Photo Injector Test Facility at DESY Zeuthen PITZ

Future plans at the Photo Injector Test facility PITZ

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Scientific goals of the PITZ project

The Photo Injector Test facility at DESY Zeuthen (PITZ) was built in order to test and optimize sources of high brightness electron beams for future free electron lasers and linear colliders. The focus is on the production of intense electron beams with very small transverse and reasonably small longitudinal emittance using the most advanced techniques in combination with key parameters of projects based on TESLA technology like TTF2, TESLA XFEL and BESSY III.

The first period of PITZ, started in 1999 with the installation of the facility. The first photo elec-trons were produced in Januarz 2002. In the meanwhile, the existing electron source has been fully characterized and beam measurements have been presented at different conferences, see e.g. [1]. As a result of this phase, the electron source will be delivered to Hamburg until autumn 2003, for subsequent use at TTF2.

Emittance compensation principle

Production of high brightness beams, being an important specification of advanced electron sources, complicates the photoinjector operation. The enhanced particle density leads to increased space charge forces, which are only cancelled in part by the beam acceleration in the rf gun. A significant part of the projected emittance growth is caused by longitudinal correlations between phase space distributions of bunch slices. By applying a solenoid field in a certain parameter range, one can inverse for a while the space charge force action. This results in two local minima of the transverse projected emittance (blue solid curve in Fig. 1). After the second emittance minimum (where the transverse phase space distributions have a similar orientation in each longitudinal slice), space charge action leads to a dramatic growth of the projected emittance. To prevent this growth, an additional accelerating cavity has to be placed at a suitable position in order to reduce space charge effects by further beam acceleration (space charge scales roughly with where is the electron beam relativistic factor). Respecting the invariant envelope matching condition, beam acceleration in the booster cavity leads to further extension of the emittance compensation process, and the projected emittance stays near the minimum level (red and green solid curves in Fig. 1).

Since the booster plays such a significant role in the emittance compensation technique, it will be the key technical element of PITZ2. The experimental study will be done in two stages: first, a normal conducting TESLA prototype cavity (preliminary booster) will be used. Later, it will be replaced by a normal conducting CDS booster specially designed for PITZ. The final booster will reach beam energies up to 30 MeV, where an even better emittance compensation takes place. The higher beam energy requires a new design for the beam diagnostics section. In order to provide the most complete characterization of the electron source as well as for detailed studies of the electron beam parameters, a number of new diagnostics elements have to be developed and installed, including devices that allow efficient and precise measurements of longitudinal and transverse phase space parameters for the full range of beam energies, see Fig.2.

Motivation for the facility upgrade

The second stage of PITZ, called PITZ2, is a large extension of the facility and its research program. This phase starts in 2004 and includes the installation of a booster cavity in order to reach higher beam energies. Using a booster enables a more complete characterization of the photo injector which is planned to be used at the VUV-FEL at TTF2, the TESLA XFEL, as well as the BESSY Soft-X-ray-FEL. One of the main objectives of PITZ2 is the proof of the emittance compensation technique and its experimental optimization, since many future FEL proposals rely on this technique [3,4,5].

The concept of PITZ2 is to basically resemble TTF2 up to that critical beam energy where emittance becomes a constant of motion for the rest of acceleration. Thus, the PITZ studies on improvement of electron beam quality can readily be transferred to TTF2 and other facilities. In addition, PITZ will be able to study injector schemes beyond TTF2 demands, e.g. for the TESLA-XFEL and BESSY III.

