

# A NEW DIAGNOSTIC BEAMLINE AT ELSA\*

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## Abstract

At the Electron Stretcher Facility ELSA, a new synchrotron light diagnostic beamline has been installed in order to perform high resolution, transversal and longitudinal beam profile measurements by analyzing the emitted synchrotron light. For this purpose, the main deflecting Al mirror selects a wide range of wavelengths from 200 to 800 nm out of the whole synchrotron spectrum. The setup of the beamline and its relevant components will be presented.

## INTRODUCTION

The Electron Stretcher Facility ELSA consists of several accelerator stages, the last one being a stretcher ring providing a beam of polarized electrons of up to 3.5 GeV. A synchrotron light monitor at the stretcher ring is the only optical diagnostic tool measuring beam profiles. The system is working at a wavelength of 480 nm and the setup is positioned in the tunnel of the accelerator, which has the disadvantage that only radiation resistant devices can be used. To improve the optical beam diagnostics for the stretcher ring, a new beamline is designed. It will guide the synchrotron light to an external laboratory to enable high flexibility in the kind of transversal and longitudinal beam profile measurements. Compared to the existing synchrotron light monitor, the resolution will be improved by choosing an operating wavelength of 200 nm. To deflect the synchrotron light out of the plane of the accelerator, a dedicated mirror was developed. The Al-alloy it is composed of ensures a sufficient reflectivity in the range between 200 nm and 800 nm wavelength. By using finite element method, the deformation caused by the heating of the synchrotron radiation was minimized. To ensure a long lifetime of the mirror, a UHV has to be provided which can be realized by creating a differential pumping trace along the 11 m of the beamline.

## PROPERTIES OF THE SYNCHROTRON RADIATION AT ELSA

Figure 1 shows the typical spectrum of the synchrotron radiation at ELSA for different energies at a current of 200 mA.

Due to the Lorentz boost, the main part of the synchrotron radiation is emitted in the plane of the accelerator (See Fig. 2). For the operating wavelength of 200 nm, the power distribution in the vertical direction becomes much broader (See Fig. 3). The diagrams shown are based on calculations assuming a nondivergent, point shaped beam [2].

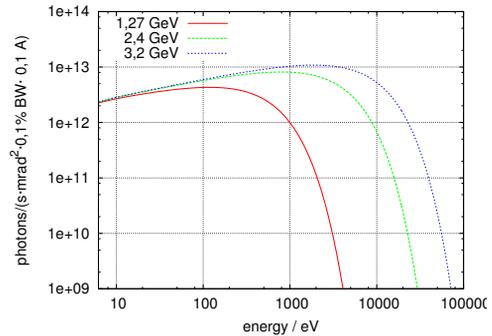


Figure 1: Spectrum of the synchrotron radiation at ELSA.

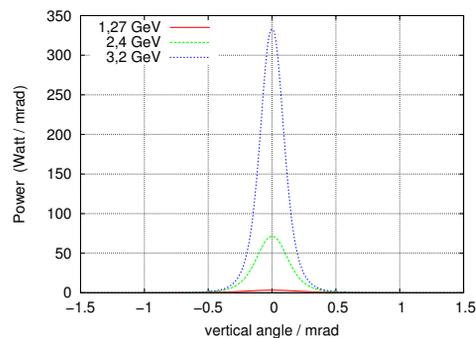


Figure 2: Power of the synchrotron light at ELSA depending on the vertical emission angle.

## Ray Tracing

For a more realistic assumption, the beam properties have to be taken into account. Therefore, the propagation of the photons was simulated with the ray tracing program SHADOW [3]. The electron beam parameters at the origin of the synchrotron radiation define the distribution and

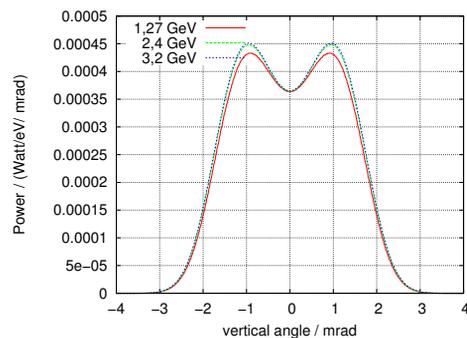


Figure 3: Vertical angular distribution at 200nm wavelength.

