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FACILITY UPGRADE AT PITZ AND FIRST OPERATION RESULTS

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Abstract

The Photo Injector Test facility at DESY, Zeuthen site (PITZ), develops, optimizes and characterizes high brightness electron sources for free electron lasers like FLASH and the European XFEL.

In the last year, the PITZ facility was significantly upgraded by the installation of a new normal conducting radio-frequency (RF) gun cavity with its new waveguide system for the RF feed, which should allow stable and reliable gun operation, as required for the European XFEL. Other relevant additions include beamline modifications for improving the electron beam transport through the PITZ accelerator and preparing the installation of a plasma cell. Furthermore, the laser hutch was re-arranged in order to house an additional, new photo cathode drive laser system which will produce 3D ellipsoidal laser pulses to further improve the electron beam quality.

This paper describes the facility upgrades and reports on the first operation experience with the new gun setup.

FACILITY UPGRADE GOALS

In the past, record low emittances at different charge levels were obtained at PITZ [1]. During the last two years, the PITZ facility was then mainly devoted to the preparation of RF guns for their later operation at FLASH and the European XFEL [2], with the main focus on operational stability, which is a critical issue for these user machines.

In view of improving both, beam quality and operation reliability, the PITZ facility was upgraded in summer 2014. The upgrade was realized under three main aspects: preparations for a new laser system for further improvement of the electron beam quality, installation of a new gun cavity together with its new RF feed system for improving the operational stability, and modifications of the PITZ beamline which will be described below.

3D ELLIPSOIDAL LASER SYSTEM

While the low beam emittances reported in [1] were obtained with a flat-top temporal laser profile, the overall brightness of a photo injector can be further improved by using an ideal electron bunch profile which, according to simulations, is ellipsoidal in space and time [3]. Due to the linearization of the space charge forces, homogeneous 3D ellipsoids are the best distributions for high brightness charged beam applications [4].

Quasi-3D ellipsoidal electron bunches can be produced by a laser system delivering 3D ellipsoidal laser pulses. For PITZ, such an advanced laser system was developed at the Institute of Applied Physics in Nizhny Novgorod, in the framework of a joint German-Russian research activity* [5]. Simulations have shown that this photo cathode laser system has the potential to significantly reduce the emittance of the electron bunches generated by the PITZ photo injector, and can also reduce the sensitivity on machine parameter changes [6], thus allowing more stable and reliable operation – key requirements for single-pass FELs like FLASH and the European XFEL.

The installation of the new laser system at PITZ required a major re-arrangement of the laser hutch, which already accommodated the flat-top photo cathode laser system used for a long time at PITZ. In late autumn 2014, the 3D laser system was installed in the re-arranged laser hutch. Meanwhile, first photo electrons have been produced with the 3D ellipsoidal laser system [5]. In the near future, comparative measurements with both photo cathode laser systems (3D ellipsoidal shape vs. cylindrical shape) are planned in terms of beam quality (emittance) and robustness against machine parameter changes (jitter).

BEAMLINE MODIFICATIONS

Extensive beam dynamics simulations have accompanied the development of the 3D ellipsoidal laser

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system. Optimization of machine parameters and jitter studies [7] have revealed an improvement of the electron beam quality by 10% when moving the post-accelerating cavity (booster) by 400 mm towards the gun. The shift of the booster cavity position was realized during the summer shutdown 2014 and became possible with minor beamline modifications between gun and booster cavity.

On the other side, some space was gained after the booster which can now accommodate two additional pairs of quadrupole magnets. They help to facilitate beam propagation and matching into the planned plasma cell and subsequent diagnostics beamline, including the transverse deflection cavity (TDS).

The TDS will enable time resolved measurements and shall be taken into operation very soon. In 2014, a commercial provider for the modulator was chosen (ScandiNova), and the system is currently in the commissioning phase at PITZ. First beam operation is expected in summer this year.

A scheme of the updated PITZ beamline including the plasma cell (which is replaced by a screen station, when not installed) is displayed in Fig. 1.

