2.2 **Topography**

2.2.1 Topography

X-ray diffraction topography is an imaging technique based on Bragg diffraction. It enables the two-dimensional intensity mapping of the beams diffracted from a crystal. It is used for the visualization of defects present in the crystal volume, such as dislocations, twins, domain walls, inclusions and impurity distribution. More exactly, it records the long-range distortion fields and/or the strain fields associated with macroscopic crystal deformation. This becomes possible, because these distortion fields may affect the diffracted intensity of X-rays, thus creating contrast (nonhomogeneous intensity distribution) in the image. Thus topography is the study of the fine structure of a Bragg spot which contains information on imperfections in the perfect crystal structure (which is investigated by structure determination methods and assumed as known), that is the defect structure.

The general topographic setup is shown in Figure 2.4. X-rays generated from the synchrotron radiation source, passing through optical elements (e.g., absorbers, slits and shutter) are incident on a sample. The image diffracted from the sample is recorded on a two-dimensional detector.

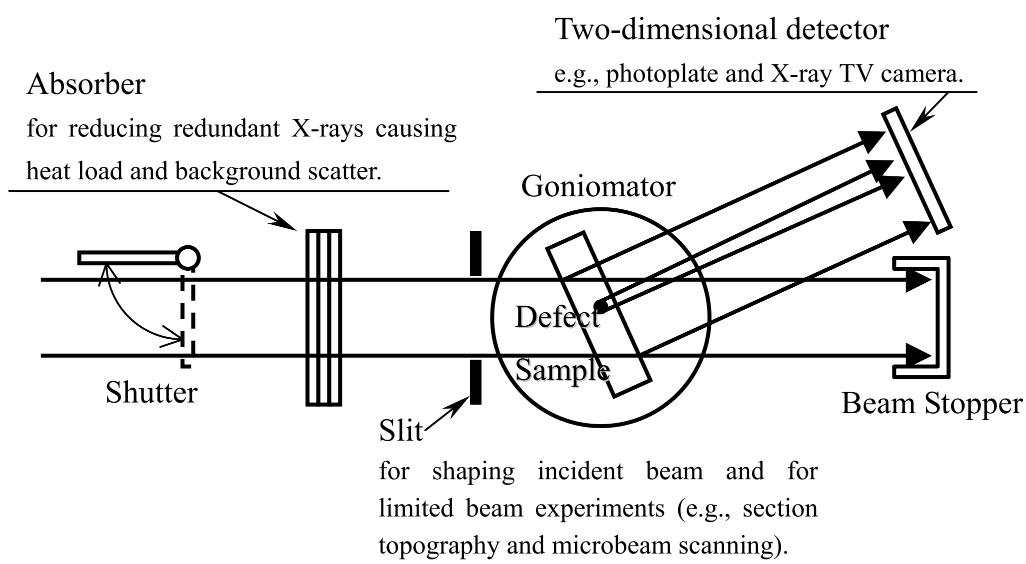


Figure 2.4. Schematic diagram of general topographic setup.

2.2.2 White X-ray Topography

White X-ray topography is a very simple but powerful technique when using synchrotron radiation. The basic arrangement adopted at BL28B2 is principally the Laue technique, which is used commonly for structure analysis or crystal orientation. White X-ray topography, which was used first with laboratory sources [1, 2] (Bremsspectrum), is now mostly used with synchrotron radiation [3], because of its use of a wide, homogeneous, low-divergence and intense beam. Figure 2.5 shows an example of the white X-ray topographs of a part of a silicon ingot. Several spots in the Laue pattern obtained using synchrotron radiation exhibiting features of a continuous spectrum, homogeneous, low-divergence shows the intensity map of diffraction from a silicon crystal. These white X-ray topographs (Laue spots) are simultaneously recorded on a large photographic plate with exposure times between milliseconds and some seconds. On the other hand, white X-ray topography using an X-ray TV camera provides the possibility of in situ observation because there is a wave satisfying Bragg conditions, although these conditions change with external field (e.g., electric fields and thermal field). The advantages and drawbacks of white X-rays are shown below.

