OPTICAL BEAM DIAGNOSTICS AT ELSA*

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Abstract

The Electron Stretcher Facility ELSA (see Fig. 1) consists of several accelerator stages, the last one being a storage ring providing a beam of polarized electrons of up to an energy of 3.5 GeV. At ELSA various diagnostics devices based on synchrotron radiation are installed or planned. A new beamline at the storage ring designed for high resolution diagnostics in the transversal plane will be presented. The measurement setup is sensitive at the UV range of the synchrotron light spectrum.

In the external beamlines beam currents below 1 nA are delivered to photoproduction experiments. Beam profiles are detected using dedicated synchrotron light monitors optimized for low intensities. The characteristics of the monitors will be described. In addition, beam parameters derived from the measured profiles at different resonance extraction setups will be shown.

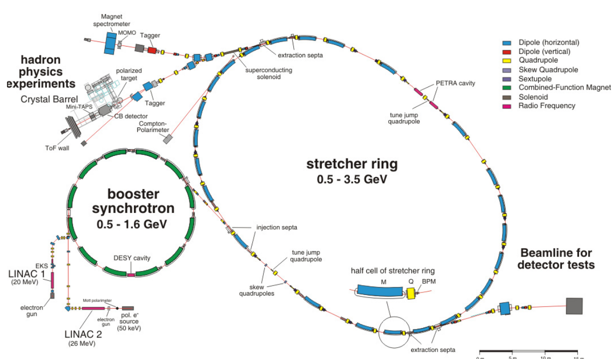

Figure 1: Electron Stretcher Facility ELSA.

INTRODUCTION

At ELSA polarized electrons are extracted via a third harmonic resonance in order to provide a high duty cycle. In order to investigate how the external beam is influenced by this extraction method, it is essential to measure the beam profile in the storage ring and at the external beamline. For this reason a system of non-disturbing beam profile monitors has been developed. At the stretcher ring a synchrotron light monitor does exist to measure the transversal beam profile, but the possibilities to improve its resolution are limited by the small area between the two magnets, where it is installed. Therefore, a second monitor, operating at the UV range, is planned outside of the stretcher ring enabling a more precise investigation of the beam profile and emittance at the stretcher ring.

In order to be able to compare the beam profile and the emittance of the storage ring with the beam characteristics at the external beamlines, two synchrotron light monitors were installed there, optimized for the low currents at the external beamlines.

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A NEW BEAMLINE FOR SYNCHROTON LIGHT DIAGNOSTICS AT ELSA

A new beamline which enables beam diagnostics outside the accelerator tunnel will be built up leading to an adjacent laboratory in order to improve the optical diagnostics at ELSA. The goals of the new setup are the improvement of the resolution and the possibility to measure the longitudinal beam profile.

The Deflecting Mirror

The most important element of the new beamline respective the beam diagnostics is the mirror used to deflect the visible and UV part of synchrotron light out of the beamline. Its flatness and roughness influence significantly the resolution of the whole device. Furthermore, the main part of the power of the synchrotron light will be deposited here (see Fig. 3). To avoid an increase of the temperature and hereby caused bending of the mirror surface, it has to be water cooled. The water pressure at the rear side of the mirror leads to an additional deformation. An FEM analysis was done to minimize the deformation by water pressure and heating of the mirror (see Fig. 2). Based on the results of the FEM analysis the final shape of the mirror was determined. The flatness could be improved to 100 nm over the lighted area of the mirror. The power absorption of the mirror should be as small as possible and depends on the mass number of the used material. The material should have a sufficient reflectivity in the UV range, too. So we chose an Al alloy, which will be polished by the Fraunhofer Institute in Aachen (Germany) down to a maximum surface roughness of 50 nm. The first test mirror has been crafted and vacuum tightness has been sucessfully tested.

Vacuum at the New Beamline

In order to achieve a long lifetime the pressure in the vicinity of the mirror has to be kept below $1 \cdot 10^{-8}$ mbar. Otherwise, crack reactions at the surface would take place and lead to a blackening of the mirror [1]. To avoid these effects the beamline will be used as a differential pump line. At 3 positions at the beamline there will be pump stations, equipped with ion getter pumps of a throughput

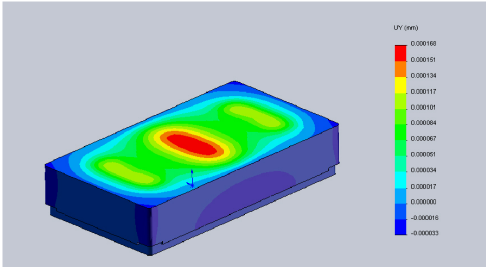

Figure 2: FEM analysis showing the deformation of the mirror surface.

