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Deforming Characteristics of Deformable Mirror for Laser Beam-Forming

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1. LASER BEAM-FORMING

An adaptive optics system is usually used for phase compensation(1)(2). We proposed a new application of deformable mirrors for a beam-forming system. This beam-forming system consists of two deformable mirrors as shown in Fig.1. The first mirror changes the laser beam intensity profiles and the second mirror compensates for the distorted phase distributions. This system can give a laser beam another intensity profile and compensate for the phase distortion for long propagation. This system can follow a beam with time varying intensity and wave front if there is a closed loop control system. In this paper, we study the deforming properties of the first mirror of this system.

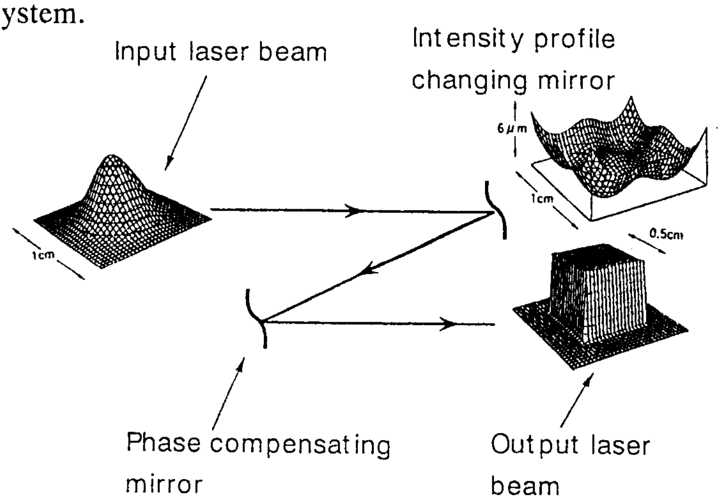


Fig.1 Laser beam-forming system using deformable mirror

2.DEFORMING PROPERTIES OF GLASS

In order to deform a mirror surface for beam-forming, the deforming properties of a glass plate are very important. The stress of the deformed mirror plate must be lower than the threshold of destruction of a glass plate, and the load which is needed for deforming must be lower than the pressing or pulling force of the actuators. We estimated the stress and load for several materials by using a simple model as shown in Fig.2. In this model, a glass disk is freely supported on its periphery and is pushed at its center. This model is similar to the center part of a deformable mirror for beam-forming from a circular Gaussian beam to a circular uniform intensity beam. The disk diameter of the model is 7mm. The calculated deforming property of a quartz disk is shown in Fig.3 as an example. From this result, the maximum displacement of the mirror center is about 2.5 μ m and is limited by the threshold of destruction of the glass. But, the actuators of a deformable mirror are PMN (Lead Magnesium Niobate: The hysteresis of PMN is much less than that of PZT) and the disk is pulled at the center, the maximum displacement is limited by the pulling force of the PMN because the pulling force of PMN is much lower than its pushing force. We can design the maximum displacement of a deformable mirror within this limitation by increasing the distance between the first mirror and the imaging point.