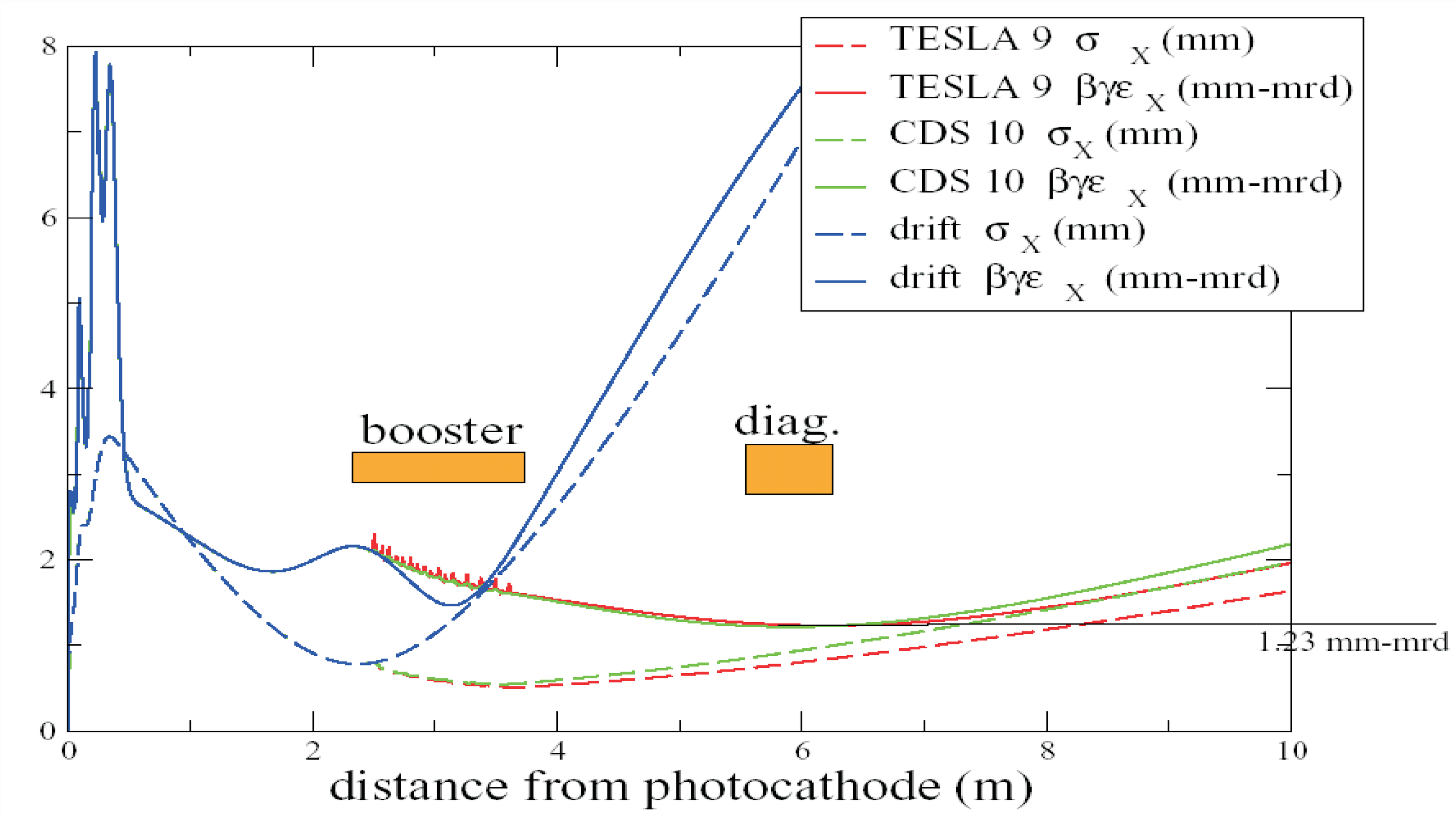

Figure 1: *Development of beam size and normalized emittance along the beamline for three different cases: without booster ('drift'), with a 9-cell TESLA prototype cavity ('TESLA 9'), and with a 10-cell PITZ booster ('CDS 10'). For comparison, the number of cells for the CDS booster was chosen such that a similar energy gain as for the 9-cell TESLA booster is achieved [2]. The strong increase of beam size and emittance in the drift case is clearly visible. The emittance minimum can be conserved by placing the booster at an optimized position. This position ('booster'), as well as the position of an emittance measurement system ('diag'), is indicated. An accelerating gradient of 40 MV/m was assumed for the gun. In this case, the optimum gradient for the booster is about 12.5 MV/m.*

