Therefore, the existing PITZ beam line is extended into a tunnel annex downstream of the existing accelerator tunnel.

The final design of the beam line extension consists of a bunch compressor, a collimation system and a beam dump in the PITZ tunnel. In the tunnel annex one LCLS-I undulator is installed for the production of the THz radiation with a quadrupole triplet in front of it for matching the beam parameters for the FEL process. Behind the undulator two screen stations couple out the THz radiation, for measurements like bunch compression, pulse energy or spatial and transverse distribution. A dipole separates the electron from the THz beam and a quadrupole doublet transports the electron beam to the beam dump. The installation progress will be presented.

INTRODUCTION

The European XFEL plans to expand the wavelength range for pump-probe experiments into the THz-regime for probing the samples. Therefore different options for the THz generation were studied [1, 2]. For the accelerator based source the installations for a proof-of-principle experiment at the Photo Injector Test Facility at DESY in Zeuthen (PITZ) are nearly finished. Here the THz radiation is produced using a Self-Amplified Spontaneous Emission (SASE) FEL in an LCLS-I undulator [3], driven by the electron bunches from the PITZ accelerator. Start-to-End simulations for this setup, i.e. beam energies of 16 to 22 MeV/c and a peak current of 200 A (i.e. 4 nC bunch charge), yielded a THz pulse energy of about 0.5 mJ at a wavelength of 100 µm [4, 5].

A schematic overview of the current PITZ beam line as well as the extension (red dashed box) currently under installation, is shown in the top part of Fig. 1. The electrons are generated in the gun, accelerated up to $\approx$ 7 MeV/c, before further acceleration by the booster to the final energy of $\approx$ 22 MeV/c takes place. The different diagnostic devices, e.g. HEDA1, EMSY and TDS, allow for a measurement of the six dimensional phase space of the electron beam and therefore to characterize the photo-injector performance.

* This work was supported by the European XFEL research and development program.

BEAM LINE DESIGN

For the THz@PITZ project the PITZ beam line had to be modified and also had to be extended into a second tunnel. A bunch compression chicane was added to the beam line in tunnel 1 allowing the generation of THz radiation with lower bunch charges than the planed 4 nC by maintaining the peak current of the electron beam through longitudinal compression [6]. In addition to that, it enables the investigation of seeding methods for the THz generation [7]. Two quadrupole triplets, one in each tunnel, were added for the matching of the electron beam into the undulator. Additionally, a collimator system reduces the number of halo particles and dark current before the beam enters tunnel 2. This should reduce the beam loss in the undulator significantly.

The beam line in tunnel 2, where the undulator is installed, starts with a dipole magnet, which is used as a switchyard to serve a second beam line in the future [8]. In addition to the matching quadrupole triplet, two additional quadrupole magnets and a dipole for the deflection of the beam to the high power beam dump are installed. The beam dump in the straight section will only be used to set up the beam or for moderate to average power operation. In total, five new BPMs were installed to measure beam position and charge. These are located in the chicane, in front of the wall as well as in front and behind the undulator. The last one is located in front of the new beam dump in tunnel 1 to ensure beam transportation to the dump.

In total three screen stations for THz diagnostics, one in front of and two behind the undulator, are installed. The first one is used for bunch compression measurements when the bunch compression chicane is used. In addition it can be used for coupling in seeding radiation for future seeding experiments and it will be used to calibrate the positions of the THz mirrors behind the undulator. The two screen stations behind the undulator are equipped with mirrors to deflect the THz radiation vertically to a view port where it is coupled out of the vacuum system and guided to the THz diagnostic table. The THz diagnostic setup is used to measure the total pulse energy, the polarization as well as the transverse and spectral distribution with a pyro detector, a Michelson interferometer set-up and a THz camera. + A detailed 3d-model of the design of the beam line extension is shown in Fig. 1 (bottom).

INSTALLATION PROGRESS

During the installation of the beam line in both tunnels, additional infrastructure work was carried out in parallel. This included power, pressured air and gas supply in both tunnels as well as cable pulling for the new beam line ele-

