THE USE OF LASER-INDUCED BREAKDOWN SPECTROSCOPY TO DISCRIMINATE BETWEEN LANDMINES AND OTHER OBJECTS

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ABSTRACT

Laser Induced Breakdown Spectroscopy (LIBS) is an emerging, minimally-destructive sensor technology for in-situ, real-time chemical species identification and analysis. The Army Research Laboratory has been engaged in LIBS analysis for over a decade and recently has been investigating the potential to apply broadband LIBS analysis to specific military problems, one of which is as a handheld, confirmatory sensor for landmine detection.

1. INTRODUCTION

LIBS is a simple spark spectrochemical technique that uses a pulsed laser to create the spark. The technique has many attributes that make it an attractive tool for chemical analysis, particularly as regards its potential as a field-portable sensor for geochemical analysis. LIBS is relatively simple and straightforward, so skilled analysts are not required. Little to no sample preparation is required, which eliminates the possibility of adulteration of the sample through improper handling or storage or cross-contamination during sample preparation. LIBS provides a real-time response and simultaneous multi-element detection and analysis. The laser plasma is formed over a very limited spatial area, so that only a very small amount of sample (pg-ng) is engaged in each laser microplasma event. All components of the instrument can be made small and rugged for field use and LIBS sensors can be operated either as a point sensor or in a standoff detection mode.

A typical LIBS system consists of a pulsed laser, optics for focusing the laser energy onto a sample surface and for delivering the light produced during the LIBS reaction event to a detector and spectrometer for resolution of the light spectrum, and a computer for system control and data processing and analysis. The foundation for LIBS is a short-pulsed, Q-switched solid-state laser that is optically focused to rapidly heat the surface of a target sample material to the point of volatilization and material ablation, which results in the generation of a high-temperature plasma on the surface of a sample. Upon cooling, the excited atomic, ionic, and molecular fragments produced within the plasma emit radiation that is characteristic of the elemental composition of the elements within the volatilized material. Fiber optic technology, which offers the potential for designing portable LIBS analysers, can be used to collect the light signal and deliver it to a detector/spectrometer that is capable of resolving part or all of the 200 to 980 nm spectral region. All elements emit within this region, so that both the detection of elemental, ionic, and molecular species on the basis of spectral line presence and the quantitative analysis based upon differences in spectral line intensity can be achieved. Recent technological developments in broadband LIBS, and the development of a handheld LIBS system (Fig. 1) by Ocean Optics, Inc. under Army Research Laboratory contract, offers a unique potential for the development of a rugged and reliable field-portable chemical sensor for the detection of explosives and landmines.

The ideal landmine sensor would detect both the exterior casing and the contained explosive charge. Broadband LIBS results covering the spectral region from 200-980 nm have been acquired under laboratory conditions for metals, explosives, and anti-personnel

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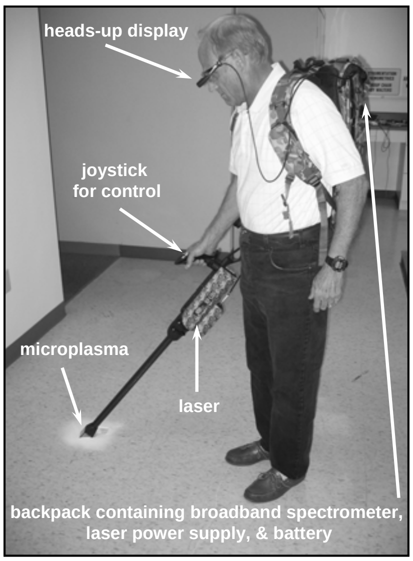
and anti-tank landmine casings. Figure 1 shows a prototype of the man-portable LIBS system under development for ARL by Ocean Optics, Inc. The concept illustrated is a backpack-size system in which a mini-laser is contained in the handle of a deminer's probe and light is delivered to and collected from the tapered tip of the probe. In such a configuration, analyses can be made readily by touching the buried object that one is interested in identifying. Such a capability could also be robot deployed for unmanned landmine detection.

Figure 1. Prototype of the man-portable LIBS system developed for ARL by Ocean Optics, Inc.



Our broadband LIBS work has demonstrated observable differences in landmine casings composition (Fig. 2). To extend the LIBS approach to the problem of landmine at an operational level, the identification issue must be addressed. The use of broadband LIBS, *i.e.* capturing the major portion of the LIBS spectrum from 200-980 nm, is based on the idea that every material yields a unique LIBS spectrum. This being the case, then a LIBS spectrum should provide 'fingerprint' of the material analyzed and LIBS spectra of different materials should be distinguishable one from another by simple statistical analysis. So, at two different times four months apart, a LIBS spectral library was assembled for a mixed suite of more than a dozen different types of AP and AT mines, together with a complex set of natural and anthropogenic 'clutter' objects that included multiple samples of six different types of plastic, wood, rocks, a variety of metal items, and the plastic and wood simulants commonly used in the detection performance testing of different landmine sensor technologies. Once the library was constructed, a single-shot 200-980 nm LIBS spectrum was acquired for 100 samples drawn sequentially from the full sample population of landmine casing and clutter items (70 for the first test and 85 for the second), taking care to ensure that multiple samples of each different type of material (e. g. AP mine, AT mine, mine simulant, plastic, rock, wood, and metal) were analyzed. Three levels of discrimination were of interest in the two tests – (i) a correct 'mine' vs. 'no-mine' classification, (ii) delineation of the mine type for a correct 'mine' classification, and (iii) identification of the exact specimen for a 'mine' classification in instances where the sample population contained multiple specimens of a particular mine type. The two independent experiments yielded essentially the same outcome (Table 2):

Figure 2. LIBS spectra of different types of antipersonnel (a) and antitank (b) landmine casings. Each spectrum was collected with a single laser shot.

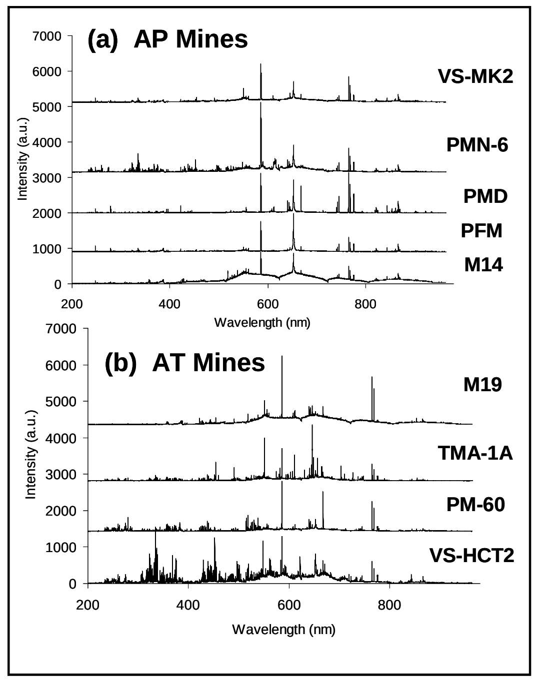


Table 1. Results from two 100-shot tests of landmine casings. Col. 1 lists # correct 'mine/'no-mine' determinations, Col. 2 lists # correct mine or material type determinations, and Col. 3 lists # correct specimen identifications.

	# LIBS analyses	**1**	**2**	**3**
TEST #1				
LM casings	56	53	45	29
plastics	24	20	19	16
wood	5	5	5	4
rocks	5	5	5	3
metal	10	10	8	8
TEST #2				
LM casings	54	49	42	25
plastics	21	19	14	12
wood	6	6	4	4
rocks	10	10	9	3
metal	9	9	8	1