Deformable Mirrors for High Power Lasers

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Introduction

It has been shown that the beam quality and the efficiency of high-power solid-state lasers could be enhanced by the use of deformable mirrors in order to compensate for optical aberrations. An intracavity compensation requires a deformable mirror which is capable of handling very high laser intensities. The active diameter of the deformable mirror should be a few millimeters in order to match typical fundamental mode laser beam diameters. There is a wide variety of commercially available deformable mirrors, but neither meets all requirements.

Mirror Design

Over the past years we have developed a new type of a unimorph deformable mirror. The approach is innovative in its combination of pre-coated high reflective substrates, the miniaturization of the unimorph principle, and the integration of a monolithic tip-/tilt functionality. The unimorph design should enable a dynamic compensation for low and medium order optical aberrations and has the advantage that it does not suffer from print-through of the actuators because the passive layer equalizes local deformations. Our unimorph mirror is fabricated with a super-polished optical glass substrate. The substrate is furnished with a sputtered dielectric multi-layer coating which yields very high reflectivity of up to 99.998 %, i.e. a residual transmission of below 20 ppm. Figure 1 shows our concept for a mirror with a 10 mm active optical area. The design is based on a laser-cut 3-arm piezoelectric disc. The piezoelectric disc is coated with two metallic electrodes on both sides, an unsegmented ground electrode on the front side and a segmented electrode on the back side. The segmentation of the electrode and the cutting of the piezoelectric ceramic is done by laser ablation with a picosecond laser. In order to provide tip-/tilt actuation, steel segments are bonded onto the three arms. The mirror structure has been optimized by analytical models as well as by finite element calculations.

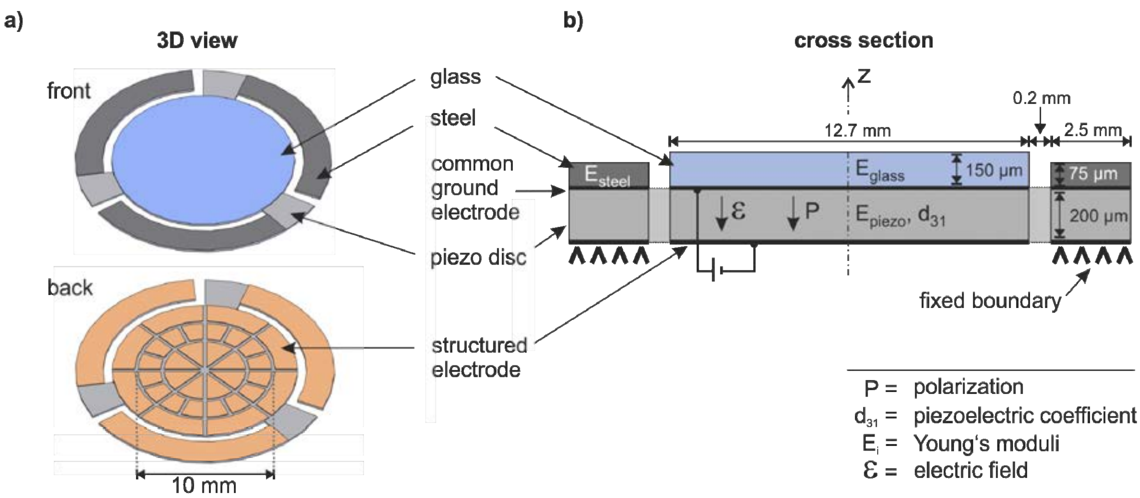

Fig. 1 a) Three-dimensional view of the unimorph structure, b) corresponding cross section

Results and Conclusion

Figure 2 shows the measured influence functions of all electrodes as well as the numerically simulated ones. The measured surface profiles are in very good agreement with our numerical and analytical calculations.

