BL35XU
High-Resolution Inelastic X-Ray Scattering

1. Introduction & Overview

During FY 2008 (April of 2008 - March of 2009) the BL35XU scientific staff included A. Baron, S. Tsutsui and H. Uchiyama, with additional support on specific projects from members of the Materials Dynamics Laboratory, D. Ishikawa, and H. Fukui. Technical support, from SES, rotated among T. Oguchi, H. Yahata and K. Fukiwake. Aside from the usual tasks involved in keeping the beamline running, work continued on the long-scan range setup for electronic excitations, surface scattering, and optimization for high-pressure diamond anvil cell (DAC) work. We also began a collaborative project with Brookhaven Lab to use kinoform lenses for micro-focusing. Great effort, mostly not discussed here, was devoted to design of a next-generation beamline for IXS using a long-undulator, in collaboration with other groups at SPring-8, of course.

Scientifically, work continued on both crystalline and disordered materials, with publications in the Journal of the Physical Society of Japan, Physical Review Letters, Physical Review B, etc. The new iron-arsenide superconductors accounted for a large part of the beamtime, with work on both the 1111 and 122 and 11 systems in collaboration with several groups inside and outside Japan. Continued work was done to investigate liquid surfaces (<10nm scale), and also to use a grazing incidence scattering geometry to select only the top few microns of a film at high temperature.

2. Long Scan Range Monochromator

Following on earlier work, efforts continued to develop a long-scan-range high-resolution backscattering monochromator, primarily aimed at investigations of electronic excitations. This included both continued effort with single reflection backscattering setup and first steps toward a multi-crystal setup. For the backscattering arrangement, a new small vacuum chamber was installed with space for additional thermal insulation, and aimed at better vacuum levels. At the same time we began to design a wider-bandwidth backscattering monochromator to increase the flux. While several schemes were considered, it seemed the best options was a multi-crystal arrangement that should increase the FWHM of the resolution to about 40meV, but keep narrow tails, with an increase, in principle of about a factor of 8 in flux on the sample[1]. The design and expected response of the system is shown in Fig.1. Note the increase full width at half maximum but reduced tails, relative to the single bounce mono. This means the tails of the analyzer will dominate. Note also that the central (symmetric) reflection in the schematic must really be 3-bounces for this to work properly.

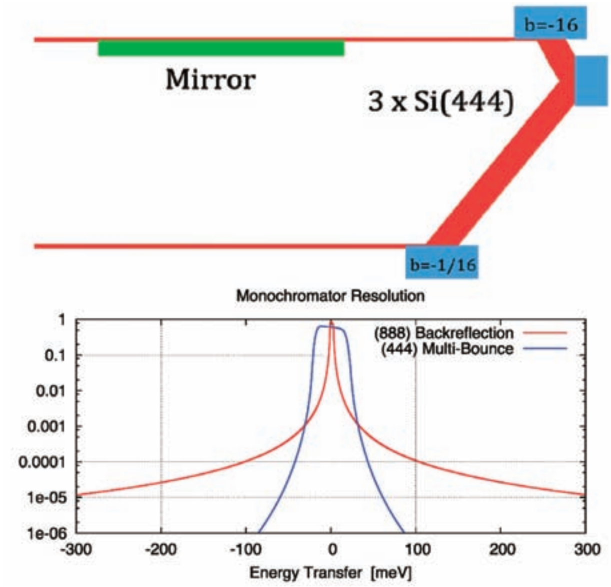

Fig.1 Backscattering multi-bounce mono.

3. Kinoform Lens

Achieving an efficient micro-focus (ie: ϕ ~5 microns) of the full x-ray beam remains a significant challenge at 3rd generation source. While just achieving a micron focus is not so hard, to make such a focus *without losses* for the full beam remains difficult, and becomes harder as the energy is increase beyond 10keV. The main problem is the horizontal focus, as there is a severe source asymmetry: the *horizontal* x-ray emittance is ~20nm-rad (FWHM^2: ~650 micron source size x ~30 micro-radian beam divergence) while the *vertical* is ~0.1nm-rad. Thus the focusing in the horizontal is qualitatively a different problem than in the vertical. In previous work, we used compound focusing, with a bent cylindrical mirror followed by a Kirkpartick-Baez (KB) mirror pair to get a ~16 micron focus of the full beam with 50% throughput. However, both at BL35 and, eventually at BL43LXU, we would like to do better – with a spot size of more like 5 microns and efficiency ~80%.

