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# Virtual instrumentation in LabVIEW for multiple optical characterizations on the same opto-mechanical system

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ABSTRACT

In this work we propose a virtual instrumentation, user-friendly, computer-controlled instrumentation and data analysis techniques, allowing an instantaneous comparison between theoretical predictions, simulations and actual experimental results. These applications in LabVIEW programming software show a virtual explosion in data acquisition and control system from the laboratory. We consider a versatile opto-mechanical system $\theta$–$2\theta$ by using the p-polarized light from a He–Ne laser in which the surface plasmon resonance, Brewster and Brewster-Abelès methods, and scattering measurements are driven by LabVIEW software that produces fast, simple and accurate measurements of samples. The application can be used for both education and specific research purposes.

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## 1. Introduction

LabVIEW is a software development environment to design systems with a graphical visual programming language (called G language). This software reduces the development time of applications and is appropriated for data acquisition system, software simulations, embedded electronics, and real time control [1].

Surface plasmon resonance (SPR), the Abelès-Brewster method, critic angle and scattering measurement are important and easy techniques in the optical characterization of thin films and optical sensors that by using the p polarization illumination is possible to implement in a same opto-mechanical system $\theta$–$2\theta$ efficiently controlled by LabVIEW software. SPR is a physical phenomenon that arises when light interacts with a conducting film under specific conditions. A resonance effect is the result of the interaction between the transversal magnetic (TM) component of the incident light through a coupling system and the surface plasmon propagating along the surface of the conductor. The resonance conditions that permit the transference of energy from photons of the incident light to plasmons require that the energy and momentum of photons and plasmons should be matched [2]. Basically, the current practice of SPR sensors employs the attenuated total internal reflection geometry where SPR causes an intensity decrease or dip in the reflected light at the sensor surface; the ratio of incoming and reflected light vs. angle of incidence passes through a minimum. The angle at which the minimum is found depends on the refractive index of the medium in the immediate vicinity of the sensor surface. On adsorption or binding of molecules, at a fixed angle, the refractive index at the sensor surface will change, causing a shift of the reflectivity curve. This shift can be observed in real time. The analytical technique based on SPR is a powerful method used to detect changes in the refractive index of the medium adjacent to a metal. Due to its many advantages, such as high sensitivity and real-time monitoring, SPR has merely established itself as a powerful technique for a variety of applications in surface interactions to probe liquid [3], solid [4] and gas [5] phase measurements. The preferred metals used in SPR are thin films of silver and gold, although bimetallic structures [6], such as films and nanoparticles [7], have attracted considerable attention for SPR excitation. The advantage of gold is that it possesses a higher shift of resonance dip at the change of the ambient refractive index. On the other hand, silver possesses a narrow full width at half maximum (FWHM), and it is the metal of choice at optical frequencies due its low dissipation of energy in heat.

The Brewster-Abelès method is very popular because it is a non-contact method, easy to set up, and very simple to use. The Brewster angle, according to the Abelès method, is where the reflectance from the uncoated substrate and the step thin film are equal [8]. This is because no light was reflected from the air-film interface

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at the Brewster's angle of the film, then, the reflectivity of the film-covered substrate is the same as that of an uncoated substrate at the Brewster angle $\theta_B$. Thus, the refractive index of the film was calculated using the expression $n = \tan\theta_B$. Usually, the Abelès-Brewster is widely used for the determination of refractive index of dielectric thin film; however, some studies on the determination of complex refractive index of thin film are done using prism or flat substrate [9].

Measuring the refractive index of absorbing and turbid liquids by means of the accurate detection of the critical angle is possible to achieve using an synchronized opto-mechanical system $\theta$–$2\theta$ [10].

The proposed experimental setup is frequently used as a part of an optical laboratory to understand the measurement of the critical angle, Brewster and Brewster-Abelès measurement, scattering, and surface plasmon resonance (with angular scanning) and to fixed angle for biosensing measurement. The experimental setup explores the main properties from the point of view of electromagnetism to produce a fast, simple and accurate measurement of samples, and it determines the properties that characterize a sample, such as a full width half maximum and height and resonance angles of the SPR curves. Also, it determines the optical characterization of the metallic thin film (complex refractive index and thickness by using the minimum squared fitting method).

As an example, liquid samples of different concentrations of ethylic alcohol/distilled water were prepared. Each sample is analyzed and measured using the SPR technique. The refractive indices of a metallic and a dielectric thin film are measured to show the different effects of the refractive index, real and/or complex, in the SPR and Brewster-Abelès curves obtained and analyzed by the system proposed. Also, the scattered light of nanoparticles of gold was realized.

In recent works, we had reported a study of the alcoholic beverage analyzing the resonant angle using a gold thin film [11], and resonant angle and width of the SPR measurements using a silver thin film [3] making an analysis of all SPR data by hand, which is laborious. In this work, we use the analysis of data of SPR curves in nearly instantaneous way using the LabVIEW instrumentation.

