Fluorosensore Lidar a scansione per il rilevamento in una scena post esplosione di detriti plastici derivanti da dispositivi esplosivi improvvisati

Il fluorosensore Lidar a scansione basato sulla fluorescenza indotta da laser (LIF) è stato applicato al fine di rilevare, in uno scenario post-esplosione, residui di plastico derivanti da dispositivi esplosivi improvvisati (IED). La sua capacità di misurazione in remoto, l'invasività minima, l'elevata sensibilità e l'applicabilità in loco rendono questo sistema molto promettente in campo forense per ottimizzare la raccolta di elementi probatori. Questa attività è stata sviluppata grazie al progetto FORLAB (FORensic LABoratory for in-situ evidence analysis in a post blast scenario), approvato e finanziato dalla Commissione Europea nell'ambito del Settimo programma quadro.

Scanning Lidar fluorosensor for detection in a post blast scene of plastic debris coming from components of Improvised Explosive Devices

The Scanning Lidar fluorosensor based on Laser Induced Fluorescence (LIF) has been applied for detection in a post blast scenario of plastic debris coming from Improvised Explosive Devices (IEDs). The advantages it offers of remote measurement capability, minimal invasiveness, high sensitivity, and in situ applicability make the system very promising in the forensic context to optimize the collection of evidences. This activity has been supported by the FORLAB project (FORensic LABoratory for in-situ evidence analysis in a post blast scenario), approved by the European Commission and funded under the FP7.

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Introduction

In a post blast scene following an IED attack, the detection of evidences that can lead to a fast identification of the terrorist group or even the bomb maker (the IEDs components, such as explosive residues, electronic debris, or plastic or metal pieces of the container, shrapnel, etc.) is very important (Fig. 1). Sensors for fast screening of post-blast evidences, reducing the number of evidences sent to

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FIGURE 1 The crater caused by the explosion in the Capaci's massacre of magistrate Giovanni Falcone [May 23th 1992]. The arrow indicates the water canal into which the explosives have been inserted
Source: http://www.palermoplanet.it/html/mafia/digilander.libero.it/inmemoria/strage_capaci.htm#immagini

the reference forensic laboratory and the time of data acquisition, and increasing the information provided by the evidences left by the explosion during the investigations, are desirable.
In this respect, the EC considers of high strategic relevance contributing to the development of new technologies in support to forensic activities, through the Security Call instrument under the 7th Framework Programme 2007-2013.
The FORLAB project, funded by FP7 grant agreement no. 285052, aims at providing End Users with portable systems that will improve their efficiency in investigating the crime scene [1]. A schematic view of the project's approach is depicted in Figure 2.
An innovative LIF-based sensor has been developed and applied in the frame of the FORLAB Project for detection in a post blast scene of plastic debris coming from IEDs components.
The Laser Induced Fluorescence technique has been already used for cultural heritage protection and restoration activities [2,3,4], but the LIF sensor capability of rapid scanning of large areas at distances up to some tens of meters with high spatial resolution [5] makes this instrument very advantageous in security applications.
Among the spectroscopic techniques appropriate to remote application, the Fluorescence Induced upon ultraviolet Laser excitation is able to supply valuable information thanks to its characteristic to give information on substances having specific spectral signature [6].

