HARWI-II, The New High-Energy Beamline for Materials Science at HASYLAB/DESY

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Abstract. The GKSS Forschungszentrum Geesthacht, Germany, will setup a new high-energy beamline specialized for texture, strain and imaging measurements for materials science at the Hamburger Synchrotronstrahlungslabor HASYLAB of the Deutsches Elektronen-Synchrotron DESY. Four different experiments will be installed at the new wiggler HARWI-II. The high pressure cell will be run by the GFZ Potsdam, Germany, the high-energy diffractometer together with a microtomography camera will be run by the GKSS. A further station will allow space for the diffraction enhanced imaging setup. The optics will provide for a small white beam (0.5 mm $\times$ 0.5 mm) and a large monochromatic X-ray beam (50 mm $\times$ 10 mm) with an energy range of 20 to 250 keV.

INTRODUCTION

The three German HGF[1] centers GKSS Forschungszentrum Geesthacht, GFZ Potsdam, and DESY Hamburg will operate a new beamline at DORIS III. The outstanding characteristic of this beamline will be the use of high energy X-rays from 20 to 250 keV which can penetrate deeply into materials. This property of X-rays will enhance the capabilities of investigating large samples for material research and industrial applications, which is currently mainly carried out using neutron scattering methods [1].

The beamline consists of three hutches: a 8 m long optics hutch, a 12 m long first experimental hutch, and a 5 m long second experimental hutch (fig. 1). The optics hutch mainly contains the vacuum tank for the different monochromators. In the first experimental hutch a big diffractometer, a tomography camera, a diffraction enhanced

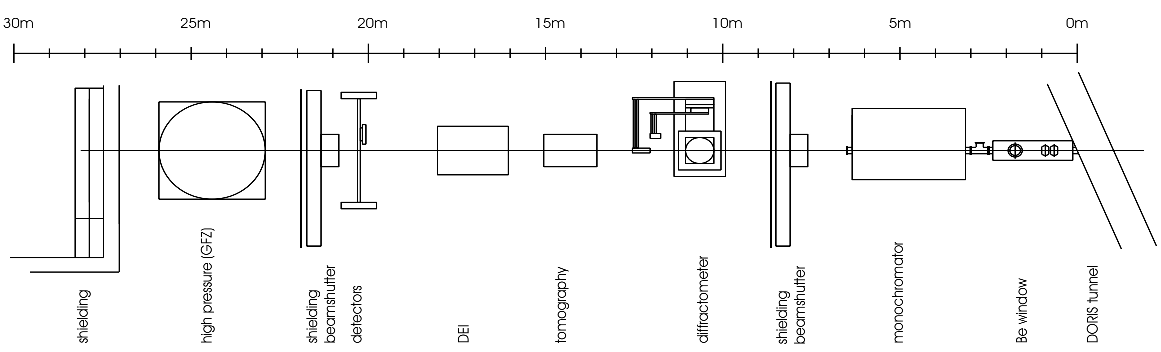


FIGURE 1. Scheme of the new high-energy beamline HARWI-II at HASYLAB.

[1] Helmholtz-Gemeinschaft Deutscher Forschungszentren

CP705, *Synchrotron Radiation Instrumentation: Eighth International Conference,* edited by T. Warwick et al.

