Freeform metal optics for New Space applications

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The global trend of the space industry towards the introduction of small satellite constellations, both for communication and observation purposes, strongly affects the design and realization of the optical instruments used for these applications. As the whole satellite manufacturing supply chain is facing enormous challenges in terms of lead time, costs, and miniaturization, also the optical subsystems involved must comply with these issues.

Space-grade optical systems based on an all-metallic approach could become a key solution to address this scaling problem. Metal optics can be fabricated both at comparable low costs, short lead times, and in increased quantities based on servo-assisted diamond turning technologies. In combination with appropriate system designs, a series production of e.g. freeform based all-mirror telescopes for optical communication or observation from small satellites or even cubesats becomes feasible.[1]

The Fraunhofer spin-off SPACEOPTIX GmbH has been founded to satisfy the demand of space companies and system integrators towards high-quality, compact, and space-grade optical systems in industrial quantities. This presentation will give an overview on the impacts and interactions between both demanding economical and technical challenges today's optical systems must fulfill. We will highlight on some specific solutions using freeform surfaces to reduce volume or enhance a specific imaging function of the optical system.[2, 3]

Fig. 1: Off-axis and light-weighted aspherical mirrors

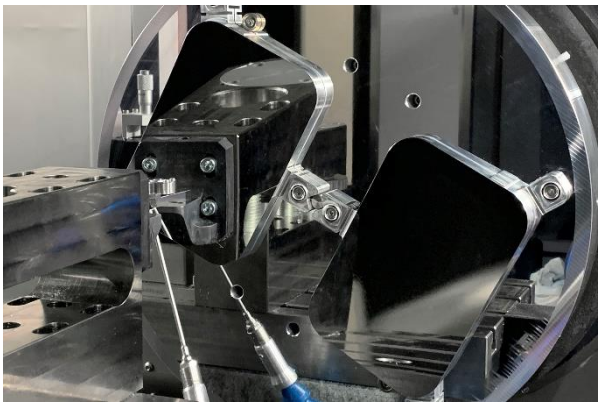

Fig. 2: Diamond turning of two aluminum mirrors.

Moreover, we will showcase the use of different metallic alloys and metal matrix composites to tune the thermal behavior of the system and to achieve an overall athermal function under thermal loads. Especially metal matrix composite materials pose severe challenges on the rapid and reliable manufacturing to enable long-term stable metallic mirror substrates. A few machining examples as well as influences coming from the production process will be highlighted.

Finally, the freeform machining approach for multi-surface telescope mirrors will be shown. It allows to directly combine two or more optical surfaces on a monolithic substrate. Relative position and alignment errors can be reduced to the precision of the ultra-precision manufacturing machine used. Therefore, a cost-effective and precise machining and system integration of metal mirror based telescopes for satellite constellation optics becomes feasible.

1. A. Zuccaro Marchi et al., "Technologies and designs for small optical missions", Proc. SPIE **11180**, pp. 111801Z-1–111801Z-10, 2018
2. M. Beier et al., "Development, fabrication, and testing of an anamorphic imaging snap-together freeform telescope", Applied Optics **54**, pp. 3530–3542, 2015
3. T. Peschel et al., "Integration and testing of an imaging spectrometer for Earth observation", Proc. SPIE **11180**, pp. 1118000O-1–1118000O-7, 2018