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HIGH-PERFORMANCE MIRROR FOR SPACE APPLICATIONS USING ANODIC BONDING TECHNOLOGY

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I. INTRODUCTION

Berliner Glas developed and manufactured the plane elliptical shaped mirrors for the Synopta Coarse Pointing Assembly (CPA) being one of the key elements of the TESAT Spacecom Laser Communication Terminals (LCT's). The first TESAT LCT containing a Synopta CPA was embarked on Sentinel 1A and is in orbit since April 2014. TESAT Spacecom LCT's have been successfully tested in space since 2007 and are now operationally used in commercial satellite communication systems [1]

II. COARSE POINTING ASSEMBLY (CPA)

The CPA is the actuator that directs the LCT line-of-sight towards a counter terminal that is located, e.g., on another satellite or at a ground station. Fig. 1 shows the CPA. This specific model is now part of the LCT embarked on ESA's Sentinel-1A satellite.

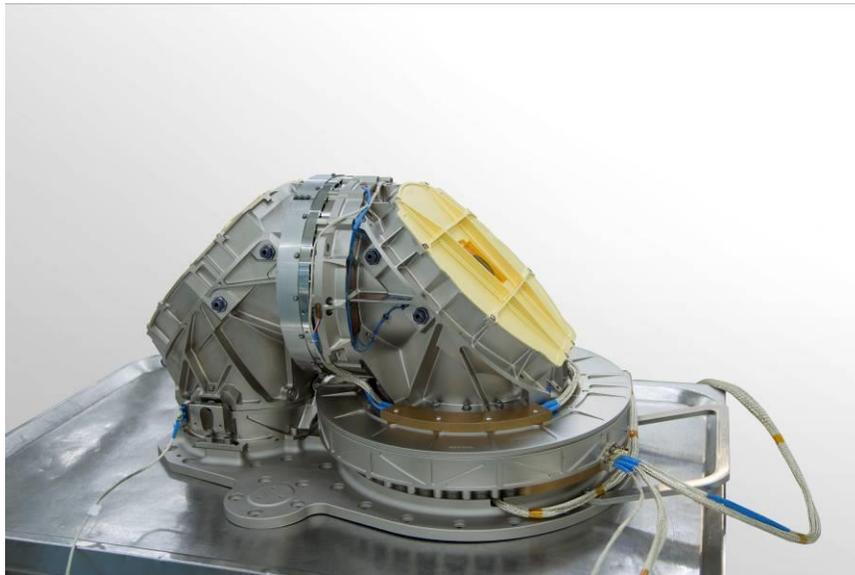


Fig.1. Synopta Coarse Pointing Assembly (CPA)

The CPA is based on a coelostat concept and comprises two mirrors that can be rotated around the mechanism's azimuth and elevation axes. Therefore, the CPA can cover any point in the hemisphere around the LCT. Driven by the needs of the application, the CPA mirrors have to fulfil several stringent requirements:

- Minimum mass at given optical aperture
- High Eigenfrequency
- Demanding optical performance requirements: Surface error, reflectivity in two wavelength ranges, solar absorption, polarisation properties, stray light
- Compliance to challenging mechanical loads, thermal loads, and radiation environment
- Lifetime

III. DESIGN AND PERFORMANCE OF THE CPA MIRROR

To fulfil the very challenging requirements we developed and manufactured an elliptical shaped plane mirror based on the anodic bonding technology [2],[3]. This technology gives us the opportunity to combine the optical advantages of Borosilicate Glass with the mechanical advantages of SiSiC, in particular the specific stiffness and the high heat conductivity. The optical aperture of the mirror is about 210 mm x 150 mm, the mirror thickness is 20 mm.

The design of the mirror is shown in Fig. 2. Two identical light weighted structures of Si infiltrated SiC are bonded with three thin layer of borofloat glass such that the design is symmetric to the BF-layer in the middle.

