Construction and evaluation of the linear polarized VUV beamline for two-dimensional Photoelectron Spectroscopy

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We have reconstructed a vacuum ultraviolet beamline BL-7 for solid state and surface science covering a photon energy range of 10-160 eV [1]. Previous monochromator at BL-7 covered a photon energy range of 35-100 eV. We have succeeded in imaging the stereo dispersion of graphite valence band and mapping the atomic orbitals of Cu at Fermi Level in three dimensional **k** space. However, the lower limit of the photon energy was too high for the investigation of surface electronic structures such as *sp*-orbital derived surface states of metal surface. On the other hand, the higher limit was needed to be extended for the access of many important core levels such as Si 2*p*. In order to solve these problems, we have renewed the beamline. In this note, we will describe the design and the performance of the beamline.

Figure 1 shows the whole optical arrangement of BL-7. The acceptance angle of the diaphragm placed at the distance of 4395 mm from the source point is ±3.41 mrad in the horizontal and ±0.85 mrad in the vertical divergence. The beam is prefocused vertically by a Au-coated toroidal mirror (M_0) onto the entrance slit (S_1) and collimated

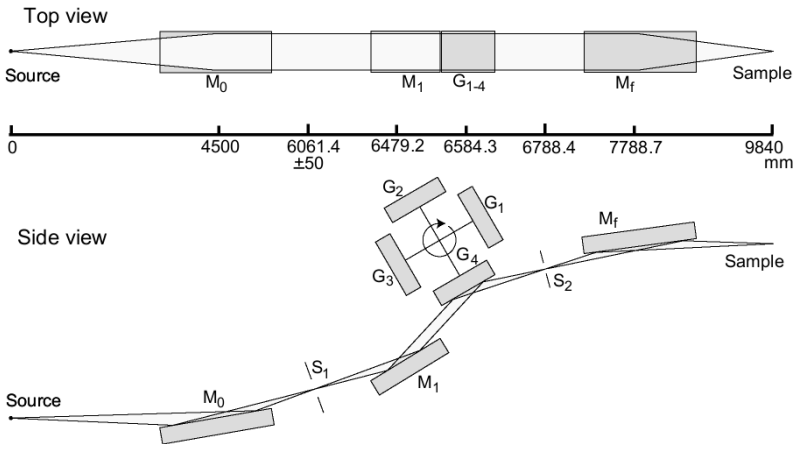

Fig. 1 Optical arrangement of BL-7. M_0, M_1, M_f: mirrors; S_1, S_2: entrance and exit slits; G_{1-4}: spherical gratings.

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horizontally. A grazing incident angle on M_0 is 3º. Vertical and horizontal radii of curvature are 45770 mm and 804 mm, respectively. S_1 is mounted on a stage which is movable along the optical axis within the limits of ±50 mm to satisfy the condition of the first-order focusing of the grating. The optical path employs a 160º deviation angle and use one of four spherical gratings, G_2, G_1, G_3 and G_4 with a curvature radius of 2000 mm with the groove densities of 300, 600, 1200 and 2400 lines / mm which are designed to cover the energy range 10-20 eV, 20-40 eV, 40-80 eV and 80-160 eV, respectively. The selection of a grating can be made by a rotary-motion feed-through. The beam is focused vertically by this one of four gratings onto the exit slit (S_2). The monochromatized beam is postfocused by a Au-coated toroidal mirror (M_f) onto a sample position. A grazing incident angle on M_1 is 3º, this vertical and horizontal radii of curvature are 26600 mm and 282 mm, respectively. Newly build Display-type spherical mirror analyzer (DIANA) is installed at the end station [2].

Dots in Fig. 2 superimposed on the photograph of beam on the fluorescent screen indicate the typical distribution of rays at the sample surface estimated from ray tracing calculation [3]. This spot size kept at approximately constant 1.2 mm (horizontal) × 0.3 mm (vertical) over the whole range of the photon energy. In ray tracing calculation, the photon flux in the order of 10^{10} photons / s / 300 mA at the energy resolution of 100 ~ 500 can be obtained in the energy range when the entrance slit is 0.07 mm, and the photon flux in the order of 10^9 photons / s / 300 mA at the energy resolution of 4000 ~ 2000 can be obtained when the entrance slit is 0.0185 mm.

