Status of the DELTA Synchrotron Light-Monitoring-System

U. Berges, K. Wille
University of Dortmund, Institute for Accelerator Physics and
Synchrotron Radiation, 44221 Dortmund, Germany

Abstract

A synchrotron radiation source like DELTA needs an optical monitoring system to measure the beam size at different points of the ring with high resolution and accuracy.

The measurements with the present synchrotron light monitors show that beam sizes larger than 250 μm can be measured. The measured emittance is of the order of the theoretical values of the optics and goes down to 8 nm rad. The magnification of the system can simply be increased by adding another lens to measure smaller emittances and beamsizes down to 100 μm. In this case you still have an optical image of the beam availiable, but sometimes the position of the camera has to be adapted due to the great magnification of the optical system. The image processing system which is based on a VME Framegrabber makes a two dimensional gaussian fit to the images from different synchrotron light-monitors.

First tests with monochromatic components of the synchrotron radiation (500 nm and 550 nm) and with short time cameras (shutter time down to 1/10000 s) have been performed. A two-dimensional PSD has been installed to measure slow beam motion. To measure small beam sizes, especially in the vertical plane, diffraction elements will be used.

This paper gives an overview over the present installation and the results.

1 INTRODUCTION

The **D**ormund **El**ectron **T**est **A**ccelerator facility DELTA consists of a 35 - 100 MeV LINAC, a 35 - 1500 MeV ramped storage ring called **Bo**oster **Do**rtmund (BoDo) and the electron storage ring called Delta (300 - 1500 MeV).

Both transverse beam sizes of the Booster and the electron storage ring Delta are measured by optical monitoring using synchrotron radiation from bending magnets and commercial CCD-cameras. Therefore, we installed several optical synchrotron radiation monitors at different points of the two rings (see figure 1). By using nearly dispersion free points of the storage ring, we are able to measure the transverse horizontal emittance down to 8 nm rad. Because of the not optimal orbit due to not optimal alignment of the magnets at the moment the beam size and emittance seems to be larger than the theoretical values.

In addition to the imaging system a photodiode is sometimes used at the synchrotron light monitor 1 to measure beam current. The results are in good agreement with the data of a BERGOZ PCT current monitor at Delta.

We also use a two-dimensional PSD at the synchrotron light monitors 2 (Delta) and 4 (BoDo) to measure slow beam motion.

2 DESIGN OF THE SYNCHROTRON LIGHT MONITORING SYSTEM

Two types of synchrotron radiation monitors both using the visible components of the synchrotron radiation are installed in the ring. One synchrotron light monitor of Delta reflects the optical part of the synchrotron radiation outside the shielding, so that parts of the optical system are accessable during runtime of the machine. The other synchrotron light monitors are completely inside the shielding.

2.1 Synchrotron light monitor inside shielding

This type of synchrotron light monitor is installed at the booster [1] and at the storage ring. Only the optical magnification of the systems is different because of the higher emittance of the booster and the corresponding beamsize. The synchrotron radiation coming from a bending magnet hits a copper mirror inside the vacuum. The optical part is reflected $90°$ in the vertical plane, the X-rays are absorbed. The mirror made of OFHC-Copper is mounted on a watercooled mirror holder and has optical quality for the visible region of the synchrotron radiation. Up to now no surface damage due to radiation or heat loading could be observed (315 mA average beam current @1.3 GeV and 170 mA @1.5GeV). After passing a vacuum quartz window the intensity of the synchrotron light can be varied by several neutral density filters (up to optical density 12.8 at the moment). The source point of the synchrotron radiation is focused on the CCD-camera. We achieve a magnification of 1.43 (Delta) respectively 0.14 (BoDo). Due to the magnification the alignment of the CCD-camera is critical. A computer driven mirror is installed so that the image of the beam on the CCD-Chip can be moved in both transverse directions as there is no access to the optical components during runtime of the machine because of the radiation protection. The longitudinal position of the camera is important to choose the correct focus point. It is adjustable during runtime of the machine. Because of the big depth of focus of the optical systems it is less critical.