PLASMA CELL INTEGRATION

As a proof-of-principle experiment for the AWAKE experiment at CERN [8], a plasma cell will be inserted in the PITZ beamline with the goal to measure the energy modulation of an electron beam passing through the plasma [9]. This plasma cell is basically a Lithium heat pipe oven with Helium buffers and side ports for coupling of the ionization laser (Fig. 2). It was designed and built in 2013 and lab tests were carried out throughout the year 2014. In parallel, the ionization laser was installed and commissioned in a new lab, and the beamline towards the plasma cell is currently set up.

The plasma cell will be inserted into the PITZ beam line, which became possible due to the beamline re-arrangement and the shift of the booster towards the gun. Its first installation is planned for May 2015. At about the same time, the TDS, which is the basic diagnostics tool for the plasma self-modulation studies, will be taken into operation.

NEW GUN AND RF FEED SYSTEM

In the 2014 summer shutdown, the existing gun cavity (Gun 4.4) with its RF feed system using a single Thales RF window was replaced. This became necessary due to a vacuum leak at the ceramics of the window after months of successful operation [2].

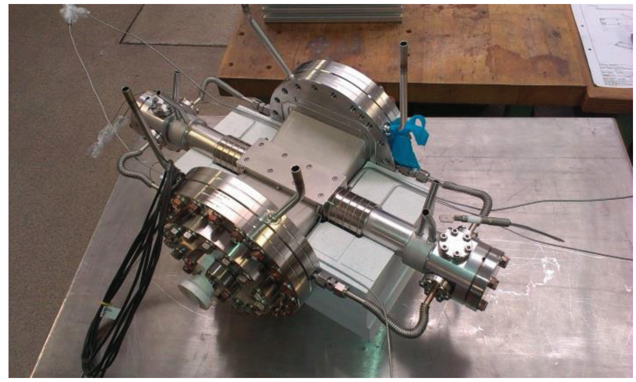

Figure 2: Photograph of the completed plasma cell. The large side ports allow the coupling of the ionization laser which generates the plasma channel at the center of the Lithium column and leave additional space for plasma diagnostics.

The new cavity (Gun 4.2) was already used at PITZ and FLASH in the years 2008 to 2012. It was dismounted from FLASH due to problems with the old RF cathode spring design (watchband design). In autumn 2012, a new RF spring design (contact stripe) was implemented by re-machining the cavity backplane. After dry-ice cleaning of the cavity, Gun 4.2 was mounted on a new setup in summer 2014, together with two Thales RF windows, see Fig. 3. The RF components were partly pre-conditioned (Thales windows at the RF test stand in Hamburg, T-Combiner and 10 MW in-vacuum directional coupler at the T-Combiner test stand in Zeuthen).

Compared to the formerly used setup with a single RF window, the use of two RF windows has the advantage that each window sees only half of the total RF power in the gun. This should help to avoid the damage of this sensitive component which has been observed in 2014 during the operation of three different gun setups utilizing a single Thales RF window at FLASH, PITZ, and European XFEL, and increase the operation reliability.

Conditioning of the complete new gun setup started in September 2014 and was slow due to the high light activity (PMT signals) on the specific Thales RF windows which showed up already during the pre-conditioning at the RF test stand in Hamburg. It is now understood as a loss of conditioning during the venting, due to the pure Ti coating of the window ceramics. After re-conditioning, the Thales windows did not cause any further problems: the two-window solution seems to work properly.

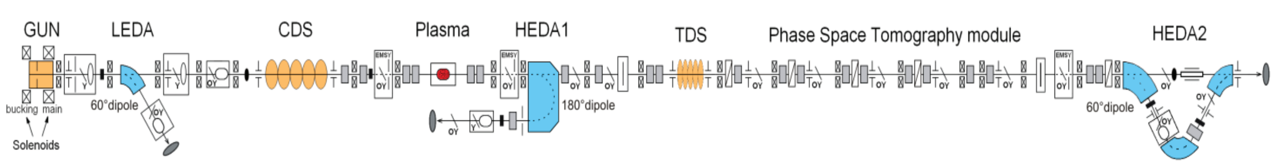

Figure 1: Layout of the current PITZ setup with the plasma chamber.

