DIAGNOSTICS FOR THE PHOTOINJECTOR TEST FACILITY IN DESY ZEUTHEN

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Abstract

A **P**hoto **I**njector **T**est facility (PITZ) is under construction at DESY-**Z**euthen. The aim is to develop and operate an optimized photo injector for future free electron lasers and linear accelerators. This concerns especially minimal transverse emittances and proper longitudinal phase space. The commissioning of the photo injector will take place in summer 2001. In the first phase the energy of the produced electrons is about 5 MeV. A short description of the setup and beam parameters are given. Optimization of an electron gun is only possible based on an extended diagnostics system. The diagnostics system for the analysis of the transversal and longitudinal phase space will be described. It consists of a measurement system of the transversal emittance, a TV-based image measurement system, a streak-camera measurement facility, a spectrometer using a dipole magnet and further detectors. Problems of the measurement of the longitudinal phase space are discussed in detail.

1 INTRODUCTION

A Photo Injector Test Facility (PITZ) is under construction in DESY Zeuthen and will be commissioned in summer of 2001. The project was originated by a collaboration of the following institutions: BESSY (Berlin), DESY (Hamburg and Zeuthen), Max-Born Institut Berlin, Technical University (Darmstadt) and is funded partially by the HGF-Vernetzungsfonds.

The goal of PITZ is to operate a test facility for laser driven RF guns and to optimize photo injectors for the operation of Free Electron Lasers (FEL) and the TESLA linear collider. Comparisons of detailed experimental results with simulations are foressen. The setup will be used for conditioning of optimized cavity resonators for subsequent operation at the TESLA Test Facility - FEL. New developed components (for example lasers, cathodes) will be tested under realistic conditions. Later questions related to the production of flat beams for linear colliders and the development of polarized electron sources will be addressed.

At present, the mounting and commissioning of different subsystems (laser, interlock systems, control system, diagnostics systems) is going on. The vacuum system including cathode section, cavity section and diagnostics section is under vacuum. The commissioning of the RF system and conditioning of the cavity are the next steps. First photoelectrons will be produced in autumn 2001 followed by the commissioning of the full setup. An upgrade with a booster cavity is foreseen in the next years.

2 DESCRIPTION OF PITZ

The schematic layout of the PITZ facility is seen in Fig. 1. It consists of the following main components:

- the photo cathode based on Cs_2Te [1])
- the copper cavity with a 1.5 cell geometry
- the laser system with output wavelength 263 nm
- the 1.3 Ghz RF-system with a klystron of 5 MW (later 10 MW)
- the control system based on DOOCS (Distributed Object-Oriented Control System)
- the diagnostics section

One of the main complex parameters and development goal is the time structure of the laser beam shown in Fig. 2.

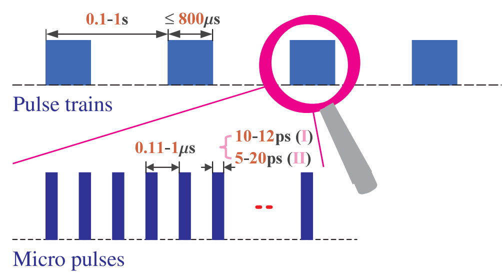

Figure 2: Schematic of the time structure of the laser beam. I) Phase I: GAUSSian-shape $\sigma \sim 6$ ps, II) Phase II: Rectangular shape with rise and fail time < 1 ps.

3 DIAGNOSTICS AT PITZ

3.1 Diagnostics of Laser Beam

- Time resolved bunch analysis of the laser beam by means of streak cameras.

