PROJECT FINAL REPORT

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1. Final publishable summary report

1.1. Executive summary

Terrorism is a real and growing threat in the world, and more than 60% of the terrorist attacks are carried out by the use of Improvised Explosive Devices (IED). The need of new security tools is a fact; OPTIX project provides a new tool for IED detection form a safe distance. OPTIX system is a transportable system that consists of laser based technologies, LIBS and Raman spectroscopies. Furthermore, research on IR spectroscopy has been done in the project framework. OPTIX is capable to detect traces and bulk amounts of explosives, in solid and liquids in certain conditions.

The use of Raman and LIBS techniques can be alternative or simultaneous. The OPTIX prototype is focussed for the detection of explosives on visible surfaces or when the IED is hidden in a transparent object. Furthermore, during the execution of the project, it has been tested that Raman technology is capable of detecting explosives inside opaque containers.

OPTIX system can perform at a standoff distance of 20 meter.

The working principles of are the following:

LIBS, atomic emission spectroscopy. High energy laser is focused on the sample's surface, creating plasma. Emissions when the plasma cools down are captured and analysed.

Raman technology is molecular spectroscopy. Laser radiation on the surface of a sample produces an energy transfer affecting the vibrational states of the molecules. Light is scattered with different wavelengths depending on the molecular structure of the material.

IR technique is molecular spectroscopy. After fragmentation of the molecules with a high energy laser pulse, absorption in the IR region of the released NO and NO_2 groups are measured, the ratio determining the explosive nature of the sample.

The three techniques share common equipment, optics and laser , which helps the integration in a single platform:

- Laser: A compact high energy laser providing 532 nm, 1064 nm and tunable IR outputs in the range from 5,2 to 6,3 µm.
- Optics: The laser has to be focused on the sample with the necessary energy density for each technology. Emissions from the distant sample in the spectral range from 350 to 950 nm and 5,2 to 6,3 µm are collected. The three technologies will share most of the optical elements.
- Spectrometry: A new ultra sensitive spectrometer has been developed for Raman and increased timing precision has been implemented on a CCD based spectrometer for LIBS.
- All the spectra generated by each technique are analysed by chemometrics module. New algorithms for spectral information extraction for the spectroscopies has been developed to increase reliability of the system.

OPTIX (Optical Technologies for the Identification of explosives) is a project funded by the European Commission under the Seventh Framework Programme (FP7). OPTIX consrtium is composed of a balanced set of technological and industrial partners, from big industry to

SMEs, from universities to research organisation, and topped with a best-in-class end user. The geographical distribution of OPTIX covers 6 EU Members States.

1.2. Project context and objectives

Context

Terrorism, as evidenced by tragic events at Madrid 2004, London 2005 and New York 2001, is a real and growing threat to Europe and the world, and attacks using Improvised Explosive Devices (IEDs) appear in the news almost every day. In fact, near 60% of the terrorist attacks are carried out by the use of such explosive devices.

