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SET UP OF A SYNCHROTRON LIGHT MONITOR AT THE 2.5 GEV BOOSTER SYNCHROTRON AT ELSA

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Abstract

For the upgrade of the accelerator facility ELSA towards higher stored beam currents, a non-destructive beam analysis is being implemented at the 2.5 GeV booster synchrotron. It is a fast ramping combined function synchrotron with an extraction repetition rate of 50 Hz. Typically, beam currents of 10 mA are accelerated from 20 MeV to the extraction energy of 1.2 GeV within 8.6 ms, hence the magnetic field is increased by up to 85 T/s. A synchrotron light monitor as the primary diagnostic tool will be utilized for measuring the transversal position and intensity distribution of the beam. Its dynamics on the fast energy ramp is of distinct interest. The proposed set-up of the synchrotron light monitor and the current development are presented.

INTRODUCTION

The Electron Stretcher Facility ELSA consists of three accelerator stages (Fig. 1). The second one is the 2.5 GeV booster synchrotron which was commissioned in 1967 [1]. Due to the upgrade of the facility towards higher stored beam currents – while conserving a high duty factor – it is of interest to improve the beam quality and also the reliability of the booster synchrotron. For this purpose, parasitic, non-destructive beam diagnostics is necessary, e.g. a synchrotron light monitor. Therefore, a new beamline is planned for guiding the synchrotron light out of the shielding tunnel, to allow the instruments to be set up in a radiation free environment. Also, the optical set up and instrumentation will be accessible while the accelerator is running. The synchrotron light monitor is specified to operate in a wide range of wavelengths, from visible up to mid-wavelength infrared radiation. The planned set-up of the beamline and the optical diagnostic system will be explained in detail. Some preliminary measurements are presented.

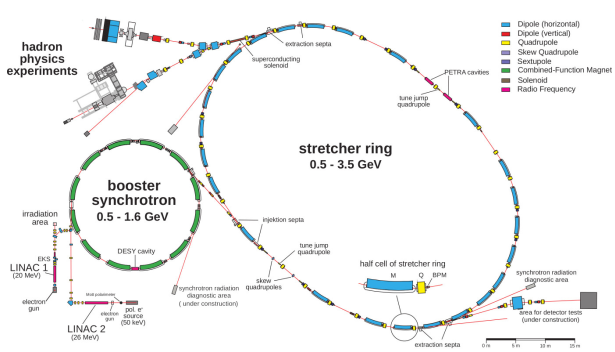

Figure 1: The electron stretcher facility ELSA.

SET-UP OF THE SYNCHROTRON LIGHT MONITOR

The synchrotron light monitor can be divided into two major parts: the vacuum beamline containing the primary mirror and the optical diagnostics section. An optical chicane will be integrated in between these two parts in order to absorb the x-ray radiation which is not reflected by the primary mirror.

The Vacuum Beamline and It's Challenges

The 8 m long vacuum system guides the synchrotron light from the bending dipole magnet through a concrete shielding, which separates the synchrotron from the instrumentation area, to a chicane upstream from the diagnostic section. It consists of elements for optical adjustment, differential pumping, a primary mirror and a viewport. The mirror is the most crucial part of the beamline since it must preserve good optical properties. So one is faced with two problems: First the mirror has to be cooled to avoid deformation from heat deposition caused by the absorption of high energy photons from the synchrotron radiation. Since the mirror will be located in an ultra high vacuum environment preventing air cooling, water cooling becomes necessary. However, the ultra high vacuum environment is needed to avoid blackening of the mirror due to chemical reactions of the residual gas on the mirror surface that are driven by the synchrotron radiation [2]. This means that the mirror has to be kept at a pressure below 10^{-9} mbar. To achieve such a good vacuum, there are three ion getter pumps (IGP) installed on the beamline, as well as a non evaporable getter (NEG) close to the mirror. The whole beamline is used as a differential pumping pipe. Starting at the source point of the synchrotron radiation inside the bending magnet (Fig. 3), there is an existing spout pipe for synchrotron radiation made of a rectangular $120 \times 35\,\mathrm{mm}^2$ aluminium oxide pipe. Since

