# Characterization of Phase Effects Due to Multilayer Coatings in a Two-Mirror Schwarzschild Imaging Objective

E. Tejnil[a,b], K. A. Goldberg[a,c], J. Bokor[a,b]

(a) Center for X-ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA 94720
(b) EECS Department, University of California, Berkeley, CA 94720
(c) Physics Department, University of California, Berkeley, CA 94720

A phase-shifting point diffraction interferometer for testing of extreme ultraviolet (EUV) optical systems has been implemented at the Advanced Light Source at Lawrence Berkeley National Laboratory. The interferometer has been used to evaluate the wavefront aberrations in a reflective, 10X-demagnification, multilayer-coated, Schwarzschild objective at wavelengths near 13 nm [1]. The EUV wavefront in this system is influenced not only by the physical geometry of the mirror surfaces but by angle-dependent phase shifts in the multilayer coatings [2]. Owing to the fact that, upon a change in wavelength, the contribution to the wavefront aberrations from multilayer phase shifts change whereas those due to purely geometric errors do not, multilayer effects can be observed directly via wavefront measurements over a range of wavelengths.

We report here on the measurements of the wavelength-dependent multilayer coating effects in a two-mirror Schwarzschild objective with point diffraction interferometry. The chromatic aberrations in the Schwarzschild optic due to the molybdenum/silicon multilayer reflective coatings are characterized near 13.4-nm wavelength and their effect on image quality is also considered. Furthermore, the measurements of the wavelength-dependent reflectivity and phase of the assembled two-mirror system are compared to calculations based on the ideal optical and multilayer coating designs as well as calculations based on independent measurements of the uniformity of the multilayer period on the individual mirrors [1].

This work was supported by the Semiconductor Research Corporation, DARPA, Intel Corp., and the Extreme Ultraviolet LLC.

[1] E. Tejnil, K. A. Goldberg, S. H. Lee, H. Medecki, P. J. Batson, P.E. Denham, A. A. MacDowell, J. Bokor, D. T. Attwood, "At-wavelength interferometry for extreme ultraviolet lithography", Journal of Vacuum Science and Technology B, 15 (6), 1997, in press.

[2] J. H. Underwood, "Reflecting multilayer coatings for EUV projection lithography", OSA Trends in Optics and Photonics Volume on Extreme Ultraviolet Lithography, vol. 4, edited by G. D. Kubiak and D. R. Kania, (Optical Society of America, Washington, DC 1996), pp. 162-166.

[3] D. L. Windt and W. K. Waskiewicz, "Multilayer facilities required for extreme-ultraviolet lithography", Journal of Vacuum Science and Technology B, vol. 12 (6), pp. 3826-32, 1994.