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Four-crystal camera at BSRF and its applications

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The four-crystal camera is one of the major items of equipment of the topography station at the Beijing Synchrotron Radiation Facility. The design and some applications of this camera are presented.

Keywords: X-ray diffraction; cameras; X-ray topography.

1. Introduction

The X-ray topography station at the Beijing Synchrotron Radiation Facility (BSRF) is an experimental station for the study of materials (Jiang *et al.*, 1993). The station is situated at the end of the wiggler beamline 4W1A. The length of the beamline is 45 m. When the Beijing Electron Positron Collider (BEPC) is operated at an energy of 2.2 GeV and the magnetic field of the wiggler at 1.8 T, the photon flux (Yang *et al.*, 1993) at λ = 1.34 Å is 6×10^{10} photons s^{-1} mA^{-1} $mrad^{-2}$ (0.1% bandwidth)$^{-1}$. The major items of equipment of the station are a white-radiation topography camera (Bowen *et al.*, 1982), three environmental chambers (Jiang & Zhao, 1992), an X-ray video imaging system and a four-crystal monochromatic camera. These are installed inside an interlocked hutch 6 m long and 3 m wide.

2. Design of four-crystal camera

The object of constructing a four-crystal camera is for monochromatic topography studies and high-accuracy diffraction studies such as X-ray standing-wave and coherency studies. The four-crystal camera consists of a double-crystal monochromator, a double-crystal diffractometer and a rotation system. An illustration of the four-crystal camera is shown in Fig. 1 and a photograph of the camera is shown in Fig. 2.

The double-crystal monochromator comprises a pair of parallel perfect Si crystals that can be rotated to fit the Bragg angle by a Huber goniometer. The second crystal can be finely adjusted in two ways to ensure that it is parallel with the first crystal. The first crystal can be moved down to allow white radiation to pass when white-radiation experiments are performed. An ion chamber is placed after the monochromator to measure the intensity of the incident photons.

The main body of the double-crystal diffractometer is a precise two-axis diffractometer made in the UK (Bede Scientific Instruments Ltd, 1986). The two fine axes of the diffractometer are controllable and measurable with a resolution of 0.05 arcsec in the region of $\pm 5^\circ$ using a computer. The separation of the axes is 300 mm. An Si reference crystal or an asymmetrically cut Si

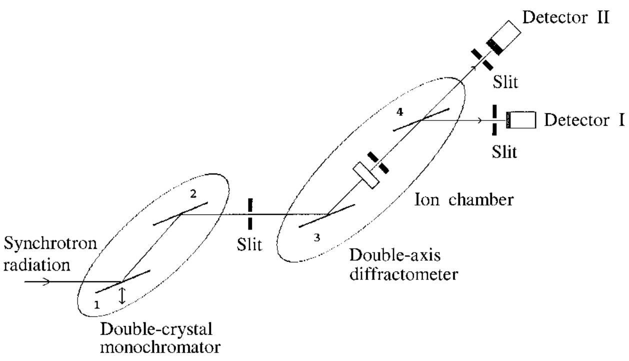

Figure 1
Schematic diagram of the four-crystal camera at BSRF.

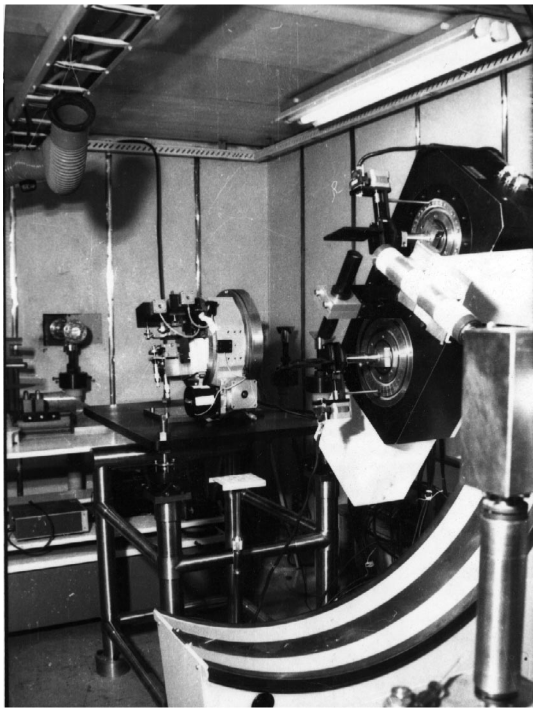

Figure 2
Photograph of the four-crystal camera at BSRF.

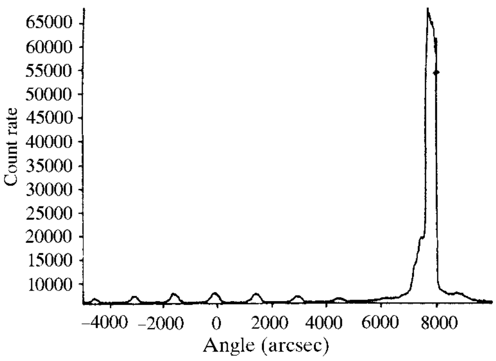

Figure 3
Rocking curve of (GeSi)15/Si(001) superlattices using synchrotron radiation of wavelength 1.54 Å and the 004 reflection.

standard crystal can be set on the first axis. The specimen is set on the second axis. Besides the θ_B rotation, the standard crystal can rotate in two ways and the specimen in three ways. The two-axis diffractometer can be rotated 360° around another axis coincident with the first axis. A scintillation counter mounted on the detector axis, which is coincident with the second axis, is used to record the intensity of the diffraction photons. In order to meet the requirements of some experiments, another detector arm can be added on the diffractometer. Therefore, photons from the diffraction and transmission beams can be detected at the same time. A set of adjustable slits and a ion chamber are mounted between the two fine axes and another slit is mounted in front of detector. The shielding system is arranged around the first axis of the diffractometer. The slits and the shielding system are very important for the reduction of the scattering background.

