Lightweight ZERODUR®: Validation of mirror performance and mirror modeling predictions

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ABSTRACT

1. Upcoming spaceborne missions, both moderate and large in scale, require extreme dimensional stability while relying both upon established lightweight mirror materials, and also upon accurate modeling methods to predict performance under varying boundary conditions.
2. We describe tests, recently performed at NASA’s XRCF chambers and laboratories in Huntsville Alabama, during which a 1.2m diameter, f/1.29 88% lightweighted SCHOTT lightweighted ZERODUR® mirror was tested for thermal stability under static loads in steps down to 230K.
3. Test results are compared to model predictions, based upon recently published data on ZERODUR®. In addition to monitoring the mirror surface for thermal perturbations in XRCF Thermal Vacuum tests, static load gravity deformations have been measured and compared to model predictions. Also the Modal Response (dynamic disturbance) was measured and compared to model.
4. We will discuss the fabrication approach and optomechanical design of the ZERODUR® mirror substrate by SCHOTT, its optical preparation for test by Arizona Optical Systems (AOS), and
5. Summarize the outcome of NASA’s XRCF tests and model validations

UPCOMING SPACE MISSIONS

Both monolithic and segmented architectures are being considered for large future space missions. While segmented mirror approaches will reference The Webb Telescope architecture, diffraction limited at λ2μm , the requirements will be much more refined for wavefront error, especially error stability over time. For exoearth imaging with large telescopes, stability at the level of 10 picometers over 10 minutes is anticipated. Even for smaller telescopes, coronagraphy and ultraviolet scence will require stability of WFE one to two orders of magnitude better than The Webb Telescope. We discuss evaluation of ZERODUR® thermal stability and the ability to model expected WFE performance of a representative lightweight ZERODUR® mirror made by SCHOTT under rigorous thermal vacuum tests at XRCF.

Modeling the Schott ELZM Thermal Soak Test

XRCF Tests

- While there may appear to be a weak linear trend, it is small compared with systematic errors. The main error is astigmatism.
- After subtraction of the first 36 Zernikes, most remaining artifacts seem to associate with the mounting points, and difficult to separate between mounting and mirror itself.
- The mount is very repeatable at ambient, but it was designed under restrictive cost constraints, and thus is neither fully athermal, nor optimized against thermal gradients.

Conclusion:

- A 5 ppb/K peak-to-valley inhomogeneity produced 9.55nm RMS of SFE and a root-sum-squared SFE estimate of 9.6nm RMS.
- Zerodur boules have been measured to have a 5 ppb/K peak-to-valley CTE inhomogeneity, therefore, 5ppb/K peak-to-valley inhomogeneity is reasonable.
- Further investigation will match test results to an even greater extend.

Conclusions:

The SCHOTT 1.2m ELZM mirror was measured for optical figure variation in thermal-vacuum in the large XRCF chamber at MSFC. The intent is to see if bulk ZERODUR® properties are maintained on a mirror blank with machined lightweighting leaving sections as thin as 2mm.

Temperature dependent of surface errors is consistent with the latest values of extensive CTE homogeneity tests at SCHOTT [Jedamzik, et al. 2016]

Measurements are consistent with a set of MSFC models assuming a ZERODUR® inhomogeneity magnitude of 5 ppb/K.

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Visit the SCHOTT AAS display and see the tested 1.2m ELZM mirror