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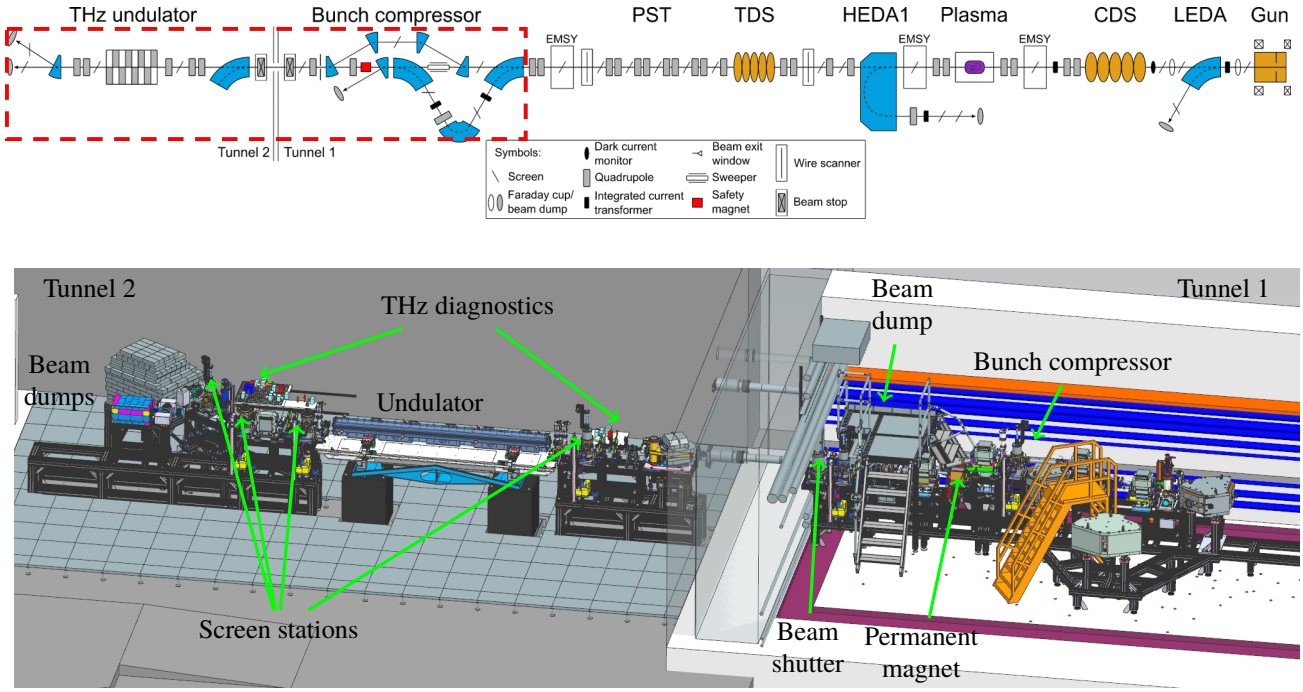

Figure 1: Schematic overview of the complete PITZ beam line (top). The beam line extension for the THz@PITZ project is surrounded by the red dashed box, while the CAD model of the beam line extension is shown in more detail in bottom of the figure.

ments. Also the integration of the new power supplies into the PITZ control system as well as the development of a new stepper motor controller for the screen stations and other motorized stages.

Since the measurement of the undulator field showed a longitudinal gradient, which was strong enough to deflect the beam by more than the diameter of the vacuum chamber, a large correction coil to compensate for the gradient was designed and build along with smaller coils to allow for a beam deflection inside the undulator for FEL gain curve measurements [9].

Tunnel 1

After the removal of some parts of the beam line in tunnel 1 including the beam dump, the installation of the beam line extension began. Most of the work was carried out after the gun exchange shut down in parallel to the gun conditioning. Without the beam dump the measurement program was limited, so the priority was to install the new beam dump including the shielding and the ladder system, to get over the beam line and the dump, as soon as possible. Due to the layout of the vacuum system and the location of valves, this required the installation of the bunch compressor chicane with its four dipole magnets, the screen station and the BPM as well as the permanent magnet and two of the three new quadrupoles.

Since the operations permit had to be updated for a beam operation in both tunnels the connection of the tunnels could only happen after receiving the updated permission. Afterwards, the tunnels was connected through the core hole and the missing beam line elements in tunnel 1 were be installed, i.e. the last quadrupole, the collimator, the screen station with the BPM and the beam shutter, which together with the permanent magnet will be used to allow for a separate tunnel operation in the future.

All beam line elements and support frames were aligned using a laser tracker. After connecting the vacuum system, a leak test was performed and the whole new beam line was pumped for several days to reach the operation pressure of $\approx 1 \times 10^{-8}$ mbar with the ion getter pumps running. In Fig. 2 a picture of the finished installation at the end of tunnel 1 is shown.

Tunnel 2

In tunnel 2 the support structures for the straight section of the beam line as well as all beam line elements (Quadrupoles, screen stations and BPMs) are installed and aligned. The switchyard dipole is the last element that has to be aligned and afterwards the installation of the bellows and beam pipes connecting the beam pipe through the wall with the undulator and to the beam dump will be installed. This includes the missing valves to close the vacuum system and the pumping of the complete beam line in tunnel 2 to get ready for commissioning. The pictures show the status of the installation work in front of (Fig. 3) and after the undulator (Fig. 4).

The high power beam dump after the deflection of the dipole with a screen station and a BPM in the dispersive section is under construction in the workshop. It will be installed during the commissioning period and allows for higher bunch charges and thus higher beam power operation.

