Fabrication of freeform mirrors: metrology and figuring

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Carl Zeiss has a long-lasting expertise in the field of optical manufacturing and material processing for reflecting and refracting optical systems [1][2]. In particular optical mirrors of various geometries ranging from small flats to large freeform mirrors are subject to the extensive research and development activities. Exceedingly stringent specifications are placed on the optical components used in these newly designed systems. Extremely high heat loads demand cooling of these optics and thus material with high heat conductivity and low thermal expansion. The increased quality of radiation sources calls for higher-quality optics: Typical requirements are slope errors significantly below 1 arcsec for aspheric elements and below 0.1 arcsec for flats or spheres. Carl Zeiss uses state-of-the-art tooling and metrology devices in order to serve his customers with highest quality optical devices made from a wide range of substrate and coating materials. In order to achieve the desired surface quality, a very close interaction between metrology and polishing is mandatory.

Testing and manufacturing are complementary tools for fabrication of highly defined optical surfaces. Carl Zeiss has available metrology devices to cover the entire spatial error range from several nm to above 1 m. Full aperture interferometry is best suited for plane and spherical surfaces with dimensions below 12". Therefore 3D profilometry steps into focus when it comes to large complex surfaces. For this purpose Carl Zeiss has developed its 3D ultrahigh-resolution coordinate measuring machine M400. This device is able to measure surfaces up to 550 mm with a resolution < 10 nm.

Interferometric metrology devices are not stricly limited to plane or spherical surfaces. Cylindrical or weak freeform aspheres can be well measured by interferometric setups. One brief example is given below (see fig. 1). It shows the capability of measuring a cylindrical specimen of 70x70 mm^2 optical surface and a cylinder radius of about 2 m. In order to record the large radius with a limited table setup a combined CGH and reference mirror setup has been used. This setup however needs careful calibration of the optical system errors from the reference mirror and CGH. Note the agreement of measurements in the order of few nm that indicates the proper system calibration in this example. Since interferometric metrology (compared to scanning profilers) is an instantaneous method the value for the application of given technique to active optics is straightforward. Even time resolved measurements of optical manipulators for dynamic and drift measurements are feasible.

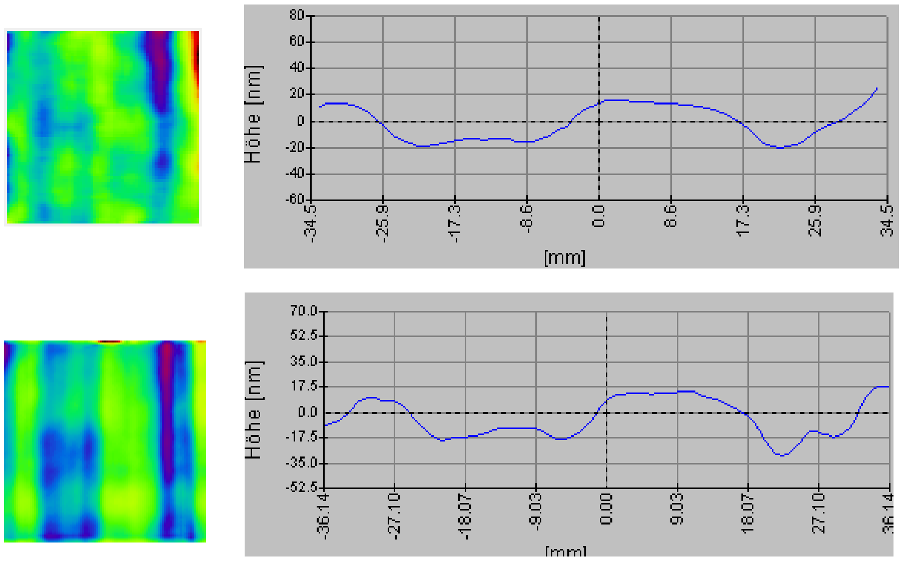

Fig.1: Comparison of tactile and interferometric measurements of a cylindrical optical surface. Quasi intererogram (top) from multi profile scan and intererogram (bottom) are shown. Note the good agreement in the order of few nm.

Future applications such as FEL and 3rd generation diffraction limited synchrotron sources implie further improvement of the achievable quality. New challenges concern the fabrication with advanced specifications of residuals for slope (< 0.05" rms) and pitch (< 0.5 nm rms) that are increasingly out of reach without proper interferometric methods. However the process technology for the manufacturing of surfaces in given precision range cannot be achieved without close cooperation with our customers.

References

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