

# COMMISSIONING OF A NEW EMITTANCE MEASUREMENT SYSTEM AT PITZ\*

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## Abstract

The goal of the Photo Injector Test facility in Zeuthen (PITZ) is to test and optimize high brightness electron sources suitable for FEL's like FLASH and the European XFEL. Such sources are characterized by very low emittance at high bunch charge. The new Emittance Measurement System (EMSY) described in this paper uses YAG and OTR screens to measure the transverse beam size and thin Tungsten slits to measure the divergence of the beam. It has been optimized to measure emittance for a beam of 1 nC in the energy range 5 - 30 MeV. The new EMSY was developed in a cooperation between DESY Zeuthen and the Institute for Nuclear Research and Nuclear Energy (INRNE) in Sofia. It was installed in the PITZ tunnel in the beginning of June and commissioning and first measurements are ongoing.

## INTRODUCTION

The Photo Injector Test Facility at DESY in Zeuthen (PITZ) was built to test and to optimize electron sources which are capable for SASE FEL operation. The main PITZ components are a photocathode laser, an L-band RF gun and space charge compensating solenoids. A major upgrade on the existing PITZ facility is ongoing since last year [1]. This upgrade includes the installation of an additional accelerating RF booster cavity and various diagnostics elements. The laser system was also upgraded in the last year, by improving the transverse imaging to the photo cathode (see [2]) and the overall stability. One of the goals of the facility is to study and optimize the conditions for the conservation of emittance compensated electron beam with short pulse length and low transverse emittance [3, 4]. Extended optimization of the photoinjector with ASTRA [5] showed that transverse emittance smaller than 1 mm.mrad at 1 nC charge can be reached (fig. 1). The Emittance Measurement System used at PITZ was upgraded for better performance in the extended momentum range [6]. Three of such devices were produced by the HITECH HEP Group in INRNE Sofia and are already installed in the PITZ tunnel. In this paper details about the new EMSY as well as first experience from the commissioning are given.

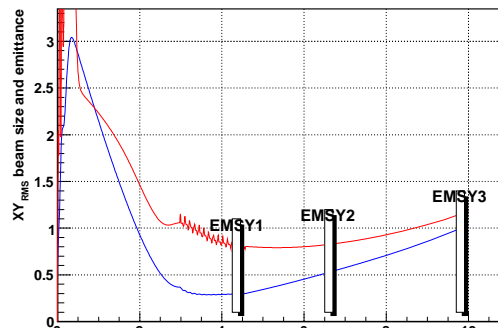


Figure 1: ASTRA simulation of the rms beam size in mm (blue) and normalized emittance in mm-mrad (red). The charge is 1 nC; accelerating gradient at the gun is 60 MV/m, phase of maximum energy gain; the focusing solenoid is at 385 A; the gradient of the booster cavity is 28.9 MV/m, phase of maximum energy gain.

## PITZ SETUP

A detailed layout of the current PITZ setup is shown on Fig. 2. The electrons are produced in the RF gun (on the right hand side) and transported through the low energy diagnostic section, further acceleration up to the maximum of 30 MeV is given in the booster cavity after which the high energy diagnostic section is installed.

The low and high energy diagnostic sections consist of different view screens, BPM's, charge measurement devices and longitudinal phase space diagnostics. The charge per bunch can be monitored non-destructively at four positions along the beamline using Integrated Current Transformers (ICT's). The beam momentum and momentum spread are measured at two dispersive dipole arms, one in the low energy section and one after the booster cavity. The low energy dispersive dipole is also equipped with a streak camera readout providing full knowledge about the longitudinal phase space distribution (see [7]). Three EMSY's are located after the booster cavity in positions 4.3, 6.6 and 9.8 m from the cathode.

