Stacked-actuator deformable mirror with rigid design made of multilayer piezoceramic combs

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Abstract

To compensate for the wavefront distortions, appeared during propagation of the laser beam through atmosphere usually adaptive optics methods are used. To reduce the technological steps during manufacturing wavefront correctors we propose to produce stacked-actuator deformable mirror (SADM), the most widely used type of wavefront corrector, by using multilayer piezoceramic combs. SADMs allow to compensate for wide range of wavefront distortions. They are distinguished for their large stroke of control elements, high operational speed, the possibility of correction for local aberrations. The SADM with 10x10 actuators placed on the aperture 50x50 mm was developed. The thickness of mirror substrate was 1 mm. The maximal deformation stroke of the SADM was about 4.5 microns under applied voltage +300 V.

Keywords

Adaptive optics, wavefront corrector, stacked-actuator deformable mirror, piezoceramic combs

1. Introduction

During the propagation of the high-power laser beam along optical trace wavefront aberrations are increasing. Main reason of this effect is atmospheric turbulence, which is originated from non-uniformity of the refractive index, that is caused by heating of air masses and ground surface. To compensate for wavefront distortions adaptive optics methods and devices are used [1]. Necessity of correction for wavefront aberrations in laser beams in various scientific or applied tasks (destruction of space debris [2], space communications [3], etc.) has predetermined the investigations in adaptive optics area. The main element of any adaptive optical system is deformable mirror (wavefront corrector). Many types of wavefront correctors were developed: MEMS-mirrors [4], LC-modulators [5], DMD-devices [6], stacked-actuator mirrors [7,8], bimorph mirrors [9,10]. The most suitable kind of mirrors for correction of high-order aberrations changing with high speed are SADMs. However, the manufacture of such a wavefront corrector is very time-consuming.

2. Conventional stacked-actuator deformable mirror

Conventional SADM consists of a thick basement substrate with the glued piezostack columns composed of the set of thin (≈100 μm) monolayer piezoceramic disks sintered with each other. A thin mirror substrate is glued to other end of the piezo actuators. The outer surface of this substrate is deposited with a multilayer dielectric or metal reflecting coating. The scheme of traditional SADM is shown in Fig. 1. Actuators are either simply multilayer piezoceramic stacks, or these stacks in a metal housing, to which springs are mounted for preliminary mechanical loading. Local deformation of the substrate surface occurs due to an increase (or decrease) of the actuator length due to the inverse piezoelectric effect when applying voltage. A high reliability, large stroke, excellent accuracy, high resonant frequencies and flexibility in actuators geometry make SADM the most attractive for use in astronomical telescopes, optical communications, radiation propagation in a turbulent atmosphere,

etc. But traditional SADMs have some shortcomings: high cost, labor-intensive process of manufacturing and large dimensions of the mirror reflecting surface [11].

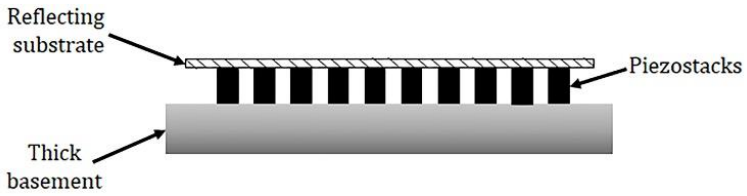

Figure 1: Conventional stacked-actuator deformable mirror

3. New design of the stacked-actuator deformable mirror

To minimize the technological steps, components and time frames, we propose to manufacture SADMs from piezoceramic combs (Fig.2). The upper part of such actuators was made of a few piezoceramic combs. During manufacturing of them, the blank with the length of 24 mm and width of 4 mm was cut in the individual piezoactuators with the size 4*4 mm with the gap between them equal to 1 mm. One comb contains 5 piezoactuators with electrical connection to every part of the comb. By combining on the rigid base made of piezoceramic material such combs we can assemble SADM with desirable configuration of actuators. In our case we chose the net of 10*10 actuators. On the next step the thin mirror substrate with thickness 1 mm was glued on the top of the actuators. The aperture of such mirror was 50x50 mm and it included the matrix of 10x10 actuators. The maximal measured local deformation of such a wavefront corrector was close to 4.5 microns.

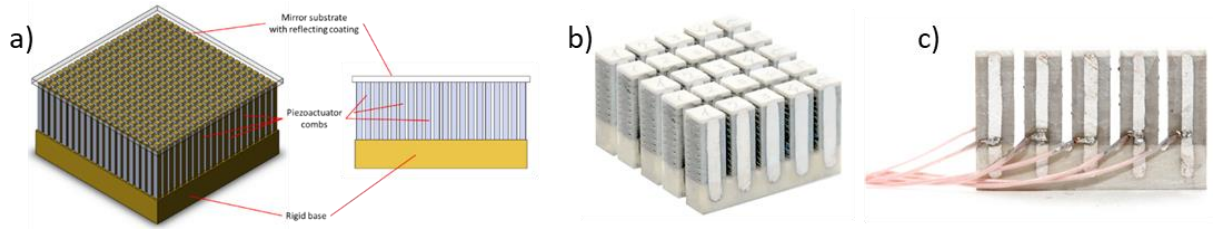

Figure 2: SADM with multilayer piezoceramic combs: a) concept of SADM, b) piezoceramic combs with multilayer actuators, c) electric connection

4. Conclusion

We developed SADM with 10x10 actuators that could compensate for wavefront aberrations up to 4.5 microns. Applied voltages for manufactured wavefront corrector are in the range from -50 to +300 V. Such wavefront correctors could be used in different scientific realms, mainly in transferring laser energy through distance due to rigid design and simplicity of construction.

5. Acknowledgements

The work was supported by Russian Scientific Foundation under grants #19-19-00706 and #20-19-00597.

6. References

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