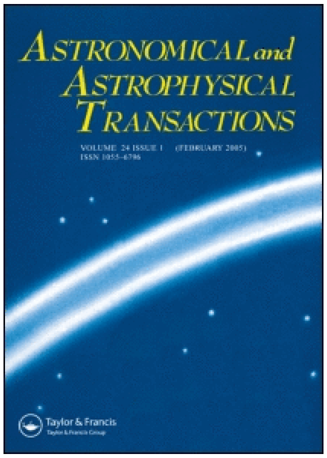

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

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Online Publication Date: 01 January 1994
To cite this Article: Baranov, Yu. V., Kirakosyants, V. E., Lazarev, A. I. and Loginov, V. A. (1994) 'A three-channel adaptiveoptical system', Astronomical & Astrophysical Transactions, 5:1, 253 - 257
To link to this article: DOI: 10.1080/10556799408245877
URL: http://dx.doi.org/10.1080/10556799408245877

Astronomical and Astrophysical Transactions, 1994,
Vol. 5, pp. 253–257
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A THREE-CHANNEL ADAPTIVE OPTICAL SYSTEM

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(Received January 10, 1992)

The structure and characteristics of a three-channel adaptive optical system for the correction of wave front tilts are described as applied to optical telescopes. The method can also be used for the construction of adaptive optical systems with flexible or segmented mirrors.

KEY WORDS Adaptive optics

A tilt compensator is one of the elements of an adaptive optical system. Usually, the tilt compensator has a flat mirror with a two-coordinate direction. The implementation of three drives (actuators) made of segnetoceramics for directing the mirror has resulted in a compact mechanism and provided the possibility of high-precision angle and longitude shifts. It has become possible because we use the actuators as backups of the mirror, so we can avoid using of separate backups which usually have clearance and friction (Figure 1). Also, the fastening of the optic elements at three points provides minimum optic aberration. However this version of the directed optic element design has a limited applicability because of difficulties in control. The reason for that is the quadrant photoreceiver with orthogonal axes generally used as a detector of the mismatch, so that it is necessary to recalculate error signals for the three actuators using trigonometrical functions. The recalculation usually leads to a narrower bandpass of the system and, therefore, to larger tracking errors.

We can avoid this difficulty by using a three-channel mismatch detector. This can be based on three photoreceivers with the image analyzer in the form of a three-facet mirror pyramid (Figures 2, 3). The transformation of the output signals of the photoreceivers (which form the control signal) can be expressed in this case as

$$U_1 = \frac{I_1 - \frac{1}{2}(I_2 + I_3)}{I_1 + I_2 + I_3},$$

$$U_2 = \frac{I_2 - \frac{1}{2}(I_1 + I_3)}{I_1 + I_2 + I_3},$$

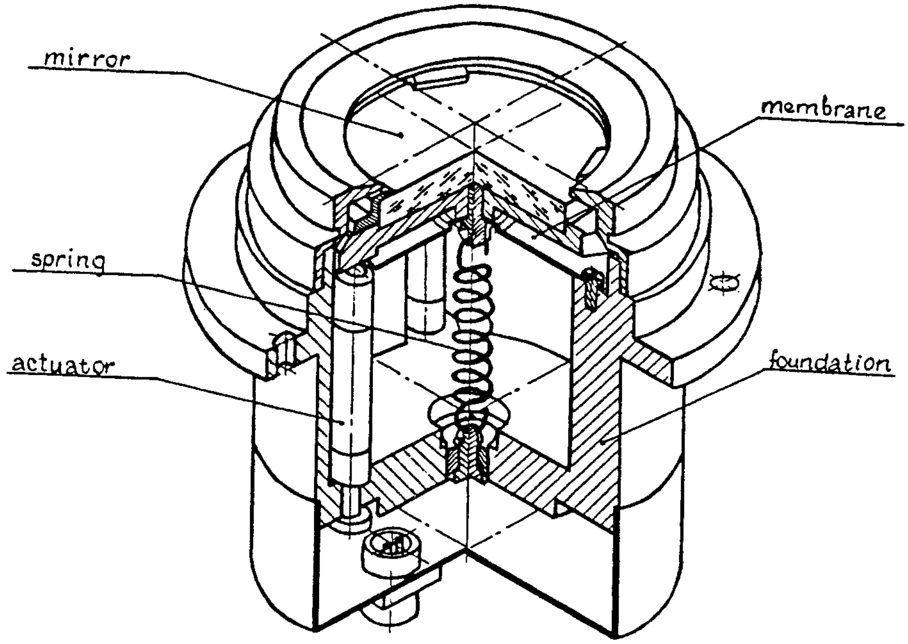

Figure 1 The construction of the three-actuator mechanism.

