OPTICAL TRANSMISSION LINE FOR STREAK CAMERA MEASUREMENTS AT PITZ

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Abstract

The photoinjector test facility at DESY Zeuthen (PITZ) produces electrons with a momentum of about 4–5 MeV/c. It is the aim to measure the temporal characteristics of the electron bunch train and single bunches with high accuracy of the order of 1 ps and better. Two types of streak cameras will be used in combination with different radiators which transform particle energy in light. The problem to be solved is the light transport over a distance of about 27 m. Basic demands to the optical system and design principles will be explained. The optical and technical solutions will be presented. The strategy of adjustment and commissioning of the optical system will be described. The system contains switchable optics for the use of different radiators (OTR, Cherenkov radiators). Diagnostic tools are foreseen at different positions along the optical axis. The results of different measurements in the laboratory will be presented. The problems on the minimalization of time dispersion in the system will be discussed.

INTRODUCTION

The photoinjector PITZ [1] at DESY Zeuthen is a dedicated facility for the investigation of rf-guns for future FELs and linear colliders. Different diagnostics methods are used to investigate the characteristics of the produced electron beam. One important goal is the measurement of the bunch length and longitudinal phase space [2] with a temporal resolution of 2ps and 0.2ps respectively limited by the streak camera to be used as basic tool.

A large fraction of the light created by the electron beam hitting or penetrating different radiators has to be transported by the optical transmission line onto the entrance slit of the streak camera. The light transport has to be performed creating minimum time dispersion and minimum light losses.

Radiators

Different radiators are foreseen to be applied basing on the effect of optical transition radiation (OTR) or the Cherenkov-effect. At a maximum beam momentum of currently about 4.7 MeV/c OTR results in a rather weak signal with a wide emission cone. Therefore the application of the Cherenkov effect will be the main method. A thin quartz plate and silica aerogel of a refractive index of n = 1.03 will be the first radiators to be investigated.

Streak Camera Data

Two types of streak cameras both from Hamamatsu are foreseen to be applied in the measurements.

The time resolution of the device C5680 is about 2 ps. The device is sensitive in the visible range and near UV and has a fiber-optical output by which the image is transmitted to the CCD. It has a synchroscan option and an internal gain of about $3*10^3$.

The second streak camera available is FESCA-200 with a time resolution of 200 fs working in the single shot mode.

Principle of Optical Transmission line

The principle of the optical transmission line consists in an optical transport of a part of the light created in the radiators by imaging the created light distribution onto the entrance slit of the streak camera. The optical system consists mainly on a chain of telescopes.

Design Principles

A few basic design principles for the optical transmission line are listed below.

- Collect a maximum of created light (depending on the optical input scheme)
- Transmit the light over large distance (27 m) using telescopes
- Project the transported light onto the entrance slit of the streak camera
- Match between the collecting optics and the transmitting optics on one hand and between the transmitting optics and the demagnifying optics before the slit otherwise
- Make an aperture match between the optical sub-system before the entrance slit and the streak camera internal optics
- Minimize the number of optical elements, maximize transmission
- Optimize optical resolution
- Fix wavelength range
- Fix maximum object distribution

INPUT OPTICAL SCHEMES

Two different optical schemes are used to match different emission characteristics. A high aperture lens system is used to collect a moderate part of the emission cone of the OTR light and of the cone of low refracting silica aerogel (see Fig.1). Subsequent imaging by telescopes takes place.

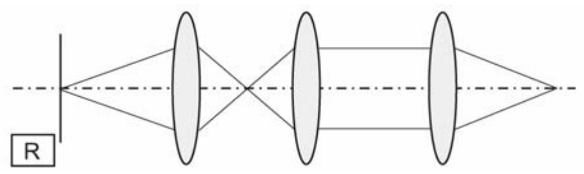

Fig.1: High aperture input scheme, (R: radiator)

For larger cones produced by Cherenkov radiators like quartz and higher refracting silica aerogel only a segment of the full cone is used and transmitted. A quasiparallel bundel is selected out of the cone and projected into the rear focal plane of the first lens. This light is then transmitted by a sequence of telescopes (see Fig.2).