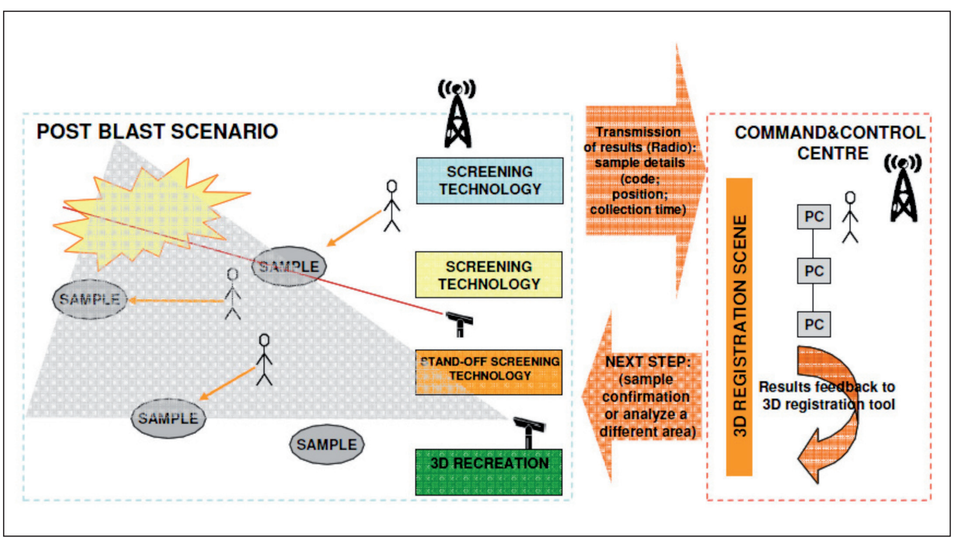

FIGURE 2 Operational diagram of the FORLAB project
Source: FORLAB Project Description of Work

In forensic applications, the additional capability of active reflectance measurements represents a significant step forward in the identification and precise localization of debris dispersed all around the crime scene.
Sophisticated data processing techniques – such as false-color imaging, principal component analysis (PCA) [7] on spectra, and spectral angle mapping (SAM)[8] on images – permit to detect and localize characteristics invisible to the naked eye[9].
LIF scanning system performances have been

FIGURE 3 LIF scanning system during in field campaigns in Bièvres (France) on January, 2013 and Wroclaw (Poland) on September, 2013

tested in real field conditions during different test campaigns (Fig. 3). The relevant results will be presented.

Experimental

The LIF technique is a molecular spectroscopy for surface analysis, based on the interaction of the ultraviolet radiation emitted by a laser with the matter[10]. The emission of radiation by luminescent materials is observed whenever an absorption of energy sufficient to activate the allowed electronic transitions occurs. In a typical LIF instrument, an ultraviolet (UV) laser beam irradiates a sample and an optical system collects and measures the emitted fluorescence signal. The spectral content of the radiation coming from the examined surface supplies information on the composition of the outer layers, once interrogated at different excitation wavelengths. It is a fast, non-invasive, remote, sensitive and selective technique.

A LIF scanning instrument (see Fig. 3), able to collect hyperspectral fluorescence images on large areas, has been realized at the ENEA's Diagnostic and Metrology laboratory in Frascati. The system has been developed with the aim of increasing the performances in terms of space resolution, time resolved capabilities and data acquisition speed with respect to the previous versions [11], by means of the line-by-line scanning process, particularly suitable for investigation on large areas. Its compact arrangement, reduced size and light weight allow for an easy transfer of the system. A typical experimental arrangement used for LIF is schematically depicted in Figure 4.

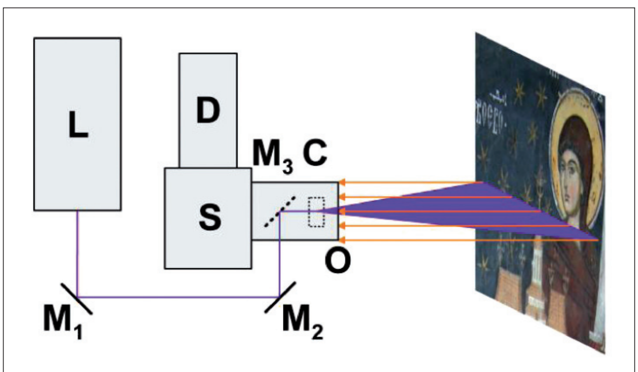

FIGURE 4 Schematic diagram of the ENEA LIF experimental set-up: L-laser, D-detector, S-spectrometer, M-mirrors, C-cylindrical lens, O-objective

The optical system based on the use of a cylindrical lens, focusing the laser spot as a line, allows to scan an image of 1.5×5 m^2 in less than 2 minutes at 25 m. This arrangement is characterized by having the target spatial and spectral information on two mutually orthogonal directions imaged on the detector, with a sub-millimeter spatial resolution and a spectral resolution higher than 2 nm. Moreover, time resolved measurements on the nanosecond scale can be performed by controlling the electronic detector gate in a boxcar-like configuration. The collected data are released as false color reflectance and fluorescence images, suitable to the identification of original and added materials.

Each scan is controlled by a portable computer, where a specific program developed in LabView allows to set experimental parameters, control data acquisition, and perform a preliminary data analysis. Data are collected as both 2D monochromatic images and LIF spectra for each pixel. Additionally, the LIF scanning system can be utilized, with the laser switched off, to collect reflectance images upon the availability of an intense standard light source. When using a continuous light source like a lamp, the synchronism for data acquisition is given by the detector itself. Both fluorescence and reflectance images can be reconstructed in false colour by using the three most intense features detected, associated to Red, Green and Blue (RGB) channels, respectively.