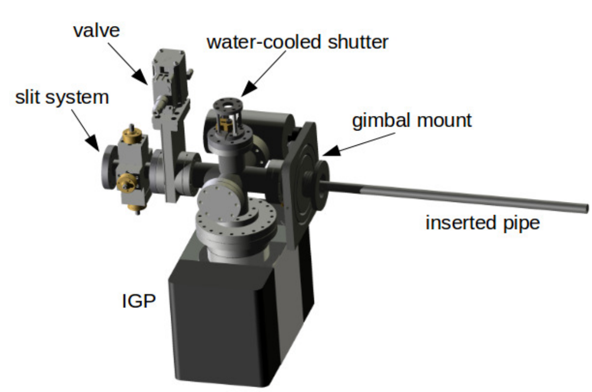

Figure 2: Set-up of the front end components.

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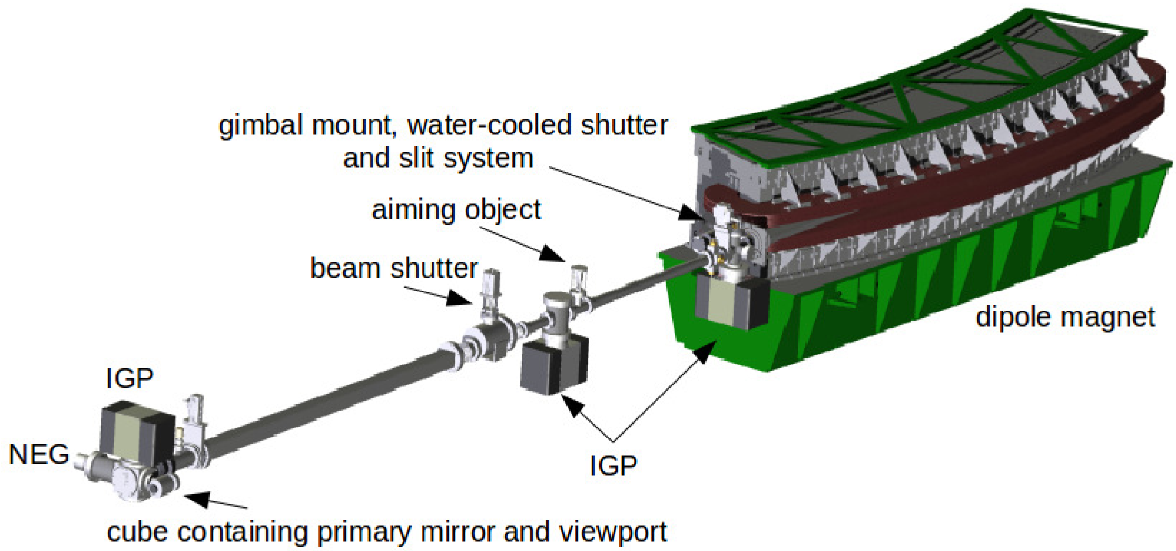

Figure 3: Planned set-up of the beamline. The beam propagates from right to left.

