Development of an automated system for polarimetry

Rafael E. de Góes, Rosane Falate, Leandro G. B. Becker, Paulo E. Martins,Claúdio A. de Lima,

Márcia Müller, Hypólito J. Kalinowski, José L. Fabris

Centro Federal de Educação Tecnológica do Paraná – Curitiba, PR, brazil

rfalate@cefetpr.br

Abstract

A low cost automated system to analyze the state of optical polarization is described. The apparatus versatility allows the assembling of different setups, suitable to each particular application. We characterize the instrument performance measuring the degree of polarization of a laser beam, and finding out the optical axes of a birefringent material.

Introduction

There are many applications in several fields of optics where is important to know and to control the state of polarization (SOP) of light. In optical communications, for example, the knowledge about the SOP is crucial in experiments to measure the polarization-mode dispersion [1], in devices where are used birefringent optical fibers [2] or fiber polarization couplers [3], and in the construction and operation of optical filters or tuning devices [4].

In the field of optical fiber based sensors, refractive index gratings produced in birefringent fibers can be used to measure parameters like stress or temperature [5,6], but the SOP of the light needs to be known for the production of the devices, as well as in their use.

Although the procedure to control the SOP can be done in a manual process, this is time consuming and subject to errors of positioning and reading. In order to overcome these difficulties, we developed an automatic system to control precisely the state of polarization of light.

Experimental Setup

The developed equipment employs two sheet linear polarizers from Shiro Photo Company, each of them held on a rotary vertical stage and driven by stepping motors with 200 steps per revolution, 4 phases and 85 mA drain current per phase. These steppers are coupled to the polarizers by means of plastic gear wheels, and the mechanical ratio of 1.5 allows to obtain a resolution of 1.2 degrees per step. To control each motor, a 4029 IC counts up or down gated by two different signals. The phase sequence generated after the decoder, which is implemented by NAND ant NOT gates (4069 IC and 4081 IC), drives the transistors that support the peak phase current. With the developed circuit, the motors work in full step mode.

The software is implemented using Microsoft Visual C++, and commands the stepper controller through the parallel port of a PC. Four pins of this port are used, two for each motor. One pine controls the direction of rotation while the other one the number of steps. The data, which corresponds to the source radiation intensity, is read from a lock-in amplifier (Stanford Research Systems SR 830) through the serial port at 19,200 bps. The software includes two motor controller threads and two applications: one to measure de degree of polarization and other to find out the birefringence axes of a sample.

The state of polarization of an optical source can be measured making the light to pass through a linear polarizer (an analyzer) that can be turned around its axes, being collected after this by a polarization insensitive optical sensor. After a 360° turn, the detector reads an upper end a lower intensity signals. The degree of polarization is defined by [7]:

$$V = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

where I_{max} and I_{min} are the upper and lower intensity values. In the measurement of the V parameter, only one stepper is used. First, the values of the initial, final, and the increment angles are given. For each value, the program rotates the analyzer and read the radiation intensity. The values are plotted in polar form and, at the end of the scan, the numerical *V* value is given and can be saved in an ASCII file. The software also allows to change the plot from polar to Cartesian form.

To find out the birefringence axes of a uniaxial crystal or a birefringent material, the SOP of the light traveling through a sample needs to be known. If the direction of the optic axis is arranged to be parallel to the front and back surfaces, and if the electric field of an incident monochromatic plane wave has only a component parallel to one of the optic axis, the SOP of the emergent light is linear. To make the measurement, a material sample is conveniently positioned in the equipment between the two polarizers sheets, the first one working like a polarizer and the second one like an analyzer. A monochromatic light beam with circular polarization (or a depolarized beam) incident in the polarizer results in a linearly polarized beam that can be turned with no intensities changes. The reading procedure consists in, for each polarizer position, to turn the analyzer looking for a maximum intensity. In this application, both steppers are employed, and the input polarizer angle for which *V* is maximum (or as close as possible to one) corresponds to the angular position of the birefringence axis.