Kinoform lenses, in principle, are an attractive solution to the problem of achieving an efficient horizontal microfocus. They offer the advantage of in-line operation and small size, like a conventional compound refractive lenses (CRL), but with an increased aperture and transmission due to the selective removal of material. Fig.2 shows a lens and a schematic of how the material removal proceeds

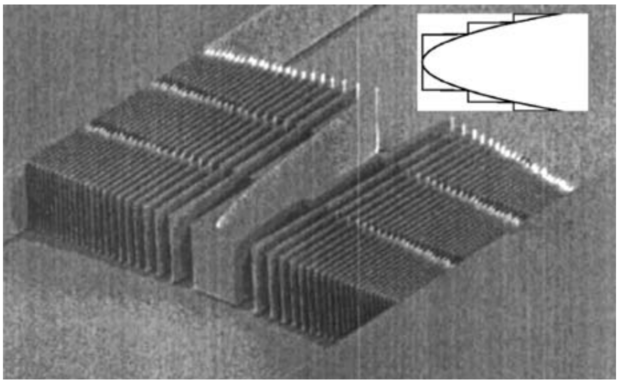

Fig.2 Electron micrograph of one design of a kinoform lens with the inset showing a schematic of how the material is removed while preserving the parabolic/focusing shape (or more properly the phase change).

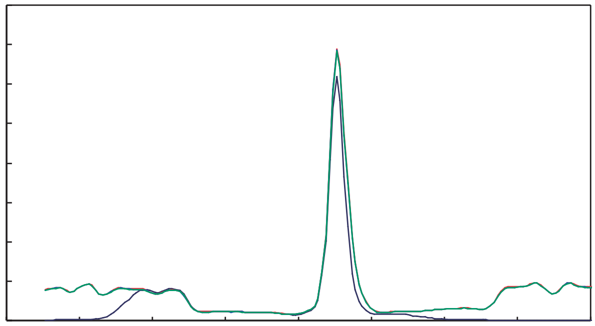

Fig.3 Measured spot sizes using a kinoform lens[2]. Horizontal tick spacing is 0.05mm, and the FWHM is about 11 microns in all cases. The different traces correspond to different incident beam sizes from 0.2mm to 1mm. The peak height does not increase much indicating the horizontal lens acceptance is still not large.

relative to the ideal parabolic shape. The major conceptual disadvantage of the lens is limited aperture out of the plane, as the height of the lithographically made structures is limited. However, given the very asymmetric nature of the source, using a mirror to focus in the vertical upstream of the lens allows placement of the horizontally-focusing lens in a beam that is already vertically small.

We have been attempting to develop a lens appropriate for IXS in collaboration with Brookhaven National Laboratory [2]. First results showed ~11 micron horizontal focal spots with a 0.7m focal length at 21.7keV and though-put up to ~90% with a 200 micron incident beam (Fig.3). This focal spot was limited by source-size (65:1 at 46m from the source). We now are working on extending the lens acceptance to more than 200 microns, and will use additional slitting to see what the lens-limited spot size will be.

4. Next Generation Beamline

Great effort forcused on starting design of BL43LXU. This included the insertion device, front-end, hutches, transport channel, spectrometer, etc, in collaboration with the relevant groups of SPring-8. Here we only mention some design work for the spectrometer. In particular, one of the main issues with a high-resolution spectrometer is that the space near the sample location is limited – this is due to the necessity of working near backscattering to achieve high-resolution, in combination with the usual Roland-circle geometry used for x-ray scattering analyzers. The Roland-circle geometry is the one that preserves the Bragg angle (and hence the energy resolution) of the analyzer crystal over a macroscopic solid angle. However, if one can precisely tailor the lattice constant of the analyzer crystal over its surface, then one can relax or modify the Roland circle condition, and make more space near the sample. We explored introducing a d-spacing gradient over the analyzer crystal by creating an appropriate temperature gradient and taking advantage of the thermal expansion of silicon. Based on extensive simulations and some tests, it appears this is a reasonable way of (1) achieving sub-meV resolution on existing spectrometers and (2) improving the resolution of smaller spectrometers [3].

5. Other

The stability of the granite base for the spectrometer continued to be a problem into the summer of 2008. However, after the realignment in the summer of 2008, it seems the stone position largely stabilized. This suggests that the motion of the granite *might* have been related to the nearby construction of the Toyota beamline and/or the XFEL. We have identified a local company (YASDA) to perform the re-alignment of the granite. It is expected that the liquid helium cryostat bought last year will be operational in the fall, after repairs at the fabricating company. Improvements are also in progress for controlling the analyzer temperature stability: the source of occasional ~10mK jumps on some analyzers was traced to poor electrical contact in some "banana" type connectors and these are being replaced.

[1] A. Baron, et al.: work in progress.

[2] H. Fukui, K. Evans-Lutterodt, A. Stein, A. Isakovic and A. Baron : work in progress.

[3] D. Ishikawa and A. Baron : Accepted for publication in the Journal of Synchrotron Radiation.

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