Table 1

$\gamma[deg]$	0	0.5	1.0	1.5	2.0	K_i
δ_{τ_1}	1.00	0.999	0.998	0.997	0.994	$K_1 = 100$
δ_{τ_2}	1.00	0.999	0.998	0.997	0.994	$K_2 = 100$
$f(\Delta)$	1.0000	1.0000	1.0000	1.0000	1.0000	$K_3 = 100$
δ_{τ_1}	0.938	0.939	0.943	0.951	0.968	$K_1 = 100$
δ_{τ_2}	1.00	0.999	0.994	0.981	0.968	$K_2 = 100$
$f(\Delta)$	1.0100	1.0100	1.0100	1.0100	1.0100	$K_3 = 110$
δ_{τ_1}	0.946	0.946	0.948	0.952	0.957	$K_1 = 100$
δ_{τ_2}	1.061	1.060	1.058	1.054	1.048	$K_2 = 90$
$f(\Delta)$	1.0236	1.0238	1.0240	1.0242	1.0244	$K_3 = 110$
δ_{τ_1}	0.910	0.911	0.915	0.923	0.938	$K_1 = 100$
δ_{τ_2}	0.968	0.967	0.963	0.955	0.938	$K_2 = 110$
$f(\Delta)$	1.0042	1.0041	1.0041	1.0040	1.0040	$K_3 = 110$

Notation:

- γ: the angle between the actuator's axis and the three-facet mirror pyramid rib projection on the surface perpendicular to the optic axis;
- $\delta_\tau = \tau/\tau_\alpha$: the ratio of the time constants of transitional processes in the real and ideal systems;
- K_i: the amplification coefficients in the channels;
- $f(\Delta) = \sigma_\epsilon^2/\sigma_{\epsilon_\alpha}^2$: the ratio of the error dispersion between the real and ideal systems.

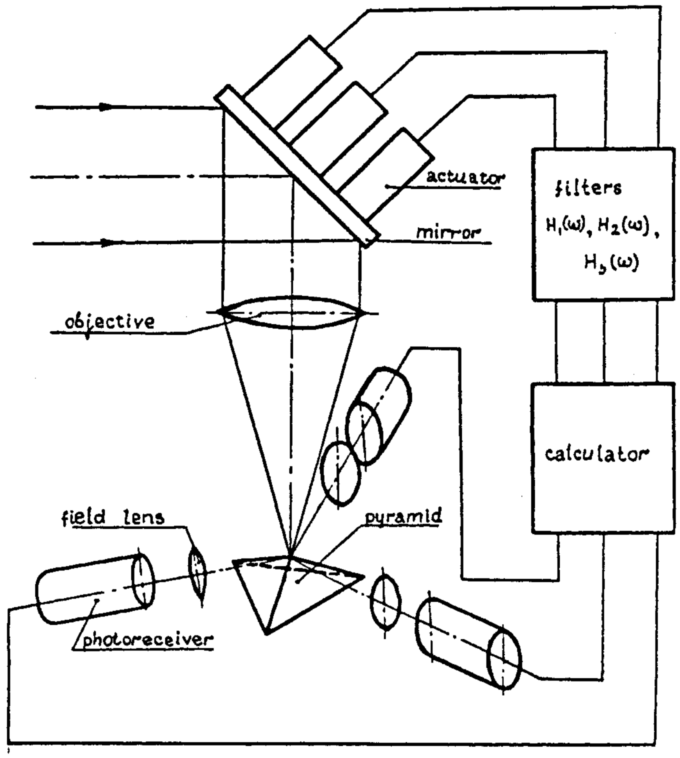

Figure 2 A scheme of the three-channel tracking system.

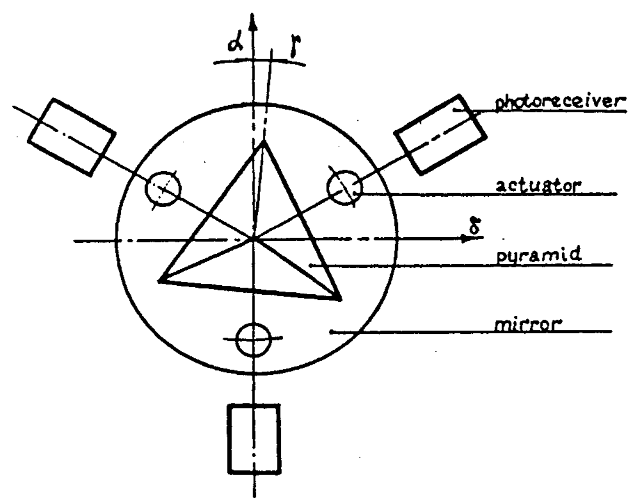

Figure 3 Mutual positions of the pyramid, actuators and photoreceivers.

