Optical characterization of a screen printed actuator deformable mirror

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Purpose

This paper reports on the properties and characterization of a screen printed deformable mirror. This unimorph mirror offers a ceramic substrate with screen printed PZT layers on its back side and a machined copper layer on its front side. The piezoelectric layer has 19 honeycomb shaped electrodes that are activated. We show the mechanical properties of the deformable mirror: actuator influence function and open-loop control of Zernike modes. A second set of experiments reports on the thermal behavior of the mirror for homogeneous loading and laser loading of the mirror.

Methods

We propose a uniform deformable mirror [1] design that is based on multilayered LTCC substrates with screen printed piezoelectric thick film actuators. Hence, in contrast to the established designs, both, LTCC multilayer technology as well as screen printing are industrially established processes which allow for batch production of deformable unimorph mirrors [2,3]. Moreover, the screen printing releases costs from actuator layout. The LTCC substrate technology offers 3D-structuralibility of the mirror substrate that is used to integrate mounting and handling structures. After the manufacturing of the substrate, five more steps are necessary to complete the deformable mirror. In a second step, the thick film actuator structure is applied onto the back side of the substrate by screen printing. In the third manufacturing step, we singularize the mirror from the LTCC wafer by ultrasonic milling and then connect the mirror with its mount. After that, electroplating of front side copper metallization is carried out. In the sixth step, the mirror surface is finished by single point diamond turning (SPDT) of the copper thick film, thus achieving excellent surface quality and high reflectance. The reflective surface might be coated afterwards.

The mounting of the mirror substrate takes place before the application of the thick film metallization and their finishing. The LTCC substrate is fixed on its reinforcements to the mounting. Therefore, we electroplate the copper metallization onto the LTCC substrate and onto the mount to ensure a good heat removal from the mirror. The SPDT flattens the surface while the mirror is already mounted. The mirror mount is attached to a back plate were the Peltier element and heat sink are fixed (cf. Fig.1). Note, the CTE of mirror substrate (LTCC), mount and back plate are thermally very well adapted. The back plate is hinged to the housing. This connection permits a free radial expansion of the mirror mount and back plate that is not suppressed by the housing. The heat dissipation between housing and back plate is also very low. The joint between heat sink, Peltier element and back plate is thermally excellent conducting and mechanically radially decoupled. This set-up ensures well thermal connection between mirror membrane and Peltier element. A weak mechanical coupling arises between mirror and housing, as well as between mirror and Peltier element (heat sink).

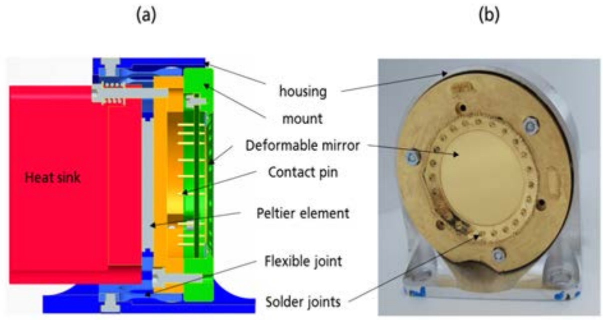

Fig. 1. (a) Cross sectional view of the deformable mirror mount with integrated Peltier element for thermal control of the mirror. (b) Picture of the mounted mirror with applied gold coating.

Results

We measure the individual stroke (actuator influence functions) of the 19 actuators with a wavefront sensor (WFS). The single actuators are ignited with 2 kV/mm and induce a speak-to-valley (PV) deformation of the membrane mirror between 1.4 µm and more than 3.5 µm. The largest stoke was measured in the centre of the mirror at actuators 1 – 7 (cf. Fig 2). The single actuator stroke can be combined to build Zernike polynoms. We will demonstrate the ability of setting different Zernike polynoms of the mirror, e.g. astigmatism, coma spherical aberration and trifoil. A second set of experiments evaluates the mirror response upon homogeneous loading. The mirror is heated in its mount with a Peltier element. The induced temperature change is 30 K between 25°C and more than 50°C. The wavefront sensor measures the mirror surface during thermal loading. We prove that the surface of the deformable mirror changes only with a rate of -0.1 µm/K.

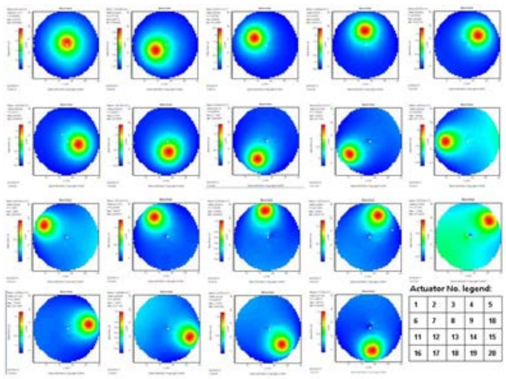

Fig. 2. Measurements of the individual stroke for al actuators measured by WFS.

Conclusions

This contribution gives a first evidence of a deformable mirror based on Low Temperature Cofired Ceramics (LTCC) with screen printed actuators and SPDT electroplated copper as reflective surface. The manufactured mirror has high actuator influence functions that shall result in a good potential of wavefront shaping.

References

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