STATUS OF THE PHOTO INJECTOR TEST FACILITY AT DESY, ZEUTHEN SITE*

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Abstract

The PITZ facility is established for the commissioning and testing of electron sources for FELs like FLASH and the European XFEL. The facility has been upgraded during the period from summer 2007 to summer 2008 to extend its capability to produce and characterize low emittance electron beams. The upgraded setup mainly includes a photocathode L-band RF gun with solenoid magnets for space charge compensation, a post acceleration booster cavity and several diagnostic systems. The diagnostic systems consist of charge and beam profile monitors, emittance measurement systems and spectrometers with related diagnostics in dispersive arms after the gun and the booster cavities. The RF gun was dry-ice cleaned and operated with an accelerating gradient of 60 MV/m at the cathode. A new photocathode laser system with broader spectral bandwidth was installed for optimizing the temporal distribution of the laser pulses regarding to electron beam properties.

In this contribution, the PITZ facility setup in the years 2008/2009 will be presented. Experimental results from this setup surpassed the electron beam quality requirements for the photoinjector source of the European XFEL [1].

INTRODUCTION

High peak brilliance and short wavelength SASE-FELs require driving electron beams with specific properties - symmetric beam size, small transverse emittance and energy spread, high peak current, etc. Whereas some of those parameters can be tuned to the requirements during the acceleration and transport to the undulator, others, like the beam emittance, are easily diluted during the beam propagation and need to be carefully optimized directly at the injector. The electron sources used at FLASH and in future at the European XFEL are developed and optimized at the Photo Injector Test facility at DESY, Zeuthen site (PITZ) [2].

The PITZ setup consists of a 1.6 cell L-band RF gun with a pair of solenoids and a newly installed Yb:YAG photocathode laser, a normal conducting post-accelerating TESLA type booster cavity and multiple diagnostics components for beam characterization. A simplified layout is shown in Fig. 1. It is divided into two sections - low and high energy sections corresponding to beam energies of about 6.5 and 14 MeV respectively. Since the first experimental demonstration of the capability to produce beam quality required for the XFEL [2, 3], PITZ has undergone significant upgrades. The conditioning and commissioning of the RF gun cavity operating at 60 MV/m at the cathode have been presented in [4, 5]. This contribution focuses on the diagnostics components used to study the beam parameters with the newly installed laser system and RF gun.

The upgrades of the beamline compared to the earlier setup [2] are:

- exchange of the RF gun cavity with one having an improved cooling system and being dry-ice cleaned [6]
- new laser system built to produce UV pulses with shorter rise/fall times [7]
- re-design of a low energy diagnostic cross with improved vacuum conductivity and a new actuator carrying a slit mask for better resolution of the measured momentum spread in the subsequent spectrometer
- re-design of the pole shoes and, thus, increase the dynamic aperture of the vacuum chamber of the spectrometer dipole in the low energy section
- shift of the booster cavity downstream in order to fit to the 60 MV/m gradient in the gun and to prepare for the installation of a future new cavity type
- emittance measurement systems - EMSYs, shifted downstream by the same distance as the booster cavity
- installation of a new 180° high energy dipole magnet with a corresponding dispersive section for measure-

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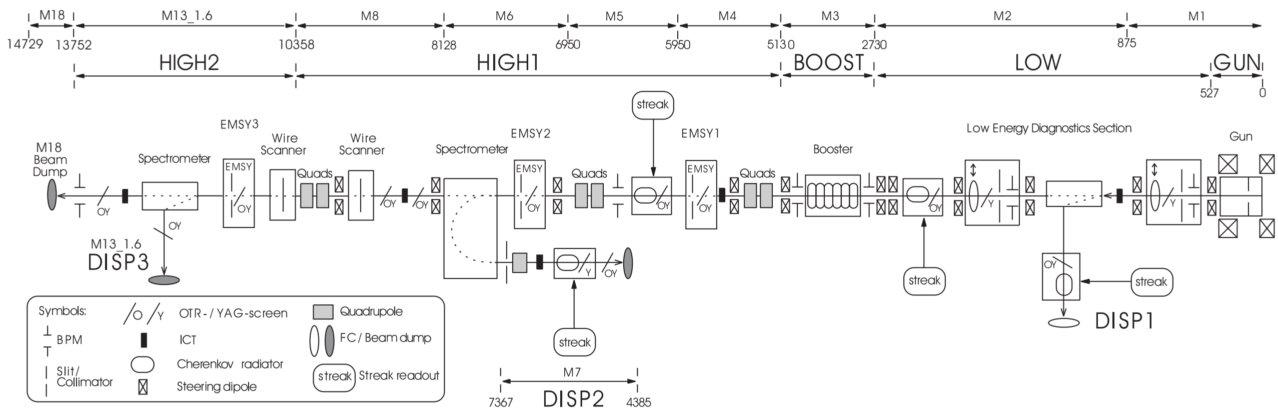

Figure 1: PITZ layout as in 2008/2009. The electron beam propagates from right to left.

ments of the longitudinal phase space and horizontal slice emittance for beam energies up to 40 MeV

- installation of quadrupole magnets for quadrupole scans, as part of a future matching section for a tomography module and to enhance the resolution of the measured momentum in the new high-energy dispersive section
- improved TV and video systems with switchable magnifying lenses and high resolution digital CCD cameras [8].

