SIMULTANEOUS MEASUREMENT OF PATH-DEPENDENT PHASE RETARDATIONS IN A BEAM SPLITTER

Ruey-Ching Twu (1), Hao-Yang Hong (1), and Hsuan-Hsien Lee (2)

(1) Department of Electro-Optical Engineering; (2) Department of Electrical Engineering,
Southern Taiwan University, Tainan 710, Taiwan, R.O.C.

Phone: +886-6-2533131 ext-3628, Fax: +886-6-2432912, Email:rctwu@mail.stut.edu.tw

Abstract: *A new method is demonstrated for the first time for simultaneously measuring the phase-retardation difference between a transmitted light and a reflected light after passing through a beam splitter. The method is based on a dual-channel common-path homodyne interferometry with an integrated Zn-indiffused phase modulator for signal modulation. Our findings confirm that the proposed instrument successfully characterizes the path-dependent phase retardations. Finally, the average phase difference of 0.311 rad with standard deviation of 0.002 rad can be achieved within a measuring period of 60 seconds.*

1. Introduction

In the optical measurement setup, a non-polarization beam splitter is an essential component that divides an incident light into difference paths [1]. Especially, the systematical measurement errors of a polarization interferometer are dependent on the variations of phase-retardation between two orthogonal polarizations among different paths. In the past, two different configurations of beam splitters have been used: the parallel plate and the cube buck. Beam-splitting cubes with embedded metal or dielectric layers have been studied widely for controlling not only the intensity ratios but also the phase retardations between the orthogonal polarizations in the transmitted and reflected lights [2]. In the optical metrology, the measurement precisions of phase retardations can be improved by using a sinusoidal phase modulation and a Fast Fourier Transform (FFT) analysis based on the homodyne polarization interferometer [3]. Traditionally, most of the signal modulations were performed using the buck electrooptic modulator with a high operation voltage of over 100V. In our previous work [4], a Zn-indiffused phase modulator (ZIPM) with a lower operation voltage of 10V and near-stable phase operation has been successfully fabricated in an x-cut/z-propagation $LiNbO_3$ at 632nm wavelength. Besides, the single-channel phase measurement system using the homodyne technique also has been developed in the LabVIEW platform (National Instrument) [4].

In this paper, a new method is proposed for simultaneously measuring the phase-retardation difference between two orthogonal paths through the beam splitter. The novel ZIPM is used as a signal modulation in the proposed dual-channel phase measurement system. Our results confirm that the proposed instrument successfully characterizes the path-dependent phase retardations.

2. Experimental setup and principles

Figure 1 presents a schematic illustration of the proposed optical metrology system. A linear polarization of an incident He-Ne laser light of 632nm is achieved by a polarization controller consisting of a polarizer (PL1) and a half-wavelength plate ($\lambda/2$ WP). The polarized light with +45° relative to the x-axis of LN substrate is focused with a lens (L1), and launched into the ZIPM. Then, the sinusoidal phase delay between the TE and TM polarizations is modulated via the driving peak-to-peak voltage of 10 V at a frequency of 100 Hz. The output light passing through another lens (L2) and a test beam splitter (BS) is divided into a transmitted light and a reflected light. The phase retardations of the transmitted and reflected lights are represented by the notion of ϕ_T and ϕ_R, respectively. The interferometric intensities are detected by the photo detectors PD1 and PD2 after passing through the corresponding analyzers AL1 and AL2 with -45°. Both the signals are connected to a laptop personal computer. Similar to the previous single-channel homodyne phase measurement system [4], the signal processing based on the FFT demodulation scheme is performed with the LabVIEW-based hardware (BNC 2120 and DAQ-6036E), and software (version 7.0).

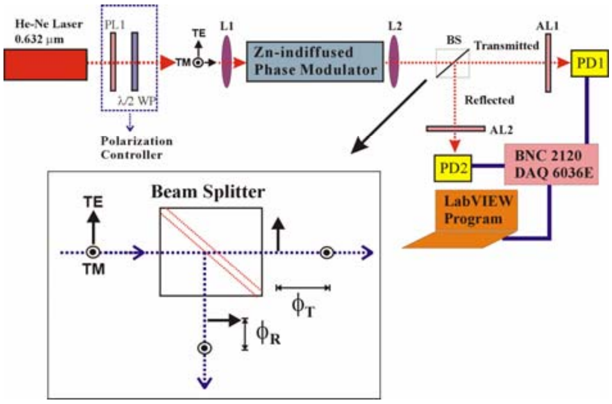

Fig. 1. Experimental setup for a simultaneous dual-channel phase measurement.

3. Results and discussions

Figure 2 shows the LabVIEW front panel for real-time dual-channel phase measurements including transmitted and reflected spectrums. Moreover, the measurement phase data can be exported into an *EXCEL* file for further analysis.

