DESIGN AND CONSTRUCTION OF THE MULTIPURPOSE DISPERSIVE SECTION AT PITZ*

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Abstract

For the characterization of RF photo-electron guns a full set of beam parameters has to be measured. For this purpose a new high energy dispersive arm (HEDA1) will be used at the Photo Injector Test Facility at DESY in Zeuthen (PITZ) in addition to the existing beam diagnostics. This multipurpose device is designed [1] for an electron energy range up to 40 MeV and will be put into operation in autumn 2007. It combines the functionality of (i) an electron spectrometer, (ii) a device for the characterization of the longitudinal phase space, and (iii) a transverse slice emittance measuring system. HEDA1 consists of a 180 degree dipole magnet followed by a slit, a quadrupole magnet, and two screen stations. One of the screen stations will be equipped with an optical read-out for a streak camera. We report about the detailed design of individual components and the construction progress.

INTRODUCTION

The test facility PITZ was built in Zeuthen in collaboration with international partners with the goal to develop and to optimize high brightness electron sources suitable for SASE FEL operation.

The PITZ facility is an electron accelerator which consists of a 1.5 cell L-band RF gun with its photo-cathode laser system, followed by a low energy diagnostics section, a normal-conducting booster cavity and a high energy diagnostics section. For the detailed description of the PITZ layout we refer to [2, 3]. In parallel to beam operation we are permanently extending the diagnostic section in order to enable more detailed studies of the beam properties. The beam line which has a present length of about 13 meters will be extended up to about 21 meters towards the middle of 2008. Several additional diagnostic components will be added to the present setup. Together with the deflecting cavity [4], the phase space tomography module [5] and the second high-energy dispersive arm (HEDA2) [6], HEDA1 will extend the existing diagnostics system of the PITZ facility. The dispersive section is designed to combine the functionality of (i) an electron spectrometer, (ii) a device for characterization of the longitudinal phase space, and (iii) a transverse slice emittance measuring system. The details of the physical design of HEDA1 were discussed in our earlier paper [1], whereas in the present paper we concentrate on some aspects of the technical implementation of the multi-purpose high energy dispersive arm.

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SETUP

The layout of the dispersive section HEDA1 is schematically shown in Fig 1. The heart of the dispersive section is a 180° dipole magnet having the bending radius of 300 mm. Main parameters of the dipole magnet are summarized in Table 1.

Table 1: Parameters of the dipole magnet.

Bending radius	300	mm
Maximum magnetic field	0.46	T
Homogeneous area	± 40	mm
Field accuracy ΔB/B	$7 \cdot 10^{-4}$	
Electrical power	4857	W
Maximum current	160	A
Current density in the conductor	7.1	A/mm^2
Total weight	650	kg
Cooling type	Water	

The bending radius has been chosen as a compromise between the ability of the spectrometer to operate within the large range of gun and booster parameters, having at the same time good momentum resolution on the one hand and space restrictions on the other hand.

The dipole magnet (Fig. 2) has been designed, manufactured, and magnetic field map was measured[1]. After its delivery to PITZ, the acceptance tests for water cooling and electric power have been performed at PITZ. For an operating condition at 160A, a maximum magnetic field of 0.46 T has been achieved with a temperature rise of ≤13°C at an operating water pressure of 5 bar, a pressure drop of 3.2 bar and a water flow rate of 5.2 l/min. The magnetic field measurements were carried out and are in a good agreement with the results provided by the manufacturer. The results of the magnetic field measurements versus applied current are shown in Fig. 3.

Being deflected in vertical plane, the electron beam enters the dispersive arm which goes back below the main beam line. The dispersive arm includes a pumping port combined with a removable slit mask, a quadrupole magnet Q_1, two screen stations, a pumping port and a beam dump.