There are many commercial SPR instruments [12], but are expensive and very specific, mostly for biosensing applications. In the proposed experimental setup we take account the rising of new, powerful, compact and inexpensive microcontrollers, the use of LabVIEW software, and the USB port, that permit to transfer a great quantity of data obtained in a fast and accuracy way.

## 2. Description of the experimental set-up

The experimental setup to measure the Brewster angle, SPR and scattered intensity is shown in Fig. 1. A polarized He–Ne laser (Uniphase mod. 1101P) centered at 632.8 nm of 1.5 mW of minimum output power, minimum polarization ratio of 500:1 and a beam diameter of 0.63 (mm, $TEM_{00}$, 1/e2 points ±3%), used as a source in p polarization, was directed toward a surface (substrate) coated with the probe film of refractive index $n$. This polarization ratio is sufficient to make SPR and Brewster measurements. The reflected measurement for a bare substrate in the Brewster technique shows that the intensity is zero at the Brewster angle; this demonstrates that the incident light is only p-polarization and there is not necessary to use a polarizer. A collimation is not necessary because the beam diameter is less than the diameter of the photodetector area (about 4) mm.

The sample was mounted on a rotatory stage (rotatory system $\theta$) to scan the incident angle of the laser beam. The incident light was reflected on the interface film/air for Brewster measurement (Fig. 1, part A) or through the prism for SPR measurement (Fig. 1, part B), or the transmitted light through gold nanoparticles (Fig. 1, part C) toward an optical photodetector mounted on a second rotatory stage (rotatory system $2\theta$) synchronized with the first rotatory system to maintain the detector-signal aligned. Each rotatory stage (Standa rotatory stage mod. 8MR180) has a resolution of 0.01°. These motorized rotatory stages are driven with a stepper motor, with a maximum rotatory speed of 8 turn/min, and zero backlashes. These characteristic eliminates the possible error for inertia. The reflected signal of the probe sample was recorded by a computer that also controlled both rotatory systems and the experimental data for samples.

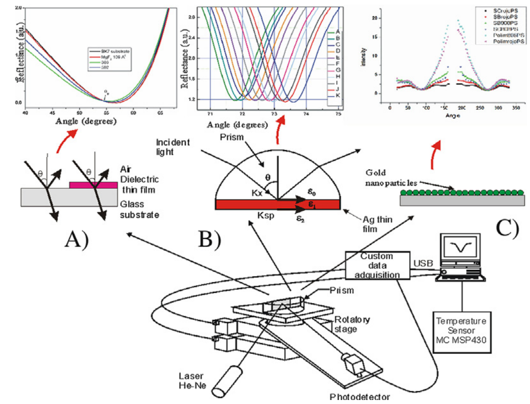


**Fig. 1.** The experimental setup consists in a rotatory stage where either are mounted, a substrate with a step of dielectric film for Brewster angle measurement (A), the prism for SPR measurement (B), or gold nanoparticles in colloidal suspension for scattered light measurement (C).

As a temperature sensor, we used the internal temperature sensor of the Texas Instruments microcontroller launch pad (mod. MSP-EXP430G2). The experimental setup registers the initial and final temperatures in each measurement. The variations of temperature have an impact on the refractive index of the layers but we can avoid the impact of these variations if we check that the temperature variations stay below 0.1 °C in the experiment, due a variation of 1 °C leads to a variation of the refractive index of water of about $2 \times 10^{-4}$ RIU [13]. In the proposed system, the order of magnitude of the variation of the refractive index using the SPR method is in the $10^{-3}$ (Refractive Index Units) RIU [14]. It is possible to increase accuracy using interferometric methods, but they have the drackbacks of limited range, high cost and configurations that are more complex to implement.

The application of the system $\theta$–$2\theta$ will depend on the opto-mechanical system employed and its calibration method. For example, for SPR measurements, we used the values widely described in literature for air and distilled water, and for Abelès-Brewster measurements, we used the refractive index value for the glass described by the maker (in this case, the Schott Glass Inc. values). Another consideration for mechanical calibration is to make a scan for a wide range of angles: if the reflected signal for the sample is centered on the area of the photodetector, throughout the entire scan, then the flat face of the hemicylindrical prism, or the substrate, is well aligned with the center of rotation.

## 3. Data acquisition system

The electronics of the experimental setup consists in a microcontroller based system (Microchip mod. 18F4550 l/P), which was selected because it has USB connectivity and facilitates the control of the system in practically any Windows operated computer, although the software can be developed practically for any platform such as Linux, and OS X. Besides, this microcontroller has an Analogical Digital Converter (ADC) with a resolution of 10 bit. The microcontroller has a 13 analogical channel for multiplexing

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