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Automatic instrumentation with a PC-based data acquisition system for experiments in optical characterization of materials

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Automatic Instrumentation with a PC-based Data Acquisition System for Experiments in Optical Characterization of Materials.

Instrumentación Automática con un Sistema de Adquisición de Datos Basado en PC para Experimentos en Caracterización Óptica de Materiales.

ABSTRACT / RESUMEN

A simple automatic control for applications of optical characterization of materials using the optical Z-scan technique is presented in this paper. The emphasis is placed in the automation process. For this purpose, a communication I/O port of a PCI-MIO-16E data acquisition card (from National Instruments) was used and the graphical programming language LabVIEW.

Se presenta un control automático simple para aplicaciones de caracterización óptica de materiales usando la técnica Z-scan. En particular, se enfatiza el proceso de automatización. Para este propósito, se usó un puerto de comunicación de I/O de una tarjeta de adquisición de datos PCI-MIO-16E (de National Instruments), así como el lenguaje de programación gráfica LabVIEW.

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INTRODUCTION

The use of *LabVIEW* is on the increase in the universities and industries especially for data acquisition and process control. *LabVIEW* gives you the flexibility and performance of a powerful programming language without the associate difficulty and complexity. Frequently, there is a need to develop *LabVIEW* application software to work with foreign hardware (for example, we use an old mechanical mechanism of a matrix printer). In this work, we use the *LabVIEW* language version 6.0 in order to obtain the appropriate virtual instrument for control of the experimental setup used for experiments in optical characterization of new materials. For this purpose, we use the well known technique called Z-scan. This is a highly sensitive technique for the determination of nonlinear refraction (NLR) and nonlinear absorption (NLA) of optical materials presented by Sheik-Bahae M, Said A. A, y Van Stryland E. W. (1989). In the following sections, we show a briefly introduction to the *LabVIEW* environment, the basic fundamentals for the Z-scan technique, the hardware and programming description. Finally, we present the general conclusions.

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LABVIEW ENVIRONMENT

LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. In *LabVIEW*, a program is called *VI* (Virtual Instrument) because it models the appearance and function of a physical instrument. In contrast to text-based programming languages, where instructions determine program execution, in *LabVIEW*, you can build a user interface by using a set of tools and objects. This explains why the software is structured in *front panels* and *block* diagrams. The user interface is known as the front panel in Fig. 1, analogous to the front panels of measuring instruments, which feature operating and display elements and serve as the actual interface between the user and the device. In *LabVIEW* the front panel is the user interface of a program and allows the user to interact with the program and to visualize the output from applications.

The block diagram contains the functional *program* code (a graphical source code that is used as a schematic diagram in the sense of a signal flow representation), in contrast to the conventional textual source code in Fig. 2, (Jamal R, y Pichlik H. 1999). The components of this block diagram can be simple mathematical operators or user-defined subVIs (similar to subroutines). These components point to the third component of a VI, the *icon/connector*, which serves as an interface of a subVI to the calling program. A great advantage for the use of *LabVIEW* is the support for communications with industrial and scientific hardware under standards such as GPIB, VXI, RS-232, RS-485, and generic plug-in data acquisition devices. Also, with the use of *LabVIEW*, you can create 32-bit compiled applications that give you the fast execution speeds needed for custom data acquisition, test, measurements, and control solutions.

THE Z-SCAN TECHNIQUE

The Z-scan method has gained rapid acceptance by the nonlinear optics community as a standard technique for separately determining the nonlinear changes in index and changes in absorption (Van Strayland E. W, y Sheik-Bahae M. 1998). This acceptance is primarily due to the simplicity of the technique as well as the simplicity of the interpretation. In most of the experiments, the index change, and absorption change, can be determined directly from the data without resorting to computer fitting. It has been used to measure nonlinear optical properties of semiconductors, dielectrics and
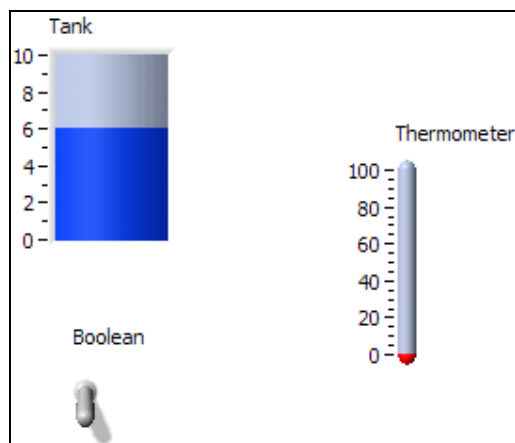

