THE SYNCHROTRON RADIATION INTERFEROMETER USING VISIBLE LIGHT AT DELTA

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Abstract

Synchrotron radiation sources such as DELTA, the **D**ortmund **el**ec**t**ron **a**ccelerator [1], rely on a synchrotron radiation monitoring system to measure the beam size and emittance with sufficient resolution. The resolution limits of different types of optical synchrotron light monitors at DELTA have been investigated. The minimum measurable beam size with the standard synchrotron light monitor using visible light at DELTA is approximately 80 µm. Due to this limitation an interferometer was built up and tested using the same beamline in the visible range. A minimum measurable beam size of approximately 8 µm could be obtained, which gives an increased resolution of one order of magnitude with the new system.

INTRODUCTION

The storage ring facility DELTA is operated by the Institute of Accelerator Physics and Synchrotron Radiation at the department of Physics. DELTA consists of a 35 – 100 MeV LINAC, the 35 – 1500 MeV ramped storage ring called **Bo**oster **Do**rtmund (BoDo) and the electron storage ring called Delta (300 – 1500 MeV). The facility serves universities and industries as a source of synchrotron radiation on a regional level. The routine mode for user runs is 1.48 GeV @ 120 mA peak value of the beam current after injection.

Both transverse beam sizes of the electron storage ring Delta are measured by optical monitoring using synchrotron radiation from bending magnets and commercial CCD-cameras. We installed two optical synchrotron radiation monitors at different points of the ring (see Figure 1). One monitor is completely inside the radiation shielding (BL 7). The other one allows use of synchrotron radiation outside the shielding, but not during injection time (BL 4). We are able to measure the horizontal beam size down to about 80 µm with a normal optical synchrotron light monitor. The resolution is not sufficient for the routine mode of DELTA, so an interferometer was built up and tested. It is used at BL 7 to measure beam sizes down to 8 µm on demand. In the routine mode the normal synchrotron light monitor is mostly used due to the easier interpretation of the image by the operator. Both monitors are installed and can be used alternatively by a remote control.

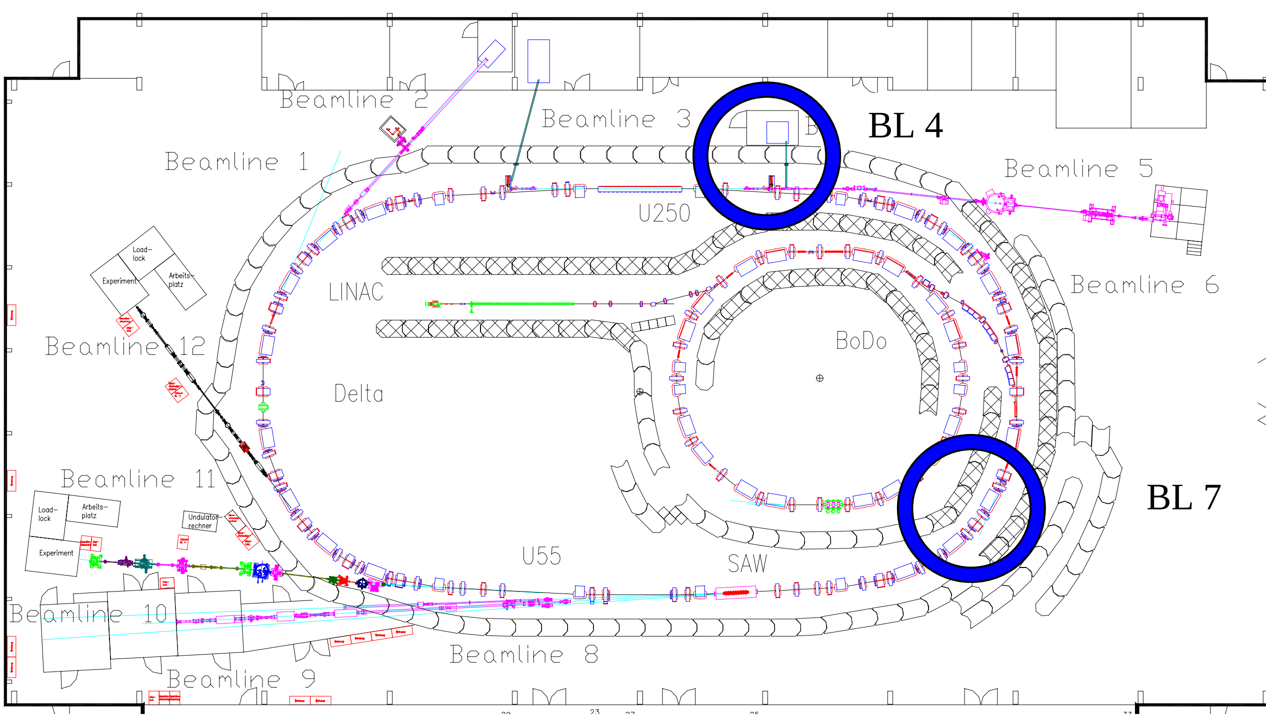

Figure 1: The DELTA facility with the two beamlines serving the storage ring synchrotron light monitors.

