ADAPTIVE OPTICAL SYSTEMS IN IOE

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The research and development of adaptive optics in China began in 1979. In 1980 the first laboratory of adaptive optics was established at the Institute of Optics and Electronics (IOE), Chinese Academy of Sciences. Since then, several adaptive optical systems have been built in this Laboratory. Among them are: (1) hill–climbing wave front correction system, (2) adaptive optical system using shear interferometers, and (3) experimental setup with a Hartmann–Shack wave–front sensor and a 37–element deformable mirror. In this paper the principles, structures, and experimental results will be briefly reported.

INTRODUCTION

Research and development of adaptive optics in China began in 1979. In 1980 the first laboratory devoted to adaptive optics was established at the Institute of Optics and Electronics, Chinese Academy of Sciences. Since then, several adaptive optical systems have been established and associated components have been built in this Laboratory.

1. HILL–CLIMBING WAVE FRONT CORRECTION SYSTEM(1–3)

The system is designed for correcting static wave front errors to improve the laser beam quality. A 19–element deformable mirror and a serial dithering hill–climbing algorithm are used in this system. Using a photomultiplier (PMT) behind a pinhole at the focal plane, the energy concentration at the focal spot is detected. The output signal of the PMT is synchronously detected with the dithering signal by a lock–in amplifier and the polarity of the lock–in amplifier output indicates the right direction of the correction. In this direction the actuator of the deformable mirror is driven through a stepper–motor, potentiometer and an HV amplifier to put the energy passing through the pinhole to its maximum. The 19 actuators of the deformable mirror are connected with the dithering control loop successively. After several steps of iteration the wave front error can be corrected and the sharpness at the focal plane reaches its maximum. To avoid the 2π ambiguity of the wave front, at the first stage of the correction, the actuator of the deformable mirror is scanned through its whole range of deformation and the main maximum of energy concentration is identified by a microcomputer and the dithering process begins around this main maximum.[3] This system has been successfully used for correcting the wave front errors caused by accumulation of fabrication and alignment errors of optical elements and inhomogeneities of working materials of a laser fuser fusion system at Shanghai Institute of Optics and Fine Mechanics.

2. ADAPTIVE OPTICAL SYSTEM USING SHEARING INTERFEROMETER[2,4–6]

This system is used for correcting dynamic wave front errors such as atmospheric turbulence. The system consists of an AC shear interferometer, a 21–element deformable mirror and control electronics. Two lenses and PMT arrays are used to detect the modulation signals of shear interferograms, which are produced by two Ronchi gratings rotating around X and Y directions, respectively. The signals from the PMT's are phase–discriminated with a reference signal. The detected phase signals which represent the wave front slopes of subapertures are processed by a wave front reconstruction network and the control signals at each of 21 actuators are obtained.

The bandwidth of the system is 300 Hz. After finishing the preliminary laboratory experiments in 1982–1984, the system was integrated with a 250 mm Cassegrainian telescope. The experiments on compensating for atmospheric turbulence along the horizontal optical path were conducted in 1987. A He–Ne laser was used as the object of observations. The distance between the object and telescope was 340 m and elevation of this horizontal optical path above the ground is about 15 m. Figure 1 shows the experimental results with different measured values of the radius r_0. The ordinate is the ratio of the measured energy concentrated within the diameter of the first dark ring of Airy disk to that within the diffraction limit.

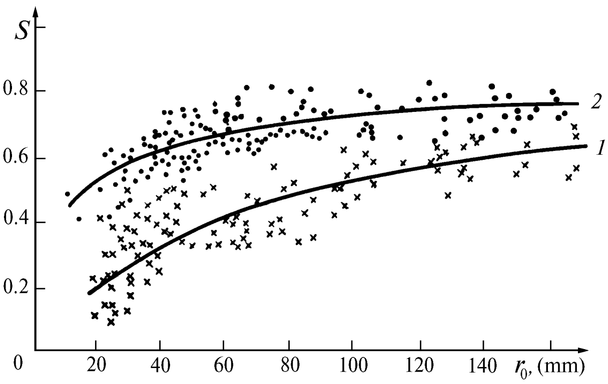

FIG. 1. Experimental results of correcting for atmospheric turbulence along a horizontal optical path. Curve 1 is for open–looped contour and curve 2 is for close–looped contour.

In 1990 this system was updated with 32 channels of photon–counting electronics for the PMT outputs and a digital wave–front processor with a TMS 320C25 DSP. The system was integrated with a 1.2 m telescope in Kunming Astronomical Observatory. In September 1990 the first successful test of compensation for atmospheric turbulence with astronomical objects was realized.

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3. MODAL MULTIDITHERING IMAGE SHARPENING ADAPTIVE OPTICAL SYSTEM FOR SOLAR APPLICATIONS[7,8]

Under support of the Large European Solar Telescope (LEST) Foundation, a modal multidithering image sharpening adaptive optical system has been investigated. In the system proposed for this purpose two zonal deformable mirrors are used, one for dithering and the other for correcting. The optical channel of multidithering and detecting is separated from that of imaging. Using mode–zone converters, which are analog networks, the modal dithering and control signals are converted into zonal signals for deformable mirrors, so that the zonal deformable mirror corrects for the phase errors with respect to Zernike aberration modes. In the detecting optical channel the modulated intensity distribution is detected with a high–speed array detector. The image sharpening function $S = (I - I_0)^2$ is computed and the modal control signals are obtained by lock–in amplifiers.

In this proposal, the signal–to–noise ratio of a detected modal signal, the fitting capability of a zonal deformable mirror to different Zernike aberrations, and the limitations of the system are discussed.

4. EXPERIMENTAL SETUP WITH HARTMANN–SHACK WAVE–FRONT SENSOR

An adaptive optical system with 37–element deformable mirror and Hartmann–Shack wave–front sensor have been built for laboratory experiments in 1990. In this system, a 37–element deformable mirror with 18 auxiliary actuators for improving influence function of the outer actuators is used as a wave–front corrector. The Hartmann–Shack wave–front sensor is composed of a prism array and a Reticon cell. The algorithm of controlling a wave–front gradients of subapertures is directly compared with the common wave–front reconstruction algorithms and the results show that the algorithm of controlling gradients is more simple and straightforward.[9] In this system a digital processor which consists of five elements TMS 320C25 DSP has been built for computing the displacements of subaperture image centers and for multiplying matrices. The sampling frequency of a H–S sensor is 380 Hz and the bandwith of the system is about 50 Hz. In this system a fast steering mirror is used for the assembly tilt correction.

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