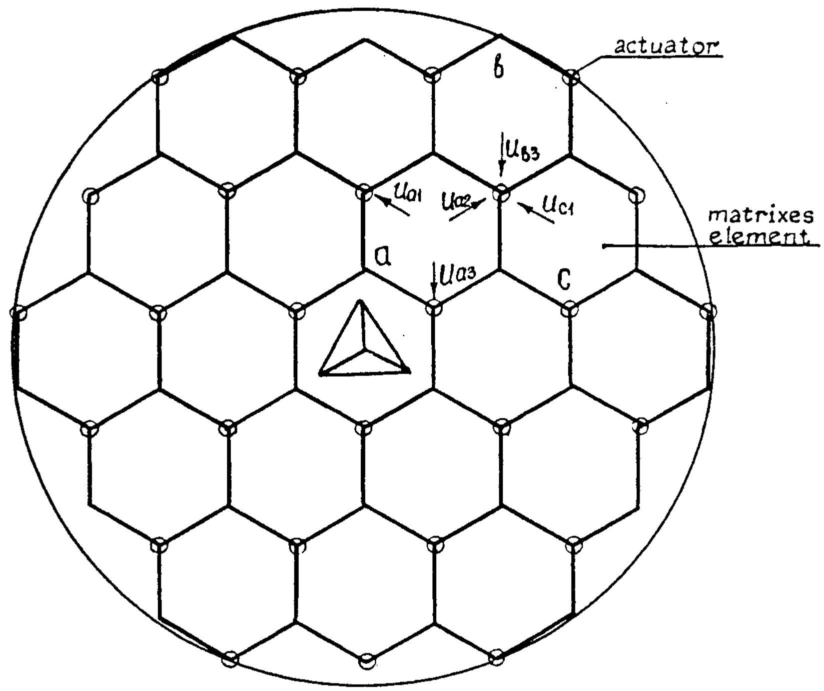

Figure 4 Mutual positions of the matrix elements and actuators on the telescope aperture.

$$U_3 = \frac{I_3 - \frac{1}{2}(I_1 + I_2)}{I_1 + I_2 + I_3}, \tag{1}$$

or, in another form,

$$U_i = \frac{3}{2}\left(\frac{I_i}{\sum_{m=1,2,3} I_m} - \frac{1}{3}\right), \quad i = 1, 2, 3,$$

where I_i is the magnitude of the signal coming from the i-th receiver.

After the recalculation, the mismatch signals are amplified and filtered in filters having the frequency response $H_i(\omega)$. Then the signals are fed to the actuators.

The system has non-orthogonal axes, so it is necessary to check up the stability and to analyze the system errors, especially if manufacture, justing and toning errors are possible. Table 1 shows results of the calculation of transitional processes and fluctuation errors of the three-channel tracking system with integrating RC-filters.

The ideal three-channel system is the system without warps in the actuator and sensor axes and with the same channel transmission coefficients. The ideal three-channel system parameters coincide with those of the system with orthogonal axes. The source of fluctuations in the system is the Poisson noise in the light beam received.

The above results show that, in the parameter range considered, both the duration of the transitional process and the fluctuation error dispersion change insignificantly in comparison with the ideal system, and the system is absolutely stable. The system considered is equivalent to a two-channel system with cross connections, it is described by a system of two dynamic equitions and has two time scales of the transitional process. So we use the notation δ_{T_1} and δ_{T_2}.

The above principle of a three-channel design of a tracking system can be used in adaptive optic systems with flexible or composite mirrors. Common construction of the system may be like this (Feinleib *et al.*, 1983), but three-facet mirror pyramid and three photoreciever matrices with six-angle photosensitive elements are used instead of a four-facet mirror pyramid and four photoreciever matrices with four-angle photosensitive elements. A scheme of that system is as shown in Figure 2. In Figure 4, the projections of the matrix elements and actuators are shown. Three photosensitive elements, one from each matrix, are co-ordinate with each subaperture. It is supposed that the mismatch signals are calculated according to the formulae (1) for each subaperture. The direct influence for the actuators, placed in the common points of the subapertures, is then calculated as (Hardy, 1976)

$$U_{abc} = U_a + U_b + U_c.$$

An advantage of that adaptive optical system construction are the symmetry of the actuator's response function and a dense packing of the telescope aperture by the six-angle subapertures or by the six-angle segments of the composite mirror.

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