The sensitivity of this synchrotron light monitor at Delta is high enough to detect the first turn. At BoDo this synchrotron light monitor works reliable at energies higher

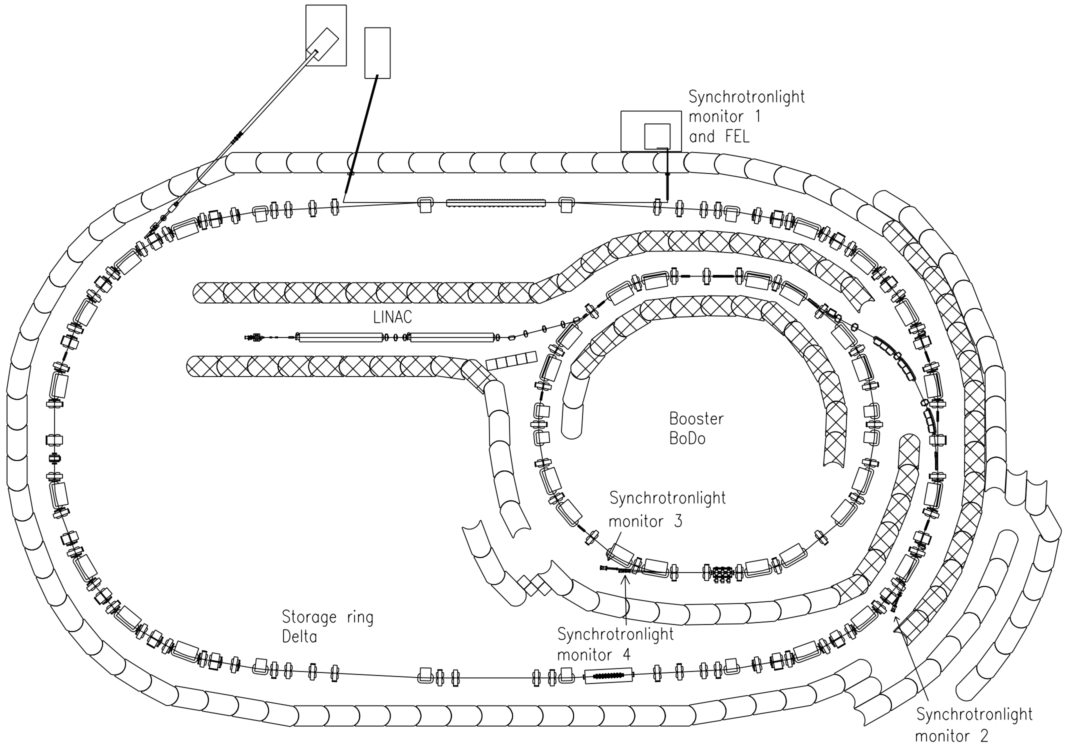

Figure 1: Positions of the Synchrotron Light Monitors at Delta

than 100 MeV. For lower energies the sensitivity is not high enough.

The advantage of these synchrotron light monitors is that the image is permanent available to the operator. Due to radiation protection beamshutters must be closed during injection time so that the image of the synchrotron light monitor outside shielding is then not available.

A two-dimesional PSD is installed at the same outlet chamber (synchrotron light monitor 4) with a magnification of 0.5 (achieved by a two lens telescope) to detect slow motion of the beam. All components are in the plane of the booster and show no radiation damage up to now. Only the vacuum quartz window becomes partly dark after 5 years of operation.

2.2 Synchrotron light monitor outside shielding

This synchrotron light monitor is installed at the end of one of the long straight sections of the storage ring. By varying the longitudinal position of the first lens it is possible to use also the spontaneous undulator radiation for diagnostic instead of the synchrotron radiaotion from bending magnets. It's design is shown in figure 2. The synchrotron radiation coming from a bending magnet hits a mirror inside the vacuum. The optical part is reflected 90° in the horizontal plane. The X-rays pass the mirror. This mirror is also used to reflect the spontaneous undulator radiation for the FEL-experiment FELICITA I. After passing a vacuum glass window the visible light crosses the shielding and is again refelected 90° in the horizontal plane. The source point of the synchrotron radiation is focused with a magnification of 0.13 by a lens (f = 1000 mm). The intensity of the synchrotron light can be varied by several neutral density filters (up to optical density 12.8) and by crossed linear polarizing filters. The synchrotron radiation is splitted. One part hits either a photodiode to measure the beam current or a 2-dimensional photosensitive detector (PSD) to measure the beam current and slow movements (below 10 kHz) of the beam simultaneously. The other part of the synchrotron radiation is focused by a second lens on a CCD-camera so that we achieve a magnification of 0.39. As this source point is nearly dispersion free the beam dimensions are less smaller than those expected at the synchrotron light monitor inside the shielding of Delta. So the magnification