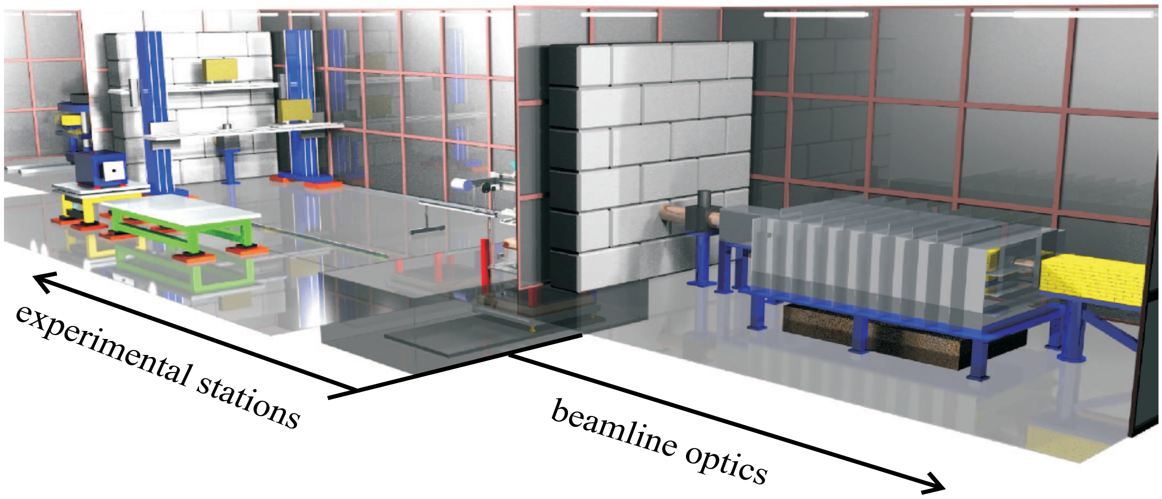


FIGURE 2. 3-dimensional view of the beamline. Three hutches: a 8 m long optics hutch (right), a 12 m long first experimental hutch (middle), and a 5 m long second experimental hutch (left).

imaging (DEI) station, and various detector systems up to 9 m away from the diffractometer are foreseen. The second experimental hutch houses the GFZ high pressure (HP) device MAX2003 for geophysical studies (Pressure: up to 25 GPa, Temperature: up to 2000 K). In this paper we will focus on the GKSS activities. Fig. 2 gives a 3-dimensional impression of the future beamline.

NEW WIGGLER HARWI-II

The design goal for the new HARWI wiggler was a maximized flux at 100 keV at an aperture of about 10 x 10 mm^2 [2]. The insertion device has a period length of 110 mm and total length of 4 m giving a flux of about 5×10^{13} ph/s/0.1% BW at 100 keV and at an aperture of $30 \times 5\,mm^2$. Fig. 3a shows that at this energy the new device delivers a factor of 20 more than the existing wiggler at the HARWI beamline and still a factor of 2 compared to the BW5 beamline. The figure shows the curves calculated for $1 \times 1\,mm^2$. In a wide range the flux scales linearly with the area of aperture. The minimal gap will be 14 mm, the peak field 1.96 T and the wiggler will have a K-value of 21 all together giving a critical energy of 26 keV. The total power is 28 kW and the on-axis power density reaches 41 $kW/mrad^2$. The horizontal/vertical divergence at 30 keV will be 4 mrad/0.15 mrad and at 100 keV 2.2 mrad/0.05 mrad. For other energies (10, 20, and 100 keV) fig. 3b shows the flux density distribution in horizontal and vertical direction and indicates the beam divergence near the entrance of the optics hutch.

BEAMLINE OPTICS

The entrance of the monochromator tank is about 39 m downstream of the new HARWI wiggler. An 1.5 mm Al filter will be permanently installed as a high pass filter. For the use of high photon energies (above 60 keV) a 1 mm Cu filter can be added. For the GFZ high pressure experiment at the end of the beamline a white beam option with a size of $0.5 \times 0.5\,mm^2$ is foreseen. Two different types of monochromators which both will be operated in vacuum will be setup.

Horizontal monochromator

The first type of monochromator will be a double Laue monochromator in horizontal geometry which will deliver beams of $10 \times 10\,mm^2$ in size. The energy range will be 50 to 250 keV and an offset of 3 cm of the diffracted beam.

These parameters determine the length of the monochromator tank which will be about 3 m long, 2 m broad and 1 m high s. fig. 2.

Vertical monochromator

The second monochromator will produce a beam size of 50 mm in width and 10 mm in height in a vertical diffraction geometry optimized for imaging techniques like tomography and diffraction enhanced imaging (DEI). The energy ranges from about 20 keV up to 200 keV. In order to accept the relatively divergent wiggler beam the first crystal will be a bent Laue Si single crystal. The 2nd crystal will be either another bent Laue crystal of the same type or a Bragg crystal. The beam offset will be about 4 cm.

