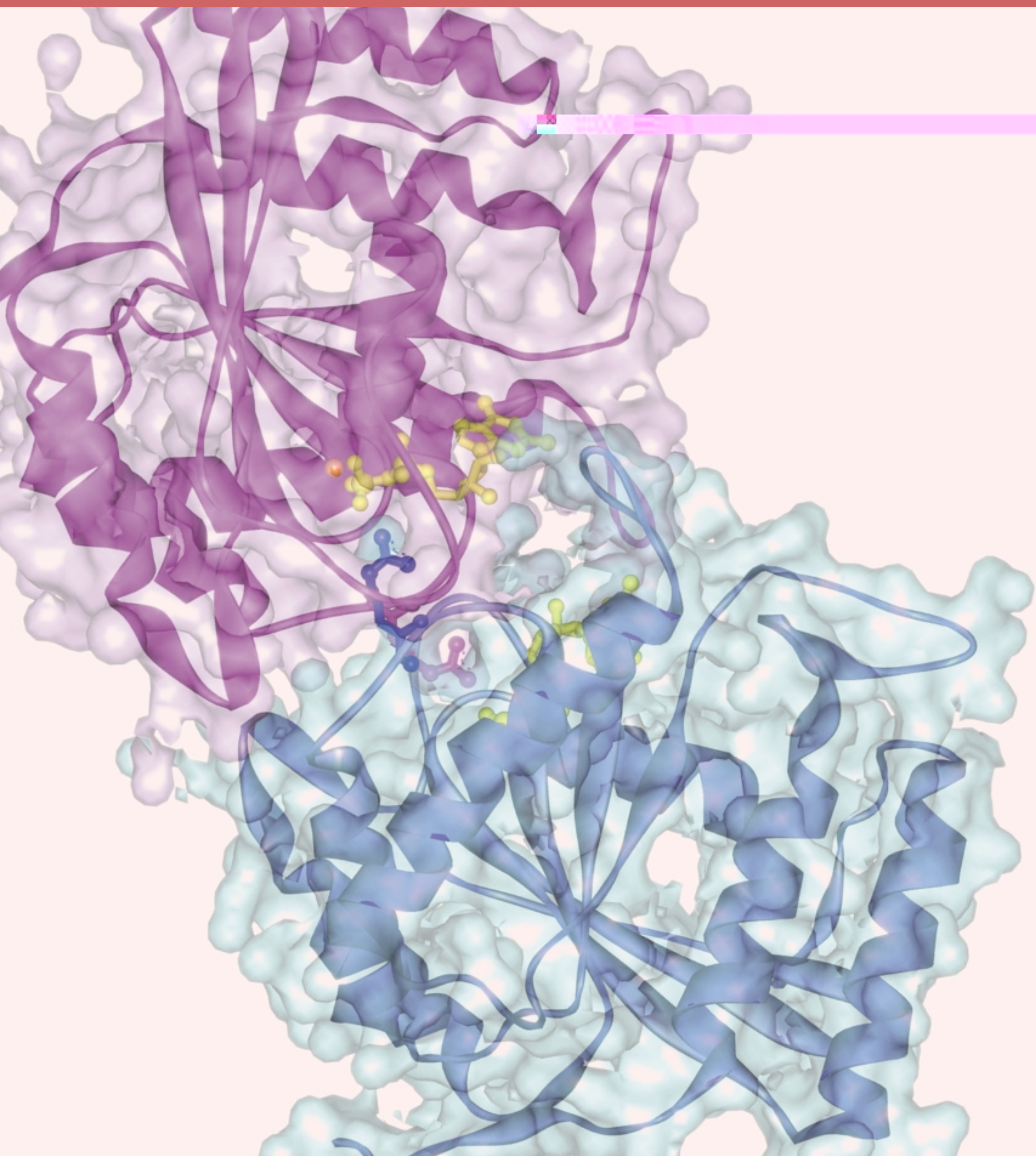
Highlights



10 Instrumentation and Technique

10-1 Novel X-ray Optics 'Trinity' for Simultaneous Imaging of Absorption, Phase-Interference and Refraction Contrast

A newly designed X-ray optics 'Trinity' [1] capable of simultaneously viewing three kinds of imaging, absorption, phase-interference and refraction contrast, has been successfully commissioned. Its working X-ray photon energy is 35 keV, diffraction index 4,4,0 and its view area 7 mm (w) × 14 mm (h). Imaging by this X-ray optics will be useful in medicine, biology and material science.

This design comprises well-established absorption contrast, phase-interference contrast [2] available since the advent of X-ray interferometry in 1965 [3], and new refraction contrast available since 1989. Refraction of X-rays is a phenomenon occurring perpendicularly to the X-ray propagation as seen in Eq. (1). If the optical path is taken along the z axis and it passes through a sample between z_0 and z_1, then the refraction can be as follows:

$$\Delta\alpha(x,y) \propto -\frac{\lambda^2 r_e}{2\pi}\frac{\partial}{\partial x}\int_{z_0}^{z_1} N(x,y,z)\,dz \qquad (1)$$

where $N(x,y,z)$ is a local density of electrons at coordinate (x,y,z), λ is the X-ray wavelength, r_e is the classical radius of the electron. This value may be in the order of 1 μrad or so range.

