Optik 125 (2014) 5025–5028

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Spherical mirror estimation with phase diversity method

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ARTICLE INFO

Article history:
Received 28 July 2013
Accepted 4 March 2014

Keywords:
Phase diversity
Spherical mirror
Zernike polynomial
Aberration

ABSTRACT

In order to verify the phase diversity wavefront detector system by using its own light source to complete the wavefront estimation task independently, this paper sets up estimation spherical mirror shape of experiment platform with the method of phase diversity. Phase diverisity method collects shorter exposure image at the same time in the focal plane and away from the focal plane, calculates the distribution of wavefront solutions and recovers the target based on known defocus, so as to realize the estimation of large mirror aberration. In order to further validate the phase diversity measurement method, the phase diversity measurement results with high accuracy ZYGO interferometer measurement results are compared. Experimental results demonstrate that agreement is obtained among the errors distribution, PV value and RMS value of ZYGO interferometer, so the phase diversity method can effectively estimate the mirror aberration, which shows the feasibility and accuracy of phase diversity method.

1. Introduction

The phase diversity (PD) technique, proposed by Gonsalves in 1979, extracts phase information from focused and defocused images and recovers the object with known defocus. The PD technique not only simplifies the optical path of wavefront and complexity, but also estimates the extended object and gets rid of the dependence on the point object for the majority of wavefront sensors [1–8]. In the field of optical estimation, PD is used to estimate the aberration, alignment errors, mirror flatness etc. Bolcar introduced PD theory into the estimation of synthetic aperture and segmented mirror [9,10]. Löfdahl et al. applied phase-diverse phase retrieval (PDPR) to calibrate the noncommon path aberrations of the AO system on KECK telescope. Mugnier et al. proposed the edge of estimation PD theory, applied PD technology to the imaging restoration of French NAOS-CONICA astronomical telescope and calibrated the static aberration of AO system [11–13].

This paper sets up estimation spherical mirror shape of experiment platform with the method of phase diversity. Experimental results demonstrate that phase diversity method can effectively estimate the mirror aberration, which shows the feasibility and accuracy of phase diversity method.

The remainder of this paper is organized as follows: Section 2 describes the basic theory of PD and the definition of variable; Section 3 describes the overall experiment; the conclusion is given in Section 4.

2. Theory

The optical path of the PD system, with focus and defocus collection channels, is illustrated in Fig. 1. Based on the engineering necessity, the numbers of collection channels can be increased. The problem of PD imaging restoration can be regarded as the inverse problem of seeking the original signal phase through the known analog of the interference signal or an adaptive filter. The related theories are in my former paper [14]. I will not repeat them.

3. The design of the experiments

A. Experimental theory and components

The schematic diagram of PD is shown in Fig. 2. Gaussian beam emitted from the laser through the pinhole into a spherical wave, passes through the lens 2 into a parallel light, the light projects in the prism through the prism is divided into two parts, a part need not be considered, another part of the parallel reflects after a light through the lens 1 converge after the measured mirror, the reflected beam with phase [15,16] information (i.e. aberration), again divided into two groups by a beam splitter, one part backtrack, the other part through the converging lens 3 converged at CCD camera, which is placed on a movable platform, move along the optical axis and the angle of the camera posture fine-tuning to get the focus before and after receiving a different amount of defocus images, used in realizing the estimated wavefront based on the PD. We can obtain aberration of the measured spherical mirror with the PD algorithm [17–25].

The focal length of measured spherical mirror is 0.2 m, the center wavelength is 632.5 nm, focal length of 3 in the experimental

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http://dx.doi.org/10.1016/j.ijleo.2014.03.011
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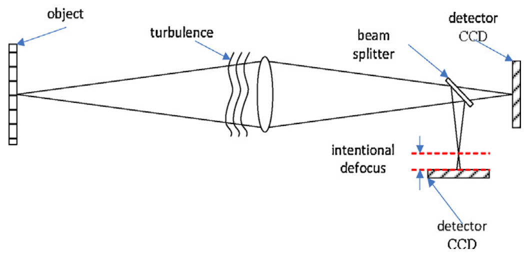

Fig. 1. Scheme of data-collection image by PD.

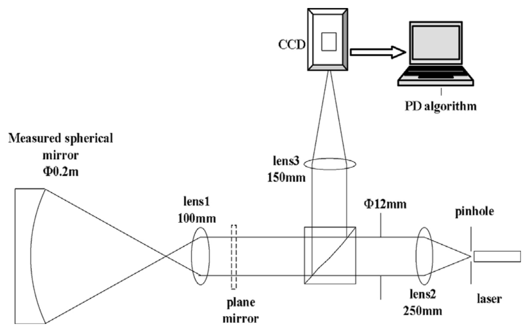

Fig. 2. Schematic diagram of PRWS.

