Measurements of the transverse emittance at the FLASH injector at DESY

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The VUV and soft x-ray free electron laser FLASH (former VUV-FEL) is a user facility at DESY (Hamburg). In order to optimize the performance of the facility, an accurate characterization of the electron beam properties is essential. The transverse projected emittance, one of the important parameters characterizing the quality of an electron beam, is measured using a four monitor method with optical transition radiation monitors. A normalized rms emittance below 2 mm mrad for a 1 nC beam has been measured. In this paper we describe the experimental setup, data analysis methods, and present experimental results.

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I. INTRODUCTION

The vacuum ultraviolet free electron laser (VUV-FEL) [1], now FLASH (Free electron LASer in Hamburg), is a FEL user facility at DESY (Hamburg). It is based on the SASE (Self-Amplified Spontaneous Emission) process [2] to produce FEL radiation in the wavelength range from vacuum ultraviolet to soft x rays. The commissioning of the facility started in the beginning of 2004 and the first lasing with a wavelength of 32 nm was achieved in January of 2005 [3]. User experiments started in the summer of 2005.

Figure 1 shows the present layout of the linac. Electron bunch trains with a bunch charge of 1 nC are generated by a laser driven rf gun [4]. Five accelerating modules with eight 9-cell superconducting niobium cavities [5] each are installed to provide an electron beam energy up to 700 MeV. Later, one additional accelerating module will be added to increase the electron beam energy to 1 GeV. The electron bunch is compressed using two magnetic chicane bunch compressors. At the location of the first bunch compressor the beam energy is 125–130 MeV, and at the second one about 380 MeV. During commissioning, the main emphasis was on lasing with a photon wavelength of 32 nm, corresponding to an electron beam energy of 445 MeV.

A high quality electron beam is required for the lasing process. At FLASH the design value of the normalized transverse emittance is 2 mm mrad, the design peak current 2500 A, and the design energy spread 0.1%. In this paper we present measurements of the transverse projected emittance at the injector with a beam energy of ~130 MeV. The measurements are performed in a special diagnostic section (Fig. 1) using a four monitor method with optical transition radiation (OTR) monitors.

II. EXPERIMENTAL SETUP

The injector consists of a laser driven rf gun with a solenoid magnet to counteract space charge induced emittance growth, a booster cavity to increase the electron beam energy up to 125–130 MeV, a bunch compressor, and a diagnostic section for measurements of the transverse emittance. More details of the injector concept, the present stage of the injector, as well as the planned future upgrades are in [6].

The diagnostic section located downstream of the first bunch compressor consists of six quadrupoles with alternating polarity and four OTR beam profile monitors combined with wire scanners. In this paper we concentrate on emittance measurements using the OTR monitors only.

A. OTR monitors

Transition radiation is electromagnetic radiation emitted when a charged particle crosses a boundary between two media of different optical properties, in practice a thin mirror like wafer. Optical transition radiation (OTR), the visible part of this radiation, provides a fast single shot measurement of the transverse charge distribution of an electron beam.

The requirements for the OTR monitors are demanding: besides delivering on-line beam images, they are used to

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