Nuclear Resonant Scattering

Yoshitaka YODA
Taikan HARAMI

1. Introduction

The specific features of nuclear resonant scattering of synchrotron radiation (SR) such as extremely namow band width, polarization property, pulse structure, small angular divergence will open up a new field in the X-ray physics. Especially the long coherence length of nuclear resonant X-rays (1~10m) resulting from its narrow bandwidth (10^{-6}~10^{-8} eV) will provide new X-ray interferometric studies.

X-ray undulator beamline BL09 is under construction for the nuclear resonant scattering SG and the structure of surfaces and interfaces SG.

2. Light Source

An in-vacuum linear undulator was installed last autumn at the section of BL-09IN. Its basic parameters are λ_u = 3.2cm, Nperiod = 140 and using the first, third and fifth harmonics X-rays from 5.2 to around 70 keV can be obtained [1]. The beam size at the experimental station 50m downstream from the light source is 1.9v x 0.6h mm^2 in 2σ at 14.4 keV X-rays.

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 mode) are very important to measure the spectra. Equal interval electron filling longer than 20 nsec is at lowest necessary for the any time resolved experiments. We consider that 21-bunch mode corresponding to the 228 nsec intervals covers about 90% of the experiments and 42-bunch mode corresponding to the 114 nsec intervals covers about 60% of that. So the study of equal interval electron filling not to degrade the beam quality comparing to the multibunch mode is strongly desired.

The purity of the undesired electron bunch is also very important for the most of the time resolved experiments. The elimination of the undesired bunch down to less than 10^{-8} compared with the main bunch is expected.

3. Frontend and Optics

The beamline hutch composed of optics hutch and experimental hutch was constructed and almost all the beamline components which are standard at SPring-8 [2] for the X-ray undulator beamline was arranged including the high heat-load monochromator developed by the JAERI-RIKEN SPring-8 project team. X-rays monochromatized ΔE/E ~10^{-4} by the fixed exit Si double crystal monochromator is led to the experimental station. The focusing instruments will be arranged downstream of the monochromator in the future.

4. Experimental Station

The constructed experimental hutch is 8.0m long, 4.0m wide and 3.3m high and two anti-vibration tables shown as Fig.1 were arranged. One is for the high resolution monochromators and Bond methods, and the other is for the applicative studies. The temperature variation make the mono-chromatized X-ray energy unstable. For example, in the case of nested monochromator using Si422 reflection and Si 1222 reflection with the resolution of 6.3meV at 14.4 keV, the change of the 0.1

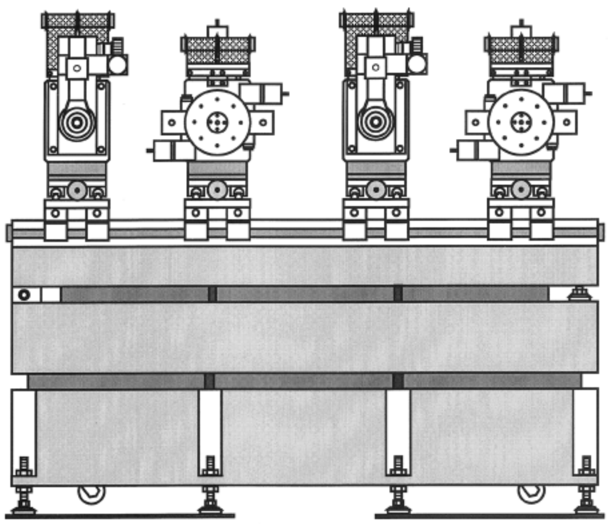

Figure 1. Schematic side view of the anti-vibrated table and high precision goniometers

degree leads to the change of 3.7 meV of the exited X-ray from the monochromator. So the temperature in the experimental hutch is controlled within ±0.1˚C and both anti-vibration tables are covered in the simple vinyl plastic hutches preventing the air from flowing.

Two kinds of versatile goniometers are prepared. One is ω-2θ goniometer whose axes are rotated for full circles by the stepping motors with the finest step 0.36 arcsec for ω and 0.72 arcsec for 2θ. The other is high precision goniometer rotated by the tangential bar with the finest step of 0.005 arcsec by the stepping motor. A11 axes are horizontal. These goniometers are smoothly moved on the anti-vibration tables by air pads equipped under the goniometers.

5. Research Subjects

Study of nuclear resonant scattering at SR will provide not only an extension of the conventional Mössbauer spectroscopy but also a new fields in the X-ray physics by its specific features. Researches planed to perform at the first phase are listed as follows.

- Intensity correlation of the X-ray photons and interferometry
- Nuclear resonant inelastic scattering (m~submeV)[3]
- Extremely high energy resolution (μ~neV) spectroscopy
- Time domain Mössbauer spectroscopy
  +Conversion electron spectroscopy
  +Mössbauer spectroscopy of the tiny samples especially under the condition of high pressure and high temperature
  +Nuclear resonant scattering process under the magnetic perturbation
- Basic features of nuclear resonant scattering
  +verification of the statistical diffraction theory by the nuclear Bragg scattering
  +Cascade decay of nuclear transitions in a single crystal
  +multiple nuclear resonant diffraction

Among these researches the first listed one is briefly explained below .

<u>Intensity correlation of the X-ray photons and interferometry.</u>

Intensity correlation makes it possible to measure the spatial coherence and longitudinal coherence resulting from the source size and energy spectrum respectively. The intensity correlation of visible lights was first measured by the Hanbury-Brown and Twiss experiment in 1956 [4]. As the number of coherence cell increases in the observed region, a pair of photons having no correlation increase and the observed correlation effect is reduced. So the shorter the wavelength is, the more difficult it is to observe the correlation. The intensity correlation of the X-ray photons was first observed using the electronic scattering monochromator by the Kikuta's group at TRISTAN Main Ring in KEK. At SPring-8 the intensity correlation of the X-ray photons using the nuclear scattering monochromator will be possible which enables to find the source size and the pulse width independently. Further in the study of the X-ray laser action the beam diagnosis may be made by the intensity correlation.

The long coherence length of nuclear resonant X-rays (1~10m) open up the new type of the interferometric studies. Interference in the case of the large difference of the optical paths (>1mm) will be observed [5].

References

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