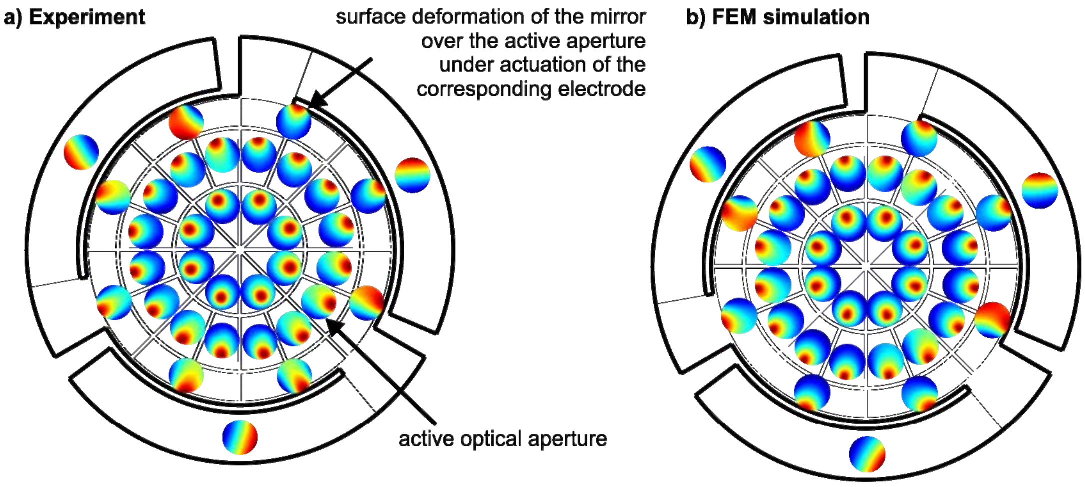

Fig. 2 Influence functions of the mirror electrodes. Shown is the deformation that results if a single electrode is supplied with a voltage of 100 V. The false-color elevation plots representing the mirror deformations are plotted at the position corresponding to the electrode that is being activated.
a) Experimentally measured deformations, b) FEM simulation

Figure 3 shows the achievable Zernike amplitudes of the mirror prototype. The evaluation of the surface deformation has been carried out across the central 10 mm active diameter.

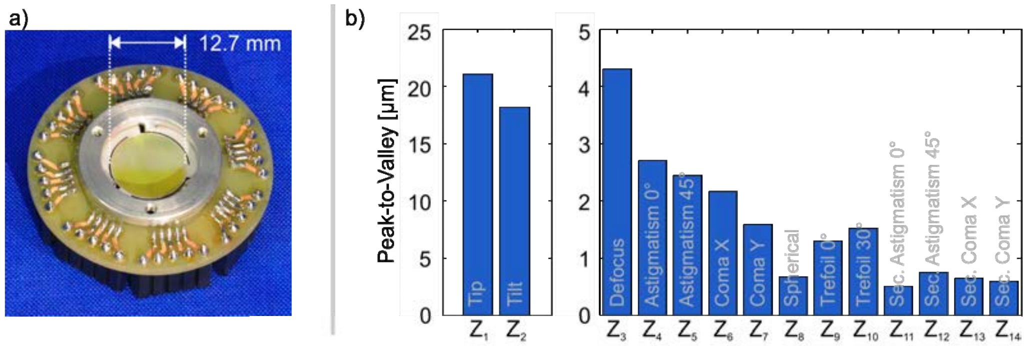

Fig. 3 a) Prototype mirror, b) Experimentally measured peak-to-valley Zernike amplitudes

We present a new concept for a unimorph deformable mirror that has the potential to be used in high-power laser resonators. The main advantages of this mirror technology are

- very low surface scattering due to the use of super-polished glass
- excellent coatings, even suitable for high power lasers
- active diameter of the mirrors of only 10 mm
- large strokes can be achieved even for small mirror diameters
- integrated monolithic tip/tilt functionality based on a spiral arm design

References

1. S. Verpoort and U. Wittrock, "Novel unimorph deformable mirror with monolithic tip-tilt functionality for solid state lasers," MEMS Adaptive Optics V (part of Photonics West 2011), Proc. SPIE **7931**, 7931-6 (2011).