<u>Advantages</u>

・No orientational tuning of sample

・Simultaneous observation of several reflections

・Simultaneous observation of all crystals

・In situ observation

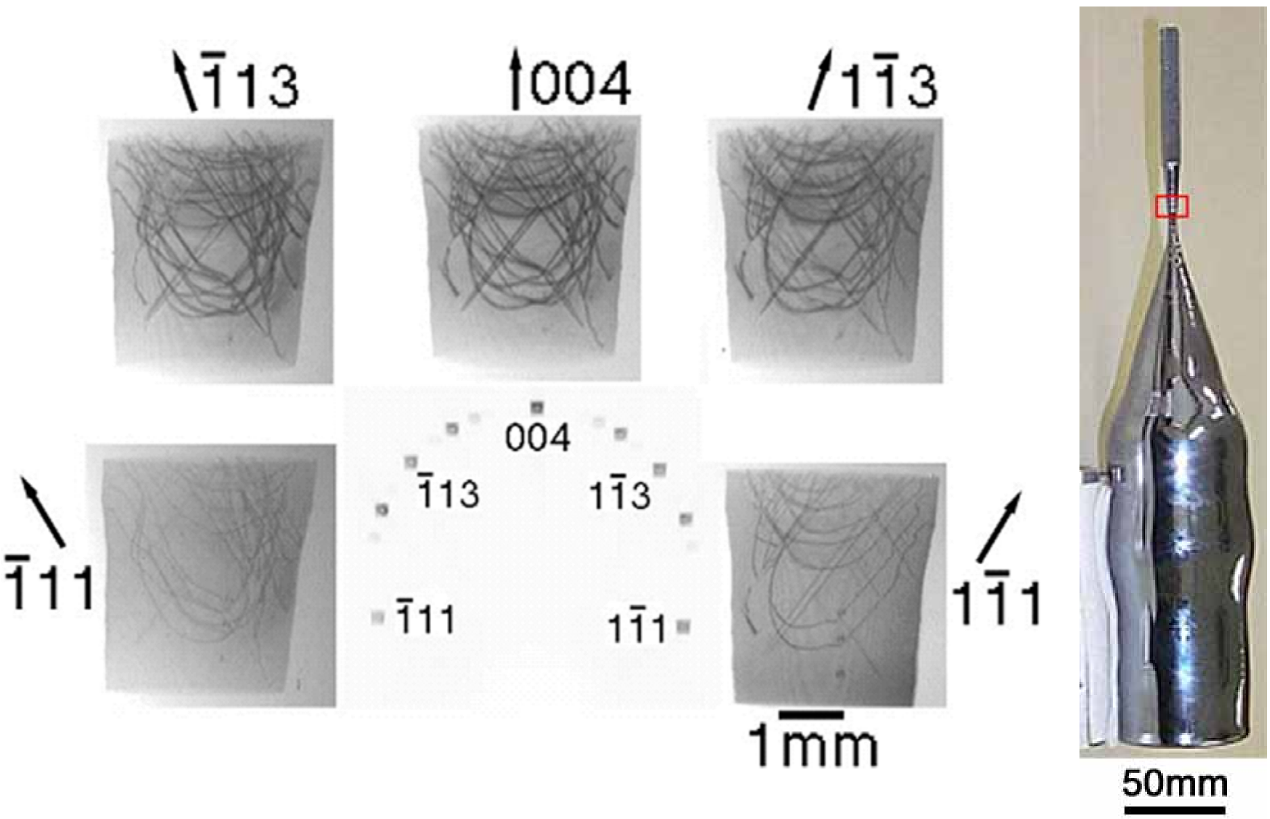
<u>Drawbacks</u>

・Large heat load

・High harmonics contamination

・Low sensitivity to weak distortion

・High background from radiation not used in image formation.