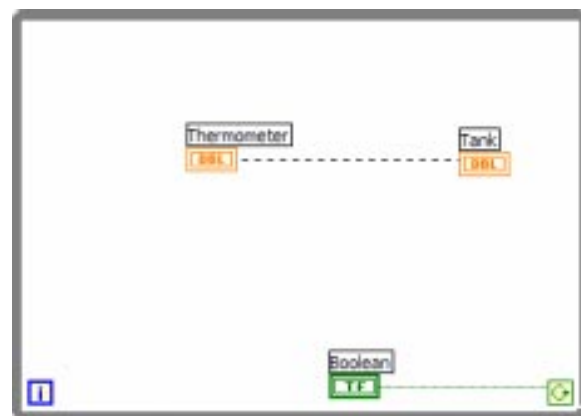**Figure 1.** The user interface or front panel of a VI (Virtual Instrument).

Figure 2. The block diagram (graphical source code of the program).

glasses, organic or carbon-based molecules and liquid crystals, with nonlinearities ranging from femtoseconds to milliseconds timescales (Chapple, P. B., Staromlynska, J, y McDuff, R. G. 1994). In the Z-scan technique, a sample is *scanned* along the optical axis (the z-direction) through the focus of a single laser beam, while the energy transmitted through an aperture in the far field is recorded as a function of sample position, see Fig. 3. It is convenient to plot T, the transmittance normalized to the linear transmittance of the system. In this experimental setup, we use a continuous wave He-Ne laser with linear polarization, focusing lens and two detectors. For example, a typical Z-scan profile for a thin sample with a purely refractive, positive nonlinearity is shown in Fig. 4. The nonlinearity can often be evaluated from the difference between the maximum and minimum values of the normalized transmittance, ΔT. For a thin optical Kerr medium (is a kind of material, where the refractive index varies linearly with irradiance in the form: $\Delta n = n + n_2 I$,) with nonlinear refractive index coefficient n_2 (in units $m^2 W^{-1}$), ΔT is proportional to the nonlinear phase shift $\Delta \Phi_o$ on the axis with the sample at the waist, and hence to n_2.

$$\Delta T = 0.406 |\Delta \Phi_o|, \qquad (1)$$

where $\Delta \Phi_o = k n_2 I_o L_{eff}$. Here, $k = 2\pi/\lambda$, λ is the wavelength, I_o is the axial irradiance at the waist and L_{eff} is the effective sample length. This is given by $L_{eff} = (1 - e^{-\alpha_o L}) / \alpha_o$, where L is the true sample length and α_o is the linear absorption coefficient ($L_{eff} = L$ in the absence of linear absorption). Equation (1) is correct to

first order in I_o (the weak interaction regime), for a Gaussian profile laser beam and an infinitesimal aperture or pinhole at the far field (Peinado R. 1998).
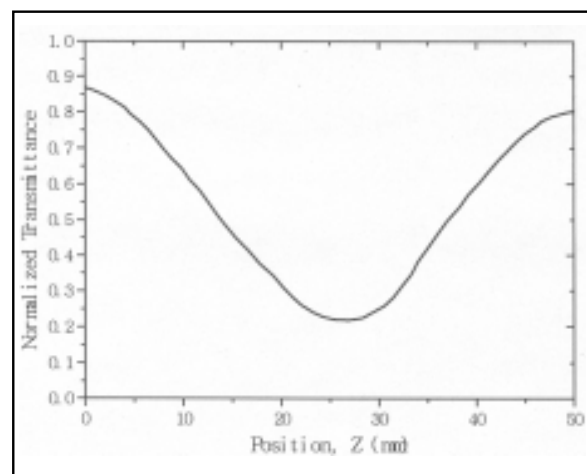

Figure 4. Theoretical fit for the Z-Scan experiment.

HARDWARE AND PROGRAMMING DESCRIPTION

The programming and interface part is a process that is crucially needed in order to collect, manipulate, and maintain precision of data. For the motion control system, we use a data acquisition card from National Instruments (PCI MIO16E-4, E Series). Some characteristics for these devices are: 16 analog inputs at 500 kS/s (single-channel) or 250 kS/s (multichannel), 12-bit resolution, 2 analog outputs at 1 MS/s, 12-bit resolution, 8digital I/O lines (5 V TTL/CMOS); two 24-bit counter/timers, analog and digital triggering.

The computer codes that were implemented into the program, had to perform the following tasks: move the position stage after each data point is taken, collect data from the detectors, decide which data is to be kept, average, compute, display, and record the data.
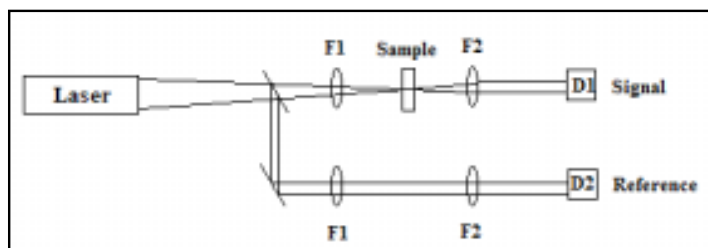

Figure 3. Z-Scan experimental setup: the sample is moved between the focusing lens F1 and the collimating lens F2 in the signal arm; the reference arm is used for noise reduction.

