Development of a TV diagnostics system for the Photo Injector Test facility at DESY Zeuthen

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A Photo Injector Test facility is under commissioning at DESY Zeuthen (PITZ). The aim is to develop and operate an optimized photo injector for future free electron lasers and linear colliders. The optimization of an electron gun is only possible based on an extended diagnostics system including a TV-system. The goal of the TV-system is measuring the electron beam position and beam profile at different positions along the beam line. Several demands of the system are described, for example the alternative of object size and high optical resolution. Radiation damage of the components has to be avoided. Solutions for the depth-of-field problem will be given. The optical system will be optimized concerning different effects on optical resolution as diffraction, depth of field, pixel size of the camera and effects of different elements of the optical system.

1. Introduction

A Photoinjector Test Facility is in commissioning phase at DESY Zeuthen (PITZ)[1]. The project was originated by a collaboration of BESSY (Berlin), DESY (Hamburg and Zeuthen), Max-Born-Institute (Berlin) and Technische Universität (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 will be produced in autumn 2001 [2].

To provide an optimization of the setup and its components a complex diagnostics system will be used [3]. One of the most flexible and universal diagnostics subsystems is the TV-system which is under development.

2. Characteristics of the TV-system

Several channels of the TV-system will be used to analyse the light distribution produced by an electron beam hitting a YAG-powder (Yttrium-Aluminium-granate) screen. Beam position, beam profile and intensity distribution will be measured. Furthermore, it is foreseen to measure the light intensity distribution behind an Emittance Measurement System (EMSY). In the dispersive arm of the magnet spectrometer the beam energy spectrum will be measured analysing the corresponding light distribution detected by the TV-system. The virtual cathode system of PITZ is also based on a TV-readout.

Basing on these general tasks, several characteristics of the PITZ TV-system can be specified. The light distribution created by a YAG screen is to be projected by lenses at different magnifications onto the camera sensor. The range of magnification is defined between an overview over the whole screen (magnification 0.24) and a "microscopic" view (magnification 10) where a resolution of $< 10\,\mu$m should be reached. It is aimed to reach a resolution of the order of $1\,\mu$m for analysing the pattern behind the EMSY system. Consequently, the object field is restricted in the operation mode of high resolution. The measurement of magnification should be possible in all operation modes basing on a grid in the screen plane. The YAG screen can be illuminated for this purpose. The resolution can be measured in all operation modes using an illuminated grid in a second arm of the system which can be activated by a movable mirror. Radiation damage and a direct illumination of the camera by X-rays will be avoided by projection in a 90^o scheme using one mirror. A schematic of the system is shown in

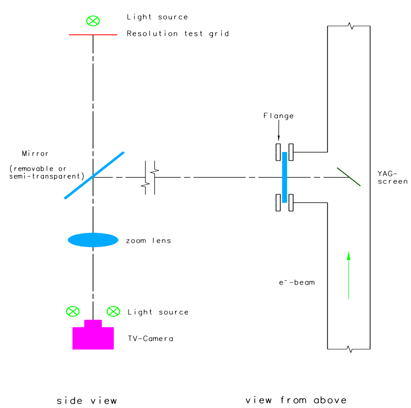

Figure 1. Schematic of the setup optical System of the TV–System.

Fig. 1. The video signal is read out and analysed by a computer based framegrabber (BESSY) over a distance of about 40 m. The camera of the type JAI M10RS has a 1/2" black/white sensor and is read out in the progressive scan mode. The sensor consists of 782×582 pixels. The pixel dimensions are $8.3\,\mu$m $\times$ $8.3\,\mu$m . External gain control and external trigger are foreseen. The control of the camera is realized via a RS 232 interface. The characteristic curve of the sensor is linear.

The depth-of-field problem which arises because of the 45^o position of the YAG screen relative to the electron beam and the optical axis can be solved using the view screen camera geometry. In this case the image plane is inclined relative to a normal position to the optical axis.

To overcome the problems of distance and of access to the setup, several functions of the TV-system as focus, diaphragm and focal length will be remotely controlled. At the present stage of the project investigations to perform a choice of lenses is performed. Especially different influences on resolution are under investigation. In Fig. 2 the influence of diffraction, depth of field, lens resolution and camera resolution are plotted to evaluate the process for different parameters of imaging. In this example the depth of field of 2 mm is the hardest limitation for resolution. One could overcome this problem applying the viewscreen camera principle. In this case the drawback is a non-uniform magnification in the field. In the case of small defocusing one can find the optimum of the combined effects of defocusing and diffraction at a f-number of about 10. In this case, the limitation of resolution is caused by lens and camera. The limitation of the camera (pixel size) can be eliminated by higher magnification, which leads to a smaller object field. Obviously, one can match f-number and magnification such, that the resolution of the lens remains the limiting factor. Hereby, the solution of the depth-of-field problem is assumed.

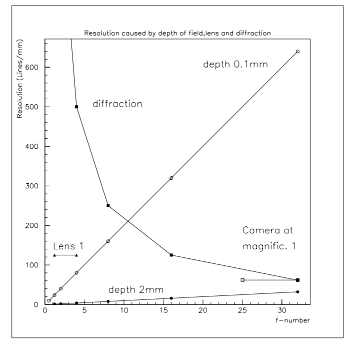

Figure 2. Influence of several effects on optical resolution

REFERENCES

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