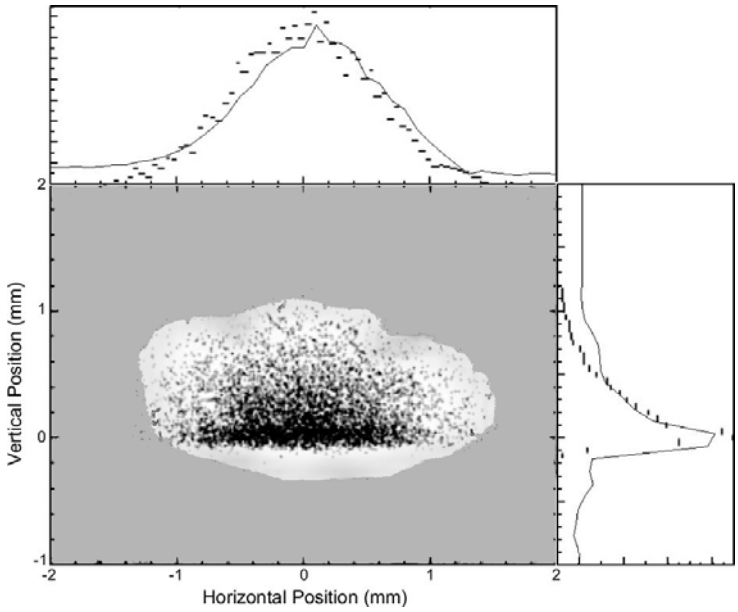

Fig. 2 Comparison between the experimentally obtained focused beam profiles (photograph and solid line) and those obtained by a ray tracing calculation (dots and dashed line) at the sample surface along the vertical and horizontal directions.

The horizontal and vertical beam profiles are obtained by measurements of differential photo current using the zeroth-order light using a knife edge. The actual spot size was 1.25 mm (horizontal) × 0.32 mm (vertical), and show agreement to the spot size in the ray tracing calculation.

In order to compare

with the photon flux of the previous beamline, the photo current spectra measured by a clean sample of Cu at the sample surface are shown in Fig. 3 when the width of both entrance and exit slits is 0.07 mm. The photocurrent measurement was larger than that of the previous beamline in the whole energy range. Figure 3 shows the total energy resolution of the beamline as measured from the Fermi edge of Au with the photon energy in the range of 10-100 eV and $4f_{7/2}$ peak of Au with the photon energy in the range of 100-180 eV when the width of both entrance and exit slits is 0.07 mm. The total energy resolution of the beamline was in good agreement with the energy resolution in the ray tracing calculation for the photon energy in the range of 140-200 eV. On the other hand, the total energy resolution was exceptionally smaller than the energy resolution of the beamline in the calculation for the photon energy in the range of 10-140 eV.

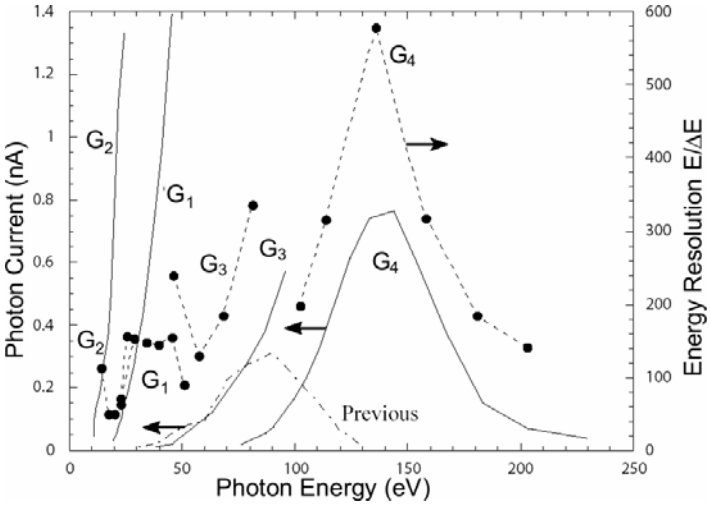

Fig. 3 Spectra of BL-7 (solid line) and the previous beamline (dot-dashed line) measured by photo current from Cu at the sample surface and measured photon energy dependences of the total energy resolution E/ΔE (black circle and dashed line).

To conclude, two-dimensional photoelectron spectroscopy VUV beamline from 10 to 160 eV was constructed. The spot size of the zeroth-order light at the sample surface was 1.25 mm (horizontal) × 0.32 mm (vertical). The photon flux evaluated by the photocurrent measurement was larger than that of the previous beamline in the whole energy range. The beamline together with new Display-type analyzer is now used for the measurement of photoelectron intensity angular distributions of various materials.

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