  Two types of streak cameras (both from Hamamatsu)): FESCA-200 (time resolution > 200 fs), which is running only in single shot mode and C5680, running in single shot mode and synchroscan (time resolution > 2 ps) are available to analyse the time structure of

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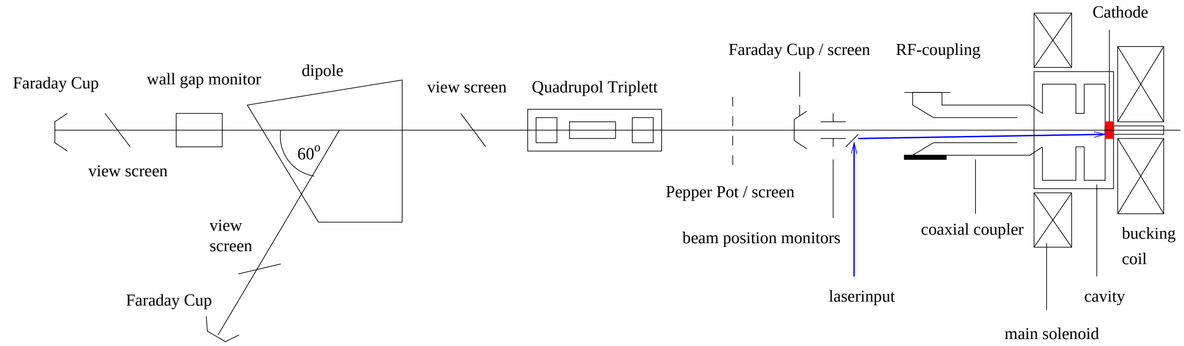

Figure 1: Schematic of the setup of the PITZ facility.

the laser beam. There are no restrictions concerning light level or aperture.

- Laser power measurement

  It is foreseen to measure the time-resolved laser power. A small fraction of the laser beam could be used for the time resolved measurement using a simple setup based on a photodiode. An alternative is the use of a commercially available laser power meter.

- Virtual cathode

  The virtual cathode simulates the cathode. Especially, the position, the shape and the energy distribution of the laser spot in a plane corresponding to the cathode plane will be measured. Either a plastic scintillator or an evaporated YAG (Yttrium-Aluminium-granate) screen will be used as converter of the UV laser light to visible light, both in transmission.

3.2 Diagnostics of Electron Beam

- EMSY - Emittance Measurement SYstem for measurement of transverse emittance.[2]

  The goal is to measure the transverse emittance of the electron beam by means of slit masks and/or hole masks (pepperpot), see Fig. 3. It is aimed to reach a tranverse emittance of $1\,\pi$ mm mrad. The beam pattern behind one of the slit or hole masks is detected about one meter downstream using screens and the TV system and is analysed later.

- TV diagnostics system

  It is the goal to measure and to analyse the position and the profile of the electron beam at different positions along the beam line.The resolution is aimed to be 1...10 μm, optionally a view camera geometry is used to overcome the depth-of-field problem.

- Time resolved bunch analysis of the electron beam using streak camera

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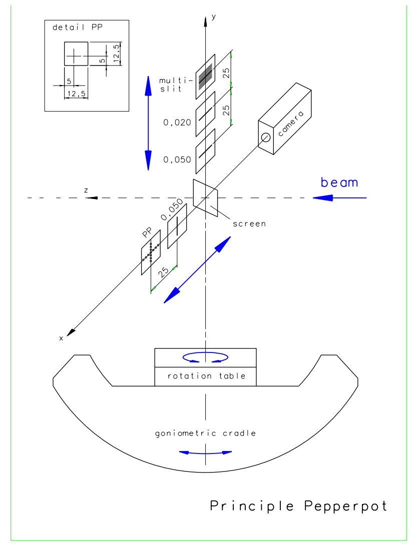

Figure 3: Transverse emittance measurement system.

Two types of streak cameras (see above) are available to analyse the time structure of the electron beam. The electron beam hits radiators based on Cherenkov effect or transition radiation. The light is transported using an optical beam-line to the streak camera lab. This 25 m long beam-line is under construction considering a high light collection efficiency, low photon losses and insignificant time dispersion to be realized.

- Measurement of magnetic field on cathode

  The magnetic field will be measured using the electron beam. The beam goes through a slit mask. In the case of a non-zero field on the cathode, the pattern of the beam on a screen behind the slit mask is rotated. The calibration is done using a laser. The laser beam is expanded and projected onto the slit mask. The orientation of the slit images gives the zero field position. The method has to be optimized so, that the calibration is not limited by diffraction of the laser beam at the mask.

