Remote detection of traces of high energetic materials

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ABSTRACT

The possibility of remote detection of traces of high energetic materials using laser fragmentation/laser-induced fluorescence (LF/LIF) method is studied. Experimental data on the remote visualization of traces of trinitrotoluene, hexogen, composition B, octogen, and tetryl obtained at a distance of 5 m with a scanning lidar detector of traces of high energetic materials are presented.

Key words: high energetic materials, traces, laser fragmentation, laser-induced fluorescence.

In previous studies [1-4], the authors experimentally demonstrated the ability to remotely detect the vapors of high-energetic materials (HEMs) in the atmosphere using the laser fragmentation/laser-induced fluorescence (LF/LIF) method. The detection range was more than 10 meters at the detection sensitivity of about 10^{-12} g/cm^3.

Further works on exploring the possibilities of the LF/LIF method allowed to prove the applicability of this technology for the detection of *traces* of HEMs and to formulate the research directions for solving the problem of creating a remote detector of traces of HEMs.

In the period from 2012 to 2013, an operative embodiment of the lidar for remote detection of traces of HEMs was designed and produced by the efforts of the three institutes of the Siberian Branch of the Russian Academy of Sciences: V.E. Zuev Institute of Atmospheric Optics, Institute of High Current Electronics, and Institute for Problems of Chemical and Energetic Technologies.

The operating principle of the lidar is based on a combination of the effects of laser fragmentation of molecules of HEMs and laser-induced fluorescence of NO-fragments excited from the second vibrational level (v "= 2) of the ground electronic state $X^2\Pi$ to a zero vibrational level (v '= 0) of the excited electronic state $A^2\Sigma^+$. In this case, the formation of both fragments presumably occurs both in the solid phase of the trace and in the vapors over the surface resulting from the laser desorption of the trace substance.

General view of the lidar is shown in Fig. 1.

Functionally, the lidar consists of an excitation radiation source, a spectral filtering system of the probe radiation, a system of the laser beam formation, a system of receiving and spectral selection of the optical signal, a 64-channel system of photodetection, and a system for collecting and processing of information.

In the lidar narrow line excimer KrF-laser, tunable in the frequency range of the $A^2\Sigma^+$ (v' = 0) ← $X^2\Pi$ (v" = 2) transition of the NO molecule is used [5]. For desorption and fragmentation of HEM traces the same frequency is applied.

To suppress the stray light from the discharge glow and from the stimulated anti-Stokes emission of optical elements of the laser cavity, a spectral filtering system of the output radiation is provided.

The system of formation of the laser beam is intended to form the illumination line in the scanning area.

The system of receiving and spectral selection of the optical signal consists of a double monochromator designed for the spectral selection of the fluorescence band of the NO molecule ($A^2\Sigma^+$ (v' = 0) → $X^2\Pi$ (v" = 0)) at a wavelength of 226.5 nm and for the suppression of the unshifted scattering line of the exciting radiation.

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Fig. 1. General view of the lidar

A multichannel photodetection system made on the basis of the combination of the two 32-anode photomultipliers H7260-04 (Hamamatsu Photonics) provides a 64 pixel of the image of the illumination line, which corresponds to the spatial resolution along the row in the scanning area of about 1 cm. Photodetection process in each of the pixels detection channel is carried out in the photon counting mode with a time resolution of 5 ns.

The 64-channel data acquisition and processing system receives data from the photodetection system and sends them to the storage. The program of the traces visualization recognizes the lidar response pattern in the scanning area according to detection criterion.

The process of scanning of the object surface is carried out by sequential moving of the horizontal illumination line from upper start position in the downward direction.

During tests of the lidar, a series of experiments was performed to investigate the possibility of remote visualization of traces of HEMs on the surface of the object.

Experiments were carried out according to the scheme shown in Fig. 2. In the detection zone at a distance of 5 m from the lidar, the sample with traces of explosives was fixed. Then, a sequential scanning of the examined area was made.

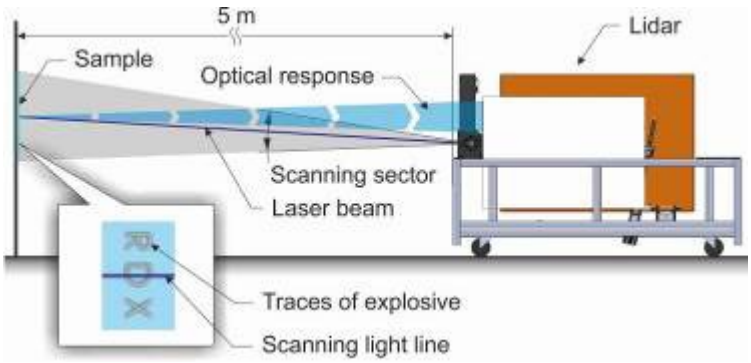

Fig. 2. The scheme of experiments on remote visualization of traces of HEMs.

