Abstract for the upcoming ASPE/ASPEN Summer Topical Meeting

In Conjunction with
The Optical Society (OSA) Optical Fabrication and Testing (OF&T) Topical Meeting and Classical Optics Congress

Manufacture and Metrology of Freeform and Off-Axis Aspheric Surfaces

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Kohala Coast, Hawaii 96743
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Conference committee: W. B. Lee, The Hong Kong Polytechnic University
Jeffrey W. Roblee, AMETEK - Precitech, Inc.
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Title of the paper to be submitted:

FIGURE CORRECTION OF FREEFORM MIRRORS WITH WELL-DEFINED REFERENCE STRUCTURES BY MRF

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*Manufacture and Metrology of Freeform and Off-Axis Aspheric Surfaces*

Short abstract (500 words):

The outstanding improvements that can be achieved by incorporating aspheric and freeform shaped mirrors into today’s high-end optical systems, e.g. for space and ground-based optical astronomy, require for fast and deterministic manufacturing and metrology approaches. Especially high-precision metrology during iterative polishing and the integration of freeforms into an optical system are time consuming, expensive and error-prone tasks in the overall process chain. Reference elements located outside of the clear aperture on an optical surface are mandatory to describe and detect the optical coordinate system of a complex geometry during metrology or system integration.

During the last years of research, a sophisticated process chain for all-metal reflective telescopes incorporating a snap-together system assembly based on ultra-precisely manufactured reference elements was successfully developed at Fraunhofer IOF Jena. The process chain is based on diamond machining as a highly deterministic manufacturing approach for aspheric and freeform single mirrors or even combinations of various optical surfaces on a common substrate. Mirrors with low figure deviations and high accuracy mounting interfaces can be fabricated in relatively short manufacturing times. However, the remaining turning structure generates unintended diffraction and scattering effects that limit diamond machined surfaces to operations in the infrared. Multi- and hyperspectral imaging telescopes, remote sensing instruments or spectrometer optics working at shorter wavelengths require for smoother surfaces and improved figure. In order to close the “spectral gap”, Magnetorheological Finishing (MRF) is intended for sub-aperture figuring and smoothing of the diamond machined optics.

The paper demonstrates the application of MRF to a diamond machined aluminum freeform mirror plated with electroless nickel as a polishing layer. The mirror exhibits different reference elements for profilometry and interferometry using Computer Generated Holograms with additional alignment features. Both metrology approaches allow for a high precision measurement of the optical freeform with respect to the generated reference elements. According to the measured shape deviation, the mirror’s figure is corrected by MRF to well below λ/100 rms (@ 633 nm) without affecting the reference elements on the optical surface. A discussion about influence of metrology and machining, e.g. residual mid-spatial frequencies, will highlight the major characteristics of the process chain. In the second part, a more detailed research of the role of reference elements as discontinuous surface features during polishing by MRF will be described. The shape of the diamond milled reference spheres is essential for freeform metrology and should not be degraded by sub-aperture figuring. Evaluation of the experimental data shows that a certain ratio between aperture and radius of curvature of the reference elements helps to maintain the shape accuracy during material removal by sub-aperture polishing.

The article summarizes the individual parts of the process chain, including diamond turning and milling, freeform metrology and sub-aperture figuring and gives an outlook for the application of high precise metal mirrors for snap-together VIS telescopes.