EXPERIMENTAL STATIONS

Diffractometer

One of the instruments at the new material science beamline at HARWI will be a diffractometer specialized for high photon energies. In order to allow many different experiments we defined the following boundary conditions: The instrument will have a standard tower setup, which is permanently installed, with an interface on top of it. Users can attach further optional goniometers and their own sample environment and equipment. The standard setup will be flexible enough to allow as many different experiments as possible and will therefore be equipped with many translation, rotation and tilt stages in order to have many degrees of freedom. The tower will be large enough to carry heavy samples and heavy environments as tanks, cryostats, stress riggs or superconducting magnets. And finally, a fine resolution and a good reproducibility of the movements is intended in order to investigate small volumes (even single grains) inside large samples. The table shown on the right side in fig. 4 lists all components of the sample tower.

As shown on the rigth side in the 3-dim. view (fig. 4 left), detectors can be mounted on two 2Θ–arms for scattering in the vertical plane. The sample–detector distance will be adjustable via additional translation stages mounted on the arms. It is planned to offer different kinds of 2–dimensional detectors: a CCD, an image plate scanner and Gas–Wire detectors as well as new detector developments. Moreover, an energy–dispersive Ge detector and a scintillation counter will be available. In addition, detectors can be mounted on a large movable frame in order to position them at any desired location behind the sample. The maximum sample–detector distance will be ≈ 9 m.

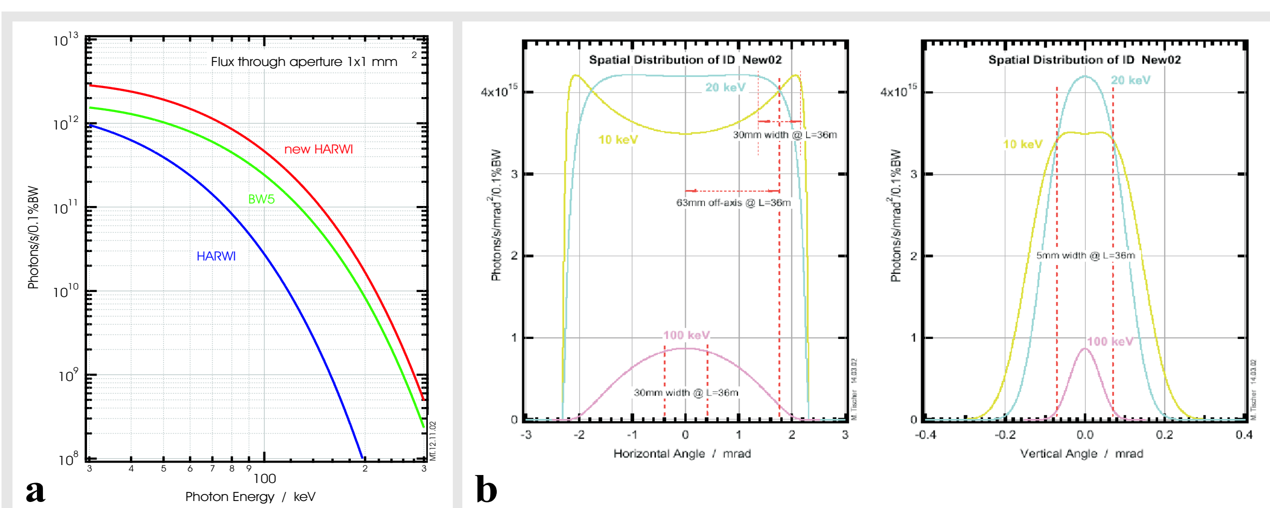
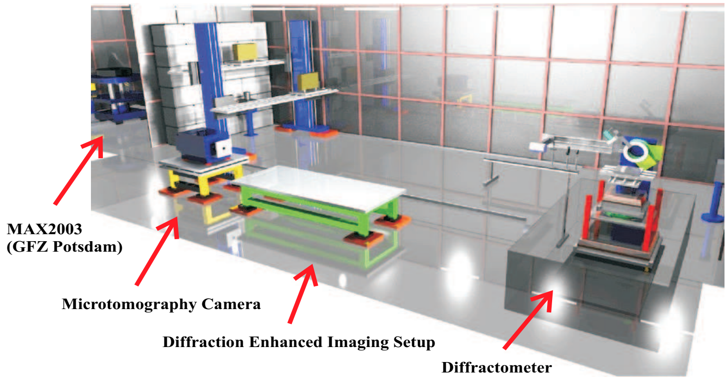