the quality of the vacuum in the synchrotron is not sufficient (about 10^{-7} mbar), a small round pipe with an outer diameter of 25 mm will be inserted into the existing rectangular chamber. This leads to a strong reduction of pressure conductance and therefore to a better vacuum within the downstream beampipe. This inserted pipe must be adjustable after installation. This will be achieved by a gimbal mount. The pipe will be attached to a subsequent water-cooled shutter with a first IGP connected to it. Then, a slit system follows which will be used to reduce reflections and to improve the vacuum by cutting out some parts of the unwanted synchrotron radiation fan. This front-end part of the beamline is illustrated in Fig. 2. The next crucial part of the beamline is the aiming system which consists of a vertical movable cross-shaped aiming object which can be illuminated either by three in-vacuum optical fibers or through a sideways built-in viewport. The fibers are mounted onto the cross at three distinct positions. The aiming system will be used to align the optical components of the diagnostic section, especially to preadjust the focus of the imaging system towards the actual source point. This allows the set up of the optical system without the need of a running synchrotron. After this a second IGP and a beam shutter follow. The beam shutter is necessary to block the radiation when the monitor is not in use. It is mounted shortly before the concrete shielding. The beam will be guided through the concrete shielding by a $10 \times 10\,\mathrm{cm}^2$ and 2.8 m long quadratic beampipe. Behind the shielding, a valve will be mounted followed by a vacuum gauge for precise measurement of the pressure. This will also allow the automatic shutdown of the vacuum valves when the vacuum is above 10^{-8} mbar. The last part of the vacuum beamline is the $20 \times 20 \times 20\,\mathrm{cm}^3$ large vacuum cube containing the mirror. Several components are mounted: To reach the ultra high vacuum, a third IGP and the NEG are connected to the cube as well as the mirror with the water cooling supplies and a calcium flouride viewport. Calcium fluoride is chosen since it exhibits a very good transmission behavior from UV to infrared, so a broadband spectrum can be provided. This part of the beamline will be covered with lead and concrete in order to absorb the unwanted x-ray radiation. Within this shielding, the secondary mirror is reflecting the light sideways onto an optical table where the diagnostic system can be set up.

The Diagnostics Section

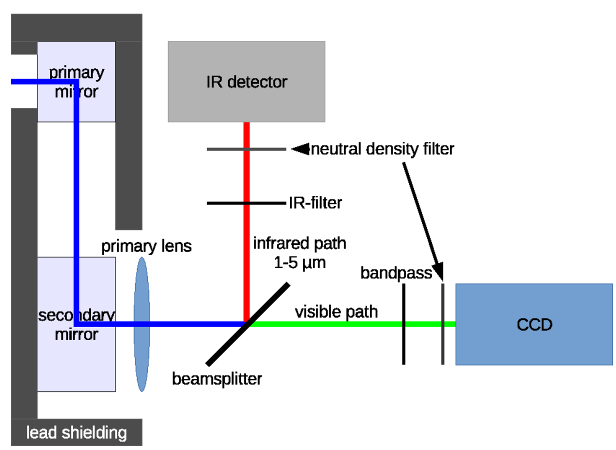

Figure 4: Scheme of the two planned optical paths.

The synchrotron light will exit the lead shielding via a hole downstream from the secondary mirror and is then focused by a primary lens ($f = 500\,\mathrm{mm}$). The beam will then be split into two paths, one consisting of the visible part of the light and one of the infrared part (see Fig. 4). The focus of the visible part will be aimed onto a CCD camera which can resolve the beam dynamics on the synchrotron's fast energy ramp. This requires frame rates of at least 1 kHz, covering

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the acceleration cycle of the synchrotron. Measuring the beam dynamics during the acceleration and extraction are expected to reveal details on how the beam is affected by the injection and acceleration process. This visible imaging system, however, only receives a sufficiently high signal when the energy of the beam exceeds approximately 100 MeV as shown in Fig. 5, which shows the synchrotron light spectra for different electron beam energies along with a typical CCD signal threshold. This means that the injection and the start of the acceleration process, due to low light intensity, cannot be displayed by visible radiation. These processes,

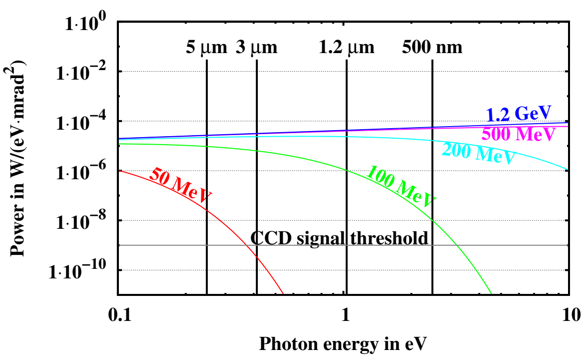

Figure 5: The synchrotron light spectra for different electron energies. A signal threshold of a common CCD camera is approximated.

