THE DIAGNOSTICS SYSTEM FOR THE PHOTOINJECTOR TEST FACILITY AT DESY ZEUTHEN (PITZ)

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Abstract

A Photo Injector Test Facility is in operation at DESY Zeuthen since end of 2001. 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. In the first phase the energy of the produced electrons is about 5 MeV. A short description of the setup and beam parameters is given. Optimization of an electron gun is only possible basing on an extended diagnostics system. For measuring transversal and longitudinal phase space high spatial and temporal resolution and low time spread are needed. Design principles, methodical measurements and first results are presented. Optical problems, design parameters and measurements of the TV-system, the optical system of the streak-camera and the laser beam-line are presented in detail.

1 INTRODUCTION

A Photoinjector Test Facility was built at DESY Zeuthen (PITZ)[1]. The project was originated by a collaboration of DESY (Hamburg and Zeuthen), BESSY (Berlin), Max-Born-Institute (Berlin) and Technische Unversität (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. First photoelectrons were produced in January 2002. To provide an optimization of the setup and its components a complex diagnostics system is used and under further development [2]. In this paper we describe in some detail optical problems and their solutions for the laser beam-line, the TV system and the optical chain for the streak-camera measurement system.

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2 DESCRIPTION OF PITZ

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

- the photo cathode based on Cs_2Te(INFN Milano)
- the copper cavity with a 1.5 cell geometry
- the laser system with output wavelength 262 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.

3 DIAGNOSTICS AT PITZ

The diagnostics system of PITZ was described in detail in [2]. There are two main goals for the use of the diagnostics system of PITZ, that is the analysis of the laser beam and the analysis of the electron beam.
Several tools for the analysis of the laser beam are available. The time structure of the laser beam can be measured by the streak-camera. There is a branch of the laser beam-line to the streak camera set-up. The position and transversal amplitude distribution of the laser beam spot can be measured by the virtual cathode. It has the same distance from the laser as the cathode, about 26 meters. An intensity measurement system for the laser beam will be developed in autumn 2002.
Several characteristics of the electron beam will be analysed by a variety of tools. The transverse emittance will be measured by the emittance measurement system EMSY. The TV-system is used to read-out optical information about the transverse beam characteristics using YAG screens. The longitudinal beam characteristics will be measured using a streak-camera. The beam momentum and

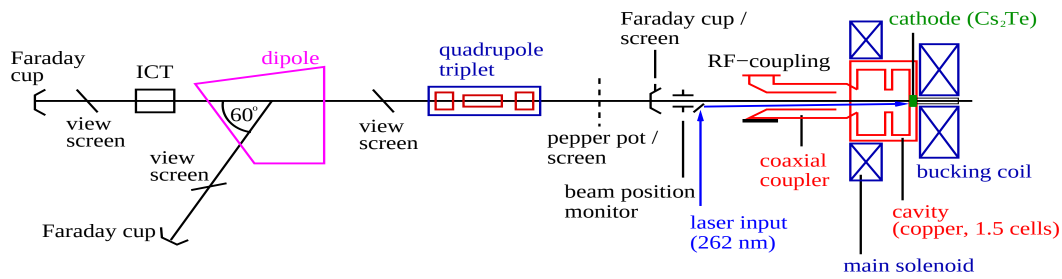

Figure 1: Schematic of the photoinjector.

longitudinal emittance is measured by the dipole spectrometer. Faraday cups are used to measure charge, beam current and dark current. Several detectors with electrical output as beam position monitors, wallgap monitors and ICT (integrating current transformer) are used to measure beam position and current.

4 OPTICAL PROBLEMS AND SOLUTIONS IN PITZ DIAGNOSTICS SYSTEM

Different optical problems had to be solved during the development of the PITZ photoinjector. Main features of the laser beam-line, special optical problems of the TV-system and the design of the optical chain of the streak-camera system are outlined in this chapter.

4.1 *Laser beam-line*

A laser beam-line is used to transport the laser light over about 26 m from the laser table in the laser room to the photocathode of the photoinjector. Besides this main branch, the laser beam-line consists of two further branches which transport the laser light to the virtual cathode and to the streak-camera room. The virtual cathode is based on a converter consisting of a thin YAG layer for the conversion of the UV light into visible light. The beam spot is recorded by a TV-camera.

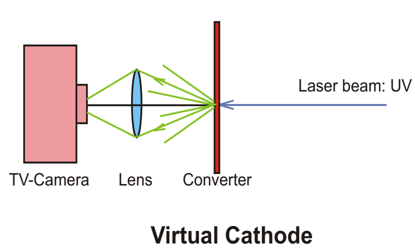

Figure 2: Schematic of virtual cathode

The virtual cathode simulates the cathode and gives the possibility to measure the position and the transversal light distribution of the beam spot. The converter is used in transmission and imaged onto the camera.

A set-up for the monitoring of the laser light will be developed in autumn 2002. A fraction of the laser beam is transported to the set-up of the streak-camera. This gives the possibility of monitoring the time structure of the laser beam. A recent measurement is was resulted in with a FWHM pulse length of about 10 ps. The main branch of the laser beam-line contains one telescope and several remote controlled movable elements, two mirrors and one pinhole. So, the laser spot can be scanned over the cathode. The size of the laser spot can be matched to certain demands by changing lenses in a telescope on the laser table.