FIGURE 3. a: Comparison of wiggler spectra for the new HARWI-II, the old HARWI and the BW5 beamline. BW5 is the only other high-energy beamline at HASYLAB. b: Flux density at different energies in the horizontal (left) and vertical (right) direction.



name	direction	range	resolution
Standard tower			
x_0 translation	horizontal, $\perp$ beam	1000 mm	0.05 mm
z_1 translation	vertical	$\pm$ 250 mm	0.01 mm
y_1 translation	horizontal, $\parallel$ beam	$\pm$ 200 mm	0.01 mm
x_1 translation	horizontal, $\perp$ beam	$\pm$ 200 mm	0.01 mm
α_i tilt		$\pm$ 5°	0.001°
ω circle		full circle	0.000025°
$\chi - \phi$ double tilt		$\pm$ 15°	0.001°
Translation unit (optional)			
z_s translation	vertical	$\pm$ 100 mm	0.01 mm
$x_s - y_s$ table	horizontal	$\pm$ 500 mm	0.01 mm
Eulerian cradle (optional)			
ω circle		full circle	0.000025°
χ circle		full circle	0.000125°
ω circle		full circle	0.00025°
2Θ unit			
$2\Theta_1$ circle		-10° – 140°	0.00025°
$2\Theta_1$ translation		0.5 m – 1.5 m	0.05 mm
$2\Theta_2$ circle		-10° – 140°	0.00025°
$2\Theta_2$ translation		0.5 m – 1.5 m	0.05 mm
Detector frame			
y_d translation	horizontal, $\parallel$ beam	$\approx$ 9 m	0.5 mm
z_d translation	vertical	$\approx$ -1 m – 2 m	0.1 mm
x_d translation	horizontal, $\perp$ beam	$\approx$ -1.5 m – 1.5 m	0.1 mm

FIGURE 4. Left: 3-dimensional view of the experimental stations. Right: Components for the sample tower of the diffractometer (from bottom to top).

Microtomography setup

The tomography camera mainly consists of an efficient X-ray detector and a high-precision sample-manipulator stage. The 2-dim. X-ray detector is specially equipped to detect the high-energy X-ray beam. Using an optics with variable focus the field of view can be adapted to the diameter of the investigated sample in the range of 3 to 50 mm. Spatial resolution up to 3 μm can be achieved in the tomogram. The sample-manipulator provides a high precision rotation, translation and reposition of the sample. This is the prerequisite for scanning micro-tomography allowing the investigation of samples larger than the field of view of the detector. The system will be designed to operate with photon energies from 20 to 200 keV.

Diffraction enhanced imaging (DEI) setup

DEI is a relatively new imaging method for biological and and other light materials. Boundary layers inside the sample produce small angle scattering which can be analyzed with single crystal reflections. At the slope of a rocking curve a high contrast enhancement can be achieved even for boundaries where the refraction index varies only little.

SUMMARY

Based on this layout, the GKSS materials science beamline will allow for high resolution and rapid in-situ measurements providing new opportunities for the analysis of residual strains and textures which are not available elsewhere at present. The two other methods offered at HARWI II, Tomography and DEI, extend the possibilities by two important imaging techniques. In combination with the high intensity and X-ray energies provided by the new wiggler at HARWI II new opportunities in the 3-dimensional imaging of materials and even of large components are given.

These new capabilities will also be essential to help increase the involvement of industry in the use of synchrotron radiation.

REFERENCES

1. Schreyer, A., Lippmann, T., Beckmann, F., Metge, J., and Liss, K. D., *HASYLAB Annual Report* (2002).
2. Tischer, M., and Pflüger, J., *HASYLAB Annual Report* (2002).