\* Funded by the DFG within the SFB / TR 16

the propagation of the emitted photons along the beamline, which, in turn, determine the diameter and the mirror size needed for the setup (See Fig. 4):

|                     |                         |                        |
|---------------------|-------------------------|------------------------|
| energy              | 2.35 GeV                |                        |
| beam width          | $\sigma_x=1.31$ mm      | $\sigma_y=0.36$ mm     |
| emittance           | $\epsilon_x=493$ nm rad | $\epsilon_y=12$ nm rad |
| distance from waist | $x=1.73$ m              | $y=3.41$ m             |
| magnet radius       | 11.01 m                 |                        |

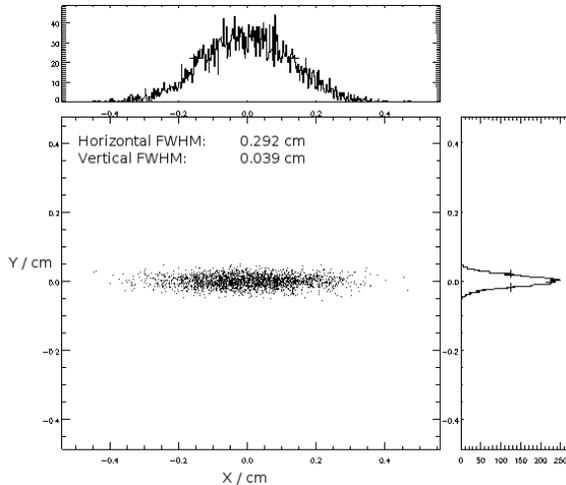


Figure 4: Starting distribution.

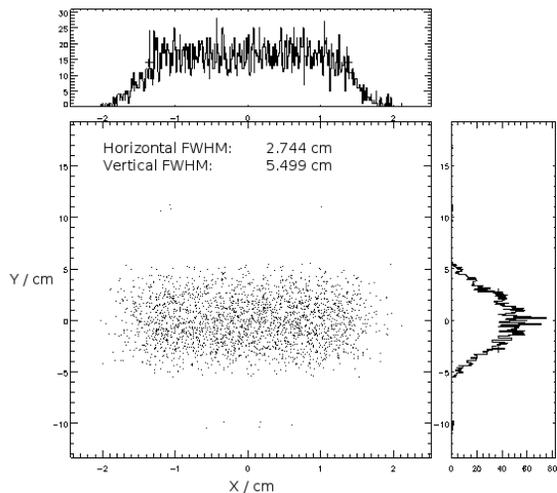


Figure 5: Distribution at the deflecting mirror.

At the source of the synchrotron light, the beam profile shows the typical gaussian distribution due to the equilibrium state (Fig.4). After a propagation of 11 meters, the photons of an energy of 6.19 eV (200 nm Wavelength) cover a much broader area due to divergence of the electron beam and the emission angle of the synchrotron light (see Fig. 6). The size of the deflecting mirror is chosen to cover more than 90 % of the photon distribution.

The bending of the electron beam, the finite depth of sharpness of the installed optics and the diffraction lead to a

broadening of the image (see Fig. 6). This broadening de-

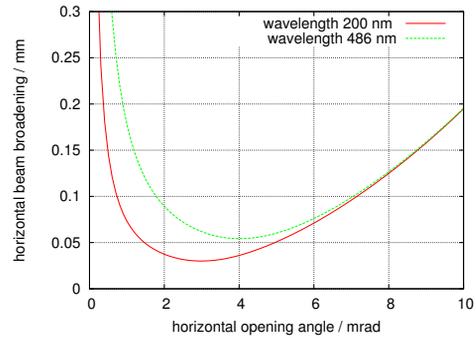


Figure 6: The broadening of the image.

depends on the observed opening angle and can be minimized by a slit system.

## HARDWARE SETUP

At the start of the beamline, the slit system is implemented to optimize the resolution and to avoid reflected synchrotron light from the stretcher ring. Also a system to focus on the source of the synchrotron light is installed. Valves divide the beamline in four different sectors to enable reconstructions with minimum interference for the remaining beamline. Three Ion getter pumps and a NEG pump assure a sufficient vacuum at the mirror (see below). An optical table at the external laboratory allows for various adjustments of the optic.