[1] By SIGMAPHI, France

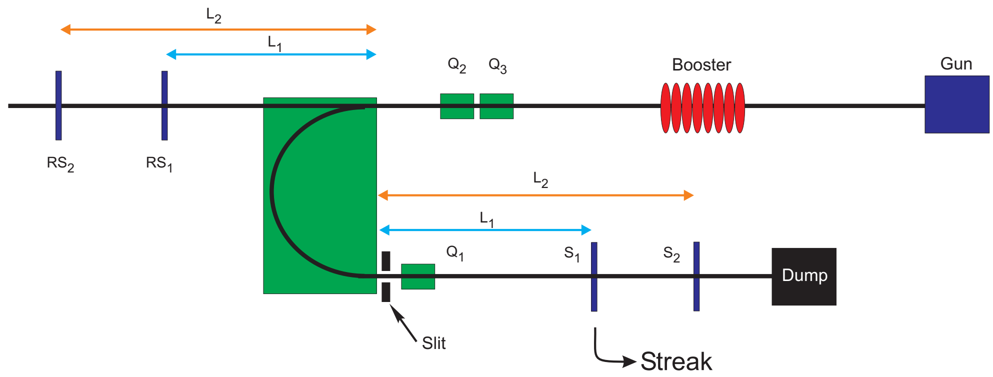

Figure 1: Simplified layout of PITZ with the first high energy dispersive section.

Figure 2: View of the dipole magnet.

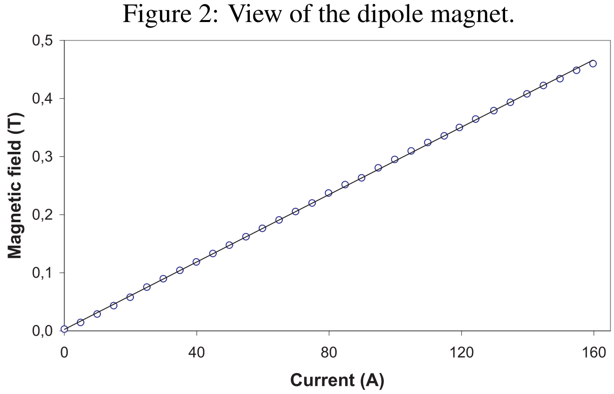

Figure 3: Magnetic field measurements versus applied current.

The functionality of HEDA1 can be enhanced with a setup that allows to measure the transverse emittance of the electron beam at different longitudinal positions along the bunch. The so-called slice emittance is providing better understanding of the physics of a photoinjector, particu-

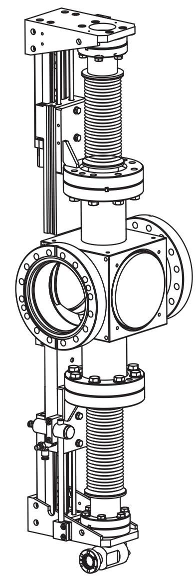

Figure 4: Simplified technical drawing of the screen station.

lary the emittance compensation and conservation principles. Using proper phasing of the booster cavity one can obtain linear correlation between the momentum and longitudinal distribution of the electrons in the bunch. A slit at the dipole exit selects the necessary slice from the energy chirped beam. This slice is scanned with the quadrupole magnet Q_1 focusing in a plane orthogonal to the dispersion plane and the beam distribution is observed on screen S_2. The slit mask for the slice emittance measurements is made from a 3 mm thick tungsten with a slit opening of 30 mm ± 1 mm. The possibility to exchange a slit mask by one with a smaller opening is foreseen. The slit is oriented perpendicularly to the bending plane with the accuracy of better than $\pm 1°$. The tilt of the slit with respect to the reference trajectory around the horizontal axis should be less than $\pm 4°$.

The quadrupole magnet Q_1 has parameters which are listed in Table 2. It is followed by a drift space and two screen stations. Since the dispersive arm is only 600 mm below the main beamline and due to the need of a long drift space after the quadrupole magnet exit for slice emittance measurements, two screen stations will be included in HEDA1. Each screen station has two actuators and two

Table 2: Parameters of the quadrupole magnet used for slice emittance measurements.