All these computations are needed with maximum accuracy and minimum time. The computer collects data from the detectors via the data acquisition card and communicates with the positioning stage by using drivers for the translation module (with the use of one stepper motor). A stepper motor is a device that positions loads by operating in discrete increments (or steps). The stepping is accomplished by switching the power to the motor windings so that the motor phases are energized in a specific sequence.

The computer language used for software interfacing is *LabVIEW*, and we have seen in the Fig. 5, the frontal panel of the program used for the control. In the Fig. 6, we show the electrical schematic diagram of the motion control setup.
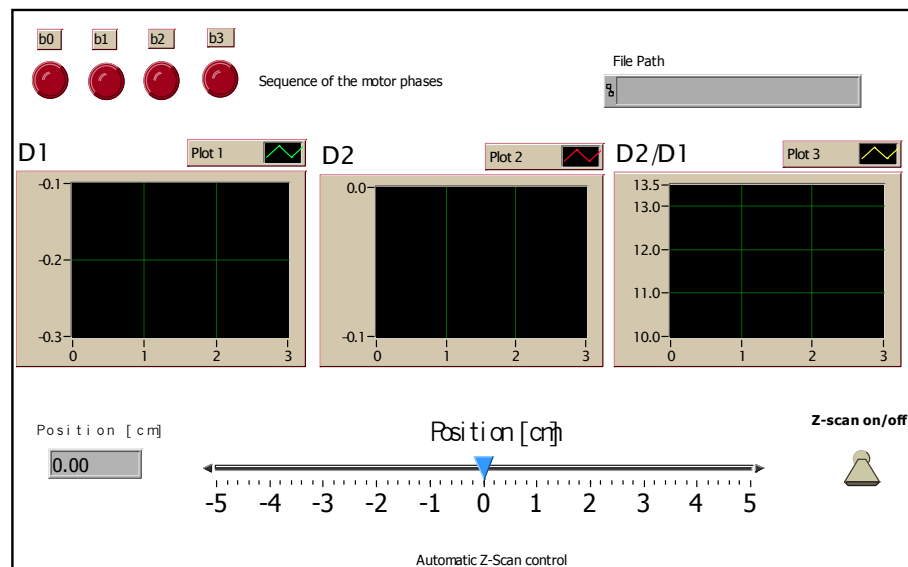

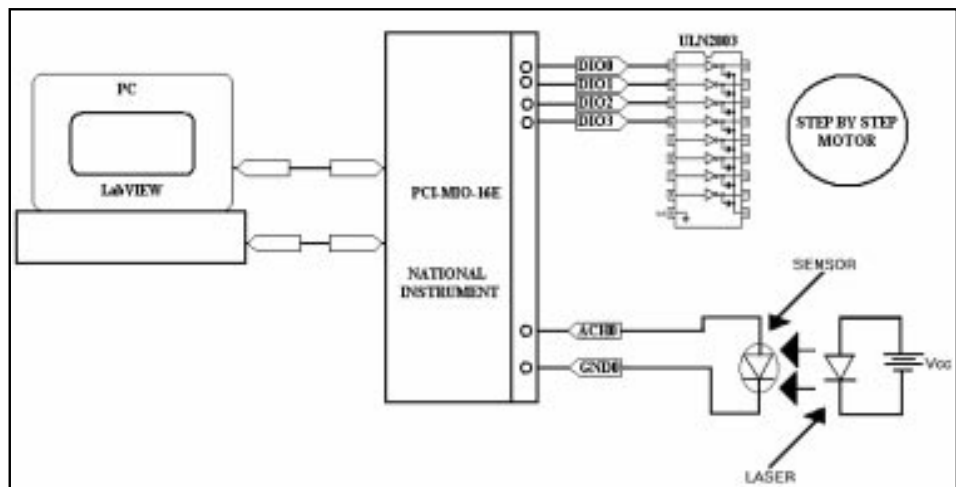**Figure 5.** User interface of the designed VI for the experiment.

Figure 6. Electrical schematic diagram of the motion control setup.

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CONCLUSIONS

We have successfully built an optical experiment called Z-scan in order to measure optical nonlinearities. The measurement is based on moving a sample through a focused beam, taking advantage of higher nonlinearities at the beam focal point. We have interfaced the experimental setup with the computer using *LabVIEW* software and a data acquisition card from National Instruments Corporation.

ACKNOWLEDGMENTS

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