Rapid & Sensitive XAFS Using Tunable X-Ray Undulator

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1. Optics

For rapid and sensitive XAFS experiments planned at XU10, the fluorescence yield is measured over a typical energy range of ~1 keV with an energy resolution DE/E ~2 x 10^{-4}. As an optics for a standard undulator (32V) beamline XU10, a double-crystal monochromator with a rotated-inclined geometry [1] and a variable critical angle flat mirror are used. Undulator tunability in XAFS is: spectroscopic tuning (DE ~ 1 keV) and edge-to-edge tuning (DE < 26 keV). For independent tuning, the K_y value or the undulator gap is varied so that the either 1st or 3rd higher harmonic peak coincides the energy selected by a monochromator. The calculated energy resolution DE/E given as the convolution of rocking curve width and an angular divergence multiplied by cotq_B is 2.6 x 10^{-4} at 8 keV for Si(111). The degradation of energy resolution is due to the asymmetric reflection in a (+,-) geometry. For a Rh-coated flat mirror, q_C should be varied from 6.6 mrad to 3.3 mrad in order to cover the cut-off energy range 10-20 keV. As the variation of beam height is in the order of micron, the exit beam position is regarded as a constant. Beam size at sample positions (1:1 focusing) 0.2 mm high, 1 mm wide. In Fig. 1, the optics for XU10 is schematically shown.

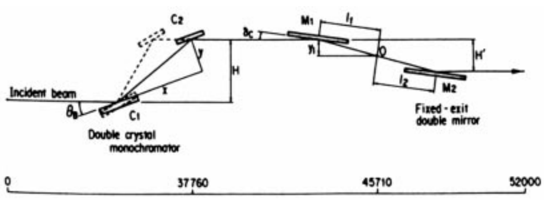

Fig. 1 Schematic of the beamline optics for XU10.

2. Detector

In the experimental hutch of XU10, a 100-element "monolithic" Ge detector array is to be installed together with the goniometer for the polarized fluorescence XAFS. The arrangements of Ge elements are illustrated in Fig. 2, together with a 19-element Ge detector based on a conventional technique of assembling independent element with a close packing arrangement [2]. In the latter arrangement, the packing ratio is 57% which increased from the previous standard 13-element detector (38%) [3].

In a monolithic approach, the dead region between the two elements is only 10 micron and the packing ratio is almost 100%. In this design, each element is 10 mm thick and has an effective area of 5 mm x 5 mm. A typical energy resolution is 190 eV at 5.9 keV at a medium count rate. We estimate the energy resolution at a high count rate ($3x10^5$ cps) to be about 240 eV using a 0.5 msec time constant.

Each detector element is equipped with PSC941 preamplifier (Penta FET). In total, 3 x 10^7 cps is expected. For energy analysis and counting, a digital signal processor (DXP, X-ray Instrum. Assoc.) is used. Each module has 4 input channels for which an energy analysis based on a digital signal processor is available. In total, DXP 25 modules are controlled by a work station running on linux 2.1.30 via CAMAC interface. The data acquisition software developed by Oyanagi [4] has been recently revised to be compatible with C/UNIX operating system.

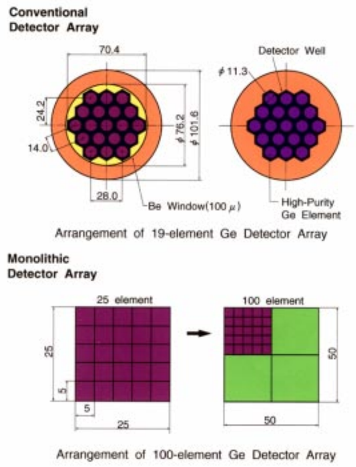

Fig. 2 Arrangements of detector elements for 19-element (above) and 100-element Gedetectors (bottom).

3. Fluorescence XAFS Setup

As illustrated in Fig. 3, in the experimental hutch of XU10, two sets of Huber goniometers are installed. This allows more freedom for sample orientation than ref. 4. A He closed cycle refrigerator mounted on c-circle can be either vertically or horizontally aligned, for the purpose of two different polarization geometries. In addition to the f and c axes for varying the sample orientation, we added 2q motion for the transmitted and/or reflected beam intensity monitor. This allows us to measure also the X-ray standing wave using a fluorescence detector for XAFS experiments. An ionization beam monitor is attatched to the 2q arm and rotate around a horizontal axis.

Recently, temperature-dependent polarized XAFS in a fluorescence mode has been successfully applied to the studies of spatial modulations in the CuO_2 plane of high T_C superconductors [5]. As the experiments on single crystals require precise sample orientation at low temperature, the present setup is particularly convenient.

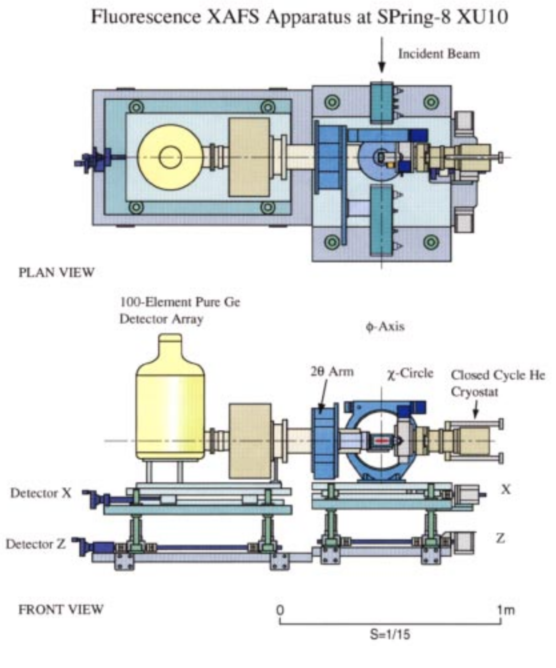

Fig. 3 Plan view (above) and front view (bottom) of the XAFS apparatus at XU10.

References

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