Measurement of linear birefringence using a rotating-wave-plate Stokes polarimeter

Jing-Fung Lin

Far East University, Department of Computer Application Engineering, No. 49, Jhonghua Road, Sinshih Township, Tainan County 74448, Taiwan

A R T I C L E   I N F O

Article history:
Received 16 March 2009
Accepted 1 September 2009

Keywords:
Birefringence
Principal axis
Retardance
Stokes parameter

A B S T R A C T

In this study, a compact polarimeter is developed to measure the linear birefringence property of optical materials. The principal axis angle and the retardance are obtained by a simple signal-processing algorithm, which is derived via Stokes parameters extractions when using an incident light linearly polarized at 45°. There exists an absolute error of 0.029° on average in the principal axis angle measurement and a relative error of 2.54% in the retardance measurement of a quarter-wave-plate sample with its principal axis ranging from −40° to 40°. The standard deviations for the principal axis angle and retardance measurements are determined to be 0.015° and 0.018°, respectively, while one standard deviation to the average value of the principal axis angle and retardance, respectively, are just 0.066° and 0.020°, with high repeatability, and corresponding dynamic ranges of −45° to 45° and −180° to 180°, respectively. Consequently, the developed polarimeter has a potential in linear birefringence measurement, especially in the retardance measurement.

© 2009 Elsevier GmbH. All rights reserved.

1. Introduction

Many optical materials exhibit a linear birefringence (LB) effect as a result of the different phase retardations experienced by the two orthogonal linearly polarized rays of the transmitted light. It is well-known that many crystals such as quartz exhibit the optical property of linear birefringence. For example, the linear birefringence measurement of the quarter-wave-plate is one of the most troublesome in polarimetry setups due to the specific role of this plate in polarimetry-transformation of the polarization states into linear or circular ones [1]. Also, the linearly birefringent quarter-wave-plate needs to have a precise value of retardance to ensure the polarization of light and successful operation in different applications such as the amplitude-only and phase-only modulations of a liquid crystal display [2].

Over the past decade, several researchers have proposed methods using the modulated technique to simultaneously measure the principal axis and the various retardance levels of linearly birefringent materials, with different dynamic ranges [2–9]. For example, Wang [4] developed an instrument for measuring linear retardance in transparent optical components using two photoelastic modulators and displayed both retardance magnitude and angle of fast axis. However, the dynamic range of principal axis angle measurement is from 0° to 45°, and due to the use of an arcsine function in the calculation, this system has an upper retardance limit of 90°. Lo et al. [7] proposed a polariscope with electro-optic modulation, which is capable of simultaneous measurement of the principal axis and the phase retardation of linearly birefringent medium by means of two phase-locked extractions. However, a phase compensator is needed to suppress the transmission phase-retardation effect of the beam splitter, thereby enhancing the precision of the measuring performance.

Apart from the modulation technique approach, Ohkubo and Umeda [8] used the heterodyning of Zeeman laser and developed an optical configuration for a near-field scanning optical microscope with birefringence contrast imaging. The intensity signal-processing is required to achieve the azimuth angle and the retardance measurements, and the dynamic range of the retardance was restricted to just 57.3°. Furthermore, Lin et al. [9] presented a new optical system that uses a transverse Zeeman laser in conjunction with a plane polariscope to simultaneously measure both principal axis angle and retardance of the linearly birefringent materials. Using the amplitudes of a reference signal and of two measuring signals, a simply derived algorithm can obtain the principal axis angle and the retardance directly and easily.

In this study, a compact polarimeter based on Stokes-parameters extractions is proposed in order to overcome problems such as the normalized intensity jump and limited measurement range in the retardance of 90° in the previously proposed configuration [6]. There are two unique characteristics in this proposed metrology system. One characteristic is that to enhance the accuracy of the measurement results, the current optical configuration deliberately utilizes a rotating-wave-plate Stokes polarimeter since such a device is known to be one of the...