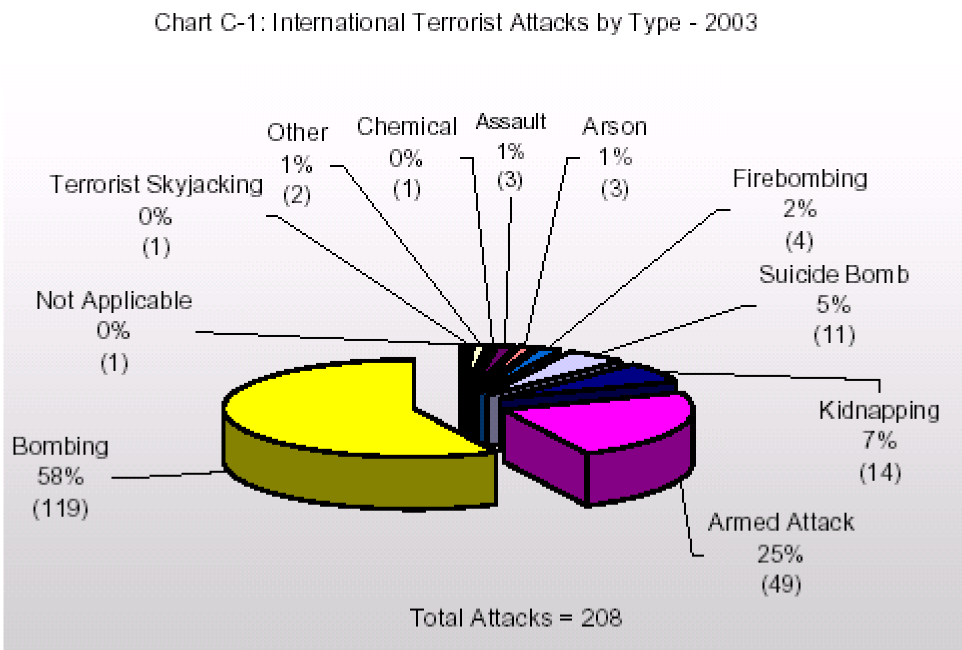

Figure 1. Evolution of terrorist attacks in the last years. Bombing attacks percentage.

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Security forces demand new tools to fight against this threat and due to the growth of terrorist attacks using explosives, the industry is making a big effort in the last few years to provide such tools. Every year a number of new products to detect and identify concealed explosives reach the market but the usefulness and deployment of these products is limited and restricted to some specific applications (airports and checkpoint applications for example), because these new systems do not meet the full operational capabilities demanded by the end users such as:

- Standoff detection and identification of explosives.
- Detection of very small or trace amounts of explosive material.

- Fast and reliable (very low false alarm rates) detection and identification of
- explosives.
- Large operational availability.
- High degree of automation possible and therefore ability to be operated by unskilled personnel
- Short deployment time
- Adaptability to variable environmental conditions
- Adaptability to new threats such as (new explosives).

Probably the most demanded by the end users is the capability for standoff detection and identification of explosives, in order to be able to anticipate the threat from a safe distance and to avoid entering into the lethality area of an Improvised Explosive Device (IED). Such standoff detection capability is also very demanded for intelligence operations to identify materials, people or places involved in the preparation and transportation of explosives.

For any method to be widely applicable for standoff explosives detection, it has to fulfil the highly set requirements for explosives trace detection; to provide a high degree of species selectivity as well as detection sensitivity. To be applicable in scenarios where detection of conventional explosives and home-made explosives (HMEs) are of essence, a wide threat substance repertoire as well as sensitivity to match the trace amounts available in the vicinity of a concealed IED is required.

On the other hand, particle trace residues are sometimes described as the amount of residues left in e.g. a fingerprint after handling of explosives. In this context, the weight of the residues as well as the particle size distribution are relevant measurements. The approach of considering discrete particles as left on a surface after handling an explosive would in many cases be the more relevant approach when evaluating detection performance, as it resembles the residues that are typically targeted in trace detection – secondary transfer of explosive residues.

Figure 2. The terrorist timeline.

The figure below shows the concept of use of the OPTIX system. The scenario depicted below is just one of the many possible situations where OPTIX can be deployed, but other scenarios like check point for cars, preventive search in buildings must be also considered.

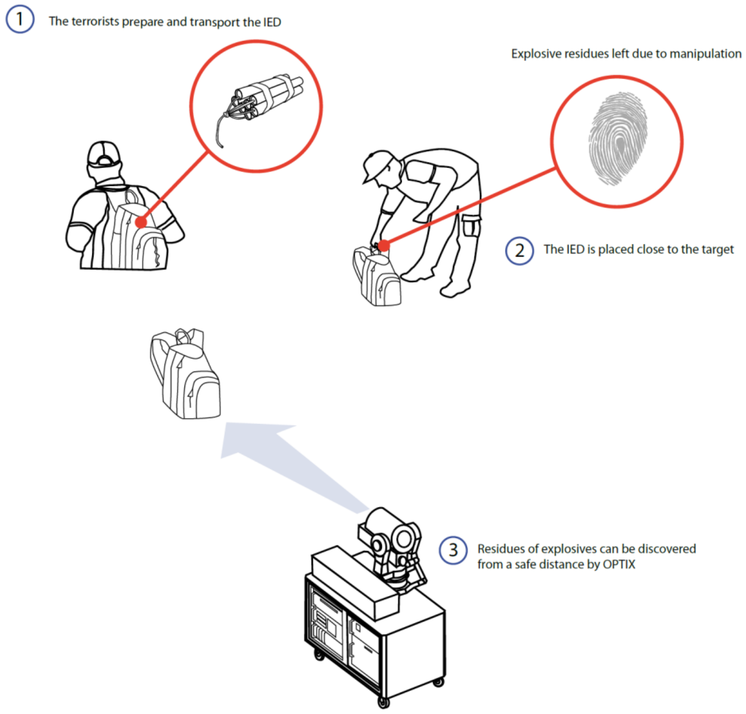


Figure 3. Concept of use of OPTIX.

