

Novel method for remotely detecting explosives

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Identifying trace levels of explosives at ranges of tens of meters may be possible using a UV laser to create relatively strong and clutter-free fluorescence.

When explosive devices are prepared, transported, or handled, quantifiable amounts of the constituent materials frequently end up on surfaces. Because these chemical residues may serve as indicators of attempts at concealed assembly or transport of explosive substances and devices, being able to rapidly detect them in a noninvasive, remote manner would be very useful. Consequently, a variety of efforts are under way to develop a technique for picking out trace quantities of explosives at a distance.

Laser-based detection methods show the most promise in achieving desired ranges and necessary sensitivity levels. Some of the more widely investigated methods use either Raman spectroscopy and/or laser-induced breakdown spectroscopy (LIBS). In Raman spectroscopy, the inelastic scattering of a probe laser results in a frequency shift of the scattered light. While these frequency shifts can be used as highly specific indicators of explosives, the fraction of light that exhibits a Raman shift is exceedingly small. The LIBS technique uses a laser to determine the nitrogen-to-oxygen (N/O) ratio in a sampled area. The resulting signal is relatively strong, but it is highly susceptible to false alarms since similar N/O ratios may be exhibited by many other non-explosive materials. To avoid these difficulties, we have been investigating a technique based on photodissociation followed by laser-induced fluorescence (PD-LIF).

PD-LIF uses a pulsed UV laser to dissociate nitro-bearing explosives molecules (including most military explosives such as TNT, dynamite, and C4) into smaller fragment molecules including nitric oxide (NO). Previous studies¹ have demonstrated that when explosives are dissociated, NO fragments are formed in a short-lived vibrationally excited state, and these fragments can be used as an indicator of the presence of the parent explosive compound. Detection of vibrationally excited NO is achieved by optically pumping the NO fragments from their vibrationally

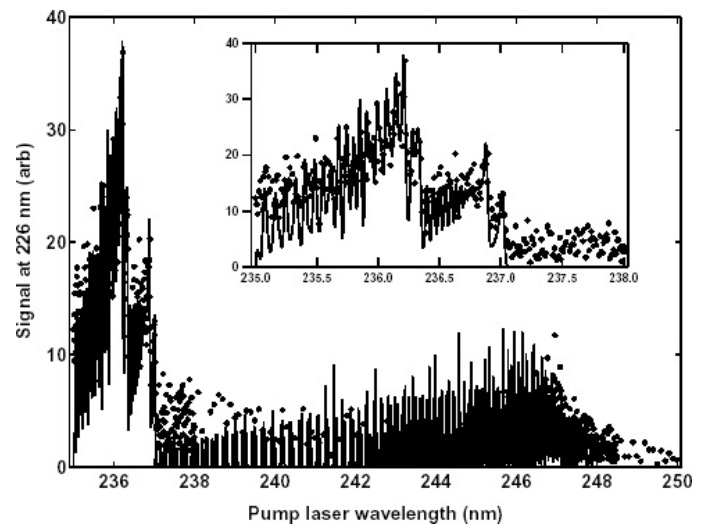


Figure 1. Blue-shifted fluorescence of liquid DNT as a function of pump laser wavelength. The markers are experimental data for liquid DNT. The lines represent the predicted NO fluorescence. The inset is a close-up near the first vibrationally excited state.

excited state to an electronically excited state. The subsequent fluorescence, which happens as the NO molecule decays to its ground state, occurs at a shorter wavelength (226nm) than the pump laser (236.2nm for the first vibrationally excited state, $v'' = 1$). The advantages of this detection method include relatively strong fluorescence that can be generated at eye-safe excitation laser intensities and a low false alarm rate. (The low false alarm rate is expected because relatively few processes produce light at shorter wavelengths than the source laser.) As such, this technique will not be susceptible to false alarms from traditional fluorescence, for which the photons emitted typically are at longer wavelengths.

Whereas previous studies examined the PD-LIF signature from explosive vapors, we probed the solid and liquid explosives themselves. This is important, since the vapor pressure of

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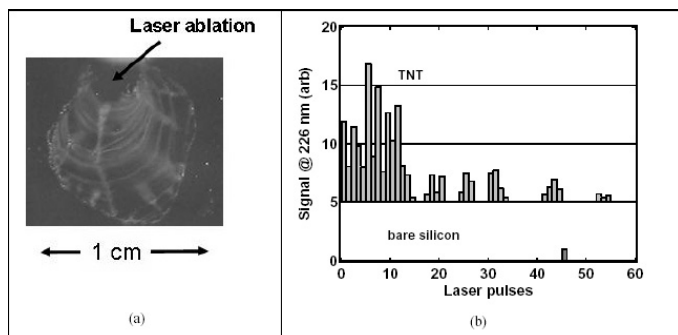


Figure 2. Trace detection of dropcast TNT. (a) Image of dropcast TNT (concentration is $2\mu\text{g}/\text{cm}^2$). The laser spot (causing ablation) is labeled. (b) Time series data displaying signal photons as a function of laser pulse. Top curve is TNT (offset for clarity). Bottom curve represents a bare silicon wafer.

most explosives is very low. Figure 1 shows our PD-LIF detection for liquid dinitrotoluene (DNT). We obtained similar results for solid DNT, TNT, C4, and penthrite (PETN). The expected fluorescence from NO fragments is overlaid on the experimental results in Figure 1, and the good overlap is strong evidence that excited NO fragments are being produced. The maximum peak in the signal at 236.2nm is caused by NO fragments pumped from $v'' = 1$, while the peak near 247nm is from $v'' = 2$. The fine structure in the data is not noise, but rather is due to the additional rotational energy of the fragments.

We demonstrated trace level detection using calibrated quantities of explosives dissolved in acetone. These were dropcast on silicon wafers to yield areal concentrations of $2\mu\text{g}/\text{cm}^2$ (see Figure 2). We investigated both RDX (cyclotrimethylenetrinitramine) and TNT in this manner, obtaining signals roughly half of those measured for the bulk materials. Laser-induced ablation of the trace material is evident in the top portion of Figure 2(a). For laser fluences of $10\text{mJ}/\text{cm}^2/\text{pulse}$ and a wavelength of 236.2nm, complete ablation of TNT takes about 10 laser pulses, as shown in Figure 2(b). Figure 2(b) also displays the photoresponse from a control sample (the bare silicon wafer), which is significantly weaker than that of the TNT, indicating a relatively high signal-to-noise ratio for detection.

Quantitative analysis of our results indicates that it will be feasible to achieve detection of trace levels of explosives at distances of tens of meters with a single pulse of eye-safe UV irradiation. While our initial studies do not indicate the presence of significant sources of false alarms, further work is still needed. In addition, a fieldable system will require the development of a robust, all-solid-state laser at 236nm with suitable pulse repetition rate, power, and spectral bandwidth. In parallel with the laboratory

experiments summarized above, we have also identified an engineering concept of such a laser.

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