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Study on the correction method of the deformable mirror surface profile

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ABSTRACT

Before using the deformable mirror (DM) for wavefront beam shaping, it is necessary to correct its surface profile to reduce the high-order aberrations, because the DM surface profile is different from the original set plane. In this paper, we demonstrate a simple method to correct the DM surface profile. The method is verified experimentally by using He-Ne laser. Results show that the DM surface profile is corrected to be near flat-topped by using the method. The output peak-to valley value changes from 2.38 λ to 0.21 λ of the He-Ne laser and the RMS value changes from 0.49 λ to 0.04 λ after correcting the DM surface.

1. Introduction

The uniform wavefront is an important part of the beam quality for high power lasers [1–5]. It is necessary to control the wavefront of laser beam and compensate the wavefront distortion in high-power laser system. Deformable mirror (DM) is a widely used device for wavefront wavefront correction in high power laser systems [6–13]. However, the commercially available DM surface profile is different from the original set plane over time. Therefore, it is necessary to correct its surface profile to reduce the high-order aberrations before using the DM for wavefront beam shaping.

In this paper, we demonstrate a simple method to correct the DM surface profile. The DM surface is correct in experiment by using an expanded He-Ne laser. The output beam wavefront is measured by the wavefront sensor as the feedback to adjust the DM surface. At the same time the output laser farfield is measured by a scientific-grade CCD as the reference. The experimental results are presented of after correct the DM surface.

2. Method

As shown in Fig. 1, the DM surface correction system consists of a standard laser source, the DM, the image relay system and the wavefront measurement (i.e. Hartmann wavefront sensor). The standard laser source is the He-Ne laser with the expanded beam with a good beam quality. The initial wavefront distribution of the expander He-Ne laser can be expressed by $\varphi_{in}(x,y)$. The beam propagates successively reflected by the DM, and then passes through the image relay system and arrives into the wavefront measurement in the end. The output wavefront distribution expressed by $\varphi_{out}(x,y)$ can be measured by a Hartmann wavefront sensor

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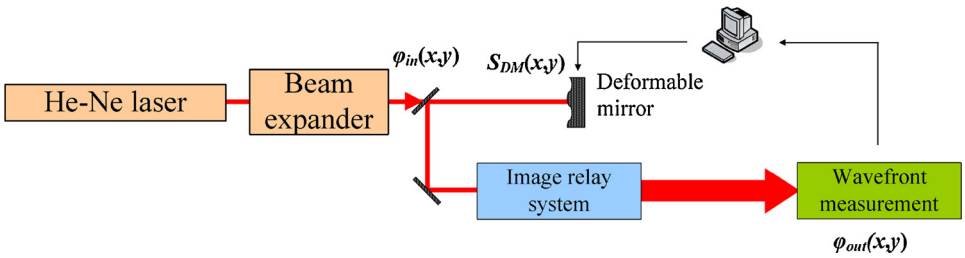

Fig. 1. The structure of the DM surface correction system.

accurately. The whole processes has the form as following [12]

$$\varphi_{\text{in}}(x, y) + 2S_{\text{DM}}(x, y) = \varphi_{\text{out}}(x, y), \tag{1}$$

where S_{DM}(x,y) is the surface distribution of DM. The initial wavefront distribution of the expander He-Ne laser can be assumed to be flat-topped. Therefore the value of φ_{in}(x,y) is 0. In the image relay system, the DM and the wavefront sensor are in conjugated positions. Therefore, the whole process can be simply expressed as

$$2S_{\text{DM}}(x, y) = \varphi_{\text{out}}(x, y). \tag{2}$$

Ideally, the DM surface can be correct after measure the output wavefront in the system, because the system itself is actually linear. However, the mirror actuators may not be linear. Thus, the aimed output flat-top wavefront distribution φ_{aim}(x,y) cannot be achieved after the first correction. Under the circumstances, the iterative method is used for the DM surface correction [14]. The iterative format is as following,

$$S_{\text{DM}}^{(n+1)}(x, y) = \frac{1}{2}[\varphi_{\text{aim}}(x, y) - \varphi_{\text{out}}^{(n)}(x, y)] + S_{\text{DM}}^{(n)}(x, y), \tag{3}$$

where $S_{\text{DM}}^{(n)}(x, y)$ represents the DM surface distribution at the n-th iteration and $n = 0$, the initial. $\varphi_{\text{out}}^{(n)}(x, y)$ represents the n-th output wavefront distribution and $n = 0$, the initial.

3. Experimental results and discussion

The DM surface must be corrected before the DM is used for wavefront shaping is the laser system. In general, the DM has been corrected when it leaves the factory for sale. That is to say, the DM surface is flat when uploading the voltage matrix of the initial flat file to the DM. However, the DM surface will change over time due to the influence of the environment in the working and storage process. Therefore, the DM surface needs to be corrected again.

The experimental setup is shown in Fig. 2. The laser source used for demarcating the DM is a continuous He-Ne laser. The laser beam propagates a range of distance and enters into the 1:8 beam expansion system with the beam size to be 13 mm in the end after passed a small aperture. Then, the laser is reflected by the DM with the incident angle to be less than 5 degrees, which is a small angle and equivalent to 0 degrees here. After the beam reflected by the DM, it enters into the wavefront sensor after a 4:1 beam imaging relay system. The wavefront sensor is placed in the end for measuring the output wavefront distribution. The DM and the wavefront sensor are at the image-conjugate-plane. At the same time, a beam splitter is added in the measurement system to export the beam into the far-field CCD. The far-field CCD can be used to analyze the far-field of the output beam. There are suitable attenuation plates before the wavefront sensor and the far-field CCD.

The electromagnetic DM (Imagine Eyes, Mirao-52e) is used to control the wavefront of the reflected laser by adjusting its mirror

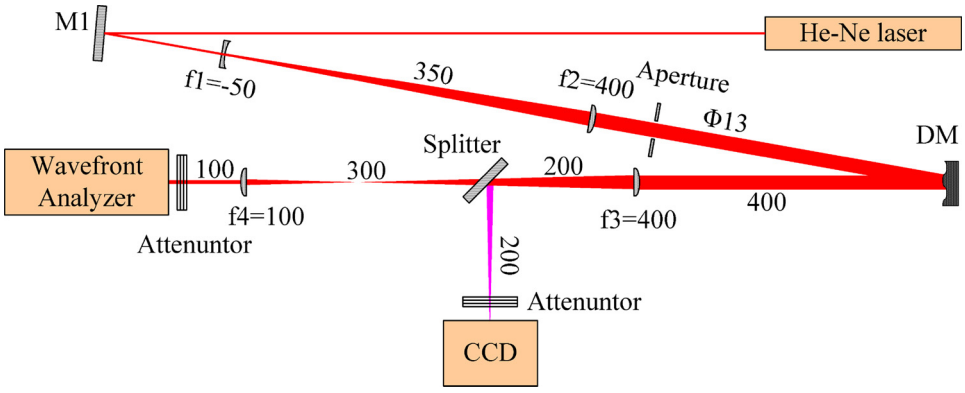

Fig. 2. Experimental setup of the DM surface correction system.