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A Monolithic X-ray Achromatic Lens

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Chromatic aberration has been a long-standing challenge for lens-based X-ray microscopy, significantly limiting image resolution or reducing the usable portion of the photon flux since the field's inception in the 1970s. However, recent advancements have led to the development of the first achromatic and apochromatic lenses for X-rays, both exhibiting a constant focal length over wide photon energy ranges. Regrettably, the potential performance in this first demonstration has been limited by the challenges associated with accurate alignment of the single elements that compose the doublet. In this study, we introduce the development of a monolithic X-ray achromat, in which the two elements composing the achromatic double are produced in a single substrate, thus accurately aligned during the fabrication steps (Figure 1).
As in the original X-ray achromatic lens [1], the optical device is composed of a Fresnel zone plate (FZP and compound refractive lens (CRL). The FZP was fabricated with high-resolution electron beam lithography and gold electroplating on a 250-nm thick silicon nitride membrane. In the monolithic approach, we employed two-photon polymerization to print the CRL directly on the FZP substrate frame, a method that ensures an alignment accuracy in the order of 100 nm. The 3D printing design of the CRL has been modified integrating enhanced structural reinforcements to strengthen its robustness as well as enabling the fabrication of taller structures. In particular, a robust arch-like support structure for the lens is also adopted to improve the mechanical stability in an intense X-ray beam for a high aspect ratio CRL structure. This approach reduces the alignment degree of freedom during an experiment from 6 to 2, thereby dramatically enhancing imaging quality and data collection efficiency. A comparison of STXM images of the same sample of the monolithic design and the previous doublet design is shown in Figure 2. High efficiency and quality fluorescence imaging across a broad energy range for multiple elements, as well as transmission X-ray microscopy (TXM) imaging with micro-bot samples have successfully demonstrated the advantages of using a monolithic achromat. [2]
Our monolithic X-ray achromat overcomes the technical limitations of using individual elements, thus establishing a better paradigm for implementing such X-ray lenses in X-ray microscopy setups. This breakthrough is paving the way for a more generalized use of X-ray achromatic, thus pushing further the applications of X-ray microscopy for academic and industrial research.

[1] A. Kubec, M.-C. Zdora, U. T. Sanli, A. Diaz, J. Vila-Comamala, and C. David, An achromatic X-ray lens, Nat. Commun., vol. 13, no. 1, p. 1305 (2022), doi: 10.1038/s41467-022-28902-8.
[2] P. Qi et al., Monolithic achromatic X-ray lens, in preparation.

I plan to submit also conference proceedings

No

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