

## Detection of energetic materials by laser induced breakdown spectroscopy technique.

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**Abstract-** A standoff laser Induced Break down Spectroscopy (L-I-B-S) technique has been used to detection and characterization the energetic materials such as C<sub>4</sub>, NH<sub>3</sub>(NO)<sub>4</sub> and TNT, a Q-switched Nd:YAG laser (1064 nm wavelength, 9 ns pulse width and 1 Hz repetition rate, 300 mJ ) is focused to the targets to generate plasma. Ocean optics (HR 4000 CG-UV-NIR) spectrum analyzer was used to collect the generated plasmaemissions, aspecificsignature of each explosive material can be obtained by analysis the plasma emission spectrum, Peak ratio analysis technique is used for the identification of energetic materials.

### I. Introduction

Laser-induced breakdown spectroscopy (LIBS) is an atomic emission spectroscopic technique, where a high energy pulsed laser focused onto a material generates transient high-density plasma as the laser intensity exceeds the breakdown threshold of the material (~1-10 MW/cm<sup>2</sup>) [1]. leading to a breakdown of the analyte into ions and free electrons resulting in a plasma characterized by atomic emission [2]. The UV and visible emission from the plasma can be spectrally resolved for qualitative and quantitative analysis of the samples component.

LIBS has many advantages as an analytical technique, There is no need of sample preparation, The analysis process is fast and can be used for both non-conducting and conducting samples, regardless of their physical states. LIBS is also applicable to the analysis of extremely hard materials that are difficult to digest or dissolve, Its capability for simultaneous multi-element determination and it has been used successfully in difficult environmental conditions to study remotely located samples [3], [4].

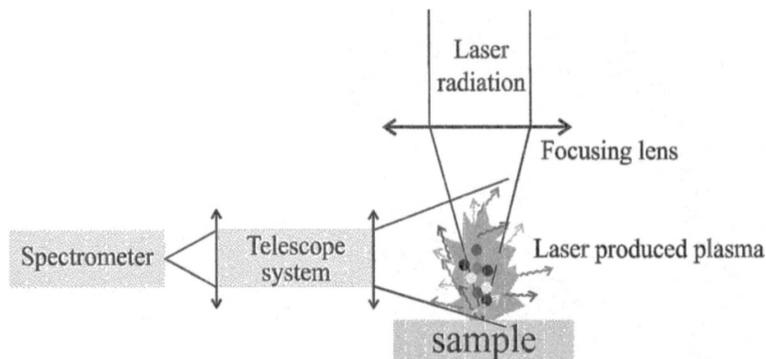
so LIBS has been found as a suitable technique for detection and identification performed in the atmospheric environment.

,The energetic material chosen are mainly of military use or homemade such as (TNT<sub>2</sub>, C<sub>4</sub>, NH<sub>3</sub>(NO)<sub>4</sub>), The major challenge in identifying high energy materials is the presence of common elements (C, N, O, and H) in all these materials. Moreover, identifying explosive materials among themselves is also another huge challenge. Herein, we present some of our experimental results from the LIBS measurements of simple high energy materials such as C<sub>4</sub> TNT Ammonium nitrate (AN).

### II. Experiment

A schematic diagram of the experimental setup is shown in figure 1. in our experiments, the energy source was a Q-switched Nd:YAG pulsed laser operating at the fundamental wavelength (1064 nm), having pulse duration of 9 ns and 1 Hz repetition rate. The energy per pulse at the target surface was fixed at a level of 300 mJ. The laser beam was focused on the targets by a lens of focal length 10 cm. the targets were an explosives materials, C<sub>4</sub> (91% RDX, 2.1 % poly isobutylene, 1.6 % motor oil

and 5.3 % 2-ethylhexyl sebacate) and 2- Trinitrotoluene (TNT2), amonum nitrate (AN) in the form of solid thin films on a glass slides. The laser spot was measured at the target surface using an optical microscope and gives a circle of area  $5 \times 10^{-3} \text{ cm}^2$  and hence laser intensity of the order of  $6.628 \text{ GW/cm}^2$  was calculated. Plasma emission spectroscopy was performed with an Ocean optics (HR 4000 CG-UV-NIR) spectrum analyzer having resolution in the 320-740 nm wavelength interval. An optical fiber was positioned at a distance of 3 cm from the surface of the targets.



