Extreme Ultraviolet Metaoptics

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Modern attosecond science and state-of-the-art semiconductor lithography require extreme ultraviolet (EUV) light. However, the unavailability of optics for this spectral regime halts progress. Here [1], we realize the first metalenses for EUV radiation with 50 nm vacuum wavelength, which is less than a quarter of the current low wavelength cutoff of dielectric metasurfaces [2-5]. The technology constitutes the first universal approach for achieving EUV optics, and devices can be manufactured using only semiconductor-foundry-compatible processes.

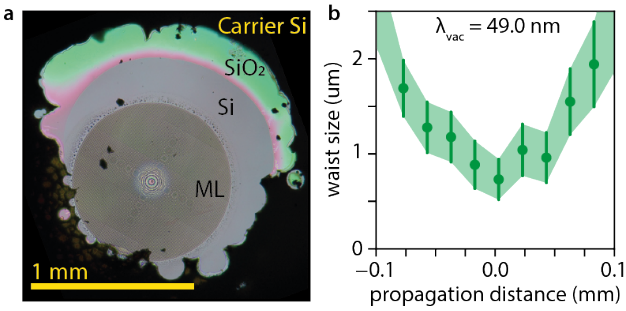

Figure 1: Experimental knife-edge characterization of a metalens focusing extreme ultraviolet light. a) Light microscope picture of a fabricated metalens (ML, focal length $f = 10$ mm, optics diameter 1 mm, $\lambda_{\text{vac}} = 49$ nm). b) Position-dependent waist size (green dots) of the metalens-focused light beam around the focus located at $z = 0$ mm. The error bars mark 95% confidence

To achieve the EUV metaoptics, we exploit that holes etched in a silicon membrane have a considerably higher index ($n = 1$) than the surrounding silicon ($n = 0.77$), allowing us to guide light and shift the phase of transmitted EUV radiation by varying the diameter of the holes. To design a metalens, we first digitize the phase profile of an aspheric lens and then match the required position-dependent transmission phase with the correct hole diameter.

Via electron beam lithography and reactive ion etching, we fabricated a metalens with 10 mm focal length and 1 mm diameter from the device layer of a silicon on insulator wafer. Fig. 1a shows a light microscope image of the final optics. To characterize this metalens, we generated EUV radiation using high-harmonic generation and focused the 21st harmonic of the driving laser (49 nm wavelength). Fig. 1b presents the waist evolution of the focused EUV light beam using a knife-edge measurement. Focusing by the metalens is proved by the clear beam size minimum along the propagation direction. The metalens achieves a minimum beam waist of $w_0^{\text{metalens}} = (0.7 \pm 0.3)$ um, which is only 1.6 times the diffraction limit determined by the nominal lens parameters and the incoming beam profile.

References

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