PETRA III Special Optics

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Abstract. The technical design and mechanical engineering of the three large monochromator systems at the beamlines P03, P06 and P08 will be presented. To achieve a compact arrangement of the canted undulator beamlines at Sectors 2 and 6, it is necessary to shift one of the two beamlines in vertical direction. This is done by Large Offset Monochromators (LOM). LOM500 installed at beamline P03 is cooled with liquid nitrogen as it accepts the white beam. LOM1250 installed at beamline P08 accepts a monochromatic beam and therefore needs no cooling system. The challenge with this monochromator is its large beam offset by 1.25 m. The energy range in combination with this large vertical beam offset requires a relative crystal movement of roughly 3 m along the beam direction. A third monochromator at the beamline P06 shifts the beam only by 21 mm upwards but has a linear travel of one crystal by 3.9 m. This is due to its large energy range of 4.4 - 90 keV using multilayer crystals.

1. Introduction
The main purpose of the Large Offset Monochromators LOM500 and LOM1250 is to separate the two beams coming from a canted undulator setup. This is done by a vertical shift of the beam by 500 mm and 1250 mm, respectively. The Mono-P06 shifts the white beam only by 21 mm upwards. Because of the long travel of the linear stage of the Mono-P06 and the need for cryocooling it is build up by components similar to the LOM500.

The cryostats used for LOM500 and Mono-P06 are of the same type as for the generic High Heat Load Monochromators. This simplifies the maintenance and usability of the installations. Further the wire rope guide of the liquid nitrogen hoses for LOM500 and Mono-P06 is built with identical components. The translations and goniometers are of similar type so that the same control concept and hardware can be used for all three monochromators. All systems are equipped with the same kind of piezo stage which allows to fine-tune the optics in height, pitch and roll.

2. LOM500
This monochromator can be used with a Si 111 pair (8 – 25 keV) and a multilayer pair (8.4 – 11.5 keV for 20 Å spacing). Two plane mirrors are provided behind the LOM500 for higher order suppression. When bypassing the mirrors the offset of the monochromator is set to 500 mm downwards, when using the mirrors the offset is set to 490 mm. All optical components of the monochromator are cryoooled. The second crystal is cooled by a lower flowrate as there is no heatload. Additionally a heater below the crystal mount has been installed to improve the thermal balance of both crystals.
aim is to keep the physical conditions of the second crystal as close to the ones of the first crystal as possible. Special care has been taken to develop a reliable handling system for the moving liquid nitrogen hoses (Fig. 1). The first crystal is placed in the small chamber of the LOM500 (left in Fig. 2).

The second crystal and second multilayer are mounted on a 2.5 m linear translation. The optical components can be changed by a lateral drive. The first multilayer is placed in a separate vessel 6m in front of the main vessel. When the multilayer option is used a second beam pipe in front of the LOM500 is used and so the first crystal and the small chamber of the LOM500 is bypassed.
3. LOM1250
The energy range for the Si 311 is 5.4 – 18.8 keV and 8.4 – 29.4 keV for the Si 511 crystal pairs. The crystals can be changed by a lateral drive. The offset of the LOM1250 is 1.25 m upwards and it is equipped with two 1.5 m long linear translations for the crystals.

This monochromator has been equipped with a laser-based stabilisation which allows compensating thermal drift of the mechanical components involved in the positioning of the crystals. A laser beam points parallel to the X-ray beam starting in front of the LOM1250 until the experimental hutch. This monochromator and the subsequent beamline are equipped with additional monitors to measure the position of the laser beam [1]. This is done with a transparent screen with a reticle behind the first crystal and by two CCD monitors (distance 15 m) behind the second crystal. The laser beam is reflected by the same crystal as the X-ray beam. To achieve similar behaviour concerning the deviation of the beams the crystal planes and the surface of the crystal are parallel within 85 µrad. With this setup one can determine the misalignment of the first crystal in pitch and roll and of the second crystal in pitch, roll and height separately. Using this information, these misalignments are compensated by the piezo stages with three dimensions of freedom each.

Besides this there are monitors for the X-ray beam itself: a metal foil behind the first crystal measures the intensity of the beam using the induced photo current. Two X-ray beam position monitors are situated behind the LOM1250. The first is directly behind the monochromator and the second one at a distance of 15 m in the experimental hutch. These monitors detect the back-scattered light emitted from a metal foil using four pin diodes. Without any stabilisation the X-Ray beam is stable within approx. +/- 0.26 µrad measured at the end station of the beamline at 9 keV which was one design criterium. This is equal to +/- 4µm movement of the beam at the end station. The laser stabilisation of the beam position at the experiment enables a control of pitch, roll and height with an overall standard deviation smaller than +/- 0.25 µrad for the position of the laser spot at the experiment.

One has to consider that the measured positions at the three monitors are used for the calculation of the positions of 5 piezo actors (the height of the first piezo stage is not used as this degree of freedom is not observable in this setup). If only the pitch piezo of the second crystal is used for stabilisation the standard deviation of the laser spot position at the end station decreases to +/- 0.05 µrad (equal to +/- 0.75 µm). In this mode of operation an error in height could be mistaken for an error in pitch and could lead to a mistuned crystal.

Special care has to be taken concerning the thermal stability in the optics hutch. The support of the laser incoupling is sensitive for changes in temperature, which pretends a change in crystal position. This would lead to a mistuned crystal and loss of intensity at the experiment. A granite socket should be used for the laser incoupling and the temperature should be stable within +/- 0.1 °C.

We plan to do an upgrade of the LOM1250 optics: As the mechanical setup shows excellent stability it is possible to use the area for reflection of the laser beam as space for additional 2 crystal sets. The new design is shown in Fig. (4). In addition to the 2 silicon crystals there is space for 2 germanium crystals. These are proposed by the beamline scientist to reach even higher intensity of the monochromatic as germanium has higher density compared to silicon.
4. Mono-P06
The multilayer monochromator at beamline P06 has a large energy range of 4.4 keV–90 keV. Therefore it is equipped with a long linear translation of 3.9 m for the second multilayer while the first one remains in place. The offset is relatively small (21 mm). The experience gained at the LOM 500 and LOM 1250 influenced the design of this monochromator. As this monochromator accepts the white beam both crystals have to be cryoooled. Due to this the optical elements are kept at the same temperature to guarantee fixed exit of the beam.

Fig. 4: LOM1250 (P08) crystal cage for the planned upgrade.

Fig. 5: Mono-P06 CAD Model.

References
[1] M. Degenhardt, U. Hahn, T. Ramm and H. Schulte-Schrepping: CVD Diamond Laser Alignment and X-Ray Fluorescent Screens for PETRA III, SNI 2010, Berlin, Germany