Design Proposal of a VUV Undulator Beamline for HiSOR-II

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A new 600 MeV synchrotron radiation ring, HiSOR-II, is currently being planned at Hiroshima University as an upgrade of the existing HiSOR facility. We are developing a high-resolution undulator beamline dedicated to ARPES and Spin-ARPES experiments. A 56 mm period APPLE-II undulator will be installed in a two-meter-long straight section as the photon source. The expected photon energy range is 7.4–250 eV for horizontally and vertically linear polarization and 5–55 eV for circular polarization [1], which is comparable to that of the present HiSOR BL-1 beamline.

Although the emittance of HiSOR-II is 17.6 nm·rad, the relatively low beam energy results in a comparatively large electron beam size, and consequently a large photon source size. At a photon energy of 50 eV, simulations predict FWHM source sizes of 645 µm horizontally and 147 µm vertically. The angular divergences (RMS) are estimated to be 100 µrad horizontally and 88 µrad vertically [1,2]. In order to achieve high energy resolution over a wide photon energy range under these source conditions, several monochromator concepts were investigated by means of ray-tracing simulations [2]. Among them, a divergent-beam incidence variable-line-space (VLS) plane grating monochromator (d-VLSPGM) was selected because of its large design flexibility in the magnification factor *Cff* and its potential for high resolving power over a wide energy range. Considering the relatively large source size and the expected long-term beam fluctuations during top-up operation in a compact storage ring, a front-end focusing system with an entrance slit was adopted. The total beamline length from the source point to the experimental focus point is approximately 40 m, which corresponds to the maximum available length in the planned HiSOR-II ring hall. The pre-focusing optics and the refocusing optics are each designed to occupy approximately 8 m, while the distance between the entrance and exit slits is kept within 24 m.

The beamline layout is shown in Figure 1, and the optical parameters are summarized in Table 1. The pre-focusing system consists of a horizontally deflecting toroidal mirror (M0). With a vertical demagnification factor of 0.4, the vertical beam size at the entrance slit is reduced to 75 µm in FWHM at 50 eV. In the horizontal direction, the beam is collimated before entering the monochromator section. A plane mirror (M1) is used to vary the included angle in the range of 153° to 168° and to direct the beam onto the VLS plane grating (Gr). Three gratings are assumed to cover the photon energy range from 10 to 260 eV. The VLS parameters were optimized to achieve target energy resolutions of less than 1 meV at 20 eV and 50 eV, and approximately 5 meV at 150 eV, as summarized in Table 2. After diffraction, the horizontally collimated beam is focused onto the exit slit position by a cylindrical mirror (M2) placed upstream of the exit slit.

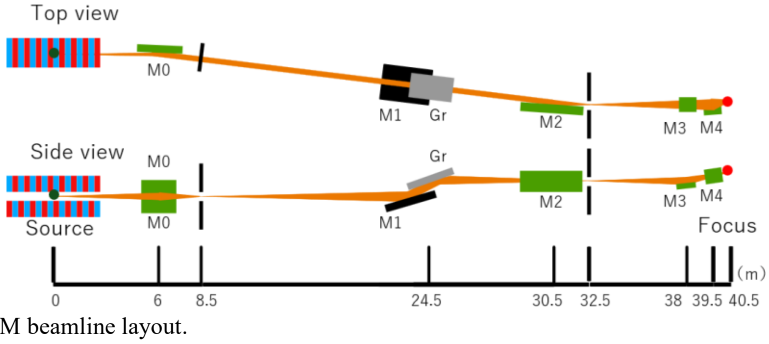

FIGURE 1. d-VLSPGM beamline layout.

TABLE 1. Parameters of the optical elements

Opt. element	Figure	Direction	Angle(deg.)	Slope error (μrad)
M0	Toroidal	Horizontal	88	0.5/2
M1	Plane	Vertical	153-168(Include)	0.5/2
Gr	VLS-Plane G	Vertical	Variable	0.2/2
M2	Cylindrical	Horizontal	88	0.5/2
M3	Elliptical cylinder	Vertical	88	0.2/2
M4	Elliptical cylinder	Horizontal	88	0.2/2

TABLE 2. Parameters of the Gratings

Gratings	VLS parameters n10(Groove density L/mm), n20, n30	Energy Range (eV)	*Cff*
GL	300, 0.0984837, 1.04468×10^{-5}	10-36	2.3 @ 10eV
GM	1200, 0.344057, 3.83313×10^{-5}	27-120	3 @ 27eV
GL	2000, 0.636682, 6.80726×10^{-5}	55-256	2.4 @ 100eV

To evaluate the energy resolution at a photon energy of 50 eV, three closely spaced photon energies of 49.999 eV, 50.000 eV, and 50.001 eV were introduced through a fully opened entrance slit. Figure 2a shows the simulated intensity distributions at the exit slit. The results demonstrate that the three photon energies are clearly resolved. When the exit slit width is set to 20 μm, the estimated energy resolution is 1.07 meV (FWHM) at 50 eV.

Recent ARPES experiments increasingly require a smaller beam spot size at the sample position. Therefore, the beam from the exit slit is focused using a Kirkpatrick–Baez configuration consisting of two elliptical cylindrical mirrors. The vertical and horizontal demagnification factors are designed to be 0.55 and 0.13, respectively. Figure 2b shows the simulated beam spot at the sample position, showing that a spot size of 31.4 μm horizontally and 8.5 μm vertically in FWHM can be achieved. These results demonstrate that the proposed beamline design can provide both high energy resolution and a sufficiently small spot size for advanced ARPES and Spin-ARPES experiments. Further reduction of the horizontal spot size is expected through additional optimization of the K-B mirror configuration.

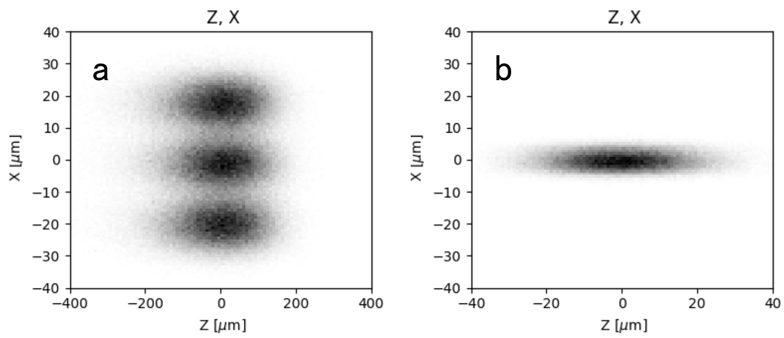

FIGURE 2. (a) Simulated energy dispersion for photon energies of 49.999, 50.000, and 50.001 eV at the exit slit. **(b)** Simulated beam spot at the sample position with FWHM sizes of 31.4 μm (horizontal) and 8.5 μm (vertical).

REFERENCES

1. L. Rebuffi and M. S. del Rio, Proc. SPIE 10388,169 (2017).
2. T. Tanaka and H. Kitamura, J. Synchrotron Radiat. 8, 1221 (2001).