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Advanced simultaneous phase-shifting Fizeau interferometer

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HIGHLIGHTS

- An advanced simultaneous phase-shifting Fizeau interferometer.
- High imaging resolution and measurement accuraccy.
- Optical zoom is achieved in measuring.

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ABSTRACT

This study proposes an advanced simultaneous phase-shifting Fizeau interferometer. The proposed interferometer introduces a beam expander into the simultaneous phase-shifting Fizeau interferometer which employs four point sources to produce four phase shifting interferograms on a detector simutaneously. The beam expander is used to increase the aperture of the lens array and to decrease the inclination of the beam incident on the test surface such that the imaging resolution and the measurement accuracy of the interferometer can be improved. In addition, the optical zoom can be achieved by changing the magnification of the beam expander. A step plate was experimentally measured using the proposed interferometer. The phase step is clearly imaged in the detector, and the measured results are in good agreement with those obtained by the temporal phase-shifting Fizeau interferometer, which indicates that the proposed interferometer is suitable for normal apertures.

1. Introduction

Fizeau interferometers are widely used for optical measurements because of their common-path configuration, where the aberrations of the optical system can be removed from the measured results [1]. However, these Fizeau interferometers are based on temporal phase shifting interferometry, which enables them to extract phase information such that the measurement results are inaccurate in the presence of unstable conditions such as vibration, air turbulence, or when the object under test is in motion [2].

In recent years, there has been an increasing interest in dynamic measurements especially in astronomical optics and high-power laser fields [3,4]. In order to apply Fizeau interferometers to dynamic measurements, several methods have been proposed [5–7]. However, many of them break the common-path configuration of the Fizeau interferometer, thereby introducing retrace errors. For example, Sykora and Groot realized dynamic measurement by tilting the reference mirror to introduce a high linear-carrier frequency to the interferogram [8]; Szwaykowski et al. captured three phase-shifting interferograms simultaneously using three charge-coupled devices (CCDs), and the reference and test wavefronts were separated [9]; Chatterjee and Kumar proposed a cyclic path optical configuration with the reference and test beam couples tilted mutually such that they realized dynamic measurement in the Fizeau interferometer [10]. In order to increase the measurement accuracy, the retrace errors must be avoided. Abdelsalam et al. presented a method that replaces the reference mirror with a quarter waveplate [11]. This configuration appears to be perfect in terms of performing dynamic Fizeau interferometry, but it is difficult to fabricate a quarter waveplate with high flatness, especially in large apertures. Kimbrough et al. designed a low-coherence polarized light source [12]. Two couples of reference and test beams are superimposed on the CCD target, but only one pair of beams is coherent, and then the fringe contrast is lowered. Recently, we proposed a dynamic Fizeau interferometry, where the simultaneous phase shifting is achieved by changing the positions of four point sources [13]. While the point sources are not required to be polarized, the reference and test beams share a common path. This method exhibits good performance in a large aperture Fizeau interferometer, but for normal apertures such as

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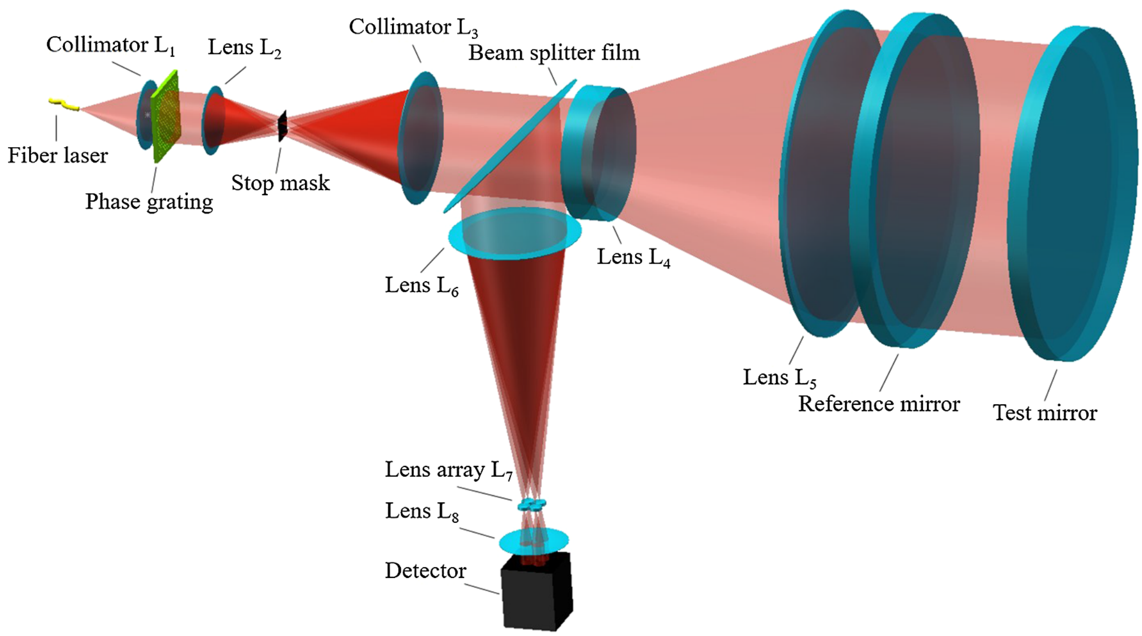

