Nuclear Resonant Scattering

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1. Introduction

The commissioning of nuclear resonant scattering beamline BL09 was started at July and the monochromatized X-ray beam was introduced to the experimental station before the summer rest. The undulator spectra were measured at October and after that the beam time including the adjustment of the instruments such as fast timing electronics, high resolution monochromators and multi-array avalanche photo-diode (APD) detectors was started. Some preliminary experimental results which shows the potential of Spring-8 were obtained.

2. Undulator Spectra

The energy spectra from the in-vacuum linear undulator l_u = 3.2 cm [1] were measured by the NaI scintillation detector rotating the inclined double crystal monochromator [2]. One of the spectra measured at the undulator gap = 8 mm was shown in Fig. 1.

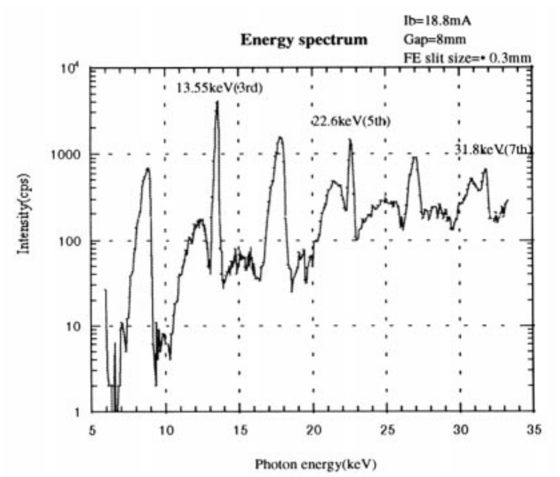

Fig.1 Energy spectrum from the linear undulator at the gap of 8 mm.

The flux at 14.4 keV which corresponds to the nuclear excitation energy of the ^{57}Fe was measured below the Si 111 double crystal monochromator by the p-i-n photo-diode detector. The flux of 2x10^{12} was obtained by the first harmonics at the undulator gap = 19.8 mm at the ring current of 17 mA.

3. Bunch structure

Since the time resolved experiments are the main parts in the case of nuclear resonant scattering, the timing properties of the X-ray beam (electron bunch filling) are very important. The 228 nsec equal interval 21-bunch filling was conducted from the end of November. The bunch purity (the ratio of electrons in the undesired bunch to the main bunch) less than 10^{-7} was achieved at last.

4. High resolution monochromators

Several high energy-resolution monochromators for 14.4 keV X-rays with fixed energy bandwidth and another one with adjustable bandwidth from several meV to sub-meV have been built and tested. A nested channel-cut crystal monochromator using the Si 511 and 975 reflections with the energy resolution of 2.4 meV and the acceptance of 16 mrad has been shown to be suitable for this beamline to achieve high throughput of the beam. A higher energy resolution monochromators composed of two asymmetric Si 975 diffraction in (+,+) arrangement with the energy resolution of 1.6 meV was proved to be in good performance. A bandwidth adjustable high energy-resolution monochromator has been first time built. The asymmetric factor b of an asymmetric-cut crystal could be adjusted by rotating the crystal along the reciprocal vector of a diffraction. The experimental results has shown the possibilities to obtain varied energy-resolution by the same device.

5. Preliminary experimental results

Several experiments of nuclear resonant scattering listed below were performed preliminarily.

<u>Inelastic nuclear resonant scattering</u>

An inelastic nuclear resonant scattering is a novel method to investigate the phonon [3]. A typical energy spectrum from the ^{57}Fe foil was measured as shown in Fig.2.