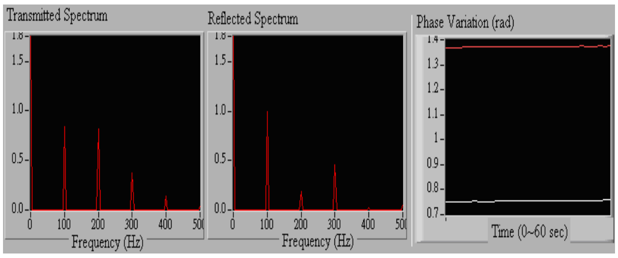

Fig. 2. LabVIEW front panel for real-time dual-channel phase measurements including transmitted and reflected FFT spectrums.

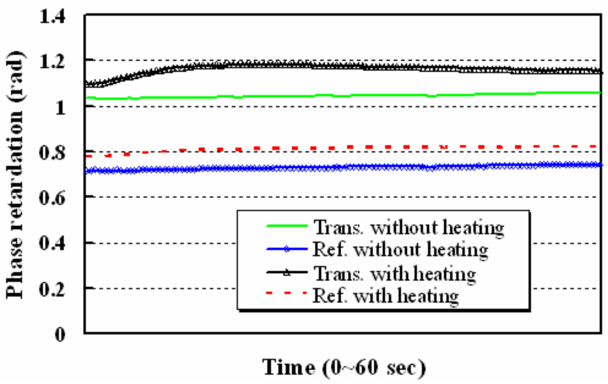

Fig. 3. Phase-retardation measurements as a function of time for different paths with different thermal conditions

Figure 3 shows that the phase-retardation measurements as a function of time for the transmitted and reflected paths with different thermal conditions. In the room-temperature measurement at 25°C, the average values of phase retardations are 1.037 and 0.727 rad for the transmitted (green trace) and reflected (blue trace) lights, respectively. The corresponding standard deviation values are 0.007 and 0.008 rad. These results show that the measurements are stable, and the phase stability of the ZIPM is enough for the required precise. To compare the phase retardations under temperature changes, the beam splitter was heated with temperature variations from 35°C to 55°C. The phase retardation of transmitted light (black trace) gradually changes when the temperature changes. In contrast, the phase variation of reflected light is stable, and the standard deviation value is 0.012 rad. In comparison with the reflected light without heating (red trace), this value is larger due to the thermal impacts. When simultaneously measuring for both transmitted and reflected lights, the phase-retardation differences between both paths were studied for different thermal conditions, shown in Fig. 4. The phase difference was stable of about 0.311 rad, and the stand deviation value of 0.002 rad was achieved when measuring at room-temperature. It means that the measurement precision can be enhanced greatly by using the proposed instrument. Besides, the phase difference increases when the cube's temperature increases. The phase difference also gradually decreases in the natural cooling region. The results indicate that the temperature variations from 35°C to 55°C cause the changes of phase difference from 0.32 rad to 0.37 rad. The calculated ratio of phase changes versus temperature variations is about 0.0025 rad/°C.

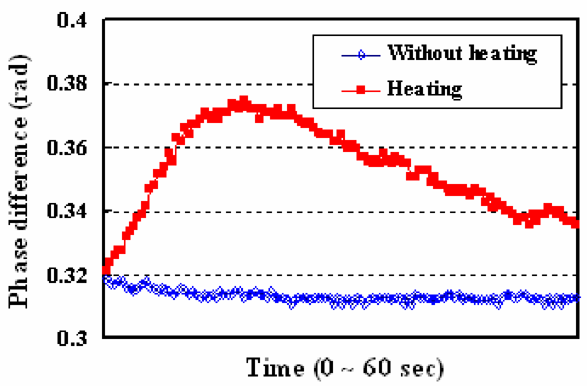

Fig. 4. Comparison results of phase-retardation differences as a function of time for different thermal conditions.

4. Summary

A novel dual-channel polarization interferometer has been successfully developed for measuring the path-dependent phase retardations of an incident light passing through a beam splitter. This method is particularly useful for improving the measurement precision due to the parallel signal processing performed on a LabVIEW-based platform. The temperature-dependent phase differences between two different paths were obtained for the first time. Lastly, the experimental results show that the developed instrument provides the capability of characterizing beam splitter very precisely.

Acknowledgement

This work was supported by the National Science Council, Taiwan, R.O.C., under Grant No. NSC 96-2221-E-218-026.

References

[1] C. M. Wu and M. C. Pao, "Sensitivity-tunable optical sensors based on surface plasmon resonance and phase detection," Opt. Express **12**, 3509-3514 (2004).

[2] J. Ciosek, J. A. Dobrowolski, G. A. Clarke, and G. Laframboise, "Design and manufacture of all-dielectric nonpolarizing beam splitters," Appl Opt. **38**, 1244–1250 (1999).

[3] P. P. Markowicz, W. C. Law, A. Baev, P. N. Prasad, S. Patskovsky, and A. V. Kabashin, "Phase-sensitive time-modulated surface plasmon resonance polarimetry for wide dynamic range biosensing," Opt. Express 15, 1745–1754 (2007).

[4] R. C. Twu, H. Y. Hong, and H. H. Lee, "An optical homodyne technique to measure photorefractive-induced phase drifts in lithium niobate phase modulators," Opt. Express **16**, 4366-4374 (2008).