# **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).