PhotonMEADOW2023

Contribution ID: **6** Type: **Poster**

Soft X-ray wavefront sensing at an ellipsoidal mirror in the lab

We report on a fast and reliable method for wavefront sensing in the soft X-ray domain, developed for the characterization of rotationally symmetric optical elements, like an ellipsoidal mirror shell. In our laboratory setup, the mirror sample is irradiated by an electron-excited (4.4 keV), micron-sized ($\approx 2\,\mu$m) fluorescence source (Carbon K_α, 277 eV). The near-focal, 3-D intensity distribution $I(\vec{r})$ is recorded by a CCD camera (512×512 pixels à $13.5\,\mu$m) at multiple positions along the optical axis, displaced by $(20 - 25)\,\%$ from the focus. The transport-of-intensity equation is interpreted in a geometrical sense from plane to plane and implemented as a ray tracing code in Mathematica^{TM} / Optica^{TM}, to retrieve the phase $\phi(\vec{r})$ from the radial intensity gradient on a sub-pixel scale. 15 intra-focal CCD image pairs are evaluated in this way and averaged to an annular 2-D map of the wavefront error. In units of the test wavelength (C K_α), we find $\sigma = \pm 47\,\lambda$ (rms) and a P-V of $\pm 118\,\lambda$. The wavefront can be used in a threefold purpose: First, the focus is predicted with a result of $48.3\,\mu$m (rms), in reasonable agreement with the direct experimental observation of $55.3\,\mu$m (FWHM). Secondly, the combined figure and alignment error of the ellipsoid is reconstructed – and again, the statistical mean of ± 9.4 arcsec (rms) roughly coincides with independent estimations from the measured focal intensity distribution (± 11.8 arcsec). At last, a diffractive wavefront corrector may be computed and fabricated, for wavelength-dispersive spectroscopy with high efficiency and optimized resolution.

Journal of Synchrotron Radiation Special Issue: will you submit your contribution?

yes

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Session Classification: Poster Session