Multiple pinholes to produce a clean hard-x-ray beam for coherent diffractive imaging

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Signal intensities for a coherent diffractive imaging (CDI) experiment decrease in proportion to the fourth power of the scattering angle. High-resolution information is encoded in this high-angle data. Accordingly, it is necessary to use a clean x-ray beam with minimal high-angle intensity.

We have investigated the production of a clean beam using multiple pinholes to select a highly coherent portion of the x-ray beam and to remove divergent beam components. These divergent components arise from the regular shape of the aperture - resulting in an Airy diffraction pattern, for instance - and from aperture imperfections, resulting in parasitic scattering.

Figure 1 shows the arrangement that we have employed in a recent experiment at 32-ID-B of the APS. A 10-μm pinhole was used to select the coherent beam fraction. However, use of such a pinhole produces higher-order background. This background would overwhelm the high-angle signal if allowed to reach the detector.

In order to place the pinholes at the optimum location we have calculated near-field intensities along the beam axis. The first propagation (Fig. 1a) shows that a 25-μm pinhole can be located so that its perimeter coincides with the second minimum of the Airy pattern. By choosing this location we are able to reduce the amount of scatter originating from this second pinhole. Figure 1(b) shows the intensity after propagation to the plane of a 45-μm pinhole that was used to guard in the first minimum of the Airy pattern. Further propagation to the specimen plane shows the intensity profile of the illuminating beam. We have found that such simulations are very useful for visualising the experimental illumination conditions.

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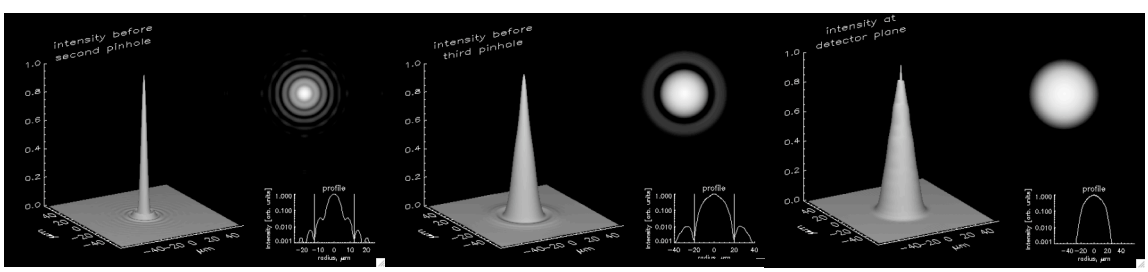

Fig. 1. Three pinholes are used to produce the illuminating beam. Pinhole 1 is selects the coherent beam fraction. Pinholes 2 and 3 remove the higher-order Airy fringes and unwanted pinhole scattering from the incident beam. The diameters and position of pinholes 2 and 3 are chosen so that their perimeters coincide with the second and first minima of the Airy pattern, respectively. The three figures show the intensity distribution at (a) the plane of the second pinhole, (b) the plane of the third pinhole, and; (c) the sample plane.