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Reconstruction of BL7B for UV, VIS and IR spectroscopy with a 3 m normal-incidence monochromator

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The beamline BL7B at the UVSOR facility for solid-state spectroscopy is currently under reconstruction. This reconstruction mainly involves the replacement of the 1 m Seya–Namioka-type monochromator (50–600 nm) with a 3 m NIM (modified version of McPherson model 2253), which covers the 50–1000 nm range with three gratings. The deviation angle of the gratings is 15°. For linear and circular polarization experiments, the beamline optics consist of a two-grazing-incidence (87.5°) pre-mirror system and a normal-incidence (15°) post-mirror.

Keywords: UVSOR; NIM; polarization.

1. Introduction

The beamline BL7B at the UVSOR facility has been a powerful multipurpose experimental station, especially for solid-state spectroscopy, with a 1 m Seya–Namioka-type VUV monochromator covering the wavelength region from 50 to 600 nm. This beamline is now under reconstruction on the basis that synchrotron radiation is still an important light source, not only for the VUV region but also for the UV, VIS and IR regions, owing to the wavelength continuity of synchrotron radiation with no structure. The 1 m Seya–Namioka-type monochromator is replaced by a 3 m normal-incidence monochromator (NIM) for extended research of the highest level with higher resolution and sufficient intensity to make the wider wavelength regions available. It will also be possible to utilize the linear and circular polarization inherent in synchrotron radiation and to realize combined experimental systems, for example, with synchronization to the synchrotron radiation pulse or with the external magnetic field. Research on gaseous, liquid and biochemical samples and at extremely low temperatures in the conventional wavelength region will also be possible.

This paper describes the optical design of this reconstructed beamline, which is based on the above requirements, and some estimated results.

2. Optical design

The new beamline has to cover up to 1000 nm to maintain wavelength continuity with the other beamlines at the UVSOR. Therefore, the normal-incidence-type monochromator is the best choice. The NIM is also the best choice for two other reasons. One is that the NIM is able to transfer the input polarization to the output with relatively small additional rotation of the polarization. The other is that the V-shape configuration of the NIM means that the final focus point may be situated on a second level, because this beamline has severe floor limitation. The total length from the light-source point to the back end of this beamline area is about 8700 mm. This suggests that without the second-floor area there is no space for combined experimental systems, which need relatively wide areas for equipment such as superconducting magnets, variable-wavelength lasers *etc.*

2.1. *Set-up*

The set-up of this beamline is illustrated in Fig. 1 and the optical design is shown in Fig. 2. The design parameters of the optical elements are summarized in Table 1. All optical elements are on a vertical plane. The synchrotron radiation source point is located on the left-hand side in Fig. 1. The overall beamline set-up forms a Z (or inverse Z) configuration. This Z-shaped beamline consists of four main parts: a pre-mirror focusing system (Fig. 1, left-hand side, ground level), a 3 m NIM (right-hand side, ground level), a post-mirror focusing system (left-hand side, second level), and the experimental station space (right-hand side, second level). Three large columns support both the pre-mirror chamber and the post-mirror chamber. There is a two-jaw water-cooled aperture

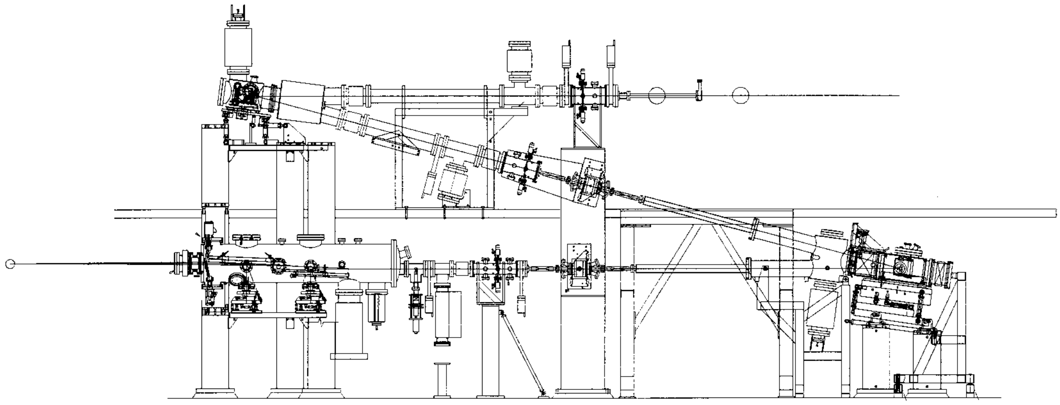

Figure 1
Schematic drawing of the reconstructed BL7B beamline.

