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Honing the accuracy of extreme ultraviolet optical system testing: at-wavelength and visible-light measurements of the ETS Set-2 projection optic

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When performed in concert with high-accuracy visible-light interferometry, at-wavelength extreme ultraviolet (EUV) interferometry provides a valuable opportunity to reveal systematic measurement differences between the two techniques. These measurements enable us to hone the accuracy of both and push toward levels of agreement in the tenth-nanometer regime.

The EUV phase-shifting point diffraction interferometer (PS/PDI), a tool for optical system testing, has the demonstrated high accuracy required for the alignment and characterization of EUV lithographic optical systems. During the past several years, the PS/PDI has been used in the measurement of seven prototype EUV optical systems developed for research in EUV lithography. At a numerical aperture of 0.1, the wavefront-measuring rms accuracy of the interferometer, measured *in situ* with a two-pinhole null test, falls below 0.05 nm under normal operating conditions. The precision, or measurement repeatability, is several times smaller.

Recently, at-wavelength testing was conducted on the “Set-2” projection optic produced for the Engineering Test Stand, now operating at Sandia National Laboratories. Conducted at Lawrence Berkeley National Laboratory, the interferometric measurements provided the first at-wavelength verification of the diffraction-limited performance of this optical system. Micro-field EUV-imaging experiments conducted following the EUV interferometry have confirmed the predictions of the wavefront measurements, and are the subject of a separate presentation at these proceedings (Naulleau, *et al.*).

Visible-light interferometry is performed at Lawrence Livermore National Laboratory before and after at-wavelength testing. While excellent agreement has been achieved for isolated and high-spatial-frequency features in the system wavefronts, the low-spatial frequency *figure* aberrations still pose a significant challenge. In general, it is these lowest-spatial frequency aberrations (astigmatism, coma, etc.) that can be controlled during alignment of multi-element optical systems, and it is these aberrations which are the most difficult to measure accurately.

We will present EUV wavefront measurements of the ETS Set-2 projection optic across the field of view of the optical system, and discuss the most recent comparisons of EUV and visible-light interferometry.

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