A new generation of aberration minimized soft X-ray mirrors and diffraction gratings

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Diffractive wavefront correction (DWC) of mirror-based spectrometers is, rather than the refractive approach, suitable for the XUV and soft X-ray range. Form and figure errors of the collecting mirror with its toroidal profile are measured *ex situ* or *in situ*.

In the 1st case, a newly developed method uses a differential interferometer (SIOS SP-DIS) that enables 3D mapping with 0.1 nm resolution: The mirror under test and a reference mirror are statically fixed in the setup. The interferometer is moved in a *x*-*y* scan while it detects the *z*-distance variations between the mirrors. By subtracting the form deviations of the reference, the *z*-topography of the mirror under test is determined. *Z*-motion errors of the scanning stage do not affect the measurements. The interferometer beam is focused with a convex lens onto the mirror under test. Hence, in contrast to Fizeau setups, also curved and sloped mirrors can be measured without the need for expensive spherical reference optics. Focusing enables a lateral resolution of ~ 10 µm. Amongst others, a spherical mirror with a radius of $R \sim 29$ m was investigated (Fig. 1) with a repeatability of the *z*-topography of < 2 nm at specific *x*-*y* locations.

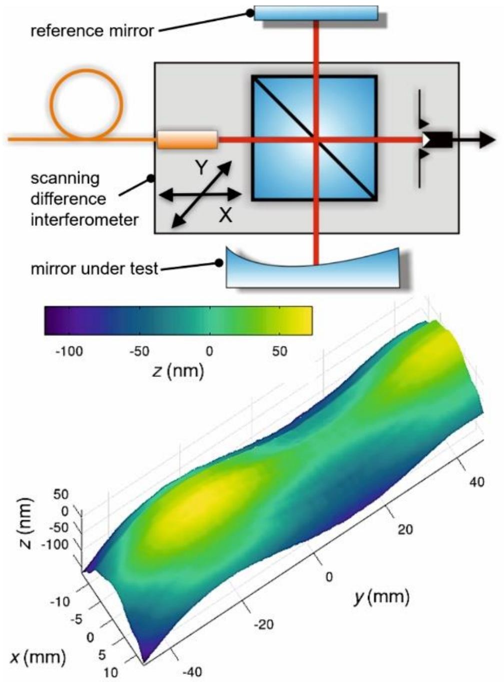

Fig. 1: Upper sketch: Measurement of curved mirrors. Bottom plot: Figure error of the mirror under test after subtraction of the fitted sphere.

The 2nd option retrieves the physical height distribution via phase reconstruction from the detected X-ray wavefront. Its shape is subsequently converted into the Fresnel groove structure of the customized DWC device, an irregular 2D varied line space grating on a planar or curved substrate. Depending on the configuration, various mathematical methods have been developed and applied to calculate this generalized reflection zone plate. The computation is performed by a reliable algorithm, e.g. as a fast Python routine. Figure 2 shows an example. The DWC not only compensates for aberrations to a far extent, but also provides dispersion to be used in spectroscopy. For highest sensitivity, the DWC grating may be integrated into the erroneous collecting mirror to an all-in-one component. Simulations promise the potential to almost diffraction-limited focusing and a resolving power E / ΔE up to 4.1×10^4 near 0.5 keV for our laboratory experiment at IAP e.V. Initial evaluations of real mirror profiles with R < 4 m and DWC samples fabricated by 3D laser writing demonstrate the practical feasibility of our ideas.

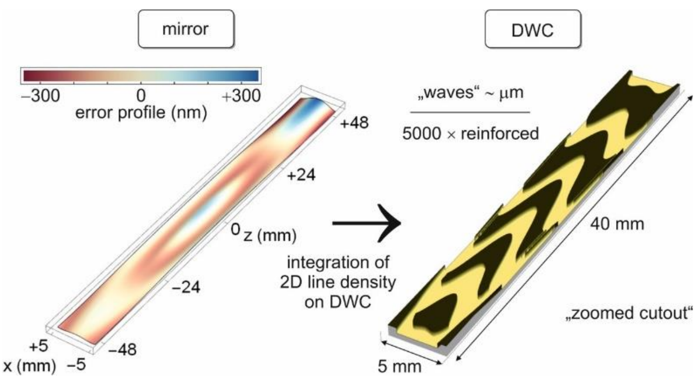

Fig. 2: Wavefront correction of a mirror‘s form and figure error (left) via 2D integration of the line density on the DWC substrate (right). The wavy structure of the grating is exaggerated for presentation purposes.