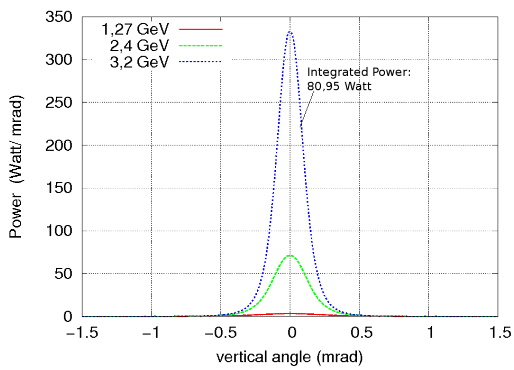

Figure 3: Power of the synchrotron light at ELSA depending on the vertical angle.

of 150 l/s and 300 l/s, respectively. The pressure along the beamline is shown in Fig. 4 for different apertures and for baked and unbaked tubes. The biggest influence on the pressure at the end of the beamline is exerted by the desorption along the tubes. If tubes are baked, a pressure of one magnitude lower can be achieved. Therefore, all of our used tubes will be baked, to assure a pressure of $1 \cdot 10^{-10}$ mbar at the surface of the mirror.

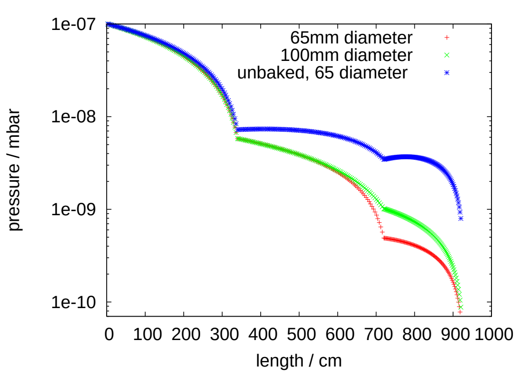

Figure 4: Pressure along the new beamline.

SYNCHROTRON LIGHT MONITORS AT THE EXTERNAL BEAMLINE

At the external electron beamline leading to the hadron physics experimental setups, a synchrotron light monitor for each of the experimental areas is provided at the dipoles MB2 and MB3 (see Fig. 5). The low current at the external beamline and the resulting low intensities of the synchrotron light (a factor 10^{-7} lower than at the storage ring) pose totally different demands on synchrotron light monitors in this region as compared to those at the stretcher ring. Due to the low intensity, the primary mirror does not have to be cooled and a regular commercial mirror can be used. This enables a very compact setup. The transverse intensity profile is recorded by means of a CCD camera which has to be very sensitive. The installed camera detects a minimal intensity of $I_{min} = 0,003$ Lux.

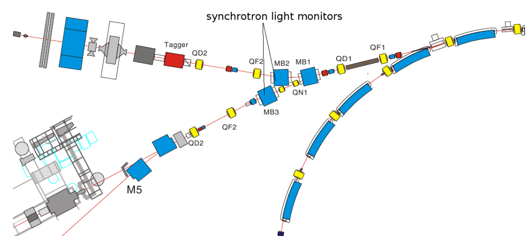

Figure 5: Synchrotron light monitors at the external beamline.

The synchrotron light monitors are optimized to a wavelength of 500 nm. They have a reproduction scale of 28 µm × 28 µm per pixel, but the resolution is limited by the diffraction and depth of sharpness to 150 µm.

The width of the beam profile measured by synchrotron light monitors is not only determined by the emittance ϵ, but also by the dispersion D(s):

$$\sigma_x(s) = \sqrt{\epsilon_x \cdot \beta_x(s) + \left(D_x(s) \cdot \frac{\Delta p}{p}\right)^2}. \qquad (1)$$

Therefore, it is essential to know the dispersion for calculating the emittance ϵ . In order to identify the dispersion function, the RF power in the accelerating structures is varied. The resulting change of the path length effects a shift of the center of the beam profile $\Delta x(s,k)$. With

$$D(s,k)\left(-\frac{1}{\alpha}\frac{\Delta\nu_{RF}}{\nu_{RF}}\right) = \Delta x(s,k),$$

the dispersion can be calculated by the measured shift. The momentum compaction factor α gives the ratio of the change in the relative path length for a given relative momentum deviation and is calculated theoretically. These measurements are repeated for different quadrupole strengths which will influence the elements of the transfer matrix $m_{ik}(k)$ and by a fit of the dispersion function (see Fig. 6)

$$D(s) = m_{11}(s)D_0 + m_{12}(s)D_0' + m_{16}(s) \qquad (2)$$

the parameters D_0 and D'_0 are determined. These are the dispersion values at the location of the quadrupole whose strength is varied.