4.2 *TV-system*

A TV-system consisting of five cameras and the virtual cathode is used for the measurement of the electron beam position and transversal beam profile at different positions along the beam-line. The TV-system was presented in detail in [3]. A sketch of the geometry of one TV-port is shown in fig. 3.

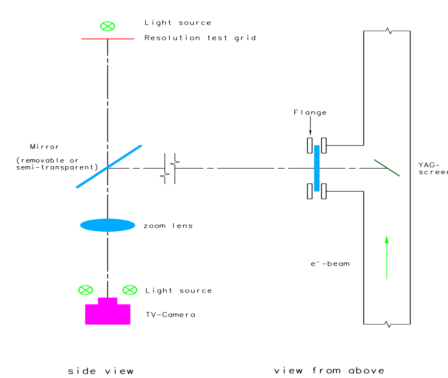

Figure 3: Schematic of the TV-system

The screen, which transforms the electrons in visible light consists of YAG. The TV-system is framegrabber based and readout over 40 m distance. The camera used is of the type JAI M10RS. It will be used in progressive scan mode. A RS-232 based control of gain, camera modes and linearity is under development. Actually, the mostly used lens is a macro-zoom lens which allows a magnification range of 0.084 up to 0.84. The lens is not suitable for high resolution measurements. The development of high resolution TV-channels will start in autumn 2002.

4.3 Light transport system for streak-camera

Two types of streak-cameras (FESCA-200, C5680 [1]), which have a time resolution of 200 fs and 2 ps respectively, will be used to measure the bunch length and the longitudinal emittance of the electron beam. The electron beam is transformed in light bunches using several radiators (quartz and silica areogel of different refractive index) under different angles relative to the beam axis.

To compensate the angle dependent phase shift, a blazed metallic grating [4] will be inserted. The produced light has to be transmitted from the radiator to the streak-camera via an optical chain. The principle is shown in fig. 4.

This optical chain of PITZ will be about 26 m long. Because of this length and the relative low amount of light produced by the radiator care has to be taken concerning a high efficiency of light collection and transmission. Also, the time dispersion caused by the optical chain should be negligible. The design principles of the optical chain for the streak-camera system are outlined as follows:

- collect maximum of light from radiator
- transfer collected light over long distance by telescopes
- match the telescope to the first high aperture system
- imaging of the original light spot onto the entrance slit of the camera (demagnification)
- match the bundle aperture on the slit to the entrance aperature of the streak camera internal lens
- minimize the number of optical elements
- maximize the transmission of the optical chain
- optimize optical resolution
- fix wavelength range
- fix dimension of object distribution: about 2 mm
- minimize additional time dispersion.

[1]Hamamatsu, Photonics K.K., Electron tube division, 314-5 Shimokanzom, Tokyooka Village, Iwagatun, Shizuoka-ken, Japan.

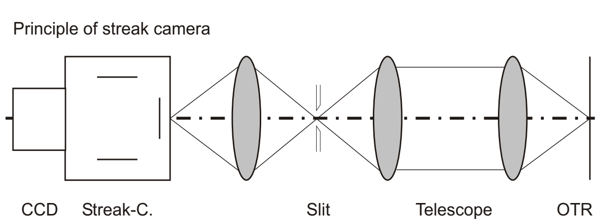

Figure 4: Principle of streak-camera setup

The designed optical chain is shown in fig. 5.

It consists of five telescopes essentially. Highly corrected systems and achromats are used to form these telescopes. Hereby it is assumed that systems with small transverse aberrations will have small longitudinal aberrations as well which is equivalent to a small contribution to time dispersion.

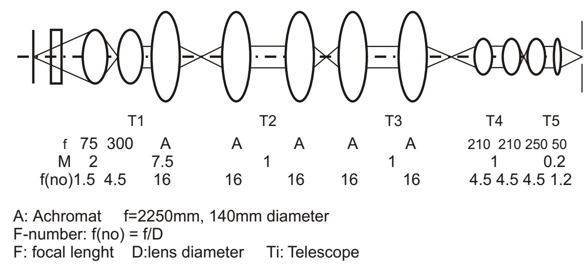

Figure 5: Optical chain, design values (M: magnification)

Different diagnostics tools are foreseen to test the functions of the optical chain. Light transmission, optical resolution and focusing can be measured and tested respectively. The diagnostics tools are distinguished in transmitters and receivers. The transmitters are realized by LEDs and illuminated resolution charts. Photomultipliers and TV-cameras are used as receivers. The contributions to time dispersion of elements of the optical chain and the whole chain is foreseen to be measured using the laser beam and beam-line described above.

5 SUMMARY AND OUTLOOK

The diagnostics system of the photoinjector test facility at DESY Zeuthen (PITZ) is presented. The photoinjector produced the first photoelectrons in January 2002. Optical problems and their solutions are discussed in detail. This concerns details of the laser beam-line, of the TV-system and the optical chain of the streak-camera system. It is foreseen to increase the optical resolution of certain TV-ports and establish remote control for several functions of the lenses. The optical chain of the streak-camera will be commissioned in summer 2002. It will be extended to further radiator ports.

REFERENCES

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[4] D.Lipka et al., Measurem. of the long. phase space at the photoinjector test facility at DESY Zeuthen, EPAC 2002, Paris.