however, can be displayed by taking the information from the infrared light path into account. Therefore an infrared pixel detector specified for wavelengths between 3 – 5 µm is planned to be used. This infrared detector should also fulfill the specifications given for the CCD camera. However, in the infared regime, the resolution of the monitor is stronger affected by diffraction, which reduces the image quality for transverse beam profile measurements. Another reason for studies in the visible spectrum is the availability of faster detectors.

FIRST PRELIMINARY MEASUREMENTS

To estimate the beam profile, a first preliminary measurement was done. The extracted booster bunch train was measured with a streak camera system in the diagnosis beamline of the pulse stretcher ring of ELSA [3]. This means that the bunch train had to move some meters through the pulse stretcher ring before reaching the diagnosis beamline. The image of the bunch train of the first injection shot from the synchrotron into the pulse stretcher ring is seen in Fig. 6. Since the bunch train is oscillating in the horizontal plane, measuring the beam profile with a normal camera system will not show the real beam profile but the integration of the oscillations over many revolutions. The curved shape reveals that the bunch train is strongly affected by the extraction and injection process. Also, the injection efficiency is about 60 %. This means one cannot infer from the measured beam profile in the pulse stretcher ring to the beam profile in the synchrotron.

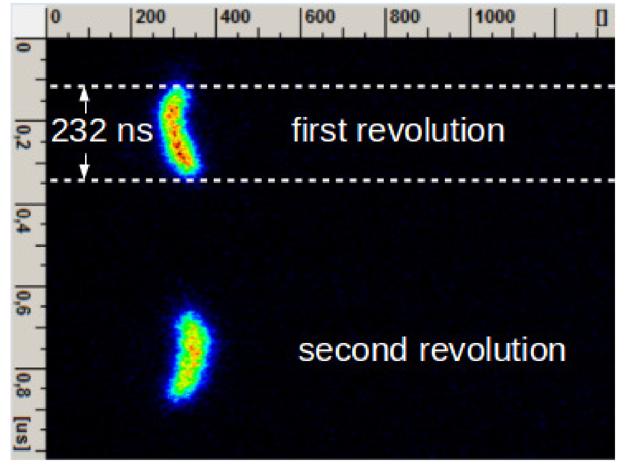

Figure 6: Streak camera image of the circulating bunch train in the pulse stretcher ring after the first injection. Horizontal oscillation is shown while the bunch train passes by two times. Each bunch train being 232 ns long.

As a second measurement, a simple set-up of a synchrotron light detector, consisting mainly of a mirror, a lens ($f = 120$ mm) and a camera has been installed in front of a viewport mounted at the spout pipe at the source point dipole. This system can only be used temporary since the viewport will be blackened soon. This measurement shows roughly a round shape, but was limited by the magnification factor of the 120 mm lens. The measurement will be repeated with a 500 mm lens to reveal more detailed information about the beam profile.

SUMMARY

The synchrotron light monitor at the 2.5 GeV booster synchrotron at ELSA will allow studies of the injection and acceleration process in the synchrotron. Preliminary measurements show interesting effects which will be subject of investigation to improve the beam quality.

REFERENCES

[1] K.H. Althoff et al., "The 2.5 GeV electron synchrotron of the University of Bonn" Nuclear instruments and methods 61 (1968) 1-30.

[2] K. Soller, Kohlenstoffkontamination der Oberflächen optischer Elemente im Synchrotronlicht, Experimentelle physikalische Diplomarbeit des Fachbereichs Physik der Universität Hamburg, Hamburg, Germany (1982).

[3] M.T. Switka et al., "Streak camera imaging at ELSA", IBIC'13, Oxford, UK.