- Dipole spectrometer

  A dipole is used to measure the momentum spectrum of the beam.

- FARADAY cup

  A water-cooled copper absorber insulated from ground is used to measure the beam charge.

- Wall gap monitor

  This monitor is used to measure the beam current using the image current on the vacuum pipes.

- Beam position monitor

  Beam position and charge are measured by a button monitor.

4 DIAGNOSTICS FOR LONGITUDINAL PHASE SPACE

The measurement of the longitudinal phase space will be done in three steps:

- Measurement of momentum

  The electron beam will be deflected by a dipole and its particle distribution will be measured with a YAG-screen.

- Measurement of bunch length

  The electron beam will be transformed by a radiator into photons which are measured by a streak camera. The temporal length of the photon bunch gives the electron bunch length.

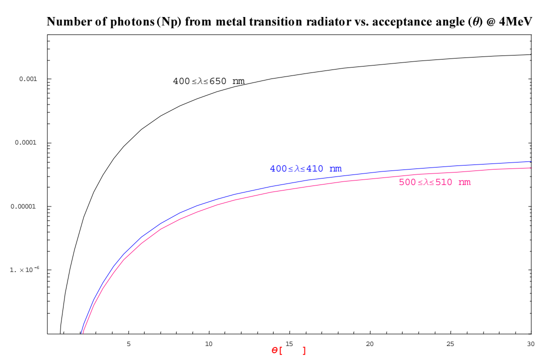

Figure 4: Number of photons from a metallic transition radiator in the acceptance angle produced by a 4 MeV electron.

Possible radiators are Optical Transition Radiator (OTR) and Cherenkov radiators. OTR produces only few photo electrons for electron energies of about

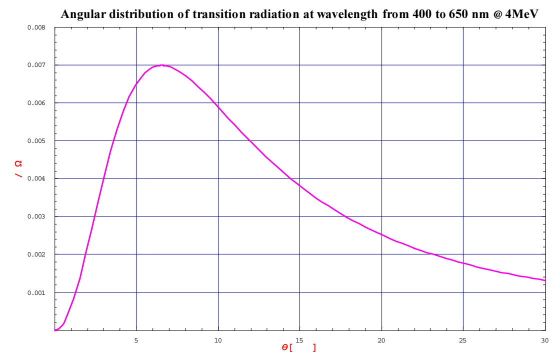

Figure 5: The angular distribution of the photons (from 400 nm to 650 nm) per solid angle produced by a metal transition radiator with 4 MeV electron beam.

4 MeV (Fig. 4) and with a broad angular distribution (Fig. 5). At the same energy Cherenkov radiators produce much more photons (Fig. 6), but the time dispersion is higher. This distribution can be improved by a special machined quartz.

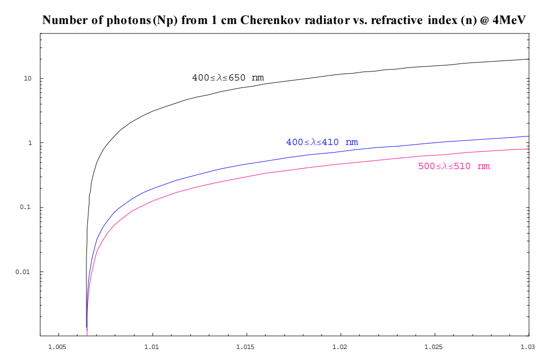

Figure 6: Number of photons from a 1 cm thick Cherenkov radiator with refrative index (n) produced by a 4 MeV electron.

- Measurement of longitudinal phase space

  A simultaneous measurement momentum and bunch length measurement gives the longitudinal phase space. This could be done by a dipole and a slit to separate the momentum and using a radiator. The streak camera measures the temporal distribution of photons. By repetition with different slit position the whole momentum distribution and temporal distribution of the electron bunch are reconstructed.