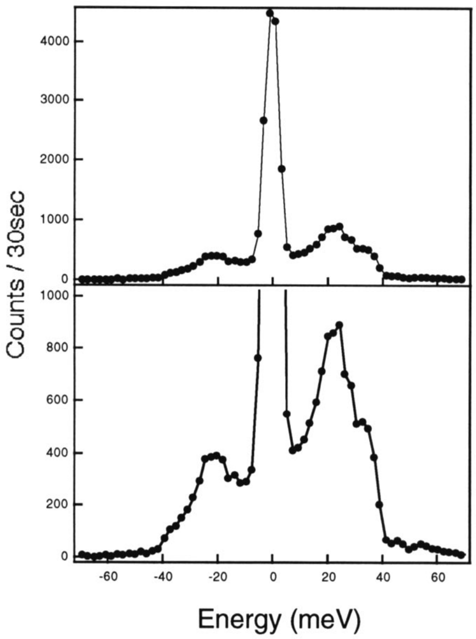

Fig.2 Inelastic nuclear resonant scattering from the ^{57}Fe foil.

The advanced researches such as the angular dependence of the inelastic nuclear resonant scattering from the intercalated $FeCl_3$ in the graphite crystal, quasi-inelastic scattering from the Nafion and the inelastic nuclear resonant scattering from Fe fine particles and the myoglobin were also conducted.

Nuclear forward scattering

The time spectra of the nuclear forward scattering from ^{57}Fe foil and the amorphous ferromagnetic material were measured to investigate the hyperfine splitting. The spin fluctuation of $^{57}FeBO_3$ after the abrupt stop of the induced magnetic fields was measured by the polarization analysis of the nuclear forward scattering which will open the new methods to investigate the spin dynamics.

Nuclear cascade scattering by ^{161}Dy

The nuclear excitation by the synchrotron radiation has been done using the first excited state so far and its energy was less than 26 keV. More than 30 nuclei exist up to 80 keV and its application is expected in the large synchrotron facilities. The cascade scattering of ^{161}Dy excited by the 75 keV X-ray which is the third excited state energy was measured. Its time spectrum is shown by the black circles in Fig. 3.

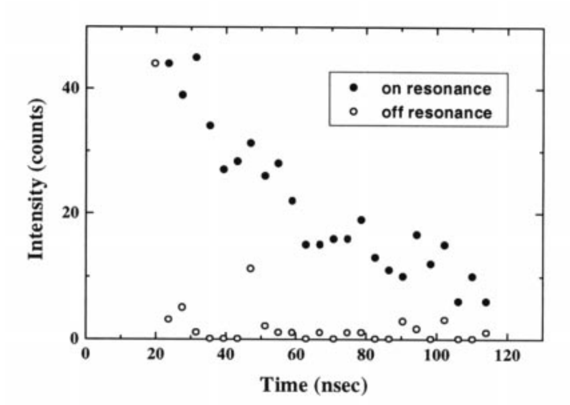

Fig.3 Time spectrum of nuclear cascade scattering from ^{161}Dy.

X-ray parametric scattering

X-ray parametric scattering is a nonlinear effect which down-converts one X-ray photon into two photons. The coincidence count rate of 0.05cps was obtained as shown in Fig. 4. The peak position satisfies the phase matching condition. The efficient noise reduction was performed using the polarization dependence.

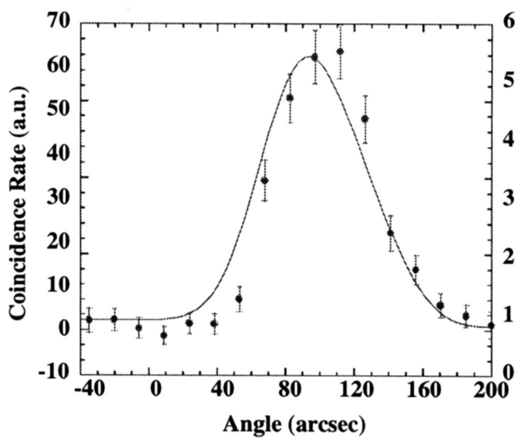

Fig.4 Fig.4 X-ray parametric scattering from a diamond crystal.

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References

[1] H. Kitamura, SPring-8 Annual Report 1994, 47
[2] T. Ishikawa, SPring-8 Annual Report 1995, 38
[3] M. Seto et al., Phys. Rev. Lett. 74 (1995) 3828