For the transverse phase space characterization we rely on YAG and OTR screens and the so called slit scan technique [8]. For this technique the uncorrelated local divergence is estimated by cutting the electron beam into thin slices and measuring their size on a screen after a drift. The so called sheared normalized RMS emittance is then calculated us-

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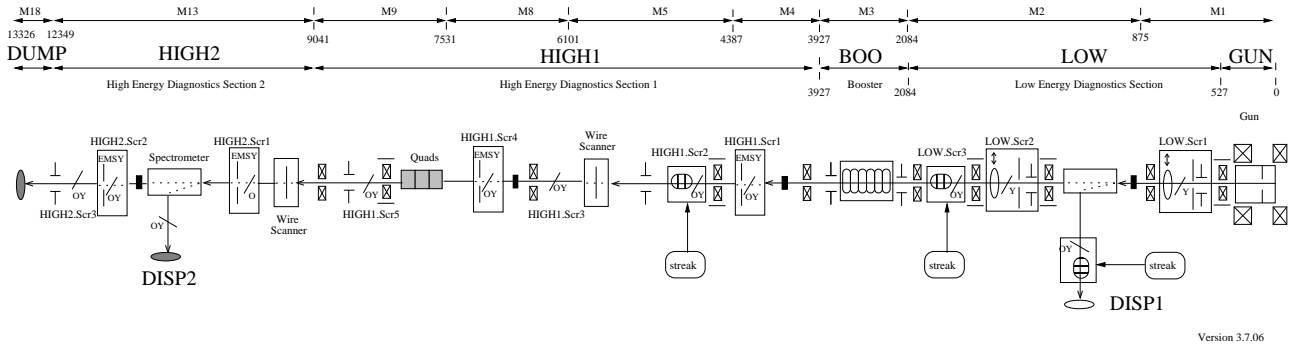


Figure 2: Layout of PITZ.

ing the following definition (1) taken from [8]:

$$\varepsilon_n = \beta\gamma \cdot \sqrt{\langle x^2 \rangle \cdot \langle x'^2 \rangle}. \quad (1)$$

Here  $\langle x^2 \rangle$  and  $\langle x'^2 \rangle$  are the second moments of the distribution of the electrons in the so called trace phase space where  $x' = \sqrt{\langle p_x^2 / p_z^2 \rangle}$  represents the divergence of the beam. The RMS beam size is measured on an OTR or YAG screen at the position of the slits along the beam axis. The uncorrelated divergence is obtained by analyzing the profiles of the beamlets produced from the slits which drift some distance  $L_d$  downstream where the spatial distribution of the beamlets corresponds to the local uncorrelated divergence,  $x'$  can be derived from the size of the beamlet using the formula in Eq. 2.

$$x' = \frac{\sqrt{\langle x_b^2 \rangle}}{L_d}. \quad (2)$$

Here  $x_b$  is the RMS size of the beamlet on the screen after distance  $L_d$ . The  $\beta\gamma$  is measured using a dispersive arm after EMSY.

### THE NEW EMITTANCE MEASUREMENT SYSTEM

EMSY consists of two orthogonal actuators (Fig. 3) which can be inserted separately to penetrate the beam in order to take images or to cut beamlets in the beam transverse planes. The actuators are driven into the beam line with stepper motors and positioned with precision better than  $10 \mu m$ , their angular orientation with respect to the electron beam can be adjusted during the measurement again using stepper motors. Each actuator is equipped with an YAG or OTR screen for measurement of the transverse RMS beam size  $\sqrt{\langle x^2 \rangle}$  and a single slit mask for estimation of the local divergence, multi slit masks are in production and will be mounted on the actuators in the next shutdown period. The design of the system enables us to measure the beam transverse parameters expected in PITZ with uncertainty less than 10 % (see [6]).

During the design the following considerations were taken into account:

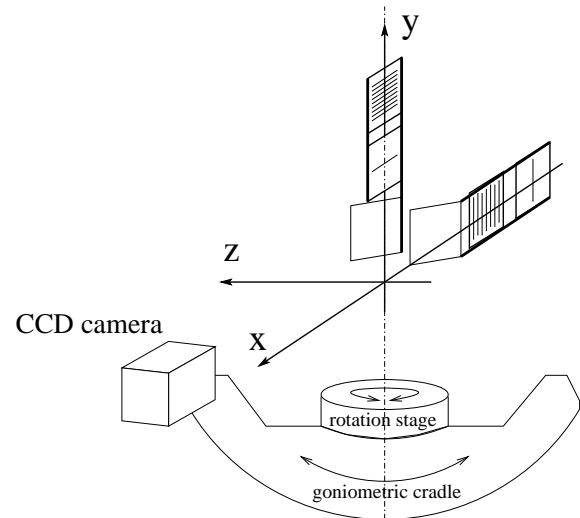


Figure 3: Layout of EMSY.