Preliminary setup of PITZ2

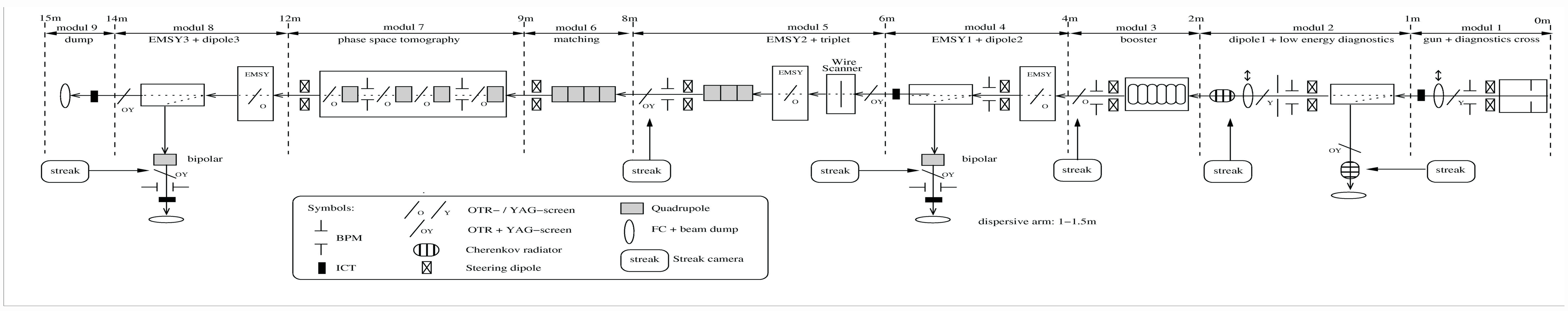

Figure 2: *PITZ2 general layout. The acceleration section consists of the gun cavity and the booster cavity. The gun is followed by a low energy diagnostics module including removable Faraday Cups (FC) (serving for charge measurement and as low energy beam dump), a dipole spectrometer, an ICT, and a collimator for dark current absorption. A Cherenkov radiator with streak camera readout for bunch length measurements is positioned afterwards, as well as in the first dispersive section. Module 3 consists of the booster cavity, which is followed by the high energy diagnostics section. It begins with an Emittance Measurement System (EMSY), followed by a screen (OTR as well as YAG) at a distance of 1.5-2 m. In the space between them, the second spectrometer should be installed. The second EMSY follows in analogy to the first one. Between EMSY and its screen of observation a quadrupole triplet is foreseen (for the beam focusing). In order to do a phase space tomography of the electron beam, a matching section in front of the tomography module consisting of 4 quadrupole magnets and 4 OTR screens is needed. At the end of the beam pipe the third EMSY will be installed, followed by the third spectrometer in order to allow beam energy measurements at this position. It follows a screen, an ICT for the beam current measurement, and finally a beam dump, which can absorb the whole beam energy. Furthermore, there must be a possibility for using the streak camera in the dispersive areas, that are also finished by a beam dump. Steering dipoles, Beam Position Monitors and view screens (OTR as well as YAG) are distributed along the whole beamline.*

Further plans at PITZ2

In order to obtain optimum electron beam parameters, a stable and reliable photo cathode laser system with flat-top temporal and transverse laser pulse shape has to be developed and installed. Further optimization of all subsystems requires extensive beam dynamics studies. It is foreseen to design and test a high duty cycle rf-gun, which is important for the operation of high repetition rate FELs and energy recovery linacs. The delivery of improved guns for the VUV FEL at TTF is also envisaged. In addition, studies on the improvement of photocathodes are planned.

PITZ2 will be realized in collaboration with BESSY Berlin, DESY, MBI Berlin and TU Darmstadt. Contributions from INFN Milan (cathodes), INR Troitsk (CDS booster), INRNE Sofia, and LAL Orsay (both diagnostics) are also included. First attempts to extend the collaboration have been started.

References:
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[2] Ph.Piot, Presentation given at the PITZ Collaboration Meeting, March 5, 2002.
[3] M.Ferrario et al. "HOMODYN study for the LCLS rf photo-injector", NLNF-00/004(P) and SLAC-PUB 9400, Contribution to the 2nd ICFA Advanced Accelerator Workshop, Los Angeles, November 1999.
[4] M.Ferrario et al., "Conceptual Design of the TESLA XFEL Photoinjector", TESLA-FEL 2001-3.
[5] L. Serafini "New perspectives and programs in Italy for advanced applications of high brightness beams", ICFA AABD Workshop, Chia Laguna, Sardenia, July 2002