DYNAMICAL CHARACTERISTICS OF A SEGMENTED PHASE-FRONT CORRECTOR FOR ADAPTIVE OPTICS SYSTEMS

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This paper reports on the results of experimental studies concerning the dynamical characteristics of a segmented phase-front correctors. We obtain values for the resonant frequencies when correcting for tilt and zero-order phase distortions. We study the characteristics of piezoelectric actuators based on the PKR-6 ceramic. We show that such actuators can be used to create adaptive optical systems with maximum test-signal frequencies as high as 60 kHz.

Controlling an optical wavefront in order to remove the nonstationary phase distortions, which arise as it propagates through the optically inhomogeneous medium, is accomplished by an adaptive optical system utilizing various servomechanisms. Interest in the design of such servomechanisms has grown significantly in recent years. For example. Vorontsov, et al.[1] and Kudryashov, et al.[2] have studied the characteristics of bimorphous piezoelectric mirrors, and Apollonov, et al.,[3] have studied a membrane mirror.

Despite the fact that phase-front correctors with a smoothly deformable surface enable one to obtain a better approximation for the distorted phase front, they are not without their disadvantages. For example, Bezuglov[4] has shown that the crosstalk which occurs in correctors with a smoothly deformable surface reduces the speed of adaptive optical systems. In general, it is not possible to fully compensate for this effect.

This paper is devoted to a study of the dynamical characteristics of a segmented phase-front corrector designed for use as a part of an adaptive optical system. Piezoelectric actuators based on PKR-6 piezoelectric ceramic[5] were used as the active elements in the corrector. These actuators were rods of X-shaped cross section (6.5×6.5 mm) 47 mm in length. The reflecting surface was made up of 7 mm-thick silver—coated segments of optical glass 20×20 mm in size. The segments were glued to the actuators with epoxy resin. The actuators were also glued in turn to an optical-glass base 30 mm thick using epoxy resin. The external appearance of the corrector is shown in Fig. 1. A total of 21 actuators are used to correct for the zero-phase distortions (shifts). Three additional actuators 5 (Fig. 1) glued to base 6 are used to correct for overall tilt.

The dynamic characteristics of the correctors were studied using the experimental setup shown In Fig. 2.

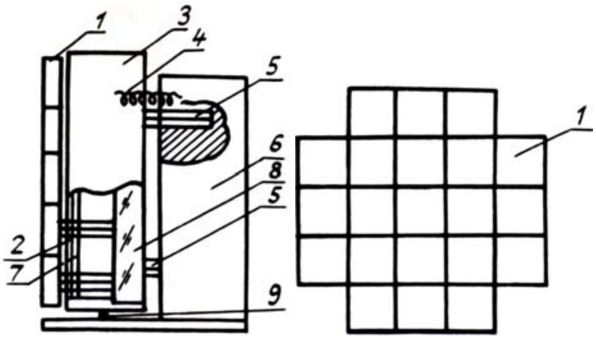

FIG. 1. Exterior view of segmented corrector: 1) front-silvered 20×20 mm *glass subaperture; 2) piezoelectric actuators; 3) housing; 4) spring; 5) piezoelectric actuators for controlling overall tilt; 6) base; 7) printed circuit with power leads; 8) glass substrate; 9) spherical support.*

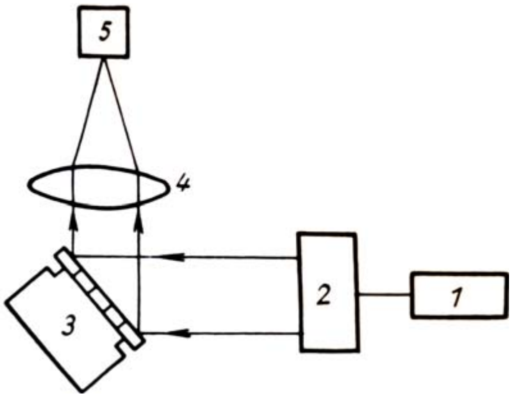

FIG. 2. Block diagram experimental setup. 1) LGN-106 laser; 2) collimator; 3) adaptive phase; 4) lens; 5) point photodetector.

