Dual Fluorescence Techniques for Explosive Detection System

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Abstract: The sensing and differentiation of explosive molecules is the key for security. By combining the fluorescence lifetimes and wave length, faster results can be obtained from smaller amounts of sample. Here, three explosives (2,4,6-trinitrotoluene (TNT), cyclotrimethylene- trinitramine (RDX), and ammonium nitrate $(NH_4(NO)_3)$. Are excited using pulsed uv laser, The sharp fluorescence emissions of that materials, can give us a complete information that make them ideal for such a system. Pattern analysis of the fluorescence spectrum data allows for standoff explosive detection and identification with limits -of-detection in the (ppb) range, providing a number of advantages, including the reduction of the effects due to photo bleaching, catering, and intensity variations in the excitation source.

Keywords: material detection, fluorescence techniques

1. Introduction

Detecting trace amounts of energetic materials using laserbased methods have been developed in the last few years [1]. It is important for military and civilian applications Lasers offer multiple approaches for explosives detection that are not possible with other techniques. These techniques based on the unique properties of lasers for long-distance propagation of intense energy or based on the actual molecular and atomic, Any detection technology must be molecules specific based because explosive have a wide variety of chemical structure, sum of them are very similar to non-explosives and the others are mixtures and have a deferent component from the pure one, Fluorescence spectroscopy have the potential to provide information about structural changes of molecules.

Several research groups reported applications of steady-state fluorescence spectroscopopy [2]. There are several disadvantages associated with taught techniques to limit its effectiveness. These limitations include relatively broad emission bands, which may reduce their capability for discrimination of spectral overlapping fluorophores: Thire-dependent measurements resolve fluorescence intensity decay in terms of lifetimes provides additional information about the underlying fluorescence dynamics. Therefore, fluorescence lifetime information could have distinct advantages in quantifiable research and practice as it may enhance the discrimination of the steady-state s fluorescence [3].

This approach has been investigated diagnosis of materials by a new direction of fluorescence detection systems focuses on multichannel sensing (a combining of the wavelength fluorescence spectrum with the spectrum time of emission) can give us a complete information about the molecule structure of that sample, fluorescence for (RDX), (TNT), and (AN) are three of the most powerful and widely used energetic materials. In this technique, an ultraviolet laser exited the energetic molecule and enables the laser-induced fluorescence spectrum to emission. The radiative emission of light from a molecule after excitation has a multiparameter na ture. The objective of a measurement is therefore to gain information concerning as many parameters as possible [4].

2. Experimental

The absorption spectrum of the explosive material was studded, and the excitation sources were chosen accordingly with wavelengths of 266nm, a pulse time 5nsec with pulse energy (15mJ). The fluorescence emission Lifetimes were detected using two types of detectors first a fast response time photo multiplier (less than half of an expected fluorescence lifetime ~500ps at least in the UV range) [1], the PMT is connected into an oscilloscope. Second un ocean optics (HR 4000 CG-UV-NIR) spectrum analyzer was used to show the fluorescence emission spectrum wavelength for a range between (300-700). Many different types of explosive materials (TNT, C4, AN) were studied, a thin residue of each sample was placed on a silver substrate.

3. Result and Dictation

In the wavelength domain the recorded fluorescence spectra for the three samples after shooting it by laser (266nm) are as shown in the figures (1,2,3).



Figure 1: Fluorescence spectrum wavelength for TNT



Figure 2: Fluorescence spectrum wavelength of AN



Figure 3: Fluorescence spectrum wavelength of c4

These fingers show that the fluorescence spectrums of energetic material are in the range between (340-345) nm which is the finger prints of each material resulted from its chemical structure and composition. Which are similar [5]. Other peaks appear according to the high percentage of impurities in that sample, and the surface structure is an important parameter reducing the absorption of the incident light by the reflection from the surface of the crystalline molecules [6]. At the time of fluorescence, for three different energetic samples (Trinitrotoluene (TNT), C4 and ammonium nitrate (NH₄NO₃)); Explosive Samples Test.



Figure 5: Fluorescence spectrum of AN material



Figure 6: Fluorescence spectrum of C4 material.

From figure 4, 5and 6, the obtained spectra are divided into 3 major parts: the first one is the laser reflection area where the laser pulse after falling on the examined material should be absorbed, but since the used wavelength is lie in the end of the absorption spectrum peak for these materials they are not completely absorbed and therefore the major part of the laser beam will be reflected in the expected time of about (5-7ns) as high peak in the signal shown in figures recorded.. The second part occurred after a (1-15nsec) represents the response of explosive molecules to the pump laser, it's the fluorescence for every measured point, the spectrum peaks represent transitions between a number of the vibrational levels for the electronic higher states and the ground state of the molecules of the explosive materials due to the energy of the UV laser pulses, The shifted peaks and shoulders show a remarkable response to different explosive materials [7].

Three main parameters can be calculated from that spectrum used for the materials identification:

- 1)The phase shift between the original peaks reflected laser pulse and the peak of fluorescence appeared after a sub nanosecond period.
- 2)The depth of modulation or the difference between the two peaks.

4. The Fluorescence Time

The table below shows the measured fluorescence time (T_m) , theoretical fluorescence time (T_t) , measured fluorescence wavelength (λ_m) and theoretical fluorescence wavelength (λ_t) for the tested materials [8]. The behavior of some explosive materials that have been targeted is shown in the detected fluorescence time domain Spectral as in fig. (5,6,4) and the calculated parameters for each material is in table (1).

Fable 1: Fluorescence	time	for some	expl	osive	mat	terial	l
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Zx4 Materials	T_m (nsec)	T_t (nse)	$\lambda_m (nm)$	$\lambda_t (nm)$
TNT	2.9	3.45	360	320
AN	3.6	3.78	340	340
<i>C4</i>	2.7	1.70	340,310	340,310

We have been drawn figure (7) that shows the phase diagram represent a time of fluorescence, wavelength as a function of intensity (arbitrary unit) for the three explosive materials.

International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

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Figure 7: Diagram shows the relation between frequency domain and time domain for the three explosive materials.

Based on the fluorescence techniques results, the used apparatus allows fast acquisition of the entire fluorescence decay at multiple wavelengths with high sensitivity, provides some intrinsic advantages over the traditional fluorescence, it acquires the whole spectrum, and it is also incorporates fast data Since the fluorescence process is fast, Using the above fluorescence techniques for test a large variety of explosive and non-explosive materials in order to build a data base helps us to develop un algorithms or more advanced statistical signal analysis.

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