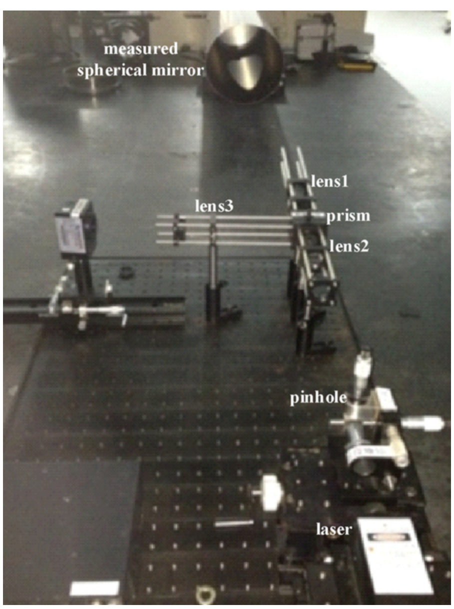

Fig. 3. The experimental system of PRWS.

system is 0.15 m, the exit pupil caliber is 0.012 m, and the depth of focus is about 0.286 mm. In the experiment, the defocus we select is 0 mm, ±1 mm, ±1.5 mm, ±2 mm. Camera pixel size is 6.45 μm, each defocus position respectively intercept 128 × 128 pixel size of target region, the exposure time is 20 ms, the accuracy of mobile platform is ±5 μm. The experimental optical path is shown in Fig. 3.

B. Experimental procedures

In the process of the entire experimental, we not only prove the estimation ability of PD, but also prove the accuracy of PD, therefore during the experimental design, in order to ensure that the position of the measured spherical mirror during the whole experiment is invariable, we need to find the good distance between spherical mirror with PD devices and between spherical mirror with ZYGO, respectively, based on the focal length of the measured spherical

Fig. 4. Tested telescope.

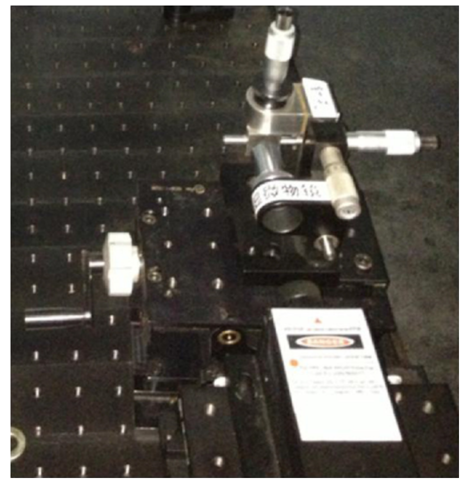

Fig. 5. Laser and pinhole.

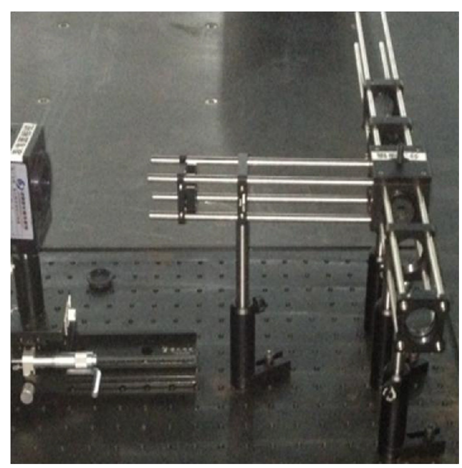

Fig. 6. Coaxial system.

mirror. Then separately measure the spherical mirror with PD and ZYGO.

- Step 1: build experiment system. Firstly, fix the 0.2 m telescope, as shown in Fig. 4; secondly, place the laser and the position of the pinhole, as shown in Fig. 5. The requirements of laser position are: laser light and the center of the telescope mirror are coaxial. After regulating, put the microscope objective and a pinhole placed in front of the laser, make the light from the pinhole is an ideal spherical wave. Lastly, reconfirm the laser, pinhole, spherical mirror are coaxial, as shown in Fig. 6.
- Step 2: add the lens 1, and adjust the position of the lens 1 to make it be coaxial with the laser and pinhole until the spherical wave emitted from the pinhole through the lens 1 into parallel light;
- Step 3: add the splitting prism, light bar and the lens 2 in the optical path, and make them be coaxial with the measured spherical