Objectives

As stated before, OPTIX project addresses an important challenge of the European security stakeholders, as it is the contribution to the security of the European citizens by combating the activities of terrorism: OPTIX project will provide the end users (security forces mainly) with improved capabilities for the standoff detection and identification of explosives.

Therefore, the general objective of the project is to contribute to increase the security of the European citizens by the development of a transportable system for the standoff detection and identification of explosives in real scenarios at distances of around 20 m (sensor to target), using alternative or simultaneous analysis of three different complementary optical technologies (LIBS, RAMAN, IR).

The desired characteristics of the system were be the following:

- Standoff distance of at least 20 m.
- Capability for the detection of explosives in bulk, trace amounts and even liquids in certain conditions.
- Very fast detection and identification of explosives (from immediate detection to less than 60 secs detection, depending on the technologies involved)
- Very high reliability due to the combination of complementary optical technologies
- Very low false alarm rate (false positives)
- Very low false negatives rate (misses)
- Very high specificity for the identification of explosives.
- Large operational availability of the system:

- Capability for operation in different real scenarios: Day and night, indoor and outdoor, dry and wet environments.
- Portability of the system and remote operation of the system using wireless technology.
- Fully automated decision system (no operator dependence).
- Easy adaptability for the detection of new explosives.

The specific objectives leading to the achievement of the general objective of the project were the following:

- To develop beyond the state of the art three laser based technologies (core technologies), LIBS, RAMAN, IR, focusing on their potential for cross integration with the others, and devoted to the standoff detection and identification of explosives.
- To develop the enabling technologies (laser, spectrometry, optics, data analysis and fusion) that support the application of the core technologies to the standoff detection and identification of explosives, again focusing on the integration concept and hardware compatibility
- To achieve the integration of all previously developed technologies (core, technologies and enabling technologies) onto a single platform.
- To make the assessment of the new detection system by the execution of a thorough testing and evaluation program
- To perform demonstrations of the developed system to the end users involved in the project and to additional stakeholders as needed
- To elaborate a technological and application roadmap for further research needs.

1.3. Main S&T (Science and Technology) results/foregrounds

1.3.1. WP1. TECHNOLOGICAL ASSESSMENT

The OPTIX project started out with two activities that established the baseline for the prototype development that was to take place. First, a global search for the status of the OPTIX technologies was performed in order to summarise the state of the art. This was reported in the form of a rather extensive literature review on the latest technological progresses for Raman and LIBS, as well as the existing background information on the novel approach of photo fragmentation mid IR absorption measurements on explosives. In this task, the potential complementarity of the technologies was considered and the available information on technology integration done in other contexts was also covered. The review was delivered in the form of report D1.1a.

Immediately following the global search of technology status, an assessment of the selected individual technologies followed, focusing on the orthogonality, complementarity and integration aspects. The different characteristics of the detection techniques were considered, such as the sensitivity and selectivity, but also possible risks associated to laser irradiation of explosives. Additionally, aspects such as different and shared hardware requirements were covered with the view of defining the OPTIX integrated technology platform design. Both similarities and differences in requirements were covered. Examples of critical components are lasers, spectrographs, detectors, telescope, beam expander and optical fibers. Aspects such as the geometric configuration of the optical setup for optimised signal acquisition are very important for trace detection. Similarly, the different needs in terms of laser wavelength, laser pulse energy and energy density at the target, detector performance, optical component's coatings etc. are all parameters that must be collected in order to decide on the prototype design. This effort was reported in D1.1b.

At the very end of the project, a technological and application roadmap for further research needs were conducted on the basis of the outcome of the OPTIX prototype testing an evaluation. So far, the OPTIX combined Raman and LIBS system has not proven sensitive enough. It was found that it cannot be expected that Raman spectroscopy in this form will be useful for the small trace amounts available for detection

Because the OPTIX system was tested under challenging conditions, it is possible to see already at this point what needs to be improved in order to meet the requirements of the end users. While the current prototype is not sensitive, selective and robust enough to be immediately placed on the market, it is quite possible to see ways to significantly improve the performance for a prototype based on Raman and LIBS technology – one option discussed in this report is the combination of imaging Raman and LIBS. As the development of enabling technologies for standoff IR spectroscopy has undergone such rapid developments, there are today many promising alternatives to consider for a next generation of OPTIX, or in a novel approach to combine technologies.