Three kinds of contrast are available with the X-ray optics 'Trinity' shown in Fig. 1. Half of the monochromatic beam from an asymmetrically cut monochromator penetrates through a sample to project its internal structure due to its absorption contrast onto an imaging device, while the other half provides phase-interference contrast as well as angle-resolved contrast. How this X-ray optics looks is shown in Fig. 2. Figure 3 shows a composite material image taken by 'Trinity'.

Extension of 'Trinity' is under way so that it can provide not only just refraction contrast but also a pair of dark- and bright-field images. This will be reported in the future elsewhere. An attempt to make the view size larger is also under way.

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References

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[3] U. Bonse and M. Hart, *Appl. Phys. Lett.* **6** (1965) 155.

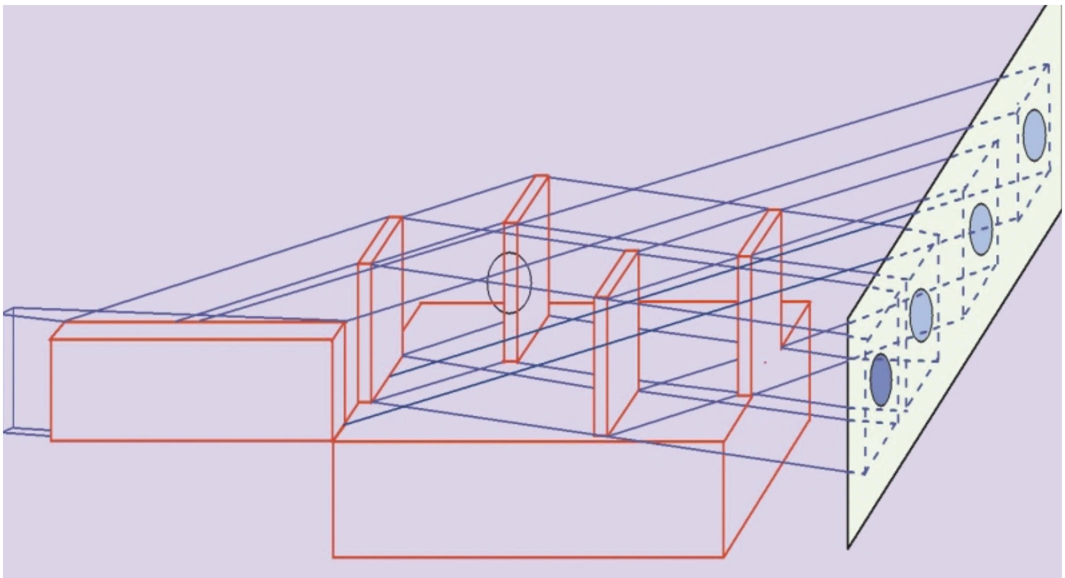

Figure 1
Schematic of an asymmetric monochromator and new X-ray optics capable of simultaneously providing three types of contrast images.

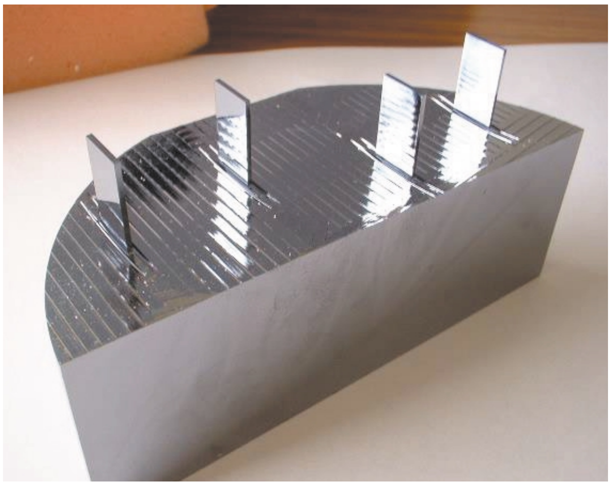

Figure 2
View of the new, home-made X-ray optics that can provide a view size of 7 mm (w) and 14 mm (h).

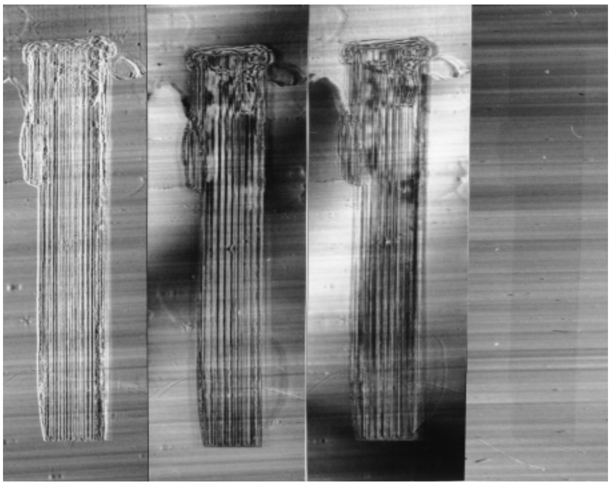

Figure 3
Image of a composite material, SiC in titanium, showing each fiber whose internal structure is invisible using a conventional X-ray technique. Very clear internal structure images are available in angle-resolved contrast (left), phase-interference contrast (two figures in the middle) as well as in absorption contrast (right). Each fiber is 140 µm in diameter. The field size is 7 mm wide by 14 mm high.