Optik 127 (2016) 8841–8846

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

An orthogonal phase-shifting interferometry and its application to the measurement of optical plate

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ARTICLE INFO

Article history:
Received 30 August 2015
Received in revised form 9 June 2016
Accepted 28 June 2016

Keywords:
Phase-shifting interferometry
Optical testing
Phase measurement
Jones matrix
PZT phase shifter

ABSTRACT

An optical interferometry named orthogonal phase-shifting interferometry (OPSI) was proposed. Compared with other interferometers, OPSI works well at air turbulence and complex environment. Phase recovery method was calculated by Jones matrix for measurement of optical elements surface shape and roughness. In order to control piezo-electric transducer (PZT) shifter, the property between voltage and phase of PZT shifter was calculated. Based on this interferometry, the roughness of an unknown transparent optical plate was measured. The results show that the error of peak to valley (PV) value is 0.0087λ (λ = 1064 nm) and the error of root mean square (RMS) value is 0.0006λ compared with WYKO(a commercial interferometer of Veeco),and this demonstrates the high stability and precision of the orthogonal phase-shifting interferometry.

1. Introduction

Optical interferometry has important significance in optical testing and the field of measurement technology. It is used for measurement of surface shape and roughness, and it has lots of advantages such as non-contact and fast response [1–5]. In the early days of interferometry, fringe patterns were analyzed manually. Recently, the development of image processing systems allows for automatic analysis of interferograms in optical methods of measurement. Phase shifter is applied by changing the optical path of reference beam [6–8]. One mirror is fastened on a piezo-electric transducer (PZT) shifter to realize the demanded shift movement. But current interferometers with PZT shifter are unstable working at air turbulence and complex environment. The precision and accuracy of measurement are affected.

In order to solve above problems, an optical interferometry named orthogonal phase-shifting interferometry (OPSI) was proposed. The system is improved on common path structure. That means that it keeps stable working at complex environment. The property between voltage and phase of PZT shifter was calculated, so the phase shifter can be control well and easily to be operated. Based on this interferometry, the roughness of an unknown transparent optical plate was measured. The accuracy and precision of measurement is proved by comparing its result with the result of WYKO (a commercial interferometer of Veeco).

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http://dx.doi.org/10.1016/j.ijleo.2016.06.096

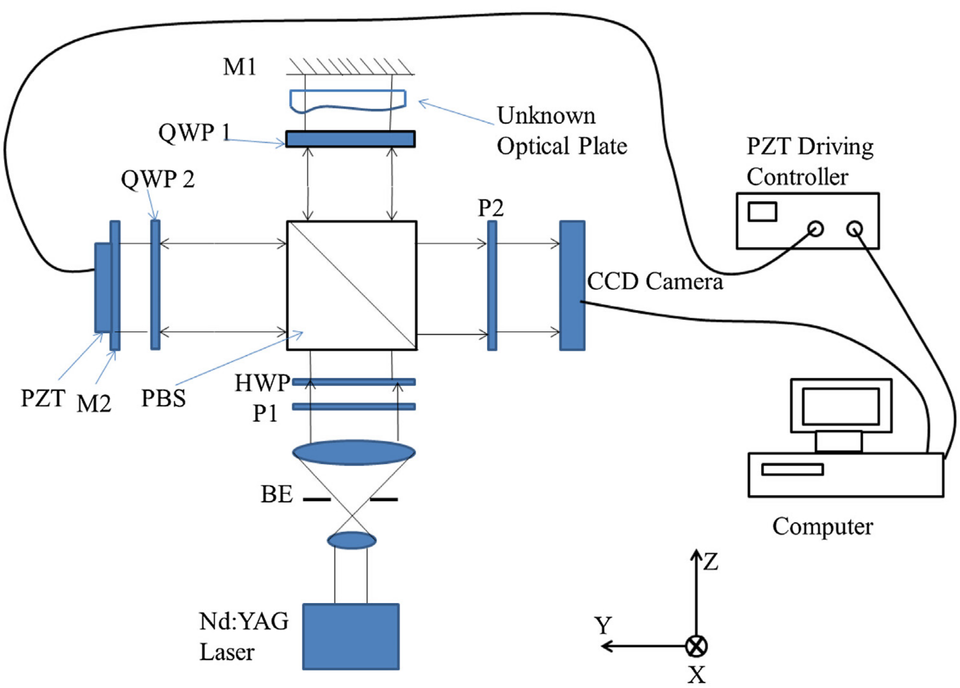

Fig. 1. Schema of the orthogonal phase-shifting interferometry; beam expander (BE), linear polarizer (P1, P2), half wave plate (HWP), polarizing beam splitter (PBS), quarter wave plate (QWP1, QWP2), mirror (M1,M2), piezo transducer (PZT).

2. Principle

2.1. Principle of OPSI measurement

As is shown in Fig. 1, the Nd: YAG laser beam (1064 nm, 50 mW) transmits through the beam expander (BE) and reaches the P1 (polarizer) formed linear polarized light. Linear polarized light transmits through the half wave plate (HWP) following the X-axis direction. Next, linear polarized laser beam is splitted into *s* and *p* polarized beams at the beam splitting plane of polarizing beam splitter (PBS).The fast axis of the quarter wave plate (QWP) is rotated by 45°. After the passage of the signal wave through QWP1, linear polarized laser beam becomes circular polarization. And it carries the information of the unknown optical plate. Mirrors M1, M2 placed equidistant from PBS, and M2 is fastened on a PZT shifter thus realizing the demanded phase shift movement. The *s* polarized beam split by PBS passes QWP2 and reaches M2, and it is the polarized reference wave. Finally, these two waves (the signal one and the reference one) pass through P2 (polarizer) and constitute the orthogonally polarized beams in common path. Two beams interfere an intensity fringe on the CCD camera.

2.2. Phase recovery method

In the case of a simplified model of the OPSI system, only the optical device under test is considered as a phase modulation. Jones matrix is commonly applied to the field of polarization interferometry [9]. Jones vector of the incident beam is $E_1 = \begin{bmatrix} A_1 \\ B_1 \end{bmatrix}$, and *p* polarized beam has none phase modulation in the CCD camera image space, while *s* polarized beam has a phase modulation caused by the unknown optical plate. The Jones matrix of *s* polarized beam is $\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$, After transmission through optical elements in path, the Jones vector reached CCD camera is $E'_1 = \begin{bmatrix} A'_1 \\ B'_1 \end{bmatrix}$, and it is simply expressed as:

$$E'_1 = \prod_{i=1}^{7} J_{8-i} E_1 \tag{1}$$