- The slit opening must be small enough to produce emittance and not space charge dominated beamlets, but still large enough to provide good transmission.
- The contribution of the initial beamlet size to the measured one at the screen of observation must be as small as possible.
- The distance between the slit mask and the screen must be big enough to resolve small beam divergence. But still short enough to prevent the space charge forces to degrade the beamlet and the overlapping of different beamlets from the multi slit mask.
- The mask thickness must be large enough to scatter the residual electrons from the beam in order to produce an uniform background for the beamlets measurements and still it must be thin enough provide sufficient acceptance angle.

The design of the slits was made using the above considerations, and GEANT4 [9] simulations for transport of the electrons through the masks and to assess the performance of the YAG screens to be used. Slits are made from 1 mm thick Tungsten with  $10 \mu m$  slit opening, the slits of the multi slit mask are separated with 0.3 mm. The screens are made from 0.3 silica wafers coated with YAG powder

or with Al (for the OTR screens). The YAG screens are placed at 90 degrees with respect to the electron beam and an Al coated silicon mirror is used to direct the light to the CCD chip, the OTR screens are with 45 degrees orientation. Both the screens are observed with 8 bit CCD camera. It was found from the beam dynamics simulations, that in some cases 8 bit camera cannot provide the desired sensitivity, therefore 12 bit cameras are ordered and are soon to be installed. On fig. 4 a scan of the position of the slit trough the beam is shown, a good signal from the camera is obtained (blue line), with red the RMS beamlet size is plotted.

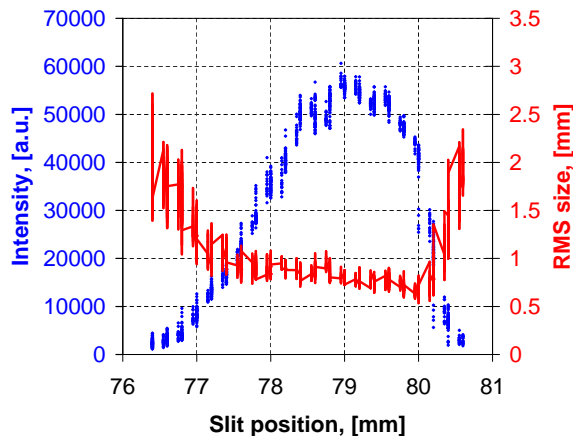


Figure 4: Scan with the 10  $\mu\text{m}$  slit.

Further optimization of the readout can be made by adjusting the angular orientation of the slit, as can be seen in fig. 5. The slit at position 79 mm in fig. 4 was selected for the angular optimization, improvement of the intensity of the signal from the camera is seen (blue dots) as well as stable reading for the beamlet size (red line) in the angular range -10 to +8 mrad, for larger angular deviations lower signal transmission takes place as well as additional effects such as scattering of the electrons from the inner surface of the slit, etc.

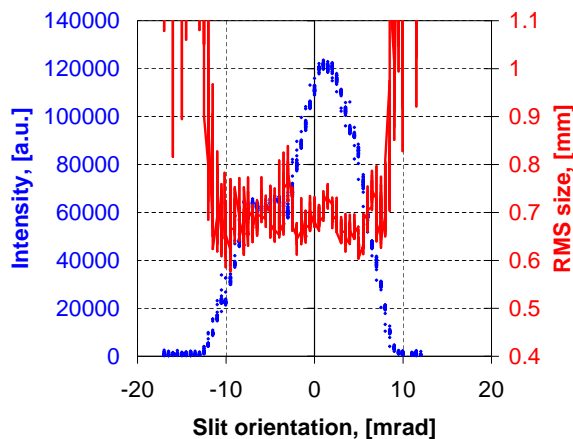


Figure 5: Scan of the angular orientation of 10  $\mu\text{m}$  slit.

## CONCLUSIONS

The 10  $\mu\text{m}$  slits can provide sufficient signal for beamlet measurements with proper angular orientation. The emittance measurement system in PITZ is installed and commissioned. All the component from the system are tested and ready for use.

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