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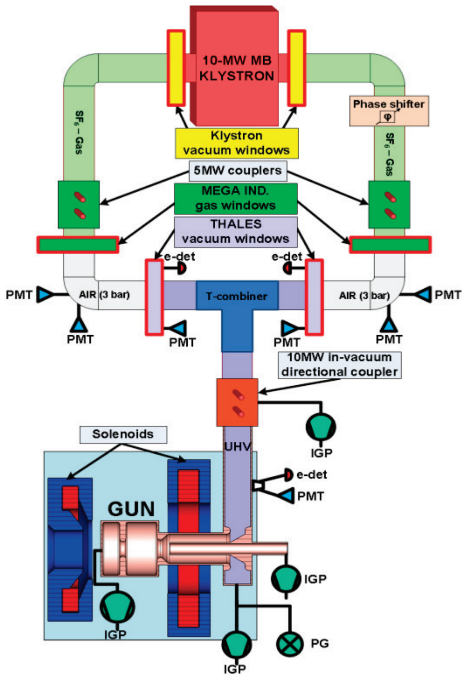

Figure 3: New gun interlock and RF distribution scheme.

After conditioning, tests for studying the long-term stability of the two-window gun setup have started. However, the goal of continuous operation at the full parameters (one week without interlock at 6MW/ 600µs/ 10Hz) has not yet been reached and is limited at highest peak and average power levels by the gun cavity itself, probably due to the operation history of the gun cavity.

Since January 2015, an intense beam measurement program has been carried out. Besides detailed gun characterization, the program includes studies for the European XFEL, such as dark current measurements (Fig. 4) and RF stability tests (Fig. 5).

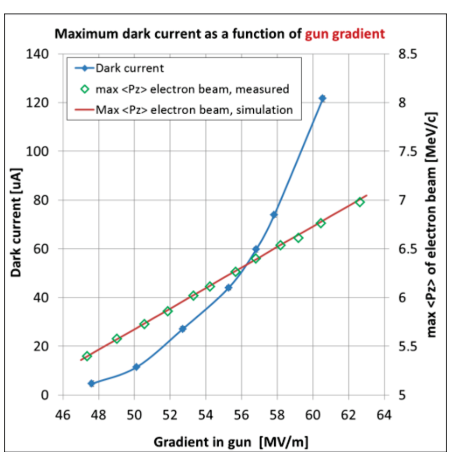

Figure 4: Dark current studies for the European XFEL: Depending on the performance of the dark current kicker which protects the superconducting modules, the transmitted dark current might limit the allowed maximum gun gradient at the injector, due to the dark current level produced by the gun (e.g. 60 MV/m ↔ 110 µA from the gun; 50 MV/m ↔ 11 µA from the gun).

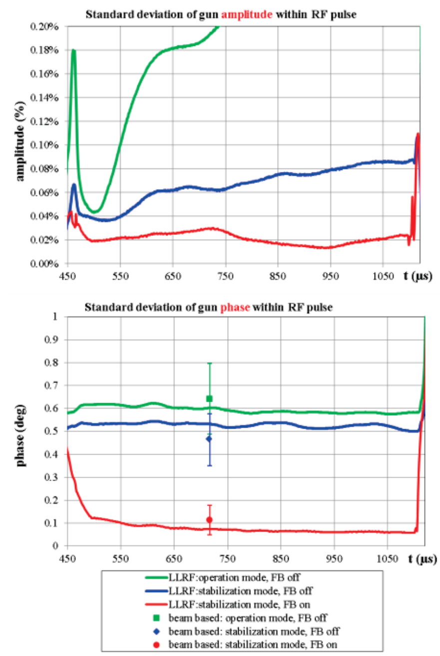

Figure 5: Amplitude (top) and phase (bottom) stability measurements with the new µTCA-based LLRF system [10]. There is still some room for improvements, compared to the results from FLASH. These are possible by a better resolution of the water temperature readout and the implementation of a µTCA fine tuning.

SUMMARY AND OUTLOOK

The PITZ facility was upgraded in the 2014 summer shutdown. The installation of a plasma cell for self-modulation studies and the commissioning of a transverse deflecting system are impending. Stability studies will enhance the understanding of the gun system for reliable operation of the photo injector at the European XFEL. Finally, the use of a new 3D ellipsoidal laser system is expected to improve again the electron beam quality at PITZ in the upcoming months and years.

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