Table 1
Design parameters of optical elements.

Pre-mirrors	Incidence angle	Radius (mm)	Dimensions (mm)	Coat	Material
M0	87.5°	∞ (plane)	700 × 140	Au	SiC
M1	87.5°	2650.4 × 115.4 (elliptical)	700 × 140	Au	SiO_2

Gratings	Deviation angle	Radius (mm)	Dimensions (mm)	Coat	Material	Grooves (mm^{-1})
G1	15°	3000	40 × 120	Au	SiO_2	1200
G2	15°	3000	40 × 120	Al	SiO_2	600
G3	15°	3000	40 × 120	Al	SiO_2	300

Post-mirrors	Incidence angle	Radius (mm)	Dimensions (mm)	Coat	Material
M_{21}	7.5°	3482.8 × 3347.8	120 × 120	Au	SiO_2
M_{22}	7.5°	3786.3 × 3632.5	120 × 120	Al + MgF_2	SiO_2

component just before the M0 mirror. This aperture is used to select the synchrotron radiation beam vertically, with an appropriate width to pass through selectively the linearly or circularly polarized light. The M0 mirror is mounted on the water-cooled Cu blade in a face-down configuration. Mirrors M0 and M1 are supported by computer-controlled adjustable manipulators. The exit beam from the pre-mirror chamber passes through a four-blade beam monitor, which is for beam adjustment. Both the entrance slit and the exit slit, which are adjustable for widths between 5 μm and 3 mm under computer control, are supported by one large column. They are flexure assembly-type slits with occulters, viewing ports and Au-mesh beam-intensity monitors.

The 3 m NIM is a modified version of the McPherson model 2253. The deviation angles of the gratings, which are all original laminar holographic-type spherical gratings, are 15°. The coverage of the three gratings is 50–150 nm for G1, 80–300 nm for G2 and 150–1000 nm for G3. Gratings are replaced one by one through the computer-controlled rotation of the turret in the grating chamber. The grating chamber is mounted on a stone table with a linear translation mechanism. Since both the entrance and the exit slits are fixed, the grating rotates along with the translational motion to keep the good focus condition under the wavelength scanning. The direction of this translation motion is along the slit bisector. The rotation and translation may be controlled independently, and three types of scanning mode can be selected: rotation only, translation only and rotation with translation.

The post-mirror chamber is mounted on a honeycomb table by kinematic mounting. Two kinds of toroidal post-mirrors provide two different focus points at the experimental station, Q1 and Q2. Full wavelength coverage is provided at Q1 under ultrahigh-vacuum conditions, and UV (longer than 110 nm due to the MgF_2 coating of M_{22}), VIS and IR wavelength coverage is provided at Q2 with the open experimental area.

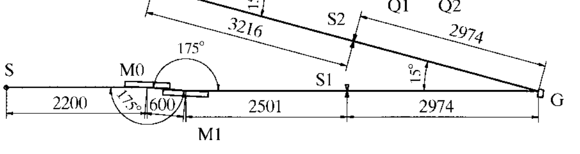

Figure 2
Optical design of the reconstructed BL7B beamline.

2.2. *Optical design*

Divergent synchrotron radiation of 60 mrad (H) × 10.7 mrad (V) is focused both vertically and horizontally at the entrance slit (S1) by an elliptical mirror M1. The focusing ratio is almost 1:1. To conserve the polarization of synchrotron radiation light and to make the beam parallel to the ground, the two-pre-mirror system is used. Incident angles of both M0 and M1 are fixed at 87.5°. The estimated degree of polarization, $(r_s - r_p)/(r_s + r_p)$, using the refractive index of Au (from 50 to 300 nm) is within 0.15.

The relation between the rotation angle of the grating and the translation length of the grating are known by the equations of Lewis (1982). According to these equations, the lateral displacement of the grating necessary for correct focus is about 1.5 mm at the minimum condition and about 35 mm at the maximum; the angle of incidence relative to the grating normal varies from about −1 to 6°.

The vertical focusing conditions at S2 are almost as good for all wavelength regions except for the 800–1000 nm range. In this range the vertical focus point gradually moves to the upper-stream direction. The horizontal focus point is always not on the exit slit. It is located about 100 mm downstream from the exit slit and moves to the downstream direction corresponding to increasing wavelength.

The standard deviations of the vertical focus size at both Q1 and Q2 are about 0.4 mm and almost independent of the wavelength. On the other hand, those of the horizontal focus size vary from about 0.6 to 2 mm.