Results and Discussions

To exemplify the system performance, we measured the SOP of a He-Ne laser, with polarization ratio of 1:500. Figure 1 shows the computer screen aspect, where is displayed the degree of polarization (GP=0.99) and the SOP graph in polar form. The “Analyse” window allows to define the motor to be used in the data acquisition, and the initial, final, and the increment angles of the movement. The “Motor 1 Controller” window can be used to move the motor independently of the data acquisition process, while the “Lockin” window displays the radiation intensity whenever the “Read” button is pressed.

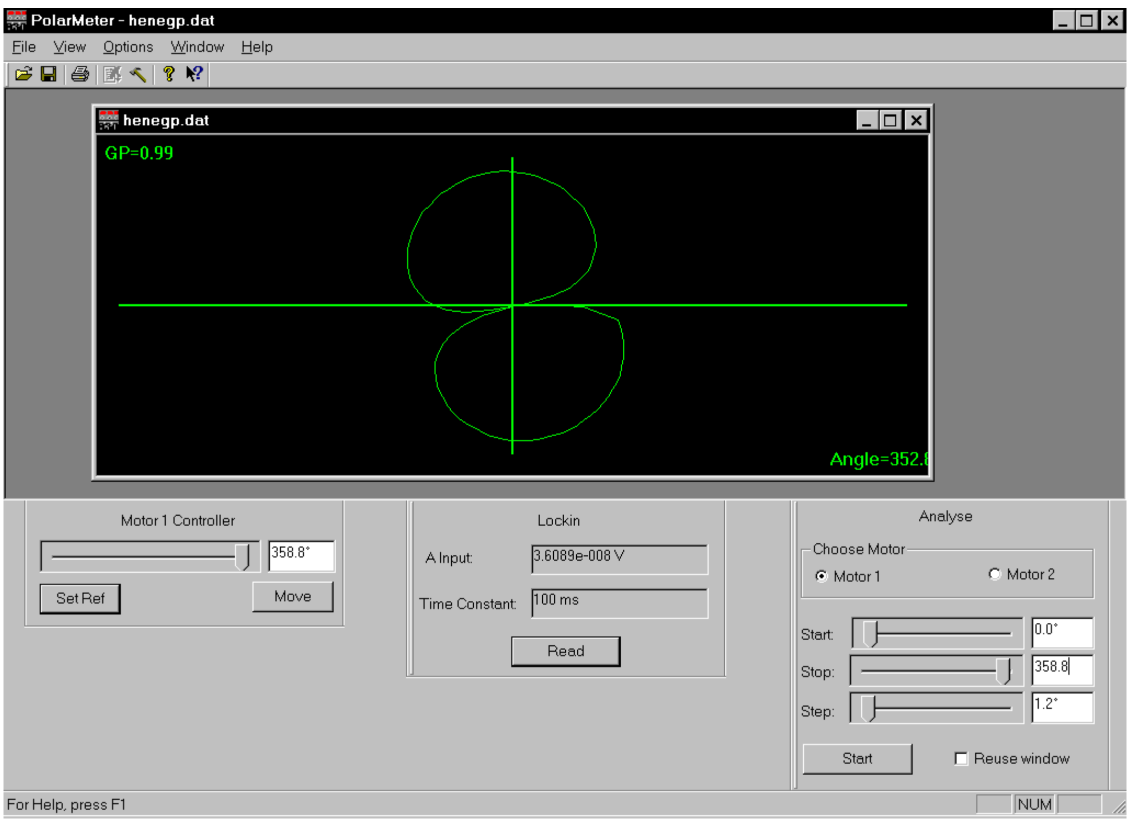

Figure 1: Aspect of the computer screen in the state of polarization measurement.