One of the important observations made is that there is no room for tradeoffs in terms of performance when integrating detection techniques – this is due to the extremely challenging requirements for explosives trace detection in most situations. Instead, the highest impact will most likely come from fusion on the data, feature or decision level. In order to develop the related algorithms, there is need for large sets of high quality reference spectra, as well as iterative and interactive testing of performance and feedback to algorithm development.

This task was conducted as a desk study with input given from all partners initially involved in the technology assessment of WP1.

1.3.2. WP2. SYSTEM & SUBSYSTEM SPECIFICATION AND DESIGN

The main objectives of this work package were:

- ✓ To involve potential end users in the different countries in the definition of the scenario and the specification of requirements (Workshops organization).
- ✓ To define the scenarios that shall include the project and the threat, having in mind the standoff distance considered.
- ✓ To elaborate system and subsystem requirements specification based on the identified scenarios and with the involvement of the end users.
- ✓ To perform system and subsystems preliminary design

Work package 2 run in the first year of the project, January 2009 –September 2009.

The following activities have been developed in the framework of this work package:

Terrorist thread is a complex threat and the number of scenarios where the capability of standoff detection of explosives is being demanded is very wide. Therefore is necessary to reduce the number of scenarios to be studied in OPTIX, in order to focus the research.

For the definition of potential scenarios, end users feedback has been crucial, thanks to GUCI's participation in the project we organized a workshop for potential scenarios definitionwhere security forces from across Europe attended.

A Workshop with end users was held the 16/17 of April of 2009 in Malaga (Spain). Security forces all over Europe attended to the event.

The workshop was structured in four major sessions:

- ✓ *Welcome and presentation of the participants and presentation of the OPTIX project*
  The OPTIX project was presented to the audience and an overview of the capabilities of the technologies was provided so that they were able to understand what possibilities are offered by OPTIX before entering on discussions about scenarios and requirements.

- ✓ *LIBS stand off prototype demonstration*.
  After a theoretical exposition of the standoff detection capabilities of OPTIX the group moved to the University of Malaga facilities to see a demonstration of a LIBS standoff detection of explosives for better understanding of the operational implications of the use of optical technologies.

Figure 4. LIBS technique demonstration.

- ✓ *Round table on scenario definitions*

The objective of this session was to present and discuss the potential operational scenarios for the OPTIX system, and try to select a reduced number of scenarios as - initial target scenarios for the development of the project.

After having a good knowledge of the expected capabilities on OPTIX prototype a set of five selected operational scenarios where presented to the audience to initiate a round table discussion on how to operate the system on those scenarios.

Five possible scenarios were initially proposed by the consortium for discussion with the end users: a car bomb search (CBS), a left-behind object in public area (LBO), a suspicious object being searched inside a building (IBS), luggage screening in an airport (LS), car access control check point (CAC).

The most relevant characteristics of the different scenarios were discussed. Each of those scenarios presents different challenges for a standoff explosive detection system:

a) The main mission on the car bomb scenario is to search for the explosive loaded car among other cars.
b) In the left behind object scenario the main mission is to determine the risk of approaching to the suspicious object.
c) To search inside a building mobility of the system is a must.
d) For luggage screening a fast analysis is required.
e) The car access check point is, somehow, a combination of the requirements of the first and fourth scenarios.

✓ *Round table on system requirements*

Once the operational context was settled, the next step was to define the most important requirements for the system on the selected operational environment (scenario).

In the context of a two days workshop it was not possible to try to define quantitative requirements for the system and therefore the efforts were focused on establishing the weight of the different parameters on the performance of the system from the point of view of the end users.

When designing the system for detection of explosives there will be some parameters that will be in opposition to others, for example if the system is very sensitive the number of false alarms will raise and the larger standoff distance will be in opposition to sensitivity of the system. The objective of this session was to clarify the most critical parameters for the operational needs of the system in the different scenarios.