Results

Preliminary laboratory measurements have been performed on some objects that can be actually found in a place invested by a blast – such as electronic debris, plastic materials, building fragments – to optimize the system characteristics and to obtain reference spectra. The results for some different target materials, also collected from a post blast scene, are reported in Figure 5. For these measurements, as well as for the

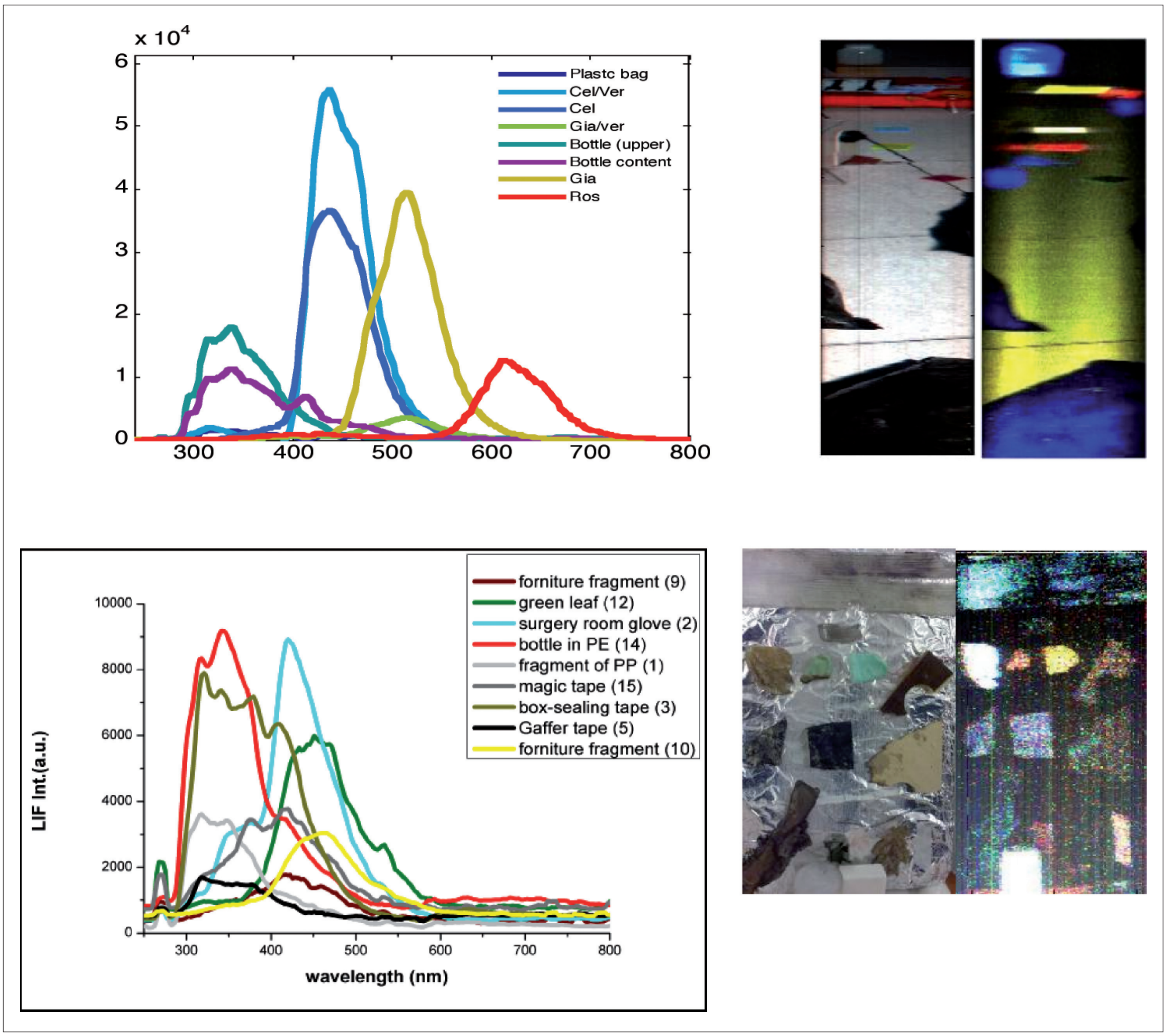

FIGURE 5 Laboratory test on different target materials, also collected from a post blast scene (below)

tests in Bièvres, the laser worked at 266 nm, with a pulse duration of 10 ns of and energy of 1.5 mJ. Distinct prevalent bands in the resulting fluorescence emission spectra have been identified depending on the target material. Fluorescence images have been obtained and the RGB false-color reconstruction has been performed by using the three most intense detected bands, the RGB channels. Conventional pictures are

