---

# Three grating monochromator for the vacuum-ultraviolet radiation beamline at the Swiss Light Source


U. Ellenberger, H. Kalt, P. Böhler, A. Schwarb, S. Sonderegger, A. Keller, S. Maag and T. Gerber



Diamond Light Source Proceedings / Volume 1 / Issue MEDSI-6 / October 2011 / e43
DOI: 10.1017/S2044820110000742, Published online: 15 December 2010

*Diamond Light Source Proceedings*, Vol 1, e43, page 1 of 4
MEDSI-6 2010

doi:10.1017/S2044820110000742

Contributed paper

# Three grating monochromator for the vacuum-ultraviolet radiation beamline at the Swiss Light Source

U. ELLENBERGER†, H. KALT, P. BÖHLER, A. SCHWARB, S. SONDEREGGER, A. KELLER, S. MAAG AND T. GERBER
Paul Scherrer Institute, 5232 Villigen PSI, Switzerland

(Received 13 June 2010; revised 22 October 2010; accepted 4 November 2010)

The beamline optics of the vacuum-ultraviolet radiation beamline installed on a bending magnet of the Swiss Light Source are to be upgraded. Supports for all three optical elements of the beamline optics (collimating mirror, plane grating monochromator and focusing mirror) have been re-designed to allow a more stable and improved fine tuning. The monochromator is composed of a set of three interchangeable gratings mounted on a rotatable platform. Each grating is framed in an optimized goniometer mount, designed and built in-house, which uses flexible elements for precise and reproducible adjustments. The roll and yaw of the gratings can be adjusted with microradian precision to minimize conical diffraction.

## 1. Introduction

The upgrade of the vacuum-ultraviolet (VUV) radiation beamline installed on a bending magnet (BM) of the Swiss Light Source (SLS) includes the beamline optics as well as the endstation (Johnson *et al.* 2009). Only the upgrade of the beamline optics is discussed here. The SLS/VUV beamline, incorporating only three optical elements, provides monochromatic light in the VUV domain of 5–30 eV within a bandwidth of about 1 meV. Currently the beamline is mainly dedicated to gas-phase photoionization and to photo-electron/photo-ion coincidence spectroscopy. One scientific aim is the investigation of molecules relevant for combustion and for atmospheric chemistry (Bodi *et al.* 2009).

## 2. Existing monochromator setup of the optics of the VUV beamline

The beamline collects synchrotron light emanating from a bending magnet with a total divergence of 4 mrad (vertical) and 8 mrad (horizontal). The BM source has an effective size of 23 μm × 200 μm and serves as the entrance slit. It is imaged on an exit slit (Se) of 400 × 400 μm using a collimating mirror (M1), a plane grating (G, $2\Theta = 130°$) and a focusing mirror (M2) (see figure 1).

† Email address for correspondence: urs.ellenberger@psi.ch

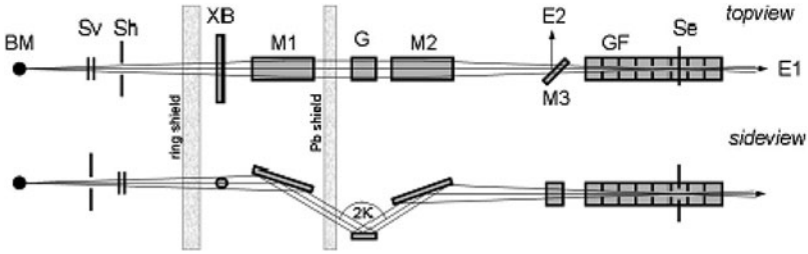


FIGURE 1. Existing optics of the VUV beamline at the SLS.

The existing monochromator has been manufactured to customer specifications by the Horiba Jobin Yvon company in France. The components M1, G and M2 are housed in individual vacuum chambers. The plane grating unit (G) has two gratings mounted on a turret and moved by an in-vacuum gear motor. Each change of grating during an experiment requires slight optical re-adjustments. The monochromator (G) as well as the two mirror vacuum chambers (M1 and M2) are adjusted using wedges and locking nuts for the pitch and roll angles.

## 3. Improved design of the new monochromator to be operated in vacuum

The existing monochromator setup requires several mechanical improvements:

(I) greater adjustment range and precision of grating roll and yaw angles;
(II) pitch angle of grating away from zero order at least ±15°;
(III) reproducible change of three gratings under ultra high vacuum (UHV) conditions ($10^{-8}$ mbar);
(IV) Independent alignment of the contained elements and of the inner components (M1, M2 and G) with six degrees of freedom (*xyz*, pitch, yaw and roll).

In the new design within the monochromator chamber the three gratings are mounted on a turn-table on a commercial precision rotation stage (Micos PRS-200) driven by a stepper motor to select one grating out of three (figure 2*a*). The precise tuning of the pitch angle is performed using a moveable bar driven by a linear vacuum feed through and a stepping motor. Several pivot flexure bearings (free of play, Rockwell Collins) define the pitch axis of the grating (figure 2*b*).

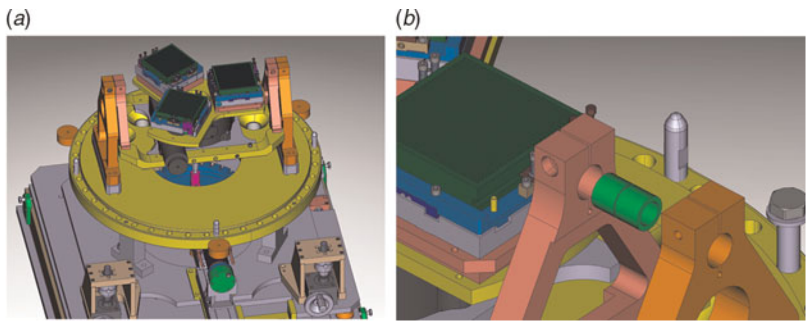


FIGURE 2. (*a*) Three cradles with their gratings mounted on a turn-table. (*b*) Details of the pitch axis bearing.