Based on the knowledge gained on the applicable scenarios and the relative wheight of criticla parameters the follwing activitity was to elaborate system and subsystem requirements specification basedThe objective of the OPTIX prototype is to evaluate the capabilities of the technologies and the possible improvementes improvements achievable by the combination of the three optical technologies over the capabilities of the individual technologies in close to real operational conditions.

A preliminary system and subsystem design has been carried out from the results obtained in work package 1 and in activities 2.1 and 2.2 of work package 2.

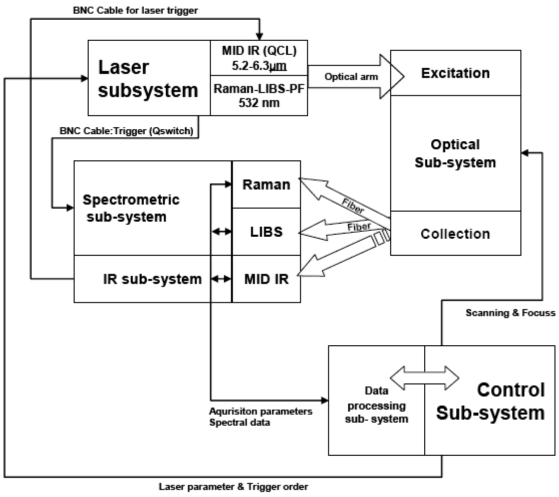


Figure 5. OPTIX system functional diagram.

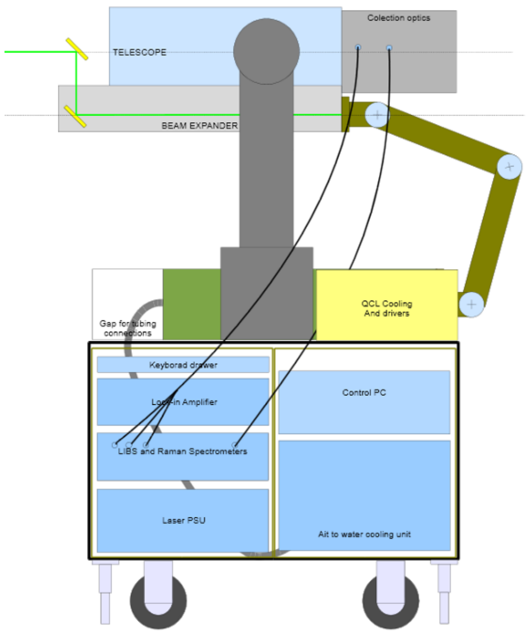


Figure 6. Preliminary system layout.

1.3.3. WP3. LIBS TECHNOLOGY DEVELOPMENT

The main first goals related to LIBS technology in the specific matter of distant detection of explosives can be summarized as follows: I) the specification of the most relevant instrumental requirements to maximize the performance at distance of the designed LIBS system but without losing sight of the ensuing integration of Raman and IR technologies, and II) a systematic experimentation over a closed-list of explosives, harmless products and supporting materials for polishing and refining the final LIBS subsystem within the OPTIX sensor. These objectives seek the definition of the most adequate parameters to produce useful analytical responses, and the subsequent knowledge of the particular emission outcomes of the different materials composing the interrogated scenario.

The final purpose of LIBS is the distant detection of explosive traces, the first task is to know the analytical response of the compounds that are tried for identifying. In this sense, some fundamental studies related to the parameterization of the most relevant experimental variables to produce the plasma plumes, the plasma behaviour itself, and the characterization of the spectral signals identifying each interrogated target, need to be done, leaving the residue factor aside.

To this end, several substances differently in nature have been considered, therefore including nitroaromatic organic substances like 4-mononitrotoluene (MNT), 2,6-dinitrotoluene (DNT) and 2,4,6-trinitrotoluene (TNT), as well as explosive related compounds namely sodium chlorate ($NaClO_3$) and ammonium nitrate ($NH4NO_3$). All samples have been prepared in bulk form, either as pellets (ca. 200 mm^2 in area, 6 mm thick) or as aggregates from melted products, depending on their manipulation requirements.

For the LIBS analysis, the most influential variables are, first, the laser energy density at the target, which will define the efficiency of the ablation process, and second, the timing parameters for the acquisition of the plasma light; in summary, a series of parameters that, ultimately, will impact on the sensitivity of the emission response.