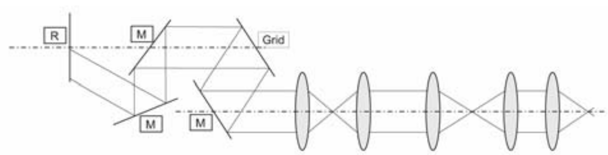

Fig.2: Scheme of cone sector imaging, (R: radiator, M: mirror)

The phase error caused by selecting a sector of the Cherenkov cone is foreseen to be compensated by use of a reflection grid [2] (principle see Fig.3).

SWITCHABLE OPTICS

A box containing three schemes of switchable optics is available and will be positioned just outside the vacuum window. One can switch between three branches of input optics:

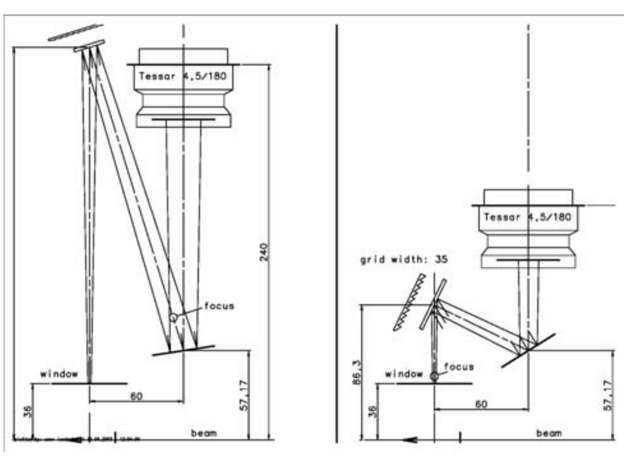

Fig. 3: Scheme using reflection grating

- A high aperture lens system 1.5/75mm for collecting part of the full cone of light emitted by OTR and the lowest refracting silica aerogel
- A scheme of reflection grating, mirror and first lens for a quartz plate radiator
- A system also consisting of a different reflection grating, mirror and first lens for higher refracting silica aerogel

The latter two systems are shown in Fig.3.

The movable optical elements are mounted on precise tables driven by air pressure.

The full scheme of the switchable optics is shown in Fig.4.

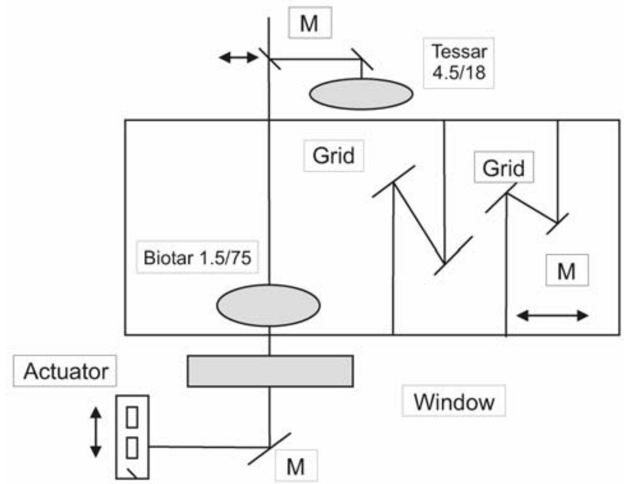

Fig.4: Scheme of switchable optics, (M:mirror), the actuator carries the radiators in vacuum

DESIGN RESULTS

As result of the designing activity the scheme shown in Fig. 5 was developed. It consists of the input optical scheme (switchable optics) and five telescopes. The basic values of the optical elements are shown in the table of Fig.5.

General Layout

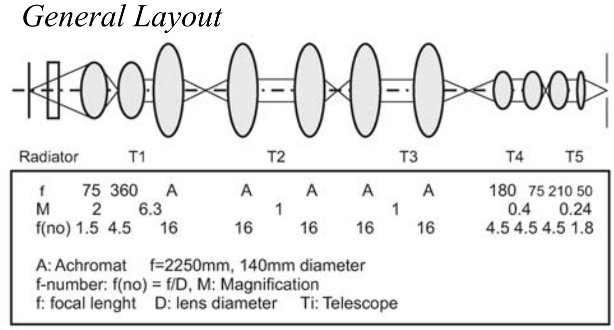

Fig. 5: Scheme of the full optical transmission line

The full system will be closed by tubes to avoid straylight and background illumination. The optical transmission is restricted to the visible range to avoid the use of expensive UV optics. The object size is restricted to a diameter of 2 mm to avoid vignetting of the inclined bundels from off-axis points. The optical resolution is aimed for at least 10 Lp/mm (corresponds to 100 microns).