BEAM DIAGNOSTICS AT PITZ

The characterization of the electron source covers measurements of the transverse beam shape, size and phase-space distribution, beam momentum and momentum spread, bunch length, longitudinal phase space and control of the emitted charge per bunch. Compared to the setup in 2007, described in details in [2], major improvements are introduced in the diagnostics used to study the transverse and longitudinal phase-space density distributions.

Transverse Beam Distribution

A beam spot or its projections are the main source of information used to monitor and study the beam transport and the transverse and longitudinal beam distributions. In order to obtain such, there are multiple screen stations along the beamline. Typically, a screen station consists of a YAG and an OTR screen. Starting with the currently described setup, 0.1 mm Si layer is used as YAG substrate as before it used to be 0.275 mm. With this the minimum resolvable spot size is expected to be improved.

In order to improve the optical resolution, a system of lenses with different magnification is employed in all the screen stations used to study the transverse beam distributions. A single lens with fixed magnification can be inserted at a time in the optical path to a CCD camera. The magnification coefficients vary between 0.25 and 1. This has proven to be of particular importance for beams with high charge density and small transverse emittance.

Transverse Beam Emittance

The beamline is equipped with three dedicated EMSYs installed at different locations behind the booster cavity. An EMSY employs the single slit scan technique according to which an emittance-dominated beamlet is cut out by a movable slit. The position of the beamlet observation screen with respect to the slit depends on the charge density of the incoming beam at the location of the slit. An advantage of the slit scan is the possibility to obtain the transverse phase-space density distribution. Details on the design considerations of the EMSY can be found in [3] and measurement results from the setup discussed here are presented in [1, 9].

Starting from the 2008/2009 run period, a newly installed section, referred to as DISP2 in Fig. 1, gives the possibility to measure also the transverse emittance of individual longitudinal slices. This section consists of a 180° dipole magnet with bending radius of 300 mm. A removable slit, a quadrupole magnet and two screen stations, located in dispersive section, follow. The specifications of the dipole are chosen in order to allow a wide range of scanned booster phases and a good resolution of the momentum measurements with this spectrometer. The procedure as employed at PITZ and measurement results are discussed in [10, 11].

Three pairs of quadrupoles are installed in the straight section downstream the booster cavity. Each of them is powered separately in order to be able to use them for quadrupole scans with more than one magnet as well as part of a future matching section. Using several quadrupoles and adjusting their strengths appropriately, it is possible to keep one of the transverse planes constantly focused while rotating the beam in the other plane in wide range of phase advances. Thus, the phase-space density distribution can be reconstructed in great details. Details on such measurements can be found in [12].

Beam Momentum and Momentum Spread

There are three spectrometer dipoles installed at about 1, 7.5 and 11.7 m downstream the photocathode. The last one has not been used as it's being re-designed. The dipole in the low energy section is a 60° bending magnet designed to measure maximum momentum of about 9 MeV/c. Its dynamic aperture used to restrict the magnetic fields of the main solenoid, needed to transport the beam well focused downstream the booster. In the last upgrade the pole shoes of the dipole have been re-designed and the diameter of the vacuum chamber has been consequently increased [13].

In order to improve on the resolution of the measured momentum spread, a slit, mounted on a pneumatic actuator, has been newly installed in the first diagnostic cross behind the gun. The expected maximum uncertainty of the measured momentum spread is estimated to be below 2% [13]. Together with the slit, the cross section of the pumping ports of this diagnostic cross has been enlarged to increase the effective pumping speed and reduce wakefields.

The second dipole magnet marks the beginning of DISP2. The optics on the screen stations in the dispersive arm include switchable magnifying lenses used to improve the resolution of the measured momentum spread. The resolution on the momentum is enhanced as a quadrupole magnet upstream the dipole is used to focus the beam in the dispersion plane. In such a case the estimated relative uncertainties of the measured momentum and momentum spread are below 1% compared to 30 - 40% without quadrupole focusing [13].

Longitudinal Beam Distribution

The bunch length is measured on a screen station in the main beamline and its correlation with momentum is measured in dispersive arms in both low and high energy sections. Usually Silica aerogel plates of different thickness and refractive index are used to transform the temporal bunch shape into a light pulse with equivalent temporal distribution which is then imaged onto a streak camera via some 30 m long optical beamline. The streak camera has a temporal resolution of about 2 ps [2]. Measurements with the newly installed setup behind the booster cavity are reported in [14].

Laser Beam Diagnostics

A new photocathode laser system has been installed and commissioned altogether with the here described setup. Its advantage is the ability to produce flat-top laser pulses with maximum duration of about 25 ps FWHM and rise and fall times of about 2 ps [7]. The temporal shape of the laser beam is monitored by optical cross-correlation technique. The resolution of the measured shape of the laser pulses is better than 1 ps - a major improvement as compared to the previously used streak camera.

The devices used to monitor the position jitter and transverse laser beam distribution are inherited from the previous setup as discussed in [2].

SUMMARY AND CONCLUSIONS

The setup of 2008/2009 has been successfully operated with a number of new or improved components. The characterized gun cavity has already been dismounted and delivered to Hamburg to be used at FLASH. A new gun has been installed and is currently undergoing conditioning. Moreover, a new booster cavity of Cut-Disc Structure type and a module for phase-space tomography diagnostic will be installed. A new high energy dispersive arm at the end of the beamline and an RF deflecting cavity together with kicker magnets for longitudinal and transverse phase space characterization of the full beam and slices are currently under design.

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