Status of the High Resolution Diffraction Beamline at PETRA III

O.H. Seeck

Introduction

At PETRA III nine straight sections will be installed [1,2]. The 6th sector is shared by the Resonant Scattering & Diffraction Beamline (RSD) and the High Resolution Diffraction Beamline (HighRes). It will be equipped with two undulators of 2 m length. The undulators and both attached beamlines can be operated completely independent.

The fact that HighRes will share the 6th sector with ResScatt has direct implications on the design. Most importantly it requires a large offset monochromator (LOffsMono) to artificially offset HighRes from the straight ResScatt beamline. Despite of creating a large vertical offset, the LOffsMono will additionally serve as the high resolution monochromator [3].

The High Resolution Diffraction Beamline is designed for investigation of condensed matter with one or more diverging length scales ( >100 nm). The methods applied are high q-resolution x-ray scattering and diffraction, micro focusing, x-ray standing waves and SAXS/GISAXS. Samples could be liquid surfaces, multilayer films, gratings and phase transition material close to the critical temperature. HighRes will be optimized for highest possible reciprocal space resolution measurements with a flux of at least $10^{11}$ cts/sec in a maximum area of 1 mm×1 mm. The photon energy should be selectable between 5.4 keV and 29.4 keV. In the micro focus mode the focal spot will be around 1 µm² at the sample position.

The Optics

The first optical element at HighRes will be a PETRA III standard fixed-offset high-heatload double crystal monochromator. Both Si(111) crystals will be permanently cooled by liquid nitrogen. This monochromator will serve as a premonochromator. A set of collimating or weakly focusing compound refractive lenses (CRLs) will be arranged behind. Lenses have been chosen instead of x-ray mirrors because they preserve the beam quality which is expressed in terms of phase space volume. After the lenses the LOffsMono follows. It will create a vertical offset of 1250 mm which is sufficient for 1000 mm beam height above the floor at the experimental hutch. The LOffsMono is realized as a fixed offset double monochromator with selectable Si(311) or Si(511) pairs. After entering the experimental hutch another set of lenses will be installed to realize micro focusing if needed. A sketch of the HighRes beamline optics is shown in Fig 1.

![Figure 1: Sketch of the optical elements of HighRes (BPM: beam position monitor, CRL: compound refractive lens). The CRLs can be removed if not needed.](image)

The design of the optics components and the optics hutch are mostly complete as can be seen in Fig. 2. Figure 2 has been taken from the technical drawings made by the HASYLAB Optics Group. The hutch itself is in process of ordering. The high heatload monochromator exists as a prototype.
and is being characterized at ESRF. The LOffsMono is fully specified. The design is ongoing and first orders of parts will be placed this year. The CRL-changer has already been built as prototype for BW4 at HASYLAB and can be similarly been made for HighRes. Other parts which are also mostly designed.

With the optical elements which are shown in Figure 1 four different working modes will be available at HighRes: 1) raw mode RM, 2) collimating mode CM, 3) weakly focusing mode FM, and 4) μ-focusing mode μM. Raytracing calculations have been carried out for the different modes. The beam parameters of the first three modes have already been discussed in [3]. An example for the RM is shown in Figure 3.

The μM was requested by the participants of the 3. HighRes Workshop. It works in addition to the CM where the first set of lenses are set to collimate the x-ray beam. In this case, the loss of beam

---

**Figure 2:** Technical drawing of the optics hutch. The main parts of the optics are labeled.

**Figure 3:** Raytracing calculations of the RM with perfect lens settings. Top-Left: Integrated intensities of wanted photons, Top-Right: Integrated intensities of higher harmonic photons, Bottom-Center: Divergence, Bottom-Right: Energy resolution.
intensity is minimized as the beam size at the second set of lenses close to the sample position matches the lens aperture (see Figure 4). With this setup 1 µm vertical focal size can be achieved with a loss of approximately a factor of 5 in intensity compared to the CM. In principle, smaller focal spots are possible. However, it has to be checked very carefully if an accuracy and stability of less than 1µm is within the capabilities of the beamline.

Figure 4: Setup of the lenses in the μM. The first set of CRLs are set to collimating mode CM so that the beam loss due to the beam divergence at the second CRL-pack is minimized. With this setup a vertical focus of 1µm is possible.

The Experimental Hutch and the Control Room

The experimental station will be installed with the floor 1.65 m above the PETRA III hall floor. The beam pipe of the RSD beamline is guided through the concrete fundament of the experimental hutch. The experimental hutch will be accessible by a lift from the PETRA III hall and through a door from the control area. A beam height of 1 m inside the hutch will be achieved. The hutch has a 9 m total length and 3 m height inside the hutch which is large enough to install a high precision 6-circle diffractometer (ordered from Kohzu, Japan), two optical tables with motorized 5-degrees of freedoms (purchased from IDT, UK, see Figure 5) and a liquid diffractometer which is part of a BMBF project under number 05KS7Fk3 and will be designed and built by University of Kiel.

Figure 5: Left: Design of the High Precision 6-Circle Diffractometer from Kohzu. The pivot point is 1000 m over the ground. Right. The two fully motorized optical tables from IDT with a table height of approx. 600 mm.

In the control room two enclosures will be installed: One is to house four electronic racks which control the instruments in the experimental station so that noise and waste heat are excluded from the working area. The second enclosure will be used for preparation of samples. It will contain a small fume hood (see Figure 6). For more details see the figure capture of Figure 6.

Both, the experimental hutch and the control hutch are fully designed and technical drawings exist. The call for tender for both hutches will be initiated in 2007.
Figure 6: Control area of HighRes. The dimensions are: 4.2 m long, 5.3 m wide and 3 m high. The floor is 1 m above the floor of the PETRA III experimental floor so that the control area has to be accessed by stairs (A). The enclosure (B) for the electronic racks (C) is situated at the wall to the experimental hutch (D). The experimental hutch can be accessed by the door (E). The safety panel (F) is located directly next to the door. The enclosure (G) contains the fume hood (H) and a small table. Three people can easily fit to the tables (J).

The Environment

Complementary to the experimental hutch and the control area two dry labs and one chemical clean room will be installed by HighRes. The clean room will house a Class 1000 (ISO 6) area and Class 10 (ISO 4) working benches. One of the benches will be equipped such that wet chemistry (bases, acids, organics, HF) will be possible. In the first stage biological hazards cannot be prepared at this bench. However, this capability may be added later.

Outlook

HighRes will be worldwide the only diffracton and scattering beamline with extreme high reciprocal space resolution from 5.4 keV to 30 keV and a flux significantly larger then $10^{11}$ cts/sec. Complementary to the diffraction capability SAXS/GISAXS, x-ray standing waves and µ-focus (1 µm² beam size) will be available without reinstalling the beamline components. Another very important part of HighRes will be the liquid diffractometer which is built by University of Kiel and which is also unique in the world as it will be the only station were photon energy scans can be executed without moving the liquid sample.

It is scheduled that HighRes will become operational early 2009. After some months of commissioning in early summer 2009 the first user proposal may be accepted.

References