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# Laser-Induced Breakdown Spectroscopy (LIBS) in Undergraduate Education

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Laser-Induced Breakdown Spectroscopy (LIBS) is an emerging technique which is being used for many different applications. Its wide range of uses spans from national defense to environmental applications. Some applications include heavy metal detection in soil, uranium detection in soils and liquids, material sorting, process monitoring, space applications, and explosive detection.

In LIBS, a high-powered laser is focused onto a sample. This heats, ablates, atomizes, and ionizes the surface material which results in the formation of a plasma. The light emitted from the plasma is spectrally resolved and detected. The benefits of LIBS include being a multi-element technique, providing both quantitative and qualitative information with rapid measurements, involving little or no sample preparation, being used in-situ and noninvasively, and requiring only optical access to the sample and very little operator training.

LIBS is an atomic technique that can easily be incorporated into undergraduate education. Due to its many applications and wide-range usage, it is important to introduce LIBS at the undergraduate level. Most undergraduate institutions introduce students to atomic absorption (AA), which is usually readily available. The introduction of LIBS is not meant to replace AA but to provide the students with another learning option using a different type of atomic technique. Currently, the Skoog et al. Instrumental Analysis textbook has a small section dedicated to LIBS and there are other books available that are solely dedicated to LIBS.

A typical LIBS system consists of a pulsed or Q-switched laser, a focusing system, a light collection system, spectral resolution device, detector, and computer. The laser provides the optical excitation; Nd: YAG lasers are commonly used. The focusing system is usually a lens that focuses the laser light onto the sample. The light collection system can be an optical fiber or a combination of lenses that collects the plasma light and brings it to a spectral resolution device which usually contains a grating. The spectral resolution device is typically a spectrometer or echelle. The detector which detects the spectrally resolved light is commonly a charged coupled device (CCD) or intensified charges coupled device (ICCD). The computer is used to view the LIBS spectrum and provide the data work-up. It is also important to keep in mind that there are commercial LIBS systems that are readily available for purchase; this could be an option for an institution considering the addition of this technique to their undergraduate curriculum.

The introduction of LIBS at the undergraduate level has been a goal of mine since I began teaching in 2004 at Alvernia University. With the acquisition of a Nd: YAG laser and an echelle spectrograph with ICCD in 2010, this goal was now in my reach. I initially began developing undergraduate labs that could be easily used at any institution. My first lab experiment developed targeted an analytical/instrumental analysis laboratory. This lab uses synthetic silicate samples, which are used as soil simulants containing varying concentrations of a variety of elements. The objective of this laboratory was for students to make and prepare calibration curves and use that information to determine detection limits and sensitivities of various elements. This lab experiment entitled "A Simple LIBS (Laser-Induced Breakdown Spectroscopy) Laboratory Experiment to Introduce Undergraduates to Calibration Functions and Atomic Spectroscopy" was published in the *Journal of Chemical Education* in January of 2012.

The next experiment developed was designed for a Physical Chemistry laboratory and used LIBS to determine electron density and plasma temperature. In this lab, students use a variety of metal surfaces from lead to copper for their analyses. The overall goals of this laboratory experiment are for the students to learn how to make and prepare Boltzmann plots to determine plasma temperature and how to measure the full width at half maximum (FWHM) of the hydrogen line and to correlate that to the plasma's electron density. This experiment entitled "Temperature and Electron Density Determination on Laser-Induced Breakdown Spectroscopy (LIBS) Plasmas: A Physical Chemistry Experiment" was published in the *Journal of Chemical Education* in December of 2012.

Overall, these two articles help to show how easily LIBS can be incorporated at the undergraduate level. Since this technique is now gaining momentum throughout industry, government, and education, LIBS is an important topic to discuss and learn at the undergraduate level. The opportunity to use LIBS at a small liberal art college like Alvernia University offers a unique, hand-on experience for our undergraduate students.

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