Nuclear Resonant Scattering (BL09XU)

1. Introduction

BL09XU is a standard X-ray beamline at SPring-8 with an in-vacuum linear undulator (λ_u=*32mm*) and an inclined Si double-crystal monochromator [1]. In 1999 the revised version of Si high heat load monochromator was installed in the optics hutch and double flat mirrors for eliminating the higher harmonics were prepared in the experimental hutch. Experiments into the nuclear resonant scattering and structure analysis of the surface and interface are conducted at BL09.

2. Bunch Structure

An operation involving several bunches is in strong demand for the time resolved experiments such as nuclear resonant scattering. Electron beams with any kinds of time structure can be obtained at the storage ring of SPring-8. Several types of bunch filling such as 7train×21, 14train×21, 2rain×116, 116, 1/12+10 were in operation until May 1999 according to the time intervals required for the assigned experiments. In June 1999, 100 mA operation was started in place of 70 mA operation. The bunch fillings of 1/12+10 and 14train×21 were conducted at 100 mA for nuclear forward scattering and nuclear inelastic scattering, respectively.

3. Optics

The improved version of the Si pin post monochromator was installed [2]. Owing to the change in channel of water flow, the typical width (FWHM) of the first crystal rocking curve for 14.4 keV with a 1×1 mm^2 aperture at 29 m from the undulator source was reduced to 8 arcsec from 10 arcsec. A distorted structure with several peaks in the horizontal beam profile at the experimental hutch [3] disappeared.

The beam profile in the momentum space i.e. the angular distribution and the energy distribution of the beam at the experimental hutch after the beamline monochromator was measured by using nuclear resonant forward scattering from ^{57}Fe foil. Figure 1 shows the contour plots of the X-ray intensity. Its peak intensity is normalized in unity. The horizontal axis shows the deviation from the resonance energy, 14.41 keV. The vertical axes are the vertical and horizontal angles of the monochromatized X-rays in Fig. 1(a) and 1(b), respectively. The each angular part was selected by the Si 840 reflection. Its intrinsic width is 0.4 arcsec. The resonant energy of ^{57}Fe is fixed, so the beamline monochromator θ was rotated to obtain energy dependence. The Gaussian fitting of the data in the Fig. 1(a) shows that the width of the vertical divergence for all the X-rays from the beamline monochromator is 4.6 arcsec (2σ) and that for the X-rays with the resonant energy is 3.8 arcsec (2σ). In a similar way Fig 1(b) shows in a that the width of horizontal divergence for all the X-rays is 47 arcsec (2σ) and that for the X-rays with the resonant energy is 35 arcsec (2σ). These values of horizontal divergence are rather large compared with the theoretical value 6.8 arcsec, which is probably due to the crystal distortion of the first monchromator still remaining [4].

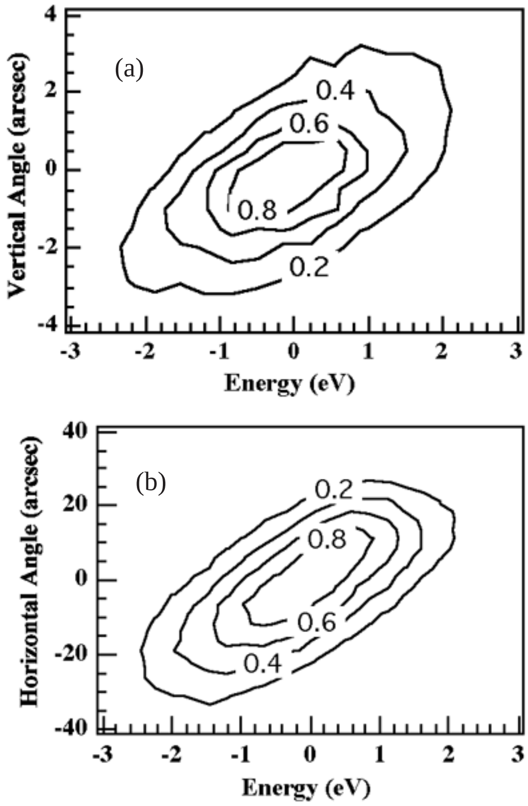

Fig. 1. Contour plots of the X-ray intensity from the beamline monochromator in the momentum space. The horizontal axis shows the deviation from the resonance energy, 14.41 keV. The vertical axes are the vertical (a) and horizontal (b) angles of the X-rays.

Although the high resolution monochromators for 14.4keV themselves were not replaced, the obtainable X-ray flux through them has increased by the improved beamline monochromator and the 100mA operation in the storage ring. Their specifications are listed in Table 1.

Double flat mirrors coated with Pt were prepared for eliminating the higher harmonics. Their surface size is 200×40 mm^2 and their thickness is 30mm. They are attached to the ω-2θ goniometers [3] in use in the experimental hutch.

Table 1. High-resolution monochromators for 14.4keV available at BL09.

reflection	ΔE	Photons/sec/100mA
Si511-Si975 (2 nested channel cuts)	3.5 meV	4×10^9
Si511-Si975 (2 nested channel cuts)	2.5 meV	1.6×10^9
Si975-Si975 (2 flat crystals)	1.6 meV	5×10^8

4. Experimental

The experiments which have been carried out at BL09 can be roughly classified into three. The first consists of nuclear resonant scattering experiment which are of course the main target at BL09, next are high precision X-ray experiment such as X-ray parametric down conversion and double crystal methods, and finally there are surface and interface studies which use the multi-axes goniometer.

As has often been pointed out, one of the features at SPring-8 is the availability of high energy X-ray photons. Several nuclei whose transition energy levels are above 30 keV have been excited including nuclear excitation by electron transition (NEET) of ^{197}Au [5] and cascade delay.

Local vibrational densities of states have been intensively studied using nuclear inelastic scattering. Study of the dilute Fe atoms in Al and Cu metals [6] and quasi-crystal are listed for example.

References

[1] Y. Yoda and T. Harami, SPring-8 Annual Report 1996 (1996) 40.

[2] H. Yamazaki *et al.*, Proc. SPIE **3773** (1999) 21.

[3] SPring-8 Annual Report 1997 (1997) 70.

[4] SPring-8 Annual Report 1998 (1998) 54.

[5] S. Kishimoto *et al.*, Phys. Rev. Lett. **85** (2000) 1831.

[6] M. Seto *et al.*, Phys. Rev. **B61** (2000) 11420.

Light Source	
In-vacuum X-ray undulator	
period	32mm
Number of periods	140
Energy range	5.2~75 keV(fundamental to 5th)
Source size (2σ)	0.77mm(h) × 0.017mm(v)
Electron beam Divergence (2σ)	0.032mrad(h) × 0.0043mrad(v)

X-rays at Sample (48m from Light Source)	
Energy range	>= 9 keV
Total flux	2.4×10^{13} (@14.4 keV)
Energy resolution	1.2×10^{-4} (@14.4 keV)
Beam size (2σ)	2.7mm(h) × 1.0mm(v)
Divergence (2σ)	0.23mrad(h) × 0.023mrad(v)

Facilities in Experimetal Station
* Experimental tables
1st : size 130 × 160 × 110 cm^3
2nd : size 180 × 120 × 110 cm^3
* Precision goniometer
resolution : 0.005 arcsec/pulse
* Two-axis (w-2q) goniometer
* Multi-axes Diffractometer
* XZ table, XY table
* Vacuum pump (TMP with scroll pump)
* Cryostat
* Avalanche photodiode detector,
P-i-n photodiode detector,
Scintillation detector,
Ionization chamber