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Achromatic and Apochromatic X-ray Lenses

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Diffractive and refractive lenses are widely utilized in high-resolution X-ray microscopy with many applications in biology, energy and materials science. However, both diffractive and refractive X-ray optics suffer from strong chromatic aberration, i.e., they focus different wavelengths at different distances. As a result, many high-resolution X-ray analysis techniques are limited to utilizing monochromatic X-ray beams, meaning that a large portion of the X-ray flux is sacrificed. Achromatic and apochromatic lenses, capable of focusing multiple colours in a single point, have been long available for visible light. They are accomplished by combining individual lenses made from glass materials with different amounts of dispersion. In the X-ray regime, the realisation of achromatic and apochromatic lenses entails some unique challenges, mainly due to the inherent nature of the X-ray interaction with matter and the resulting intricacies in the X-ray optics fabrication. An achromatic X-ray lens can be realised by combining a divergent compound refractive lens (CRL) with a converging Fresnel zone plate (FZP) in close contact, as shown in Fig. 1(a). Such approach was theoretically proposed in the past [1—4], but it was only recently experimentally realised [5]. An alternative configuration, carefully choosing the separation distance between the two individual elements, results in apochromatic X-ray focusing [Fig. 1(b)], as theoretically suggested in [4] and experimentally demonstrated in [6]. The apochromatic case offers a correction over a significantly wider range of X-ray energies as qualitatively shown in Fig. 1(c). Here, we discuss in detail the realization of achromatic and apochromatic X-ray focusing schemes [5,6]. The FZP was fabricated by electron-beam lithography and gold electroplating while the divergent CRL was produced by two-photon polymerization 3D printing. For the X-ray achromatic lens, the two elements can be now produced on the same membrane support [Fig. 1(d)]. We demonstrate the characterization of achromatic and apochromatic lenses by ptychography and scanning transmission X-ray microscopy and we present several proof-of-principle experiments for full-field transmission X-ray microscopy and for fluorescence scanning X-ray microscopy [Fig. 1(e)] realized at multiple synchrotron beamlines.

I plan to submit also conference proceedings

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