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VIBRATION AND SHOCK TESTING OF A 50MM APERTURE UNIMORPH DEFORMABLE MIRROR

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Abstract

In recent years, different deformable mirror technologies have been identified, developed and evaluated for aberration correction in space telescopes. We present our latest results on a refined unimorph deformable mirror. The isostatic mounting design allows for unhindered actuation of the mirror while withstanding launch loads and is capable of coping with residual CTE mismatch. This makes the mirror a versatile tool for space telescopes.

Mirror specifications:

- 17.8 gRMS random vibration
- 20 g sine vibration
- 300 g SRS shock testing
- Ø 50 mm correction aperture

Mirror Design

Isostatic mirror design

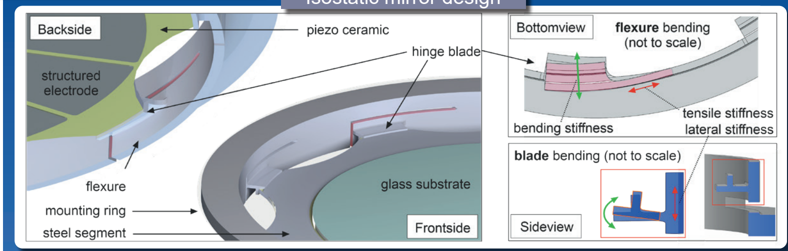

Fig. 1 Mechanical design of the isostatic mirror. The mounting ring features nine bladed flexures. Their tensile and lateral stiffness are several orders of magnitude higher than their bending stiffness. The bladed flexures define the mirror constraints without introducing high stress or bending moments to the piezoceramic.

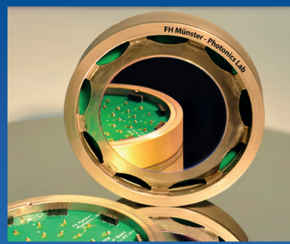

Fig. 3 Photo of the main mirror structure. The circuit board is visible in the foreground. The diameter of the mounting ring is 100 mm. The main mirror structure is then mounted in a housing with a back panel circuit board and an aperture for stray light reduction [1].

Zernike amplitudes

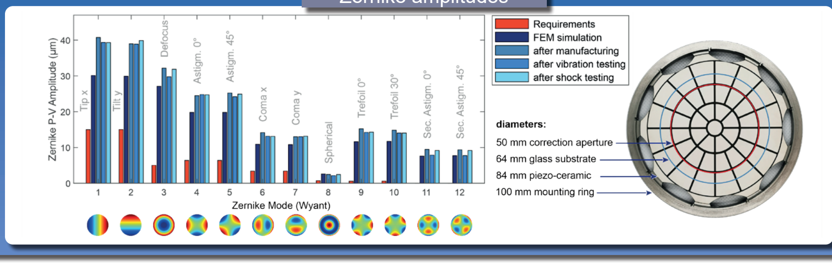

Fig. 2 Zernike amplitudes over the correction aperture of 50 mm after manufacturing, after vibration testing, and after shock testing in comparison to the project requirements as well as FEM simulations. No degradation of the amplitudes is visible. The diameters of the correction apertue, the glass substrate, the piezoceramic, and the mounting ring are indicated. The mirror has 41 actuators.

Passive Electric Shunting

Vibration damping of acoustic excitation

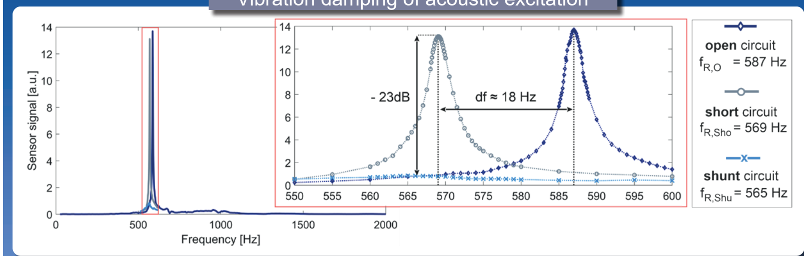

Fig. 4 The piezoelectric shunt damping technique is based on the electrical to mechanical coupling of piezoelectric materials. The passive shunt circuit dissipates electrical energy that is generated by the piezoelectric element during vibrational excitation. Previous studies have already presented the successful application of this technique to suppress vibration modes of unimorph mirrors [2]. One benefit of using shunted piezoceramics to damp mechanical systems is that it needs no sensors or advanced control systems. This reduces complexity and minimizes the susceptibility to faults.

The deflection of the mirror at the first resonant mode (570 Hz) under acoustic excitation was reduced by −23 dB.

Environmental Testing

Random vibration testing

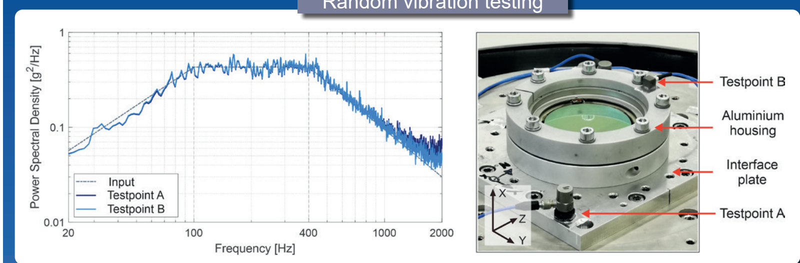

Fig. 5 The random vibration test level of 17.8 gRMS in the range 20 Hz to 2000 Hz was applied for 2 minutes per axis (parallel and perpendicular to the mirror surface).
Sine vibration was applied at 20 g (not pictured).
(Tests at ESTEC)

Shock testing

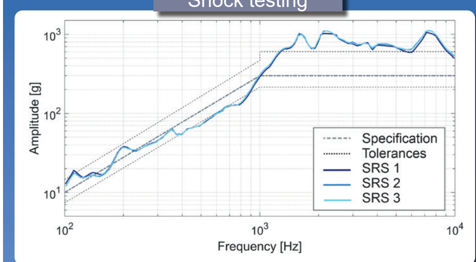

Fig. 6 The shock tests were conducted with a resonsnt plate setup. The shock level was set to 300g. The shock response spectra (SRS) are shown on the left. The tests were successful.
(Tests at KRP Mechatec, Munich)

Summary

Having demonstrated its operability in relevant environment, the unimorph isostatic deformable mirror matured to a technology readiness level five (TRL) 5. Based on the high level of maturity, this mirror is ready for incorporation in future instruments.
The unimorph mirror was extensively tested in a preceeding project **[1][3]**. Operation in thermal vacuum, exposure to ionizing irradiation, operational life time, and laser power handling capability have been tested. In this project, we also built mirrors with hard piezoceramics additionally to the ones with soft piezoceramics (PIC151). Hard piezoceramics have several superior characteristics compared to soft piezo materials, such as less creep and hysteresis and a higher E-modulus. The isostatic mirrors with the hard piezoceramic material PIC181 and PZ26 also sustained all vibration loads. This work was supported by ESA under contract number 4000123009/18/NL/PS.

References

[1] Peter Rausch et al., "Unimorph deformable mirror for space telescopes: design and manufacturing," Opt. Expr. 23, 19469–19477 (2015)
[2] D. Alaluf et al., "Damping of piezoelectric space instruments: application to an active optics deformable mirror," CEAS Space Journal 6(11), 543 – 551 (2019)
[3] Peter Rausch et al., "Unimorph deformable mirror for space telescopes: environmental testing," Opt. Expr. 24, 1528–1542 (2016).

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