NORMAL OPTICAL SYNCHROTRON LIGHT MONITORING SYSTEM

The design of the normal optical synchrotron light monitors at Delta have been described elsewhere [2][3]. These monitors work reliable in a routine way. The video signal of the CCD-cameras can permanently be displayed on TV screens in the control room. The image processing system consists of a PC frame grabber DT 3155 and a graphical surface, adapted from DESY software [4]. This allows an analysis of the beam size by a gaussian fit to a chosen part of the image and determination of the position of the beam center.

Necessary corrections of the calculated beam size are done by this software due to diffraction, curvature, depth of field and resolution of the CCD-chip. The experimental setups of the monitors are equipped with apertures to minimise the necessary corrections of the measured beam size. This limits the achievable resolution to about 80 µm @ 500 nm with even an optimised horizontal or vertical opening angle.

The correction due to diffraction has been measured in an experimental setup (see Figure 2) adapted to the installed system. A Siemensstar is illuminated by monochromatic light (LED with 660 nm) and used as a source instead of the electron beam. The image is digitised and analysed to determine the resolution by the software. The experiment gives $\sigma = (34 \pm 2)$ µm as minimal measurable beam size due to diffraction only in this setup. The result is in good agreement with the theoretical value ($\sigma = 0.61 * \lambda / \Theta = 33.55$ µm).

The influence of the opening angle of the synchrotron radiation concerning the measured beam size has been investigated at DELTA synchrotron light monitors by variation of the horizontal and vertical aperture. After subtraction of the necessary corrections due to different opening angles, the real beam size was in good agreement at the different opening angles (see Figure 3).

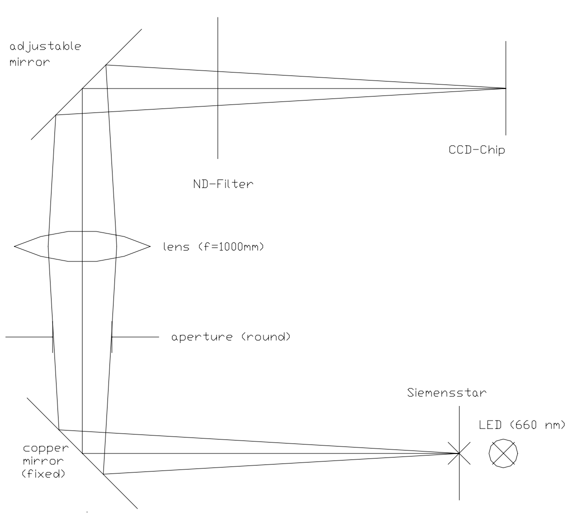

Figure 2: The experimental setup to determine the necessary correction due to diffraction at Delta.

THE OPTICAL SYNCHROTRON LIGHT INTERFEROMETER AT DELTA

A synchrotron light interferometer using visible light according to the theory of T. Mitsuhashi [5] was build up at BL 7, the same beamline at Delta as the normal optical synchrotron light monitor. A linear transfer mechanism moves either the lens and the aperture of the normal synchrotron light monitor or the double slit, linear polarisator and lens of the interferometer into the optical path of the synchrotron radiation outside the vacuum of the storage ring. Because of the interchangeable setup the operator in the control room can mostly use the normal synchrotron light monitor with its additional information included on the TV-screen (outlook, possible instabilities). The interferometer is only needed for a short check of the beam size during the run. The advantage is that no separate or new beamline using X-rays is needed to improve the achievable resolution of the monitor by a factor of 10 at low additional costs. The visibility allows an easy and direct arrangement of the components and cheap diagnostics with a normal CCD-camera. The layout of the interferometer is shown in Figure 4. It consists of a double slit (diameter 1 mm) with different slit distances D (between 2 and 8 mm) at the distance s = 1410 mm from the source point, followed by a linear polarisator, a bandwidthfilter ($\lambda = 500 \pm 3$ nm) and an achromat with a focal length f = 1500 mm. The visibility $V = (I_{max} - I_{min}) / (I_{max} + I_{min})$ of the digitized interferogramm is determined in order to achieve the beam size σ:

$$\sigma = \frac{\lambda s}{\sqrt{2}\pi D}\sqrt{\ln\frac{1}{V}}$$

The resolution of the synchrotron light interferometer has been measured in an experimental setup similar to that of the normal synchrotron light monitor. The experimental result for the resolution limit at $\lambda = 660$ nm is $\sigma = (10.3 \pm 3.4)$ µm. So the limit for the measurable electron beam size at Delta is $\sigma = (7.8 \pm 2.5)$ µm for $\lambda = 500$ nm.

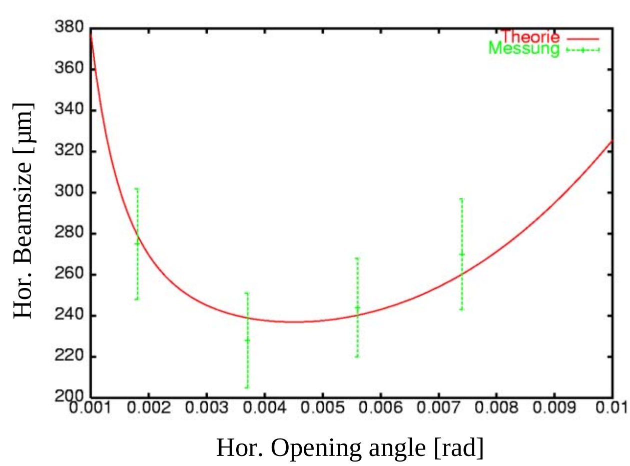

Figure 3: The measured beam size after correction versus horizontal opening angle of the synchrotron radiation.

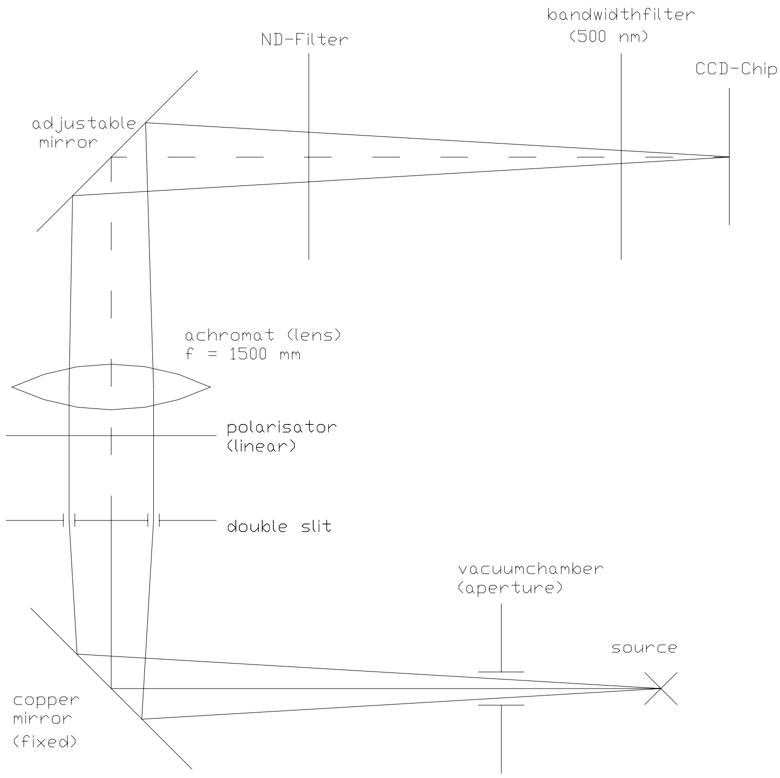

Figure 3: The optical synchrotron light interferometer at DELTA .

The electron beam size of Delta at 960 MeV has been determined to σ = (159 ± 15) µm by the optical synchrotron light monitor and to σ = (160 ± 5) µm by the interferometer. So both methods are in good agreement in their common measurement range.

CONCLUSIONS

The normal optical synchrotron light monitors at Delta work routinely down to their resolution limit σ ≈ 80 µm.

A suitable optical synchrotron light interferometer to determine beam sizes down to σ ≈ 8 µm at Delta has been developed, build up and tested.

The results of both types of optical synchrotron light monitors are in good agreement in their common range (beam sizes σ > 100 µm).

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