### The Deflecting Mirror

The most important element of the new beamline regarding the beam diagnostics is the mirror used to deflect the visible and UV part of the synchrotron light out of the beamline. Its flatness and roughness significantly limits the resolution of the whole device. Furthermore, the main part of the power of the synchrotron light will be deposited here (see Fig. 2). The mirror has to be water cooled to avoid an increase of the temperature and a hereby caused bending of the mirror surface. 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. 7). Based on the results of the FEM analysis, the final design of the mirror was determined. The deformation 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. Also, the material should have a sufficient reflectivity in the UV range, too. An Al-alloy was therefore chosen, 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 manufactured and vacuum resistance has been successfully tested.

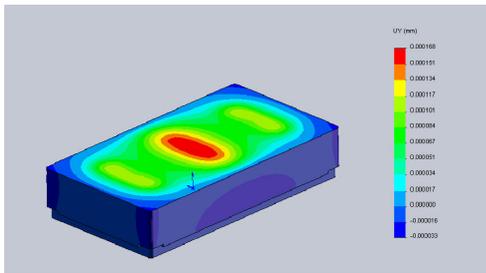


Figure 7: FEM analysis showing the deformation of the mirror surface.

### 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 three positions at the beamline, there will be pump stations equipped with ion getter pumps of a suction capacity of 150 l/s and 300 l/s, respectively. The pressure along the beamline for different apertures and for baked as well as unbaked tubes is shown in Fig. 3. The largest contribution to the pressure at the end of the beamline is exerted by the desorption along the tubes. If the 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.

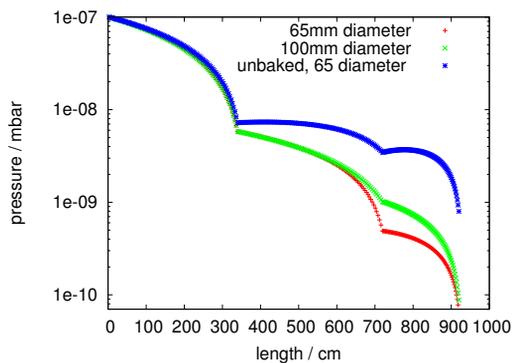


Figure 8: Pressure along the new beamline.

### STATUS QUO

Planning and preparations for the new beamline, as well as all installations connected to the stretcherring are completed (See Fig. 9).

The beamline set-up located in the laboratory, including the deflecting mirror, is in its final stages (See Fig. 10). We expect to take the first beam profile measurements during this summer, when the tubes of the beamlines have been baked.



Figure 9: Setup in the accelerator.



Figure 10: Setup in the laboratory.

### APPLICATIONS OF THE BEAMLINE

The new beamline will enable a wide range of new optical diagnostic measurements. For the first time, it will be possible to measure beam profiles in the UV range at ELSA. In connection with the existing synchrotron light monitor in the stretcher ring, the determination of the emittance in the stretcher ring will be improved. Also, time resolved beam profile measurements with rates of 100 Hz, synchronized with the cycle of ELSA, will be possible. The new beamline completes the system of synchrotron light monitors in the stretcher ring and the external beamline and will enable to investigate the influence of the resonance extraction on the beam parameters. Using a fast photodiode, the optical measurement of the bunch length will be possible, and the installation of a streak camera will enable the investigation of the charge distribution in the bunches.

### REFERENCES

- [1] Soller, K.: Kohlenstoffkontamination der Oberflächen optischer Elemente im Synchrotronlicht, Experimentelle physikalische Diplomarbeit des Fachbereichs Physik der Universität Hamburg, Hamburg 1982
- [2] Jackson, John David: Classical Electrodynamics, Third Edition, John Wiley & Sons, Inc. 1999
- [3] Peatmann, Wiliam Burling: Gratings, Mirrors and Slits, Beamline Design for Soft X-Ray Synchrotron Radiation Sources, Gordon and Breach Science Publisher, Amsterdam 1997