(a) (b)

Figure 2.5. White X-ray topographs of 2” diameter as-grown CZ-Si crystal ingot (a). Photograph of CZ-Si (b). The observation area is shown by the red solid square in (b). Dislocation disappearance during the necking process is clearly observed.

2.2.2.1 X-ray Beam Characteristics

The parameters of the beam at BL28B2 are shown in Table 2.2. The horizontal beam size of 30 mm is limited by the apertures of the pipes in optics hutch 2. The source sizes of the bending magnet at SPring-8 are 153.7±5.1 μm ($\equiv 1\sigma_x$) in the horizontal direction and 19.5±1.8 μm ($\equiv 1\sigma_y$) in the vertical direction [4]. The practical source size as the FWHM of intensity distribution in a Gaussian shape is 2.35 σ. The maximum horizontal beam divergence of 1.2 mrad is determined with the front-end slit. The vertical beam divergence is the natural divergence of synchrotron radiation. The angular source size δ is the angular size of the source seen from one point of the crystal, given by $\delta = s/L_0$, where s is the geometrical source size and L_0 the source to crystal distance. The geometrical resolution ρ (Figure 2.6) denotes the size of the image with which a dot on a sample is projected onto the detector. It is geometrically calculated using source size, source-to-sample distance and sample-to-detector distance because in most cases the angular source size δ is smaller than the FWHM of a reflectivity curve of a crystal in the angular space *ω*.

$$\omega = \frac{2|P||\chi_g|}{\sin 2\theta_B}.$$

Here, *P* is the polarization factor, χ is the electric susceptibility and θ_B is the Bragg angle.

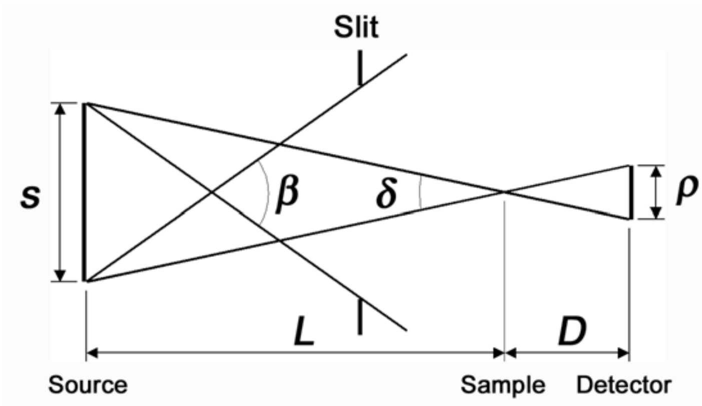


Figure 2.6. Schematic diagram showing angular source size, beam divergence and geometrical resolution.

Table 2.2. Main parameters of optics hutch 2.

	Horizontal direction	Vertical direction
Beam size at sample (44 m from light source)	30 mm	10 mm
Source size (*s*)	0.35 mm (σ_x= 0.15 mm)	0.05 mm (σ_y = 0.02 mm)
Beam divergence (β)	1.2 mrad	0.17 mrad (at 10 keV) 0.10 mrad (at 30 keV) 0.08 mrad (at 50 keV)
Angular source size (δ) (44 m from light source)	8.0 µrad	1.1 µrad
Typical geometrical resolution (ρ) (150 mm from sample)	1.19 µm	0.17 µm
Energy range	White (>5 keV owing to Be windows)	

[1] G. N. Ramachandran, *X-ray topographs of diamond*, Proc. Indian Acad. Sci., Sect. A, **19**, 280 (1945).
[2] M. Schlenker, J. Baruchel, R. Perrier de la Bâthie, *Neutron-diffraction section topography: Observing crystal slices before cutting them*, J. Appl. Phys. **46**, 2845-48 (1975).
[3] T. Tuomi, K. Naukkarinen, P. Rabe, *Use of synchrotron radiation in X-ray diffraction topography*, Phys. Stat. Sol. (a) **25**, 93-106 (1974).
[4] M. Masaki, S. Takano, DIPAC 2001 Proceedings.