

## STATUS OF THE DELTA SYNCHROTRON LIGHT-MONITORING-SYSTEM

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### *Abstract*

Synchrotron radiation sources like DELTA need an optical monitoring system to measure the beam size at different points of the ring with high resolution and accuracy. An investigation of the emittance of the storage ring can also be done by these measurements.

Scope of this paper is the investigation of the resolution limit of the different types of optical synchrotron light monitors [1] at DELTA, a third generation synchrotron radiation source. At first the normal synchrotron light monitor is analysed. The minimum measurable electron beam size at DELTA is about 80  $\mu\text{m}$ . Emphasis is then put on a special synchrotron light interferometer, developed for DELTA, which has been built up and tested. This interferometer uses the same beamline and can measure beamsizes down to about 8  $\mu\text{m}$ . So its resolution is about ten times better and sufficient for the expected small vertical beamsizes at DELTA. Measurements of the electron beam size and emittance were done with both (synchrotron light monitor and interferometer) at different energies.

The image processing system based on a PC Framegrabber generates a gaussian fit to the images from different synchrotron light-monitors and calculates the beamsizes and positions.

An investigation of possible reasons of beam movements will be appended, because the theoretical values of the present optics are smaller than the measured emittance.

### 1 INTRODUCTION

The Dortmund Electron Test Accelerator facility DELTA consists of a 35 – 100 MeV LINAC, the 35 – 1500 MeV ramped storage ring called **Booster Dortmund** (BoDo) and the electron storage ring called Delta (300 – 1500 MeV) [2].

Both transverse beamsizes 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. The other one allows use of synchrotron radiation outside the shielding, but not during injection time. We are able to measure the horizontal beam size down to about 80  $\mu\text{m}$  with a normal optical synchrotron light monitor. Because of the not optimal

orbit due to not optimal alignment of the magnets at the moment the measured beam size and emittance is larger than the theoretical values. Another reason are high frequent beam oscillations. Therefore the better resolution of a synchrotron light interferometer, which has been built up and tested, is not necessary at the moment, but will be used in near future.

### 2 OPTICAL SYNCHROTRON LIGHT MONITORING SYSTEM

The design of the optical synchrotron light monitors inside and outside the shielding at Delta have been described in DIPAC 1999 [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 has been changed to a PC frame grabber DT 3155 and a new graphical surface, adapted from DESY software [4]. This allows a faster 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 than our old system [5]. The software enables subtraction of a background image.

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 minimize the necessary corrections of the measured beam size. This limits the achievable resolution to about 80  $\mu\text{m}$  @ 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). A Siemensstar is illuminated by monochromatic light (LED with 660 nm) and used as a source instead of the electron beam. The image is digitized and analysed to determine the resolution. The experiment gives  $\sigma = (34 \pm 2) \mu\text{m}$  as minimal measurable beam size due to diffraction only in this setup. The result is in good agreement with the theoretical value ( $\sigma = 0.61 * \lambda / \Theta = 33.55 \mu\text{m}$ ).

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).