OPTICAL RESOLUTION

The optical resolution of sub-systems of the optical transmission line was measured. The results are shown in Table 1. From these measurements an optical resolution of about 35 Lp/mm was estimated for the whole system which fulfills by far the design specifications.

Table 1: Optical resolution of sub-systems

L1	L2	L3	L4	L5	L6	L7	Magn.	Resol. Object Lp/mm	Resolut. Image Lp/mm
B1.5/75	T360	A					12.6	160	12.7
A	A						1	10	10
A	A	T180	T75	T210	P1.5/50		0.1	3.3	33
B	T360	A	T210	T70	T180	P	1.2	45	38

B1.5/75: Biotar 1.5/75 A: Achromat 2250
T180: Tessar 4.5/180 (all tessars f-number 4.5) P: Pancolar 1.5/50

DISCUSSION OF TIME DISPERSION

One of the main goals of the design is a minimum contribution to time dispersion by the optical transmission line. Therefore mainly highly corrected systems are used as elements of the system, following the assumption that these elements having small transverse aberrations should have also small longitudinal aberrations. Time dispersion results immediately from longitudinal aberrations. It is foreseen to measure the contribution of the optical elements to the time dispersion in the optical system by using the PITZ laser beam coupling it into the optical system at different positions. In future a replacement of refracting elements by reflecting optics is an option of minimizing the time dispersion of the system.

ADJUSTMENT AND DIAGNOSTICS

High accuracy of alignment and diagnostics systems are preconditions for the proper quality of the optical system. The adjustment procedure is described in a separate manual which is too long to be described in this paper. Only general adjustment principles are explained below. The adjustment will be performed using different tools, like a laser, diaphragms and resolution charts in two cycles, first for the mirrors and after that for the lenses. Thereby the right position of the optical axis, the position of the optical elements, the proper focus and image position and the maximum of optical resolution are the adjustment goals. The test of the proper function of the optical transmission line can be realized by four kinds of diagnostics tools. They can be divided in two categories: transmitters and receivers. Light emitting diodes and back-illuminated resolution charts are used as transmitters, photomultipliers and TV-cameras are used as receivers. The four kinds of elements are mounted in diagnostics boxes, see Fig.6. There are four positions along the optical axis where such diagnostics elements are positioned. The diagnostics boxes are integrated in the tube construction. The active elements can be inserted manually in the active position.

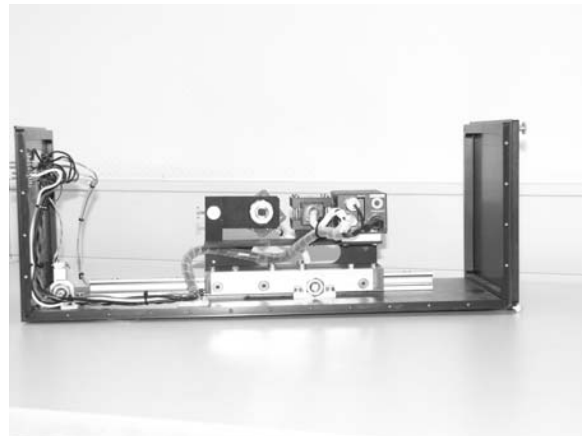

Fig.6: Diagnostics box

OUTLOOK

The commissioning of the optical transmission line is scheduled for end of May 2003. Practically all hardware elements are prepared. First measurements will start in June 2003. A similar read-out port will be realized in fall 2003 for the dispersive arm. For this port the task is to measure the full longitudinal phase space including the correlations therein. That means, not only the time characteristics have to be measured by streak camera but the momentum spectrum has to be projected onto the slit of the streak camera. This more complicated system is designed currently. The read-out will be performed by a special branch which is then matched to the main part of the optical transmission line described in this paper.

In 2004 PITZ will be extended by a booster cavity. For this a complex diagnostics section is foreseen which contains several optical branches for streak camera readout of both types described.

In future the application of reflective optics instead of lenses might be an option to minimize the time dispersion.

REFERENCES

[1] F.Stephan, et al., Photo injector test facility under construction at DESY Zeuthen, FEL 2000, Durham.

[2] D.Lipka et al., Longitudinal phase space measurements at PITZ, EPAC 2002, Paris.