Thermal-piezoelectric deformable mirror (TPDM) for high power lasers

Claudia Reinlein
Dept. of Precision Engineering
Fraunhofer Institute of Applied Optics and Precision Engineering, IOF
Jena, Germany
Claudia.Reinlein@iof.fraunhofer.de

Abstract—We introduce the 2nd generation TPDM with piezoelectric and thermal actuator functionality. Additionally, TPDM feature buried temperature sensors to enable the control of laser-induced thermal lensing. We will give the results of the characterization of the piezoelectric and thermal actuators including the temporal behavior.

Keywords—TPDM; unimorph deformable mirror; thermal actuators; characterization

I. INTRODUCTION 2ND GENERATION TPDMs

The thermal-piezoelectric deformable mirror (TPDM) is a unimorph deformable mirror with piezoelectric and thermal actuation property. The deformable mirror is based on low-temperature cofired ceramic (LTCC) substrates with piezoelectric actuators and electrical wiring screen-printed onto substrate’s rear surface. Therewith, arbitrary actuator layouts are available and the costs are independent from actuator number. Moreover, thermal actuators are screen-printed on LTCC and buried into the mirror membrane via sintering. Subsequently, the membrane is soldered with its mount and covered with a thick copper layer that is machined to best optical quality and covered with a dielectric coating in order to enable high power applications.

TPDMs that are available with the beginning of 2014 feature 41 piezoelectric actuators, five miniaturized heaters and nine miniaturized thermal sensors integrated in the multi-material set-up. In this way, the radial temperature gradient in the membrane can be measured, the reflected laser power can be estimated, and the miniaturized heater can be controlled.

II. CHARACTERIZATION RESULTS

A. Piezoelectric Actuators

The 41 actuators are arranged in a pie slice setup. Eight actuators are in a circle of 13 mm, 12 actuators are in the annulus between 13 and 23 mm and further eight actuators between 23 and 35 mm. The last actuator fully covers the annulus between 35 and 40 mm. The application of an electric field evokes a characteristic mirror deformation for each set of pie slice types. The eight central actuators induce PtV deformation of 3.16±0.13 µm. The actuator induced deformation remains on a high value of 2.83±0.13 µm for the first annulus, and 2.24±0.23 µm in the outer annulus. The actuator that fully covers the annulus showed a designed PtV deformation of 2.38 µm with magnitude in the opposed direction to the three other piezoelectric actuator types.

B. Thermal Actuators

The thermal actuators rely on heating wires in conjunction with the bi-material effect between LTCC substrate and thick copper finish. We integrate one ring heater and four sectional heater each covering a quarter of the ring heater. The applications of power to the heater evoke a temperature increase in the membrane and their deformation.

Figure 1 shows measurements of the temperature-induced defocus by heating powers between 1 W and more than 60 W. It can be seen, that the coefficient $c_3$ (defocus) decreases quadratically with the heating power. A coefficient of $-9 \mu m$ results in a PtV membrane deformation of 18 µm. This reflects the large actuation capability of the buried thermal actuators. The thermal equilibrium establishes independently from heating power and as detected for laser-loading after several seconds. The thermal actuators will be controlled with the buried temperature sensors of the substrate. Additionally, the incident laser power will be detected and their laser-induced defocus will be automatically compensated for by the thermal actuators.