Fig. 1. Optical layout of the proposed interferometer.

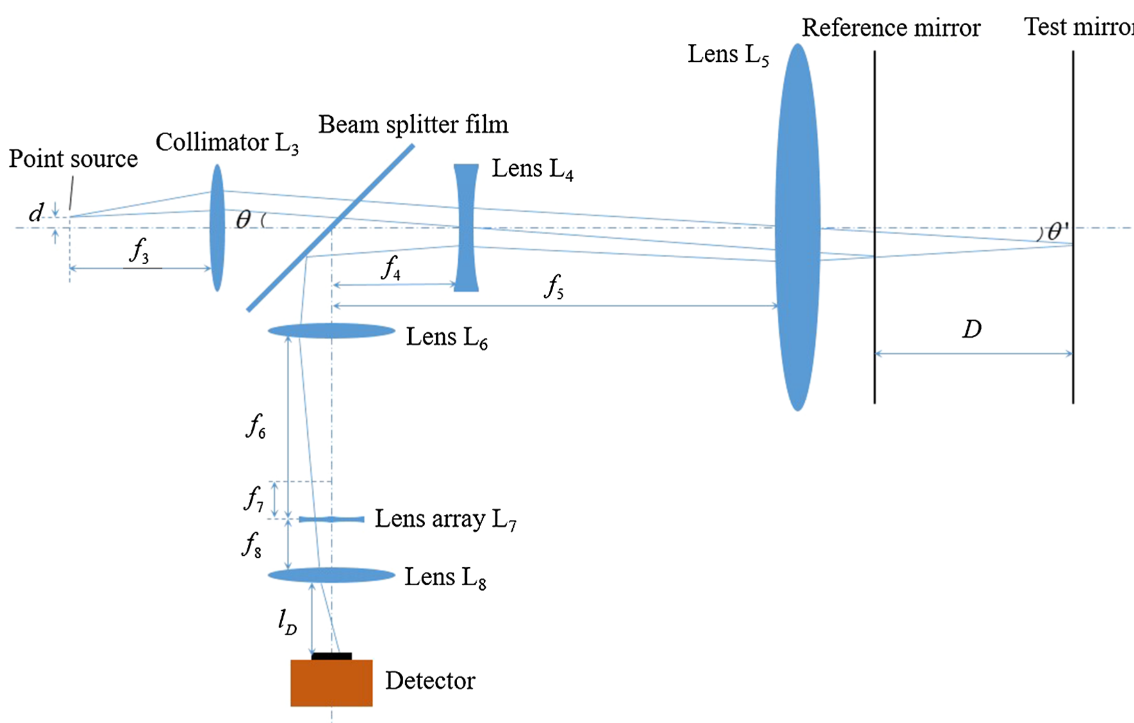

Fig. 2. Principle of phase shifting.

those with 100-mm size, there will be a decrease in the imaging resolution and measurement accuracy. The main causes for these limitations are the aperture of the image lens array and the aberrations of the collimated wavefront in the proposed Fizeau interferometer.

In this study, we present the analysis for these decreases and propose an advanced simultaneous phase-shifting Fizeau interferometer, where the decreases can be avoided such that the Fizeau interferometer with normal aperture can achieve as good a performance as that with a large aperture. In addition, the advanced configuration can realize optical zoom in measuring.

2. Theory

2.1. Optical layout

The optical layout of the advanced simultaneous phase-shifting Fizeau interferometer is shown in Fig. 1. The spherical wavefront emitted from the fiber laser is collimated by a collimator L_1 before being transmitted through a phase grating to form multiple plane wavefronts. The wavefronts are then converged to a stop mask by a lens L_2. Only the (±1, ±1) orders are selected as the point-source array, which