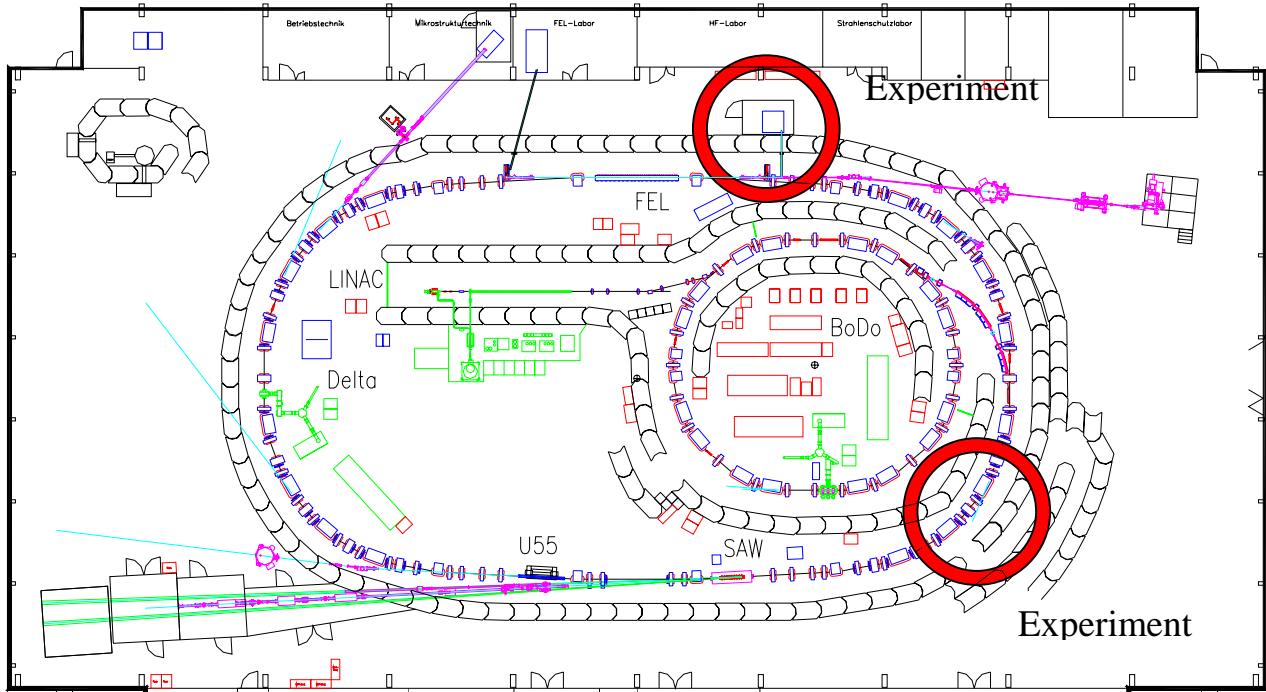


Figure 1: The Accelerator facility DELTA with the two positions of the storage ring synchrotron light monitors.

### 3 OPTICAL SYNCHROTRON LIGHT INTERFEROMETER

A synchrotron light interferometer according to the theory of T. Mitsuhashi [6] using also the visible part of the synchrotron radiation has been build up at the same beamline at Delta as the normal optical synchrotron light monitor. 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. 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  $f = 1500$  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  $\sigma$ :

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

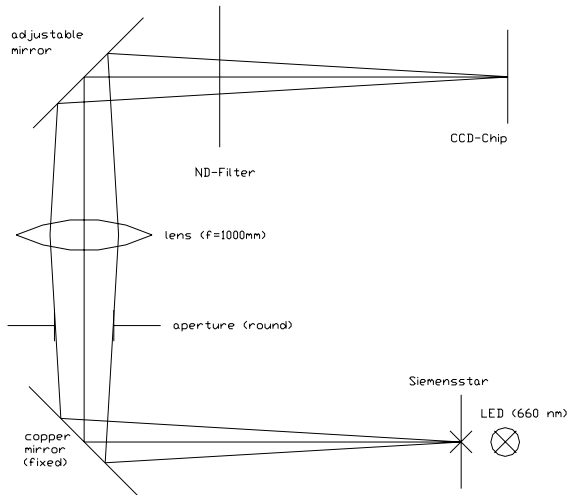


Figure 2: Experimental setup to determine the necessary correction due to diffraction at DELTA.

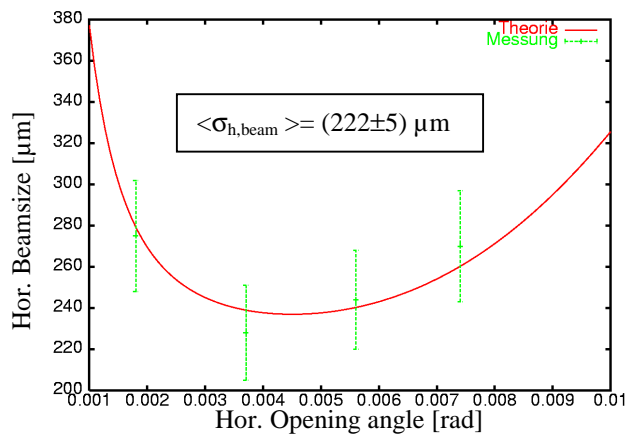


Figure 3: Measured beamsize after correction vs. opening angle of synchrotron radiation.