The whole double-crystal diffractometer can be rotated 90° around the incident beam on the rotation system by a motor. The design of the rotation system follows the principles of small volume, stability, reliability and ease of handling. A symmetrical two-arc track system, a two-axis drawing system with self-compensation and an auto-controlling system are used for this rotation system. The length of this rotation system is only 0.8 m along the incident beam.

The double-crystal diffractometer can be used by itself or together with the double-crystal monochromator. When it is used as part of the four-crystal camera, the third crystal mounted on the first axis of the diffractometer is an asymmetrically cut perfect Si(111) crystal or an Si(220) crystal for harmonics suppression and extensive beam.

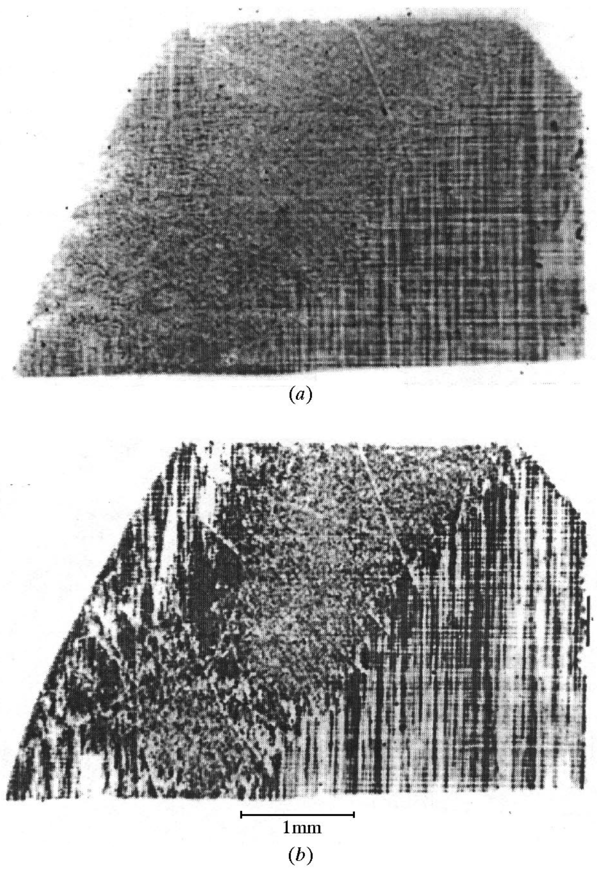

Figure 4
Monochromatic synchrotron radiation (1.59 Å) topographies of InGaAs/GaAs strained-layer superlattices (SLSs) with the 224 reflection: (*a*) taken at the substrate peak; (*b*) taken at the 0th order peak of the SLSs.

3. Examples of applications

The camera has been used for monochromatic topography and diffraction studies. Fig. 3 shows the rocking curve of (GeSi)15/Si(001) superlattices using synchrotron radiation of 1.54 Å wavelength and the 004 reflection. Ten satellite peaks are clearly shown. Fig. 4 shows topographs of InGaAs/GaAs strained layer superlattices with the 224 reflection using monochromatic synchrotron radiation of 1.59 Å wavelength.

During May 1997, a coherent experiment was performed by cooperation of Qinghua University and Institute of High Energy Physics. A schematic diagram of this experimental arrangement is shown in Fig. 5. The Si interferometer was provided by Dr Xiaowei Zhang (KEK, Japan). For the O beam, a bunch of photons that is transmitted by the first crystal and diffracted by the second and third crystals interferes with another bunch of photons that is diffracted by the first and second crystals then transmitted by the third crystal. The interference fringes are shown in Fig. 6.

The double-crystal monochromator was manufactured by the Beijing Science Instrument factory. The rotation system of the double-crystal diffractometer, the mountings of the specimen and slit, the detector arm, and the shielding system were constructed by the Institute of Beijing Boda Technology. The standard Si crystals were provided by the Sichuan Emei Semiconductor Factory. We are grateful for the remarkable working of the above items. We also heartily acknowledge Dr Jiyong Zhao, Professor

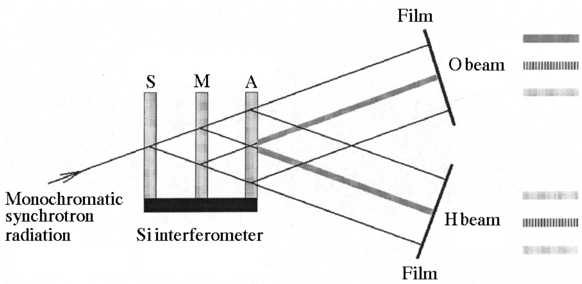

Figure 5
Schematic diagram of the coherent experimental arrangement at the BSRF.

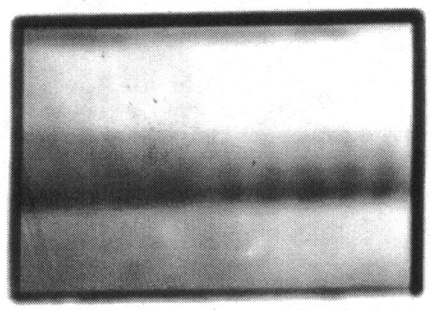

Figure 6
Photograph of the coherent O beam. The interference fringes are clearly shown.

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