Nuclear Resonant Scattering Beamline

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1. Introduction

Nuclear Bragg scattering of synchrotron radiation (SR) can yield revolutionarily X-ray beams with extremely narrow bandwidth ($10^{-6}\sim10^{-8}$eV), small angular divergence (mrad~μrad), plane or circular polarization and characteristic time spectra (few~100μsec). These characteristics resulting from the coupling of the properties of synchrotron radiation to those of the collective nuclear resonance scattering cannot be obtained with the radioactive source and surpass the radiation from the radioactive source. Nuclear resonance scattering of SR will open up new area of research and introduce excellent progress in physics and materials sciences. Very large number of photons are required because the bandwidth of the nuclear resonant X-rays is very narrow. From this reason the high power X-ray source like SPring-8 is needed for nuclear scattering experiment. The experiments listed below can be considered.

- Study of the dynamical diffraction of nuclear scattering.
- Structure determination by means of resonant scattering.
- Time domain Mössbauer spectroscopy
- Conversion electron spectroscopy
- Nuclear resonant scattering process under magnetic perturbation.
- Cascade decay of nuclear transitions in a single crystal
- Extremely high energy resolution spectroscopy
- X-ray interferometric study using nuclear resonant scattering
- Intensity correlation experiment for X-ray photons

2. Endstation

The experimental station is at about 50m from a light source.Two kinds of versatile goniometer are prepared. One has the axes along which table is rotated for 360°, and the other is rotated by tangential bar with precission of 0.005 arcsec. All axes are horizontal. These goniometers are smoothly moved on the surface of anti-vibration tables by air pads equipped under the goniometers.

Two optical tables are prepared as shown in Figs. 1 and 2. One is for the nuclear resonant scattering, and the other is for the experiments using the nuclear resonantly scattered X-rays as an incident beam. Both are in simple vinyl plastic hutchs for avoiding the influence of the flow of air. The temperature in the experimental hutch which has the size of 8.0m long, 4.0m wide, and 3.5m high is controlled with the accuracy of ±0.1°C.

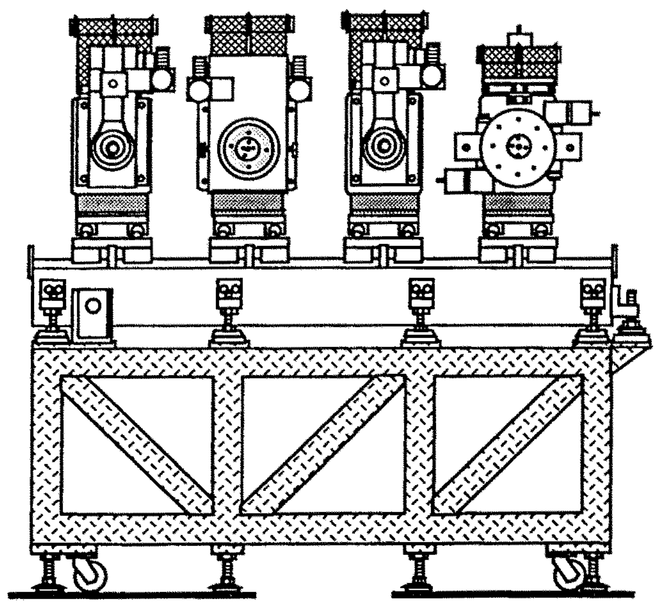

Fig. 1. Anti-vibrated table and high pecision goniometers.

3. Important Items for Design and Construction

We investigate following items for design and construction.

- Development of nuclear monochromators such as perfect crystals, GIAR films and multilayers containing the Mössbauer isotopes.
- Development of detector with high time resolution and high efficiency
- Development of detectors for the conversion electrons with high time resolution
- Development of pre-monochromator with narrow energy width
- Development of nuclear spectrometer capable of changing the detecting energy using Doppler effect
- Development of apparatus which apply the pulsed magnetic field to the sample for the fast modulation of the intensity and polarization state of nuclear resonant scattering
- Development of cryostat for nuclear resonant scattering

4. Scientific Case

Because only X-rays with an extremely small energy band width can be used effectively for nuclear resonant scattering, the highly brilliant synchrotron radiation source is demanded. Higher brilliance of X-rays emitted from a long undulator will be needed for special kinds of studies. The experiment can be classified into two groups. One is the fundamental studies such as the studies of the nuclear resonant scattering phenomena. Mössbauer experiments are also included in this group. And the other is the studies using nuclear scattered X-rays as the incident beam to the scatterer.

4-1 Mössbauer Experiments

Time domain Mössbauer experiments listed below will be performed with high precision. The time differential technique where quantum beats are measured is unique to SR experiments. The SR-excited source will be much more highly brilliant than the conventional Mössbauer isotope source. High brilliance and small beam cross-section of the SR-excited source will allow the spectroscopic experiment with tiny samples aiming at, for example, the variation with temperature and pressure.

(1) Mössbauer absorption spectroscopy

Study of magnetic clusters precipitated in solids by using the relaxation of hyperfine levels and time dependence of resonant absorption.

(2) Conversion electron spectroscopy

Surface study by the detection of internal conversion electrons from nuclei excited by synchrotron radiation.

(3) Determination of atomic structures of crystals by means of nuclear resonant scattering.