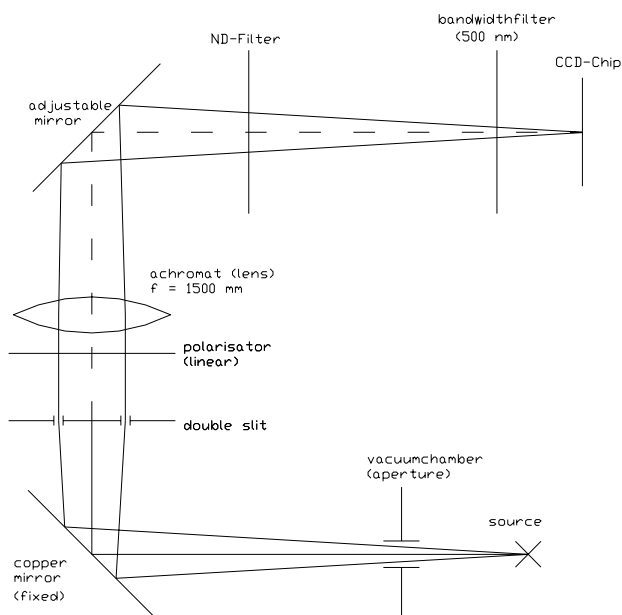


Figure 4: Layout of the optical synchrotron light interferometer at DELTA.

The resolution of the synchrotron light interferometer has been measured in an experimental setup. A Siemensstar illuminated by monochromatic light (LED with 660 nm) is used as source instead of the electron beam. The experiment gives  $\sigma = (10.3 \pm 3.4) \mu\text{m}$ . The resolution limit for the measurable electron beam size at Delta is therefore  $\sigma = (7.8 \pm 2.5) \mu\text{m}$  for  $\lambda = 500 \text{ nm}$ .

The electron beam size of Delta at 960 MeV has been determined to  $\sigma = (159 \pm 15) \mu\text{m}$  by the optical synchrotron light monitor and to  $\sigma = (160 \pm 5) \mu\text{m}$  by the interferometer. So both methods are in good agreement.

#### 4 RESULTS OF EMITTANCE MEASUREMENTS AT DELTA

The transverse emittance of the electron beam at Delta at different energies has been measured with both types of optical synchrotron light monitors, the interferometer and the normal optical synchrotron light monitor. They are in good agreement, but about a factor of 5 larger than the theoretical values @ 10% coupling [1]. The reasons are beam oscillations due to a missing feedback system and a not optimal orbit due to the not optimal alignment of magnets at the moment, which will be realigned in this summershutdown.

The time dependence of the measured electron beam sizes has been investigated. They are not varying very much in the time range between 20 ms and 10  $\mu\text{s}$ . This has been measured by a CCD-camera with variable and adjustable shutter time and by analysis of BPM-Data [7]. Therefore fast beam movements, especially betatron oscillations, have to be reduced by a necessary feedback system to improve beam stability and to reduce beam size.

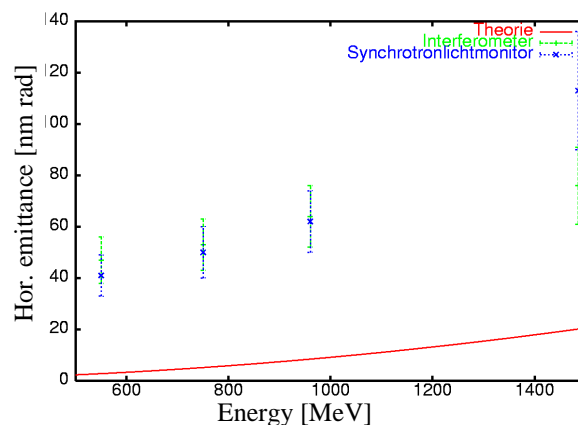


Figure 5: Results of emittance measurements at Delta. Theory is based on calculations of the ideal machine without any corrections.

## 5 CONCLUSIONS

The normal optical synchrotron light monitors at Delta work routinely down to their resolution limit  $\sigma \approx 80 \mu\text{m}$ .

A suitable optical synchrotron light interferometer to determine beamsizes down to  $\sigma \approx 8 \mu\text{m}$  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 ( $\sigma > 100 \mu\text{m}$ ).

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