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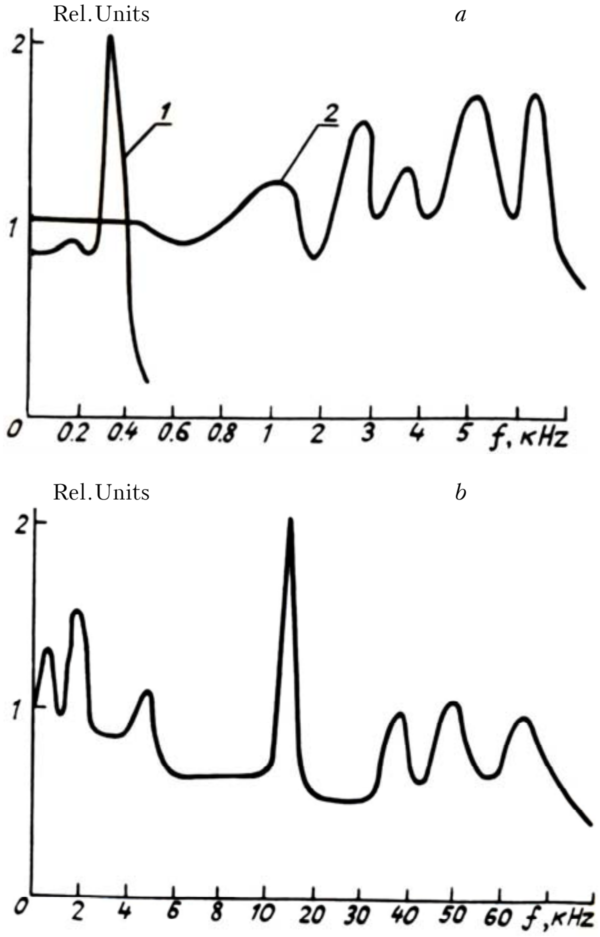

FIG. 3. Dynamical characteristics: (a) adaptive corrector (1 — tilt channel; 2 — characteristic of segment alone); (b) piezoelectric ceramic PKR-6 actuator.

The beam from an LGN-105 laser was collimated and focused on a point photodetector after reflection from the segmented mirror. A normalized control signal $U_{in} = 20$ V was fed to actuators from the output of an audio-frequency oscillator. The dynamical characteristics of the correctors are shown in Figs. 3a and 3b. A mechanical resonance of the system corresponding to a tilt was observed at 350 Hz. The mirror segment alone showed a relatively uniform dynamical characteristic up to 7 kHz; however, small peaks were observed at frequencies 1.2, 2.7, 5.2, and 6.3 kHz. Figure 3b shows the dynamical characteristic of the actuator alone without a reflecting segment. Intrinsic mechanical resonance occurs at a frequency of 14 kHz. As the frequency is increased further, we also observe nonuniformities in the characteristic at 38, 49, and 65 kHz. We see that the segments and reflective coating obviously led to smoothing of the dynamical characteristic which was accompanied by a significant decrease in the range of operating frequencies. Mirrors made from light alloys such as titanium must apparently be used to increase the frequency range of the corrector. The presence of irregularities in the dynamical characteristic of PKR-6 piezoelectric ceramic can be used to generate test oscillations at these frequencies in aperture-sensing adaptive optical systems. Additional research carried out by the present authors indicates that the increase in actuator length as a function of applied voltage is linear all the way to $U_{app} = 1000$ V. The maximum observed increase in length was 7 um.

Thus, the segmented corrector developed in this paper shows promise for use in adaptive optical systems at visible and IR wavelengths. When the dimensions of the segments are correctly chosen as a function of the degree of atmospheric turbulence, such correctors can be used to increase the speed of adaptive optical systems by virtue of the lack of crosstalk[7] in the servomechanism.

In conclusion, the authors would like to take this opportunity to thank A. A. Bezuglov for fabricating the segmented phase-front corrector.

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