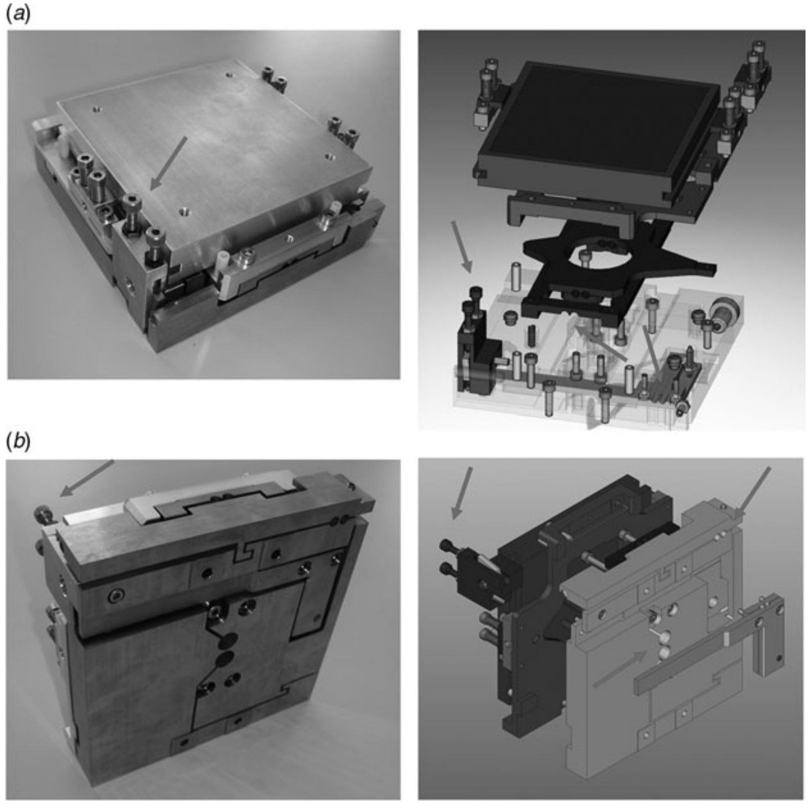


FIGURE 3. (*a*) Fine adjustment of roll. (*b*) Fine adjustment of yaw.

## 4. Stability and precision of the new grating mounts

Each grating is mounted on its own cradle allowing for roll and yaw movement. Two micro-screws actuate flexor elements with various gear reduction factors for fine adjustments of roll (figure 3*a*) and of yaw (figure 3*b*) with no hysteresis, no friction and no wear.

For the roll angle (Fig. 3a) the first and the second flexor element (indicated by arrows) divide the bars into a long and a short lever resulting in gear reduction factors on the order of 10 for each bar. Another factor of 10 in gear reduction is provided by the precise micro screw (pitch = 0.25 mm). A similar mechanism is used for the fine adjustment of the yaw angle (Fig. 3b). One solid block has been milled and wire cut. Again a first and a second flexor element (indicated by arrows) divide the two bars into a long and a short lever. Another gear reduction factor results from the micro-screw (pitch = 0.25 mm).

## 5. Investigations on a precise prototype mount

The adjustable range and precision of the roll and yaw angles of a prototype mount have been measured with an autocollimator and have been compared to specified values and calculated values with finite-element analysis (ANSYS).

The adjustment ranges of the measured and of the calculated angles are in good agreement and the measured precision is lower than stipulated (see Table 1).

| | Specified values | Calculated (FEA) | Measured |
|---|---|---|---|
| Range of roll (mrad) | ±3.5 | ±1.8 | ±1.5 |
| Precision of roll (μrad) | ±14.2 | – | ±6.0 |
| Range of yaw (mrad) | ±3.5 | ±2.7 | ±2.4 |
| Precision of yaw (μrad) | ±4.5 | – | ±3.0 |

Table 1. Comparison of designed and measured angles using a prototype mount

However, the measured adjustment ranges are a factor of two lower than expected but are still acceptable for the experiments. The stiffness of the spring that counter-balances the cantilever of one flexor is currently being further optimized to increase the adjustment range without compromising mechanical stability or setting precision.

Autocorrelation measurements revealed a certain crosstalk between yaw and roll. When actuating one angle the other angle follows on the order of 1–2% of the amplitude. One cause of a certain crosstalk may be transverse forces attributed to mechanical tolerances during manufacturing and assembling. To further reduce these effects an optimized redesign of the cradle and more detailed finite-element analysis would be required. Since the measurements are within the specified values we have decided to manufacture all three cradles with some minor design modifications.

## 6. Conclusions and outlook

The designed and manufactured prototype mount for the gratings comply with the specified values or are at least within acceptable limits. However, the design of the mounts can be further optimized to reach the specified ranges of roll and of yaw. Manufacturing of the monochromator and of all the bearings of the three vacuum chambers have just started and the final assembly will be tested, measured and compared with the specified values by end of October.

## REFERENCES

Johnson, M., Bodi, A., Schulz, L. & Gerber, T. 2009 Vacuum ultraviolet beamline at the Swiss Light Source for chemical dynamics studies. *Nucl. Instrum. Methods Phys. Res. A* **610**, 597–603.

Bodi, A., Johnson, M., Gerber, T., Gengeliczki, Z., Sztaray, B. & Baer, T. 2009 Imaging photo-electron photoion coincidence spectroscopy with velocity focusing electron optics. *Rev. Sci. Instrum.* **80**, 034101–7.