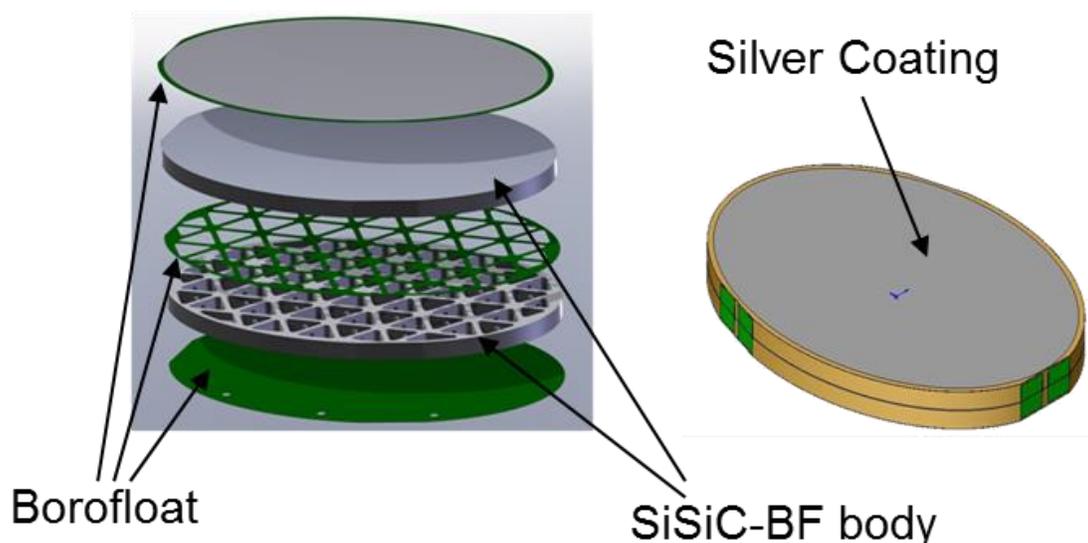


Fig. 2. Design of the CPA Mirror

A very important advantage of this technology and design is the closed light weighted structure. This gives us the possibility to realize a very stiff construction with high Eigenfrequencies. We achieved a mass reduction of about 50% to a total weight of 0,8 kg. The first Eigenfrequency of this design is higher than 3'950 Hz. The overall stress level in all components is low and the reserve is high.

Also the analysis of the thermal loads show a small impact to the stress levels between the layers, because of the thin BF-layers and the good thermal conductivity of SiSiC. All this effects are small in comparison to the specified values.

The symmetric design avoids the bi-metal effect caused by the CTE-difference of the two materials. Of course, to realize the compensation the tolerances of the layer thicknesses have to be adequate.

The top-layer of Borosilicate Glass also gives us the possibility to use well known polishing processes resulting in a very good flatness of the optical surface and a very low roughness (Fig. 3). The design is compliant to a large variety of optical coatings.

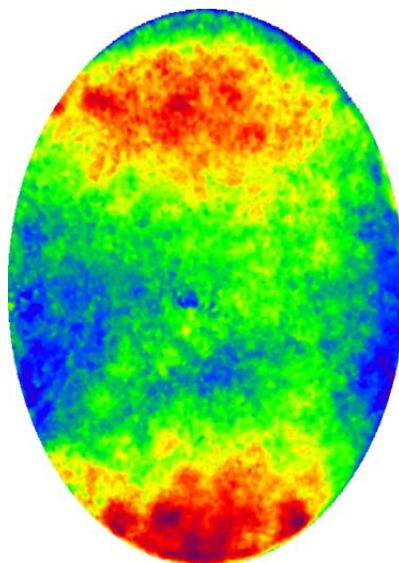


Fig. 3. Typical interferometric surface map of the CPA Mirror after polishing, PV < 10 nm, RMS < 1.5 nm, no print through effect, Roughness < 0.6 nm RMS.

IV. COATING

This key feature is driven by several challenges (e.g. solar absorption, stray light, reflectivity in two wavelength ranges, no change in polarization, resistance to different environments, no degradation over lifetime). The use of silver as a main component is state of the art and assures a reflection higher than 98%. But a simple silver coating would degrade very rapidly in space environment. Hence, additional layers of different materials had to be used.