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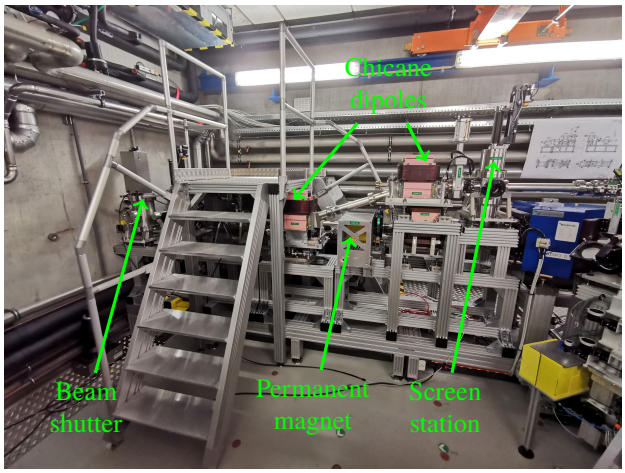

Figure 2: Picture of the finished beam line installations in tunnel 1. The last two dipoles of the bunch compressor chicane, the chicane screen station, the permanent magnet and the beam shutter are highlighted. The other elements, e.g. the collimator and another screen station are covered by the ladder system, which is on top of the new beam dump.

For the first beam in the undulator the beam dump in the straight section will be used since it is planned to run with a 100 nC bunch charge during the first commissioning stage.

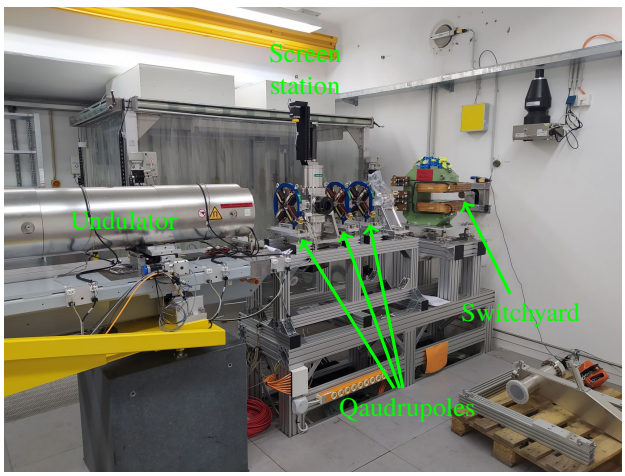

Figure 3: Most of the beam line elements in front of the undulator are installed and aligned. The switchyard magnet support frame was modified and will be aligned shortly and after that the missing bellows and beam tubes to connect the beam line to the undulator vacuum chamber can be installed.

CONCLUSION AND OUTLOOK

The installation of the beam line extension for the THz@PITZ project is nearly completed and the preparatory work for the commissioning of the beam line has already started. The final parts of the beam line, mostly bellows and connecting beam pipes, will be installed till mid of June followed by pumping of the whole vacuum system in tunnel 2.

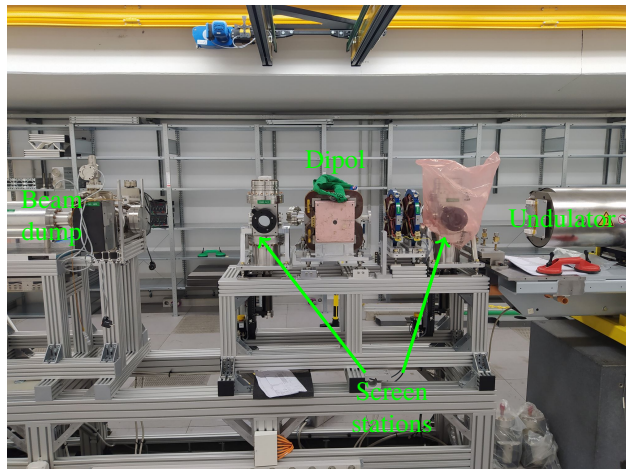

Figure 4: In the straight section all support structures for the beam line elements as well as the two screen stations and the dipole to separate electron and THz beam are installed and aligned. The bellows and beam pipes connecting the undulator and the beam dump are ready for installation. The dispersive section with the high power beam dump is currently in production.

Meanwhile the last cables will be pulled and the connections (power, pressured air and control system) for all beam line elements are being done as well as the integration into the control system.

While the installation progresses additional work on the THz diagnostics as well as the preparation for the commissioning are ongoing. We expect to have the first beam in the undulator by the end of June.

ACKNOWLEDGEMENTS

The authors would like to thank the colleagues Axel Brachmann, Manuel A. Carrasco and Heinz-Dieter Nuhn from SLAC as well as Pavel Vagin and Markus Tischer from DESY for their support with the undulator, e.g. drawings and measurements. This work was supported by the European XFEL research and development program.

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