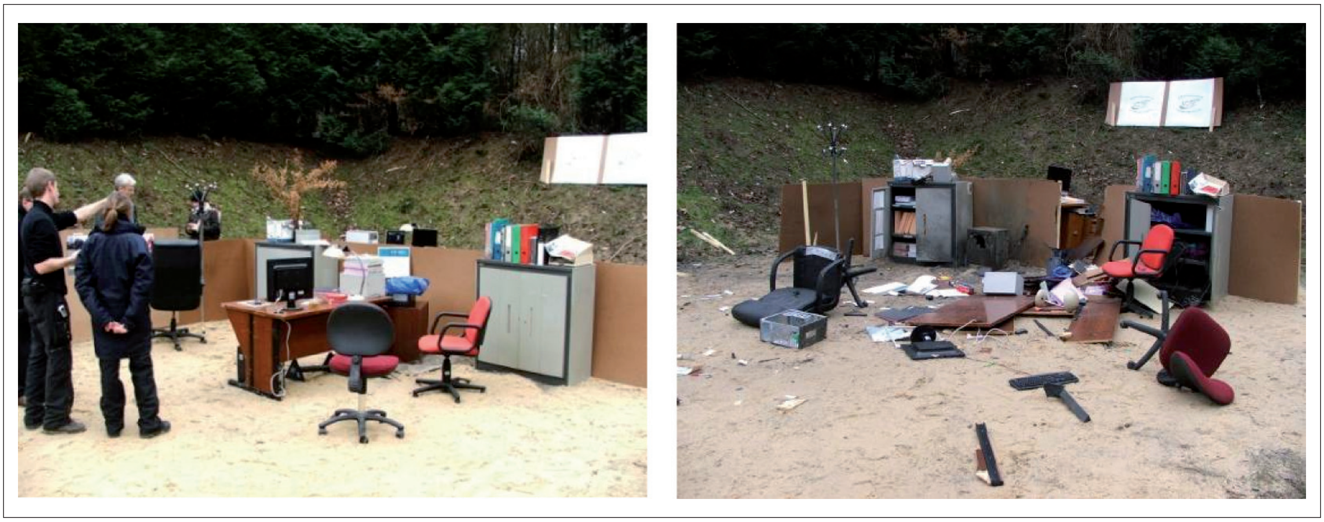

FIGURE 6 Scenario in Bièvres test before (left) and after (right) the blast
Source: FORLAB LCCP Training