Communication of the LCT is based on circular polarized light. So, the state of polarization of the incoming beam shouldn't be changed by the reflection. The PER (Polarization Extinction Ratio) has to be kept below - 23dB. To achieve this, the layer thickness accuracies must be better than 1%, including thickness deviations. Before applying the coating the whole CPA body has to be finished including surface flatness and roughness. To keep the quality constant after coating, the layer parameters like stress and substrate temperature at the coating process have to be monitored precisely. Also the backside of the mirror is coated.

V. MOUNTING WITHIN CPA: MIRROR SUPPORT

The mirror support principle, which has been developed for this CPA differs significantly from traditional designs, as can be seen in Fig. 4.

In the new CPA design the mirrors are mounted directly with the mirror suspension system to the CPA main structure, i.e. housing, and not, as usually done, at the cover of the structure. Thus, the load paths become significantly shorter and it is not necessary to have a stable back cover with tight interface tolerances (red marked).

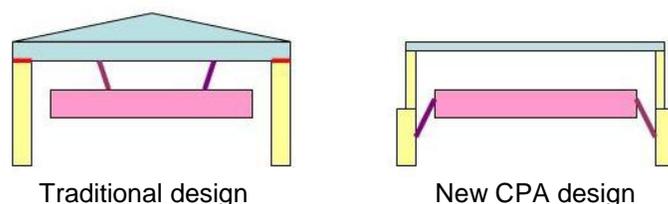


Fig. 4. CPA mirror support design principles

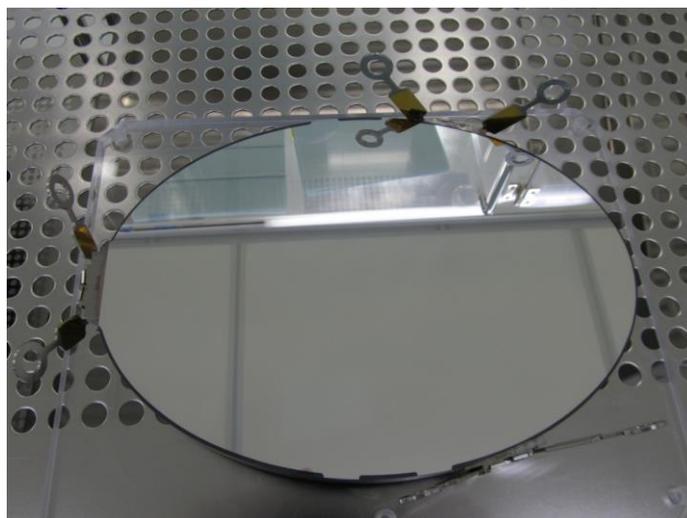


Fig. 5. CPA mirror including support legs

The CPA mirror suspension system consists of isostatic hexapod mounts. The hexapod bi-pods are manufactured from a high strength titanium alloy. In this way, these mirror supports can be made rather slim and flexible, due to the high yield strength of the selected material. As a consequence, the mirror support structure can survive the launch loads without degrading the surface error of the mirror. In fact, CPA wavefront errors below 10 nm rms have been demonstrated after final integration of both mirrors into the CPA. Fig. 5 shows an actual flight mirror with attached hexapod legs.

Metallic wedges are used between the mirror and hexapod legs to ensure a correct orientation of the hexapod legs in 3-D space. The wedges are manufactured from a material with matched thermal expansion coefficient to the mirror substrate material. Attachment of wedges to the mirror as well as wedges to hexapod legs is realized by qualified adhesive bonding processes.

During mirror integration into the CPA housing the mirror can be fine adjusted via eccentric bushings located at the hexapod leg end which is used for mirror fixation to the CPA housing. This feature enables a very fine tilting of the mirrors during integration and a high stiffness of the connections after final fixation.

ACKNOWLEDGEMENT

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