In the application that allows to find out the birefringence axis of material, we characterized a 632.8 nm quarter wave plate, using as light source a circularly polarized He-Ne laser beam. Figure 2 shows the computer screen aspect, where is displayed the axes angle (115.2 degrees) and the SOP graph in Cartesian form. The “Find Axes” window controls the polarizer movement (“Independent Variable”), with the user defined angular parameters for the initial, final and increment values. The “Dependent Variable” defines the angular increment for the analyzer movement

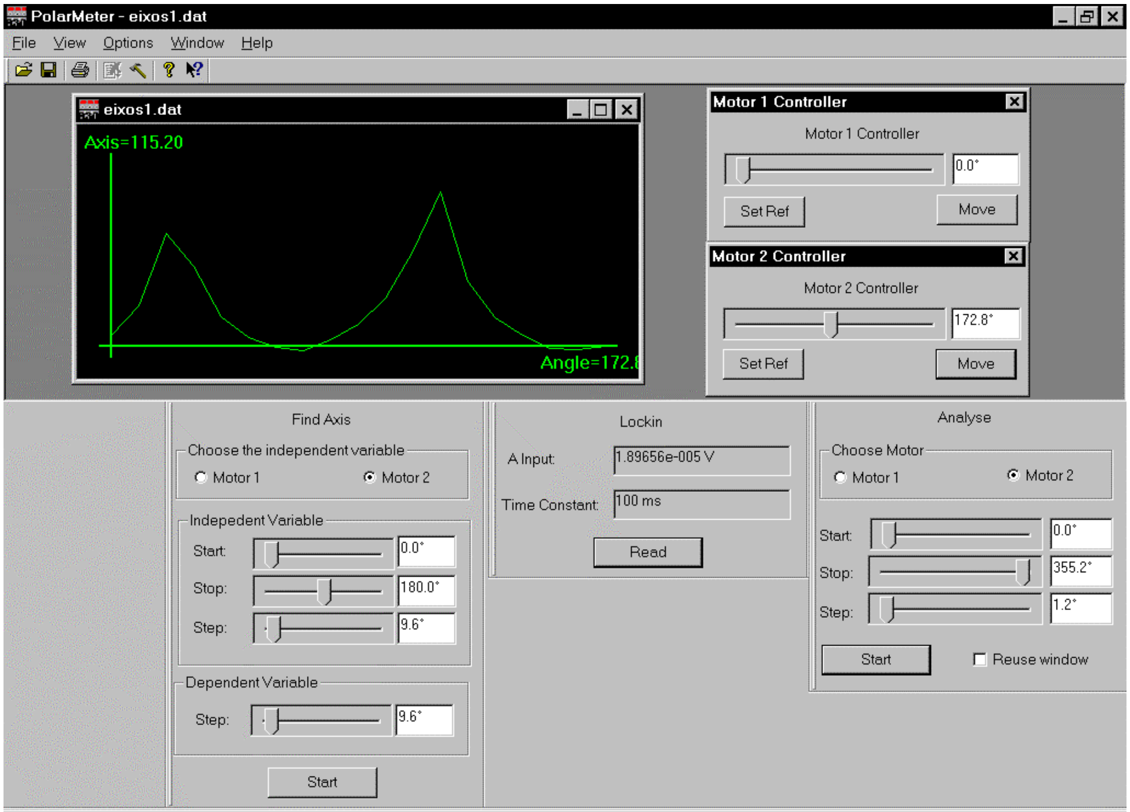

Figure 2: Aspect of the computer screen in the birefringence axis measurement.

Conclusions

We described a low cost system used to control and measure the SOP of a source radiation. The cost factor can be as low as 10% when compared to commercial equipments. The system employs sheet polaryzers used in photography, but it can be replaced by appropriated ones to expand the equipment wavelength range. The use of the parallel port of a PC eliminates the needing of internal extra interfaces, simplifying the project. We have successfully used it, helping the tasks related to polarization control in both production and characterization of birefringent Bragg gratings and Rocking filters. The limits in the determination of the SOP or principal optical axis are given by the extinction rate of the used polarizers and by the polarization scattering over the optical components used in the experimental setup where those parameters (SOP, principal axis) shall be measured.

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