**Fig 1.**Experimental setup employed for the emission spectroscopy of the plasma induced above the target.

### III. Results and discussion

The emission spectrum of the plasma produced at the surface of high energetic materials(C4 and TNT and AN, respectively), are presented in (figure 2,3 and figure4).

The spectra contain atomic lines coming from oxygen, carbon, hydrogen and nitrogen emissions, the similarity in constituents of high energetic materials results in the emission spectra of these materials sharing the same spectral lines[5].

It is found experimentally that the N emission line is located at (422nm), and the O emission lines are at (390nm), the presence of hydrogen emission line at 656.279 nm can be observed in the three spectra, the carbon emission lines are present in C4 and TNT2 samples at (517.2nm) which indicate organic components present. [7] A comparison between the O \ N atomic emission ratio is found to be 2.14% the use of that ratio to identify explosive could have 20% uncertainty according to [6] because the high percentage of N and O in the environment. [8],[9]

Also we can use the value of the NH ratio which is 0.6 % as an indicator to the explosive and non-explosive material.

To ensure the right identification of the samples we develop an algorithm on the basis of results obtained from our experiment (fig 5) shows the algorithm flowchart which can separate the explosives and non-explosives materials.

The absorbed emission lines were located on a wide spectral background essentially due to mechanisms involving free electrons (inverse Bremsstrahlung, radiative recombination and photoionization)[10].

The emission spectrum peaks were assigned using National Institute of Standards and Technology (NIST) database [11].

**Is N,O,H,C peaks PRESENT NO → NOT EXPLOSIVE**  
**YES**  
**IS N/H = 0.6 NO → IS NC ≥ 0.5 → NO → NOT EXPLOSIVE**  
**YES**  
**Is NO = 2.14 NO NOT EXPLOSIVE**  
**YES**  
**IT IS EXPLOSIVE**

Fig (5) explosive detection algorithm

### IV. Conclusions

We evaluated the performance of LIBS for sensitive detection of high energetic materials such as C4, TNT and NH<sub>3</sub>(NO)<sub>4</sub>. LIBS spectra were recorded using a spectrum analyzer. An examination of the emission spectra were enough to distinguish between explosive and non explosive material using the presence of carbon, hydrogen, nitrogen, oxygen atomic peaks in the substances. As step one of the detection process and the second step is by satisfy a spatial algorithm.

