An educational setup for a laser induced breakdown spectroscopy (LIBS) system and its usage for the characterization of cultural heritage objects

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Abstract
An experimental setup for laser induced breakdown spectroscopy (LIBS) has been developed for educational purposes, to be used in the physics curriculum of science students and of students who are specializing in the field of cultural heritage. The setup comprises a Nd:YAG laser and a fiber optic spectrometer. All components were already existing equipment at the physics laboratory at the TEI of Athens, so that they could be assembled in-house to a considerably economic LIBS setup. The proposed laboratory exercises are focused on learning how to acquire accurate spectroscopic data and to interpret the information provided by the LIBS system.

Experimental setup
The experimental setup was implemented by assembling existing components. D is is based on a Q-switched Nd:YAG laser, an optical system for focusing the laser beam and collecting the signal from the sample and a spectrometer. The timing and delay of the measurement, after each pulse of the laser, is controlled by a delay generator, which is inserted between the Q-switched Nd:YAG laser and the spectrometer. The delay times are programmable for different delay times. For triggering the spectrometer, Figure 1 presents three photographs of the setup, while the schematic connection of the individual components is presented in Figure 2.

The laser (Quantel, Brillant B) exhibits a beam energy of 850 mJ and a pulse duration and frequency of 10 and 10 Hz respectively. The 9 mm-diameter beam is focused through a convex lens and 20 mm high and 20 mm wide. The spectrometer, a high-definition camera, has a sensitivity of 200 mm and a high energy density, a neutral filter with 50% transmittance is inserted between the laser and lens. The plasma light produced by the laser pulse is measured with a cooled CCD camera, which is coupled with the optical fiber cable transmitting the plasma light from the target to the spectrometer.

The laser beam is directed towards the sample, which is placed at the focus of the convex lens, which forms the plasma sphere. The plasma sphere is the source of the emission spectrum of interest. The delay generator, commonly used as trigger in most LIBS systems, is replaced by a delay module (Figure 3). This laser has been developed as a cheap and affordable solution for triggering the laser; it is based on a Nd:YAG laser and a fiber optic cable transmitting the laser light from the target to the spectrometer. In order to minimize the response time, the controller is programmed in low level language (Propeller Assembly). In this way the delay time can be software controlled in steps of 0.012 μs with a minimum delay of 330 ns.

LIBS fundamentals
In LIBS, a high energy laser pulse is focused onto the surface of the sample. Enough energy is delivered to the small area of the sample to cause the material to vaporize, but not to break down into atoms. If the laser is switched on, different elements in the sample emit at different wavelengths. These wavelengths are then measured to identify the elements present in the sample.

LIBS applications on cultural heritage objects
Analytical examination has become an integral part of the study and conservation of cultural heritage objects in terms of material characterization and in terms of revealing deterioration processes. For this reason, students who are educated in fields of study, such as archaeology, science and conservation science, have to pass courses in the theoretical and practical training concerning the feasibility and limits of various analytical methods.

In collaboration with the Department of Conservation at the TEI of Athens a series of sample applications were developed demonstrating the principles of LIBS. Figure 6 illustrates the analysis of a metal object, which was recovered from the Patris shipwreck and which was examined in view of the suitable corrosion treatment.

Conclusions
A setup of a Laser Induced Breakdown Spectroscopy (LIBS) system has been developed in order to be used for educational purposes. The LIBS setup is comprised of a laser and a fiber optic spectrometer device, which are available in the physics laboratory at the TEI of Athens. It was configured for the realization of a number of familiar and conventional laboratory exercises, such as obtaining atomic emission spectra or qualitative evaluation of the spectra. Furthermore, the influence of several operational parameters on the quality of signal measured was investigated. The system can be used for the education of students, who are trained in the field of Cultural heritage, such as in archeological science or in conservation science. These applications were demonstrated with a series of measurements focusing on the material characterization of metal objects and pigment layers.

References