Traces of HEMs were deposited on the surface of the aluminum foil in the form of the abbreviated name of the corresponding HEM: trinitrotoluene - "TNT", hexogen - "RDX", composition B - "C-B", octogen - "HMX", and tetryl - "TET". The surface concentration of the HEM particles in the traces was 1 μg/cm^2, the title size was 7 cm × 22 cm, the location was vertical (Fig. 3).

Detection of the optical response was carried out in the photon counting mode. For the signal accumulation volume over 50 laser pulses per row, number of rows 40, and a laser pulse repetition rate of 50 Hz, the examination time of the sample area was about 30 s.

All the measurements were performed at a laser pulse energy density about 13 mJ/cm^2.

The results of experiments are shown in Fig. 4. In the figure, the variable "*Pixel #*" denotes the corresponding number of the channel of the multi-anode photomultiplier and the variable "*Row #*" denotes the illumination row number. In the right-hand side of figures, the gray scale legend is given that shows the values of the recorded signals in the number of photon counts.

Fig. 3. The sample with traces of hexogen deposited in the form of the abbreviation "RDX".

The investigations have shown the prospects of the LF/LIF method for the fabrication of detectors that enable remotely, at a distance of several meters, to detect trace amounts of explosives with the ability to visualize the places of their localization on the surfaces of objects.

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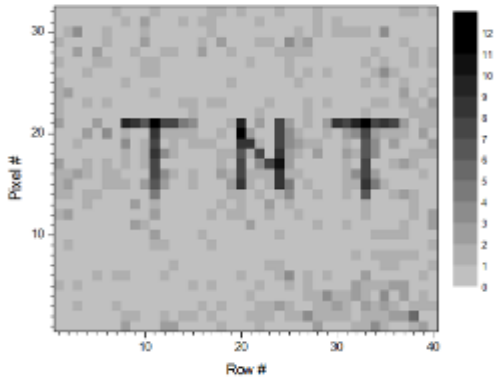
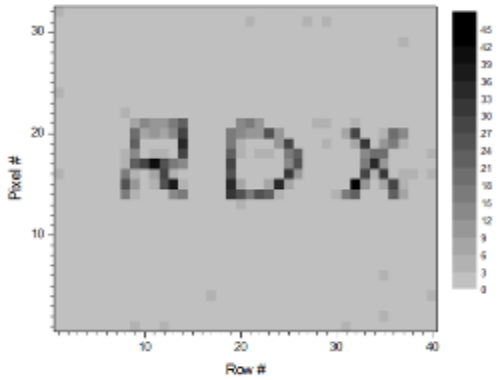


a)



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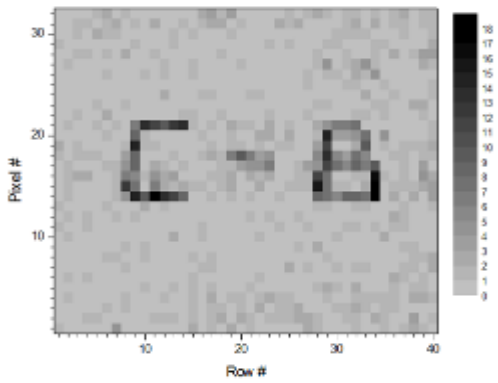
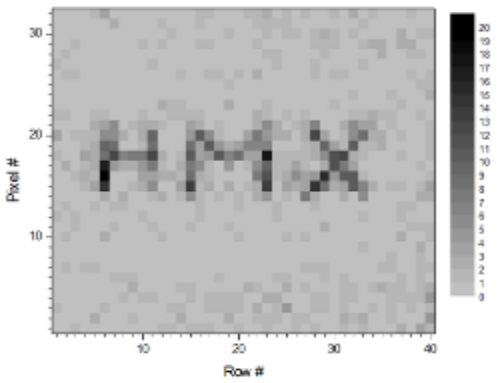
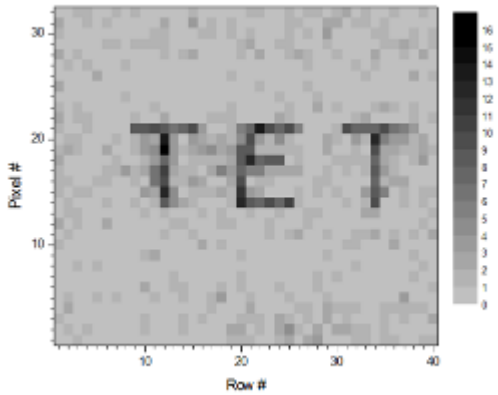


c)



d)



e)

Fig. 4. The results of remote visualization of HEM traces on the aluminum foil: a) trinitrotoluene, b) hexogen, c) composition B, d) octogen, e) tetryl.

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