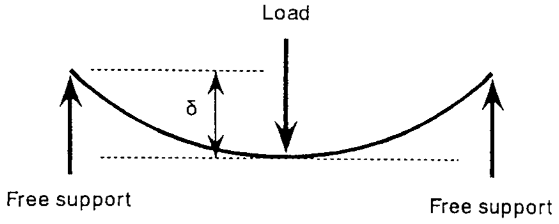


Fig.2 Simple disk model for calculation of load and stress

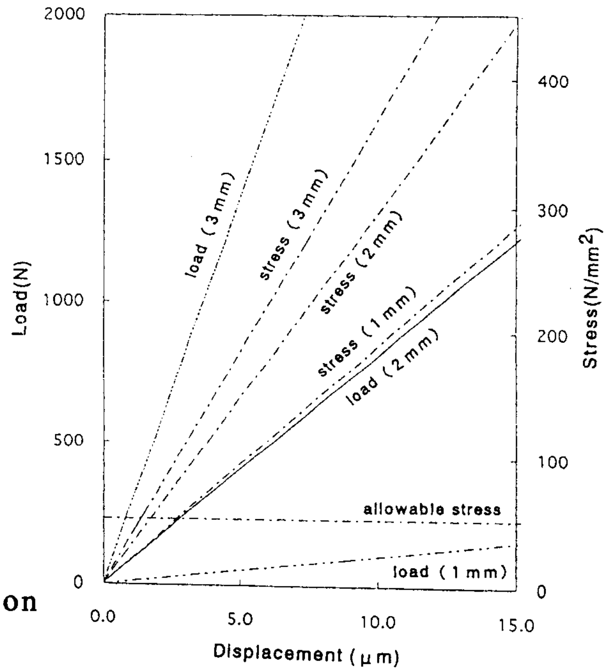
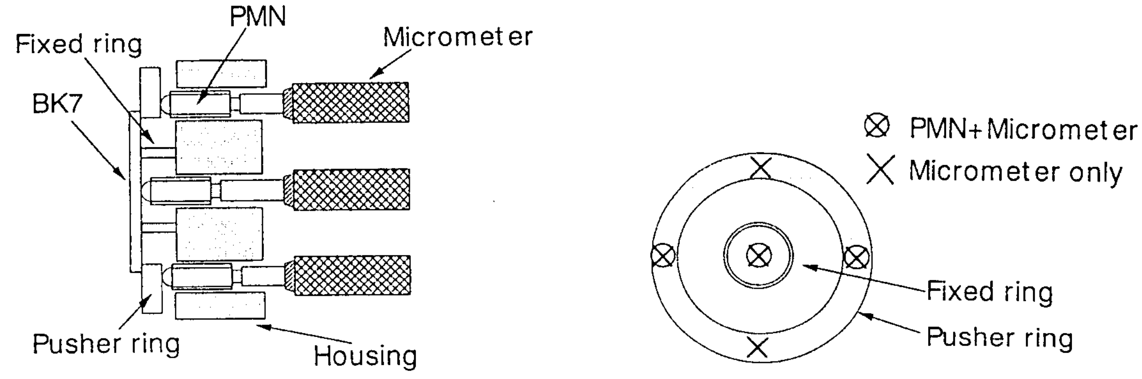


Fig.3 Load and stress of quartz disk

3.DEFORMING PROPERTIES OF DEFRMABLE MIRROR

3.1. Deformable mirror

In order to examine the deforming properties of a deformable mirror, we made a deformable mirror assembly for transforming a Gaussian-like beam profile into a circular uniform profile as shown in Fig.4. The assembly consists of a mirror and actuators; the mirror is made of BK7 and is coated with aluminum; the diameter is 30mm and the thickness is 1mm. The mirror is fixed on a ring of diameter 11mm and width 2mm, and is pushed at the center and the periphery by micrometers and PMNs. We selected PMNs as actuators for the deformable mirror because they have less hysteresis than PZT (Queens gate MT15). The pushing force is 840N and the pulling force is 50N. The stroke of the PMN is 15 μ m without stress. The mirror periphery is pushed by a pusher ring driven by four micrometers and two PMNs. Two of the four micrometers are located behind the two PMNs. The micrometers are used to position the PMNs and to roughly deform the mirror surface. The PMNs are used for fine deformation. The applied voltages of the PMNs can be input from a computer key board while monitoring the beam profiles or mirror surface profiles.



Schematic diagram of deformable mirror

Position of PMNs

Fig.4 Deformable mirror

3.2. ANALYSIS BY FEM

We analyzed the deforming properties of the deformable mirror by using FEM. In this calculation, the BK7 disc is assumed to be a rectangular shape. The surface profile of the deformable mirror is measured by a WYKO 400D. The peak to valley of the deformed mirror is about 7 λ at the wavelength of an He-Ne laser. The measured surface profile and the calculated values for the deformable mirror are shown in Fig.5, and the calculated values are very similar to the measured values. Although the surface profile of the mirror must be symmetrical about its axis, it is not axis-symmetric. The reason may be due to probable inaccuracies in the pusher ring.

3.3. COMPARISON WITH IDEAL SURFACE PROFILE

The deformed surface and the ideal surface profile of the deformable mirror for reshaping from a circular Gaussian beam to a circular uniform intensity beam is shown in Fig.6. The curve of an ideal surface profile is calculated in order to fit the measured data by choosing a sufficiently few parameters. The maximum difference between the deformed surface and ideal surface profile is about 0.5 λ within a diameter of 10mm. We will be able to improve the precision of the mirror surface by using more actuators.