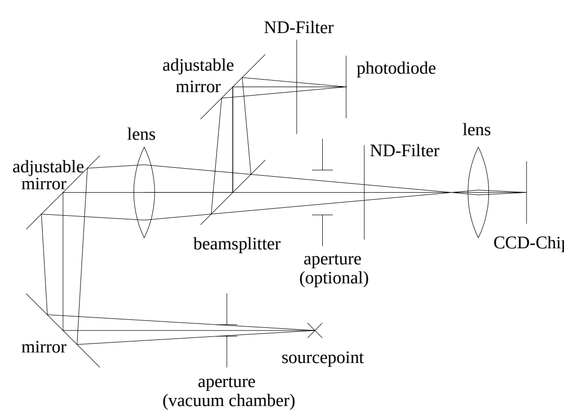

Figure 2: Schematic diagram of the DELTA synchron light monitor outside the shielding

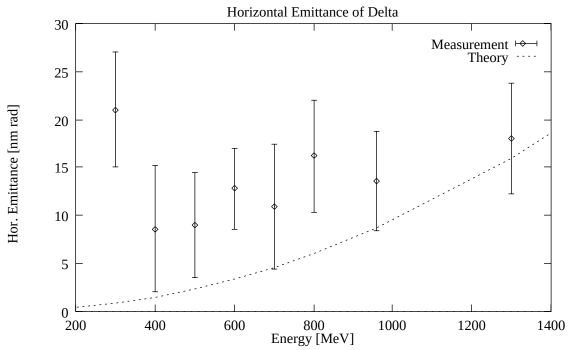

Figure 3: Horizontal Emittance of Delta versus Energy

of the synchrotron light monitor outside the shielding is increased by a third lens to resolve the low vertical beamsizes if necessary. The alignment is done by adjustable mirrors outside the shielding. This synchrotron light monitor can even detect a few microamps of stored beam.

2.3 Image processing system

The video signal of the synchrotron light monitors can permanently be displayed on TV screens in the control room. An image processing based on the VME Framegrabber ELTEC IC40 is also done. It digitizes the images from the different synchrotron radiation monitors [2]. The software enables also a calibration of the optical magnification. It generates a gaussian fit to a chosen part of the image. This fit is made iteratively until the result is stable. The software calculates also the centre of the image and enables subtraction of a constant background or another image. The digitized image is stored on a harddisk of the HP Workstations.

3 RESULTS OF THE MEASUREMENTS

3.1 Delta

Beam size and emittance measurements have been done as a function of energy (see figure 3) with the actual optics. The magnification of the system has been checked by bumps with steering coils and by measuring the movement of the center of the beam due to changes of the RF frequency.

First investigations concerning beam widening because of increasing energy spread due turbulent bunch lenghening have successfully been performed [4].

The influence of monochromatic filters in the optical path of the synchrotron radiation was not measurable.

Also beam current measurements using a photodiode have successfully been performed (see figure 4).

First measurents with the PSD show significant beam motions up to 600 Hz. This is in good agreement with the measurements done by a short time CCD-camera with variable shutter times down to 1/10000 s.

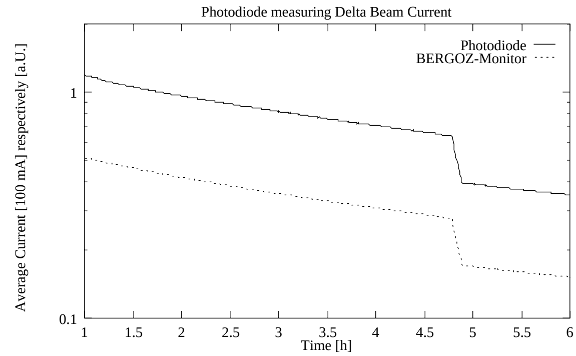

Figure 4: Average beam current of Delta measured by a photodiode and BERGOZ PCT

3.2 BoDo

Beam size and emittance measurements have been done as a function of energy and time within a diploma thesis [3].

4 FUTURE IMPROVEMENTS

- The sensitivity of the BoDo synchrotron light monitor has to be inceased.
- The lifetime measurement using a photodiode or a PSD has to be installed permanently inside the shielding. The necessary hardware is being built.
- The image processing system has to be improved. Usage of the software has to be made more comfortable.
- The lower limit of the measured vertical beam size at Delta has to be determined. To improve the measurable vertical beam size special diffraction elements and monochromatic components of the synchrotron radiation can be used.

5 CONCLUSION

The present synchrotron light monitoring system at DELTA allows to measure beam sizes larger than 100 μm and emittance larger than 8 nm rad. The sensitivity is high enough to detect first turn. After improving the system a minimal beamsize of 50 μm and an emittance of 1 nm rad should be measurable.

6 REFERENCES

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