Maximum gradient	2.0	T/m
Bore diameter	80	mm
Number of Amper turns	1328	At
Gradient accuracy ΔG/G	$5 \cdot 10^{-4}$	
Total weight	80	kg
Cooling type	Air	

view ports (see Fig. 4). The drifts from the middle of the quadrupole magnet Q_1 to the first and to the second screen stations are equal to 690 mm and 1237 mm, respectively. The first screen station S_1 contains a YAG screen which will be used for momentum measurements in general and a Cherenkov radiator (Silica aerogel, n=1.05) which is used for measurements of the longitudinal phase space. The design considerations of the aerogel chamber and optical system for the measurement of the longitudinal phase space are described in details in [7]. The second screen station S_2 contains a YAG and an optical transition radiation (OTR) screen. The YAG screen will be used for slice emittance measurements. The OTR will be used for momentum measurements with a higher number of pulses and a small momentum spread in order to prevent the burning of the YAG layer. An additional streak readout for the full cone of the OTR could be of interest especially for higher energies since the emission angle is rather small then. This is not realized in the present design but can be easily extended.

After exit from a 180° dipole magnet the electron beam size stays almost constant. Thus, the maximum screen size is defined by the inner diameter of the quadrupole magnet and is equal to 80 mm. So the size of all YAG and OTR screens was chosen with 80 mm x 60 mm, which corresponds to the ratio of CCD camera chip size. The aerogel, however, has only a size of 80mm x 18mm which is limited by the opening of the streak camera slit in non-dispersion direction. For measuring the bunch charge an integrating current transformer (ICT) is foreseen between the two screen stations. The dispersive section will be end at a beam dump.

The main advantage of the spectrometer based on a 180° dipole magnet is the simplicity to reconstruct the momentum distribution [1]. One uses the reference screen RS_i in the straight section and measures the contribution from the transverse beam size and divergence, which can be deconvoluted with the spectrum measured on the corresponding screen S_i to obtain the pure momentum distribution. This deconvolution is simple and straight forward if the distances L_1 (L_2) from the entrance of the dipole magnet to the measuring S_1 (S_2) and the reference RS_1 (RS_2) screens are equal. For this reason reference screen stations RS_1 and RS_2 are placed downstream to the dipole magnet in the main beam line. Additional components which contribute to the measurements at HEDA1 are two quadrupole magnets Q_2 and Q_3 locating in front of the dipole magnet entrance. By focusing the beam on the screen RS_i with the help of these quadrupole magnets one controls the resolution of the momentum measurement on the corresponding screen S_i. The quadrupole magnets Q_2 and Q_3 will also be used as a part of the matching section for the phase space tomography diagnostics [5]. A numerical example of the momentum measurements is shown in Fig. 5. The original momentum distribution obtained with ASTRA [8] (black) is compared with the reconstructed one after the tracking through the dipole magnet using the measured field distribution (red).

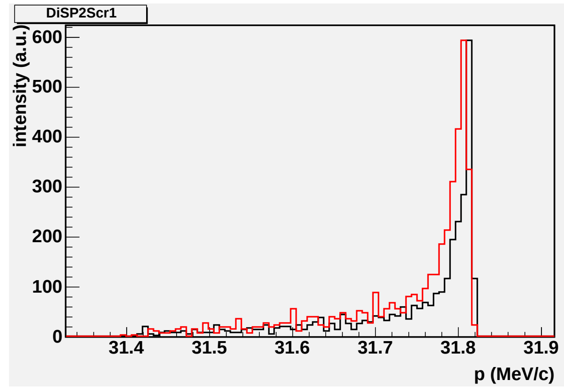

Figure 5: Original momentum distribution obtained with ASTRA (black) and the reconstructed after the tracking through the dipole magnet using the real field distribution (red).

The high energy dispersive arm HEDA1 will be installed at PITZ during the shut down of summer 2007 and will enable measurements of beam momentum, longitudinal phase space, and transverse slice emittance.

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