(4) Determination of magnetic structure

The nuclear resonant scattering from ^{57}Fe is influenced by a magnetic structure. We can study the magnetic and electronic structure by examining the hyperfine interaction and the kinetics of spin fluctuation by using a time dependent polarized nuclear resonant X-rays. It will be possible to study the dynamical behaviour of domain in soft magnetic materials by using nuclear resonant scattered X-rays combined with the application of radio-frequency magnetic field on the specimen.

4-2 Non-Mössbauer Experiment

We can carry out various experiments by using the advaced feature of the nuclear resonant X-ray as follows.

(1) Study of the local structure of non-periodic materials (amorphous solids, quasi-

crystalline alloys) by obtaining the information on the three-body correlation of the atoms by the analysis of the phase and time dependence of nuclear resonant X-ray diffraction.

(2) Interferometry

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

(3) High resolution spectroscopy

The extremely narrow band width of the nuclear resonant X-rays enables us to measure the neV spectroscopy. It will be possible to analyze the inelastic effect by the acoustic phonon and red shift of X-rays due to the gravitational field.

(4) Intensity correlation of the X-ray photons

The Hanbury-Brown and Twiss experiment in the X-ray region will be studied. It will be possible to detect the bunching effect of photons at SPring-8. We must develop the time coincidence measurement system for this experiment.

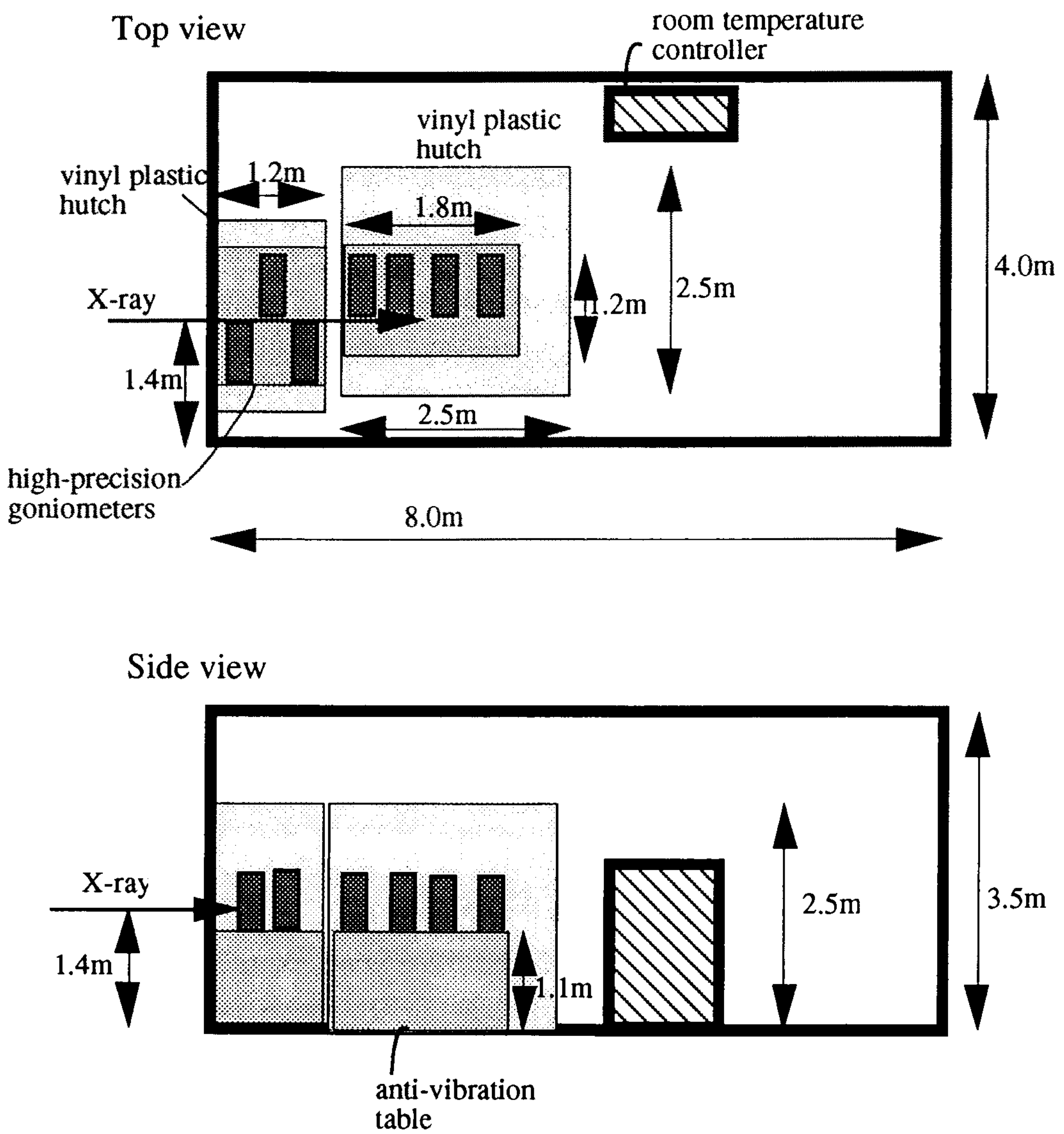

Fig. 2. Outline of experimental staion.