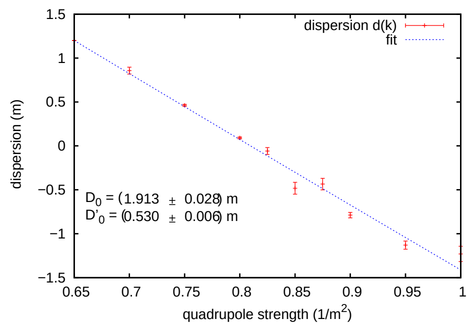

Figure 6: Dispersion fit.

The emittance of the extracted beam is determined by the so called quadrupole scan method. The measurement of the beam width σ depending on the quadrupole strength k enables a fit depending on the parameters$(\epsilon\beta_0)$, $(\epsilon\alpha_0)$, $(\epsilon\gamma_0)$ (see Fig.: 7).

$$\sigma(k)^2 = m_{11}(s,k)^2(\epsilon\beta_0) \\ -2m_{11}(s,k)m_{12}(s,k)(\epsilon\alpha_0) + m_{12}(s,k)^2(\epsilon\gamma_0). \quad (3)$$

Here the matrix elements m_{11} and m_{12} are depending on

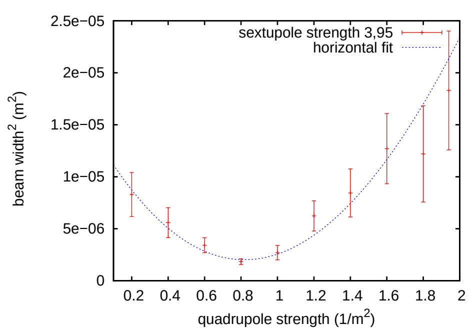

Figure 7: Quadrupole scan.

the optics between the monitor and the varied quadrupole. The unambiguous determination of the emittance ϵ is only possible if the minimum of the beam width is crossed, while the quadrupole strength k is varied.

By a general transformation of the twiss parameters (α, β, γ), one obtains:

$$\gamma(s) = m_{21}(s)^2\beta_0 - 2m_{21}(s)m_{22}(s)\alpha_0 + m_{22}(s)^2\gamma_0 \quad (4)$$

For the beam waist the condition $\gamma_t = \frac{1}{\beta_t}$ holds.

Now, the beta function can be expressed by the width of the beam waist σ_t which leads to the emittance ϵ:

$$\epsilon^2 = \sigma_t^2[m_{21}(s)^2(\epsilon\beta_0) \\ -2m_{11}(s)m_{12}(s)(\epsilon\alpha_0) + m_{12}(s)^2(\epsilon\gamma_0)]. \quad (5)$$

By repeating the procedure of the quadrupole scan for different setups, the influence of the sextupole strength and the horizontal tune is investigated.

In Fig. 8 the emittance depending on the sextupole strength and horizontal tune is shown. For a certain set of

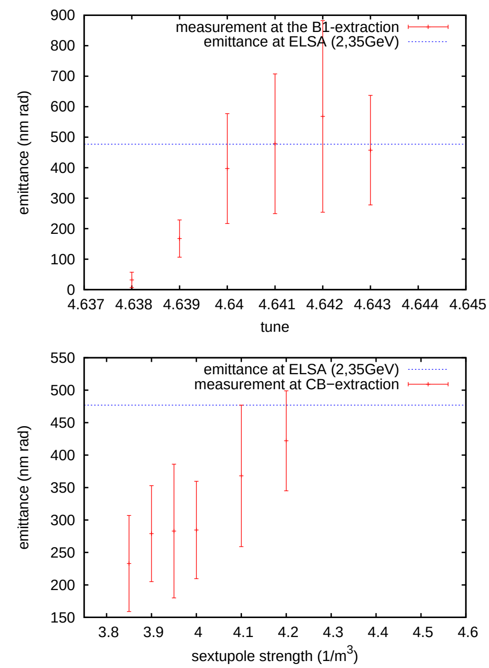

Figure 8: Emittance depending on the extraction parameters. The blue line shows the equilibrium emittance at the stretcher ring.

values for the sextupole strength and the tune, a reduction of the emittance at the external beamline can be achieved in relation to the emittance at ELSA, if a reduction of the extraction efficiency is acceptable.

CONCLUSION

At ELSA optical beam diagnostics in a wide intensity range takes place. A new optical beamline at the stretcher ring will improve the resolution of the beam profile measurements. The emittance of the extracted beam can be determined by the quadrupole scan method. The influence of the sextupole strength and the tune on it were investigated.

REFERENCES

[1] Soller, K.: Kohlenstoffkontamination der Oberflächen optischer Elemente im Synchrotronlicht, Experimentelle physikalische Diplomarbeit des Fachbereichs Physik der Universitt Hamburg, Hamburg 1982