2.3. *Total output*

Fig. 3 shows the estimated resolving power ($\lambda/\Delta\lambda$) for the whole wavelength coverage. The slit width of both the entrance and the exit slits is 10 μm. The definition of resolving power is according to that of Koike (1995). Since the three gratings together cover the whole wavelength region, high resolution will be expected except for the IR region. Fig. 4 shows the efficiency of the 3 m NIM with both pre- and post-mirrors at the G1 region, calculated using the optical constants table for Au (Windt *et al.*, 1988). The reflection efficiency of the gratings is assumed to be the same as that of the mirrors. The efficiency of the short-wavelength region is suppressed, because the grating and the post-mirror are

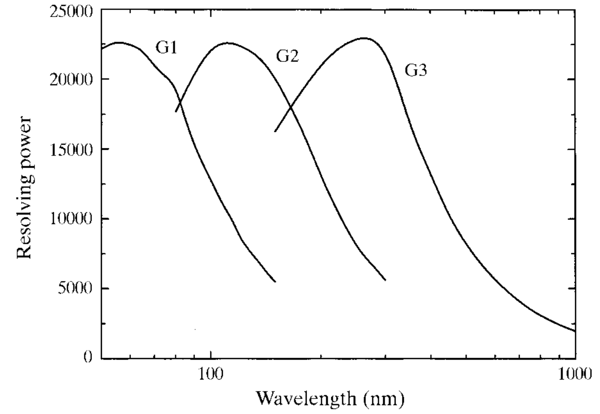

Figure 3
Calculated spectral resolving power of the 3 m NIM at a slit width of 10 μm.

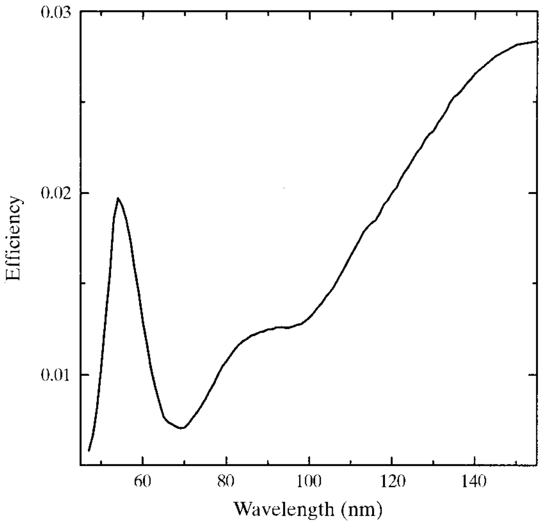

Figure 4
Calculated efficiencies of the reconstructed BL7B beamline. The gratings are assumed to be mirrors without diffraction.

the normal-incidence mount. The photon flux with a resolving power of about 1000 is estimated to be 2 × 10^{10} photons s^{-1} (100 mA)$^{-1}$ at 100 nm when the diffraction efficiency of the gratings is assumed to be 5%. This is one of the disadvantages of this design. Fig. 4 also shows that the threshold around 45 nm may indicate that the second-order light is well suppressed. Good purity of the monochromated light is expected over the whole wavelength coverage by using indium thin films, LiF, quartz and various coloured glasses as the filters. Three four-blade beam monitors and two occulters are also expected to prevent scattered light, which is one of the important factors for a good monochromated light source. The degree of circular polarization is calculated to be better than 95% for values of λ between 45 and 155 nm.

3. Summary

The optical design of the new normal-incidence-monochromator beamline at the UVSOR has been reported. We have estimated the performance by means of ray tracings (using the ray-tracing program *SHADOW*) and calculations. The beamline optics consist of two-grazing-incidence (87.5°) pre-mirror system, a 3 m NIM and a normal-incidence (15°) post-mirror for linear and circular polarization experiments. High resolution with high purity of monochromated light for solid-state experiments and a high degree of circular polarization are expected. Furthermore, under the severe limitation of the floor space, this configuration on the second floor makes it possible to create a free area for installing some combined experimental systems. However, the performance of this optical system strongly depends on the accuracy of the M1 mirror curvature. We have been simulating the case of toroidal M1 mirror for safety.

The reconstruction of the beamline was performed by Shimadzu Corporation with McPherson Ltd. The grating and the mirrors were supplied from Shimadzu Corporation, Nippon Pillar Packing Co. Ltd and Hidaka Kogaku Ltd. We are also indebted to the young students of the working group.

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