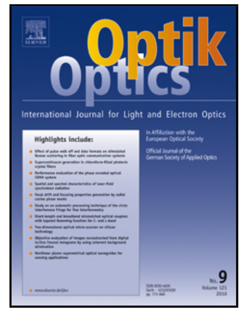

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Authors: Xiaochuan Hu, Zhen Wu, Lixia Chen, Bin Zhang

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A Self-Correction Method for Deformable Mirror with Thermal Deformation

XIAOCHUAN HU, ZHEN WU, LIXIA CHEN, BIN ZHANG*

College of Electronics and Information Engineering, Sichuan University, Chengdu, 610064, China
**Corresponding author:*[*]*zhangbinff@sohu.com*

In high-power laser systems, temperature gradient distribution arises in optical components irradiated by a high-power continuous wave (CW) laser, leading to the thermal deformation of the optical components and further the degradation of the beam quality. The deformable mirrors (DMs) are commonly used to improve the beam quality, but the thermal deformation of the DM irradiated by the high-power CW laser also exist and is more complex than that of conventional reflecting mirrors, resulting in high-frequency distortion of the corrected wavefront. In this paper, a finite element model for the DM with high reflectivity films is built up, and then the thermal deformation of the DM is simulated and analyzed. According to the deformable feature of the DM, a self-correction method is proposed, i.e., the DM corrects its thermal deformation by itself, and a self-correction function is established to control the actuators of the DM. Finally, effects of the self-correction method on beam quality are discussed quantitatively. Results show that the self-correction method can compensate the thermal deformation distribution of the DM and even constrain the generation of high-frequency distortion. Consequently, the self-correction method is feasible to compensate the thermal deformation of the DM, and further improves the beam quality.

Key words: lasers, deformable mirror, thermal deformation, self-correction

1. Introduction

In high-power laser systems, the thermal deformation of optical components due to continuous irradiation of high-power lasers makes the wavefront distort and beam quality degrade [1–4]. With the increase of laser power and irradiation time, this problem becomes more serious. To solve the problem, the water-cooled mirror were presented to decrease the temperature rise by transferring the absorbed heat to the coolant [5–8], mirrors with self-compensation for thermal deformation were proposed to decrease the thermal deformation of the local areas irradiated by laser beam [9], and adaptive optics have also commonly been used to compensate the wavefront distortion caused by the thermal deformation of the optical components [10-11]. Due to the complexity of the water-cooling-system and the limitation of the self-compensation mirror, adaptive optics technique is gradually applied in high-power laser systems.

In a high-power CW laser system with adaptive optics technique, the DM is commonly placed on the incident laser to minimize the phase aberrations of emitted laser, and the thermal deformation aberration of mirrors is detected using a beacon and a wavefront sensor at the exit of the system. However, the distortion phase error of beacon introduces phase error to the wavefront sensor, including primary tilt and astigmatism, and makes the corrected effect worsen again [11].

In addition, the temperature rise and thermal deformation inevitably happen to the DM while irradiated by high-power lasers to correct distorted wavefronts, resulting that additional distortion emerge to the corrected wavefront, especially the high-frequency distortion due to its discrete actuating mechanical structure and smaller thickness than that of the conventional reflecting mirrors [12–15]. In order to solve these problems, effects of the materials and structure parameters of the DM and the operating environment temperature on the thermal deformation of the DM have been discussed [13], whereas the choice of the materials and the structure parameters of the DM are usually restricted in some cases. In Ref. [14], a water-cooling-system was further proposed to decrease the temperature of the DM, in which a middle metal coating layer for conduction was applied to increase the total thermal conductivity of the DM. However, the cooling effect on the thermal deformation of the DM mainly depends on the water flow which is limited by the temperature of water at its inlet and the number of the water-channels, yielding a complicated cooling system to implement conveniently. For simplicity, we proposed an air-cooling-system for the DM and the heat exchanging area was further optimized based on the incident laser beam [15], but the air-cooling-system is not efficient enough due to the finite heat exchange ability of its air flow.

In this paper, a model of the DM coated with high reflectivity films has been built up by using the finite element analysis software ANSYS. Then, we have found from the theoretical analysis that the thermal deformation of the DM can be effectively corrected by actuators with a specific organized distribution, and further proposed a self-correction method, which is unaffected by the phase error of beacon. Finally, the effect of the self-correction method on beam quality has been analyzed quantitatively, and the correction capability of our method has also been