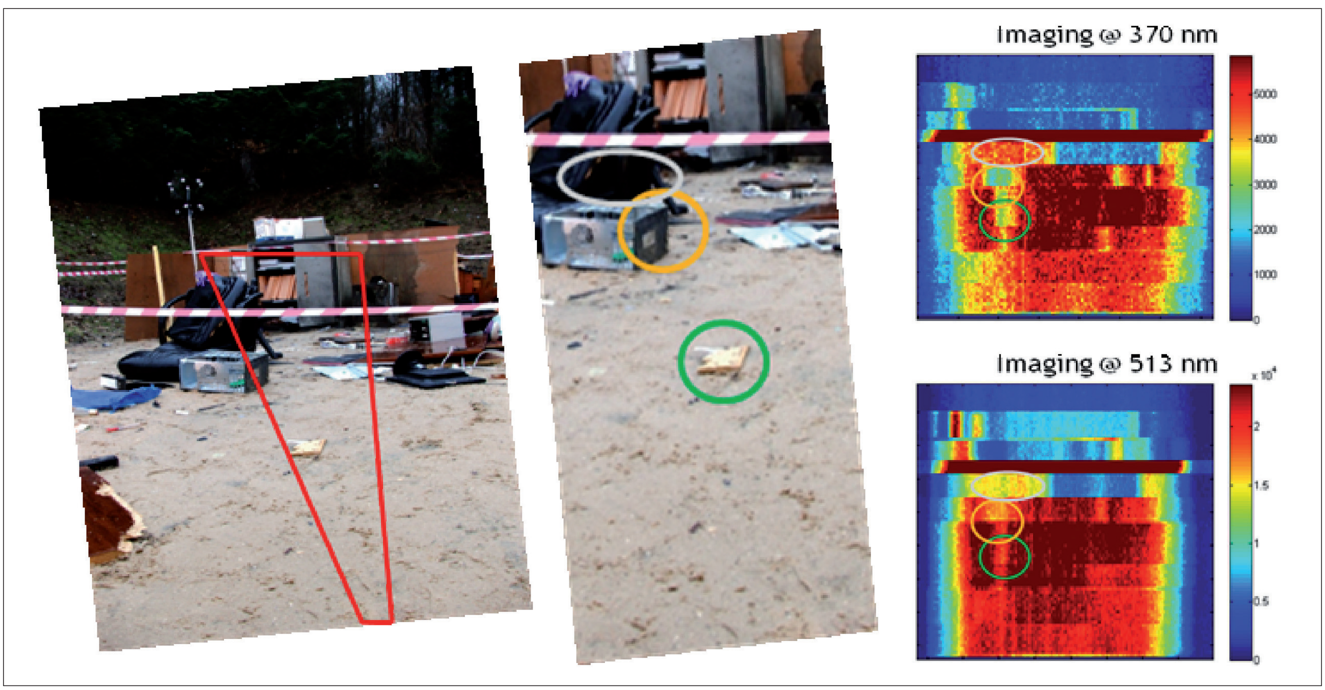

FIGURE 7 Fluorescence images by LIF system at two selected bands (370 nm and 513 nm)

FIGURE 8 Post-blast outdoor and indoor scenarios in Wroclaw's test

FIGURE 9 Fluorescence images of areas of the outdoor (left) and indoor (right) scenarios reconstructed by the RGB method

shown for comparison.
A first database of fluorescence spectra of materials that can be found in an IED has been created. Based on the reference spectra it was possible to identify plastic materials in real scenes reconstructed for in situ tests.
During the training test in Bièvres (Fig. 6), measurements on a post–blast scenario have been performed by the LIF scanning system. Fluorescence images have been obtained and by the analysis performed at different spectral bands, conveniently selected, some plastic debris have been evidenced on the scene.
In particular, fluorescence images at 370 nm and 513 nm (Fig. 7) have been analyzed and some different plastic debris individuated on the scene, circled in the figure, can be discriminated by their different spectral signature.
The second test campaign has been organized within

the project to test the capabilities of the screening technologies developed in the first stage of the project and the integration level of all developed sub-systems. Main goal of the campaign in Wroclaw was testing the ability of the LIF system to identify plastic debris in complex environment, i.e. that of a typical post-blast site contaminated by debris and shrapnel of any sort of shape and origin. Two indoor and outdoor environments were simulated, since materials mixed with IED remains were different: fragments of furniture, appliances and paper for the first scenario (indoor), fragments of buildings, plants and cars in the second scenario (outdoor) (Fig. 8). Furthermore, distances, light conditions, and spaces were also very dissimilar. The outdoor scenario, for example, has been investigated looking at the area in the explosion site at a 4-to-15-meter distance, with a field of view of 6 degrees. Several scans were run and the corresponding fluorescence images were acquired. Images acquired in outdoor and indoor environments are shown in Figure 9. The conventional photograph and a red frame indicating the portion scanned with the LIF sensor are reported. The corresponding fluorescence image is reported as well, where several polymeric debris are clearly visible. The system high spatial resolution allows to detect debris of average size less than 1 centimeter.
As far as the latter is concerned, the RGB technique was used for rendering to enhance specific spectral signature and allow the discrimination among different polymeric materials.

Conclusions

The LIF scanning system has shown, in conclusion, its ability in obtaining valuable information on the presence and distribution of evidences of different materials on large areas.
The possibility to identify by the system small single debris out of a very crowded and confusing area commonly found in post-blast scenarios has been verified.
Tests on post-blast scenes have demonstrated the ability of the system to discriminate plastics from other materials, and among plastics for an effective discrimination of materials that can be used for an IED preparation. Easy-to-read spectral images have been produced with short acquisition times both in laboratory conditions and in situ.
The capability of remote material identification by means of the available data processing methods on raw hyperspectral images has been demonstrated.

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