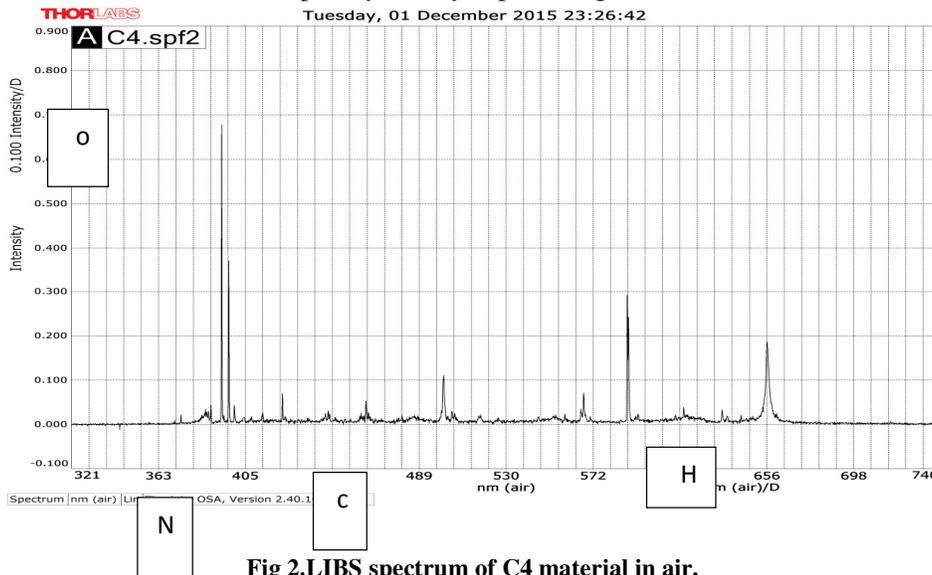
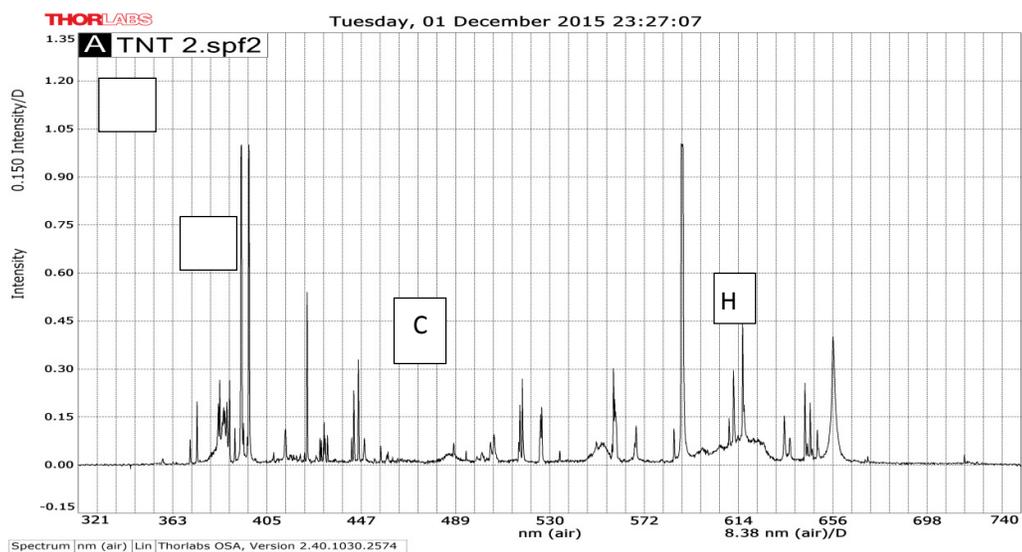
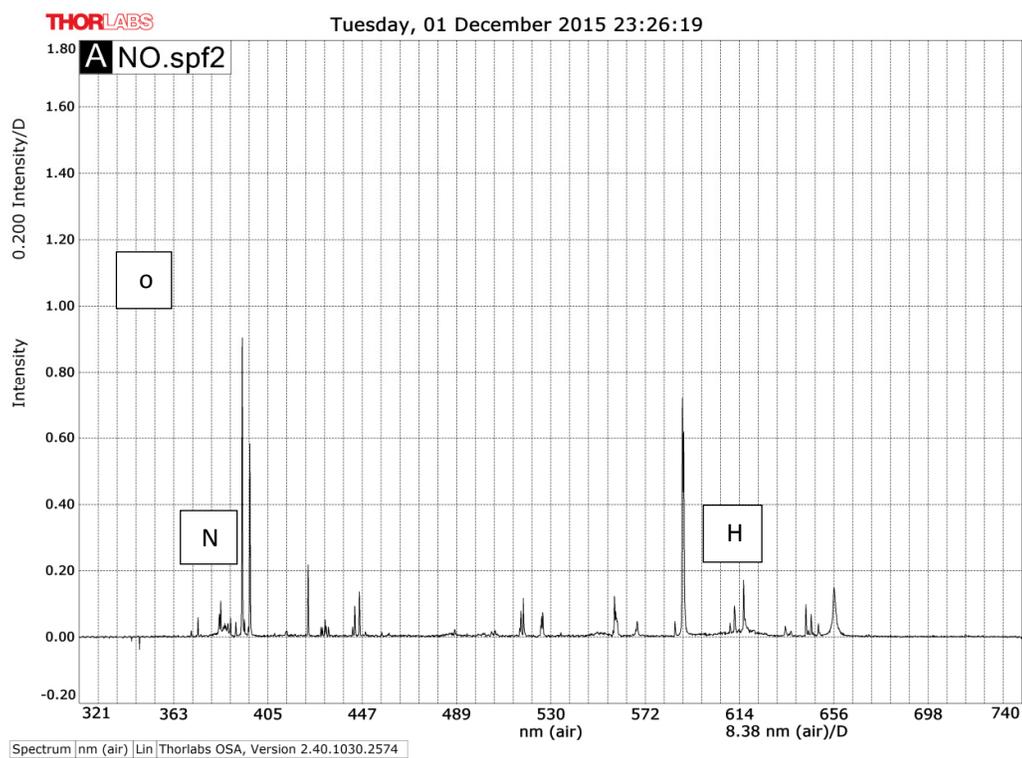


Fig 2. LIBS spectrum of C4 material in air.



**Fig 2. LIBS spectrum of TNT2 material in air.**



**Fig 2. LIBS spectrum of  $\text{oNH}_3(\text{NO})_4\text{f}$  material in air.**

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