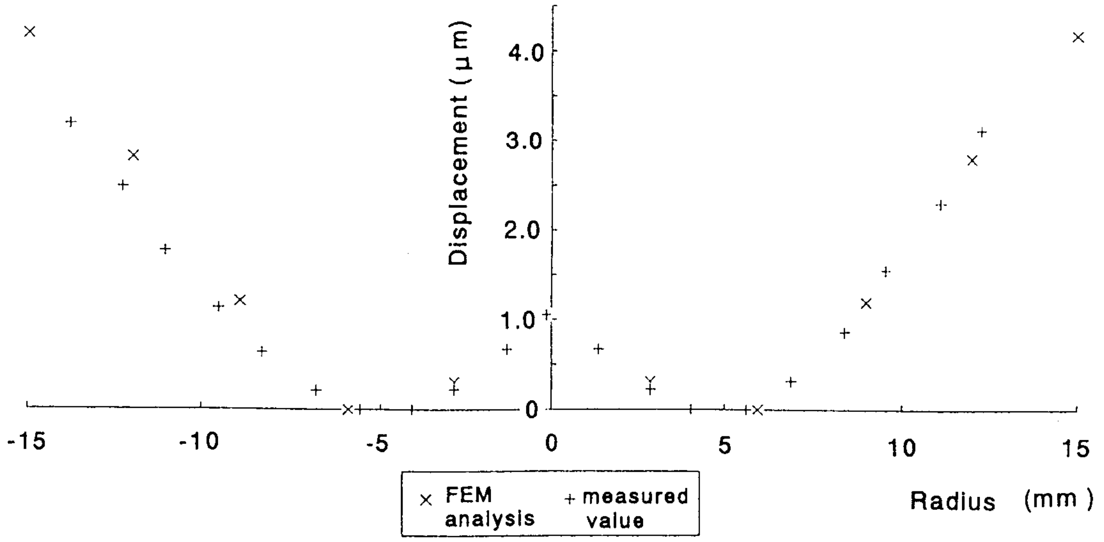


Fig.5 Deformable mirror surface and FEM analysis

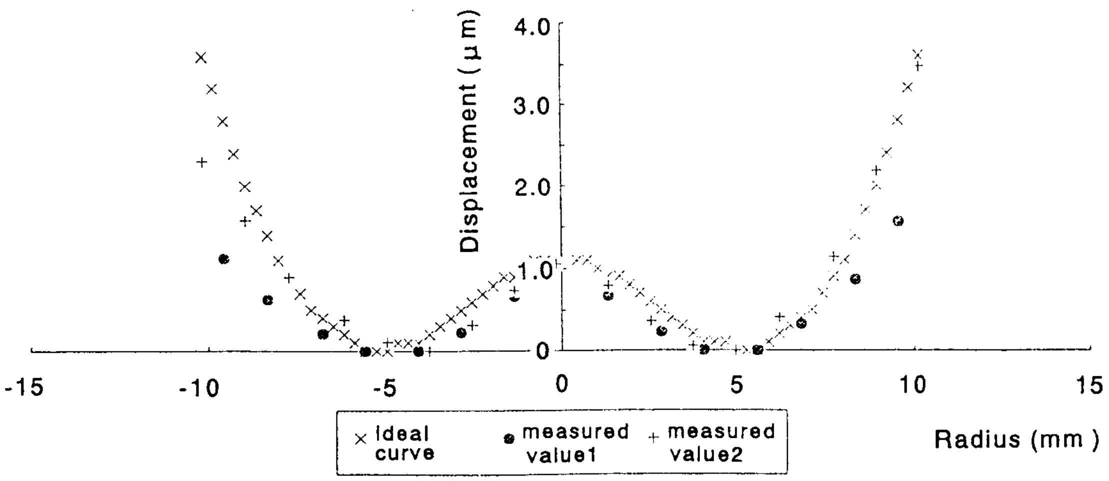


Fig.6 Deformed mirror surface and ideal curve

4. ACKNOWLEDGEMENTS

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