In order to assess the effect of the irradiance, the resulting emission signals from some compounds after the focusing of laser pulses at variable energy on spots of different size were evaluated. Findings revealed that, as expected, LIBS analytically useful emission signals take place when high laser energies (usually higher than 300 mJ per pulse) were focused on reduced areas. Thus, for areas larger than 5 mm^2, the breakdown threshold was not reached and, consequently, LIBS signals are not revealed. In summary, LIBS data collecting is only possible if irradiance is well above the threshold level required for inducing the dielectric breakdown of the material. At the same time, it must be noticed that this plasma threshold is a variable factor that depends on the material interrogated. Hence, because of their properties, metallic and inorganic targets are materials more easily ablated than the organic compounds.

On the other hand, since the emission signals are transient in nature, the temporal window at which the plasma light is gathered will have significant repercussions on the final emission outcome. In this sense, when, and during how long the acquisition of plasma light is most valuable as analytical signal must be evaluated. Thus, different delay times from an external trigger input that is supplied by the Q-switch output signal of the laser (considered 0 time) to opening of the camera intensifier tube have been tested. In addition, several exposure times have been assessed. Results revealed that a delay time of about 1 µs is required for avoiding the unspecific background. But, like the ablation process, the transition of emission signals differs between compounds. Thus, while for organic substances LIBS signal lasts longer, for inorganic compounds the signal should be acquired during just a few µs after mitigating of the unspecific spectral background.

As a conclusion, a trade-off for both ablation and collection parameters must be adopted. From results, while ca. 3 GW cm^{-2} is considered a sufficient energy density for the production of analytical plasmas, a delay time of 900 ns and a gate width of 9 µs are adequate for acquisition of useful emission signals from both organic and inorganic analytes.

Once defined operational parameters, it is mandatory to analytically label the spectral responses of each target that will serve as their identification features for future. In addition to those spectral features related to the potential residues, the emission signals coming from any substrate need also to be identified. The breakdown based nature of the technique causes that, when a thin layer of residue is present over the surface of a substrate, a partial ablation of the support occurs. This circumstance leads to a more complex emission response as compared to that gathered from the bulk compound. This is why a spectral library of explosives and non explosives substances, as well as supports based on LIBS technology, for its detection and subsequent identification has been prepared. Furthermore, it must be highlighted that the support will influence the trace analysis both qualitatively and quantitatively. Some supports, mainly metallic, may enhance the ablation process. This event leads to more sensitive signals within spectra and, as a consequence, more sensitivity in the detection task. In contrast, other substrates, like plastics, may difficult the breakdown process. This fact deteriorates the sensitivity at par that afflicts the selectivity because of the similar atomic compositions for both organic residues and organic supports. In summary, it is a difficulty that will require the use of algorithms and a deeper data treatment for solving the issues at hand.

From the setting point of view, the sharing of instrumental components between LIBS and the other involved technologies (Raman and IR) makes the design of the system be any easier. Whether the incident laser energy is destined for ablation (LIBS), for the scattering (Raman) or for the fragmentation (IR), its delivering to the target follows the same optical path. Since the differences on how to get the analytical information for each technique lie on the energy density distribution, an optical system capable of modifying the cross section of the laser front (a motorized beam expander) is the most plausible solution. Thus, it will be possible to get a reduced laser spot size for LIBS analysis whereas a larger spot area for Raman evaluation.

On the other hand, the different requirements in terms of both temporal and spectral window, force to use distinct optical pathways as well as independent detection devices for gathering the analytical responses from each technology. It is true that the use of a telescope is necessary in order to bring the signal up to the sensor. However, once the signal has been gathered it must be guided by a specific via up to the particular detection device.

In this sense, a LIBS instrument able to remotely work at 30 m distance has been designed. The LIBS system consists of a pulsed Nd:YAG laser, a transmitter telescope, a large receiver telescope, and a wavelength dispersive unit equipped with a intensified charge-coupled device (iCCD) detector. The instrument uses a Quantel Brilliant Twins Q-switched Nd:YAG laser (10 Hz, 400 mJ/pulse, @ 532 nm, 5.5 ns pulse width) as excitation source. The beam is first expanded and then focused on a well defined spot on the distant sample using a 10x large output beam expander (Special Optics, Wharton, New Jersey). The beam transmission line has been accommodated to operate with the second harmonic of the fundamental wavelength (1064 nm) from the Nd:YAG laser. Once plume is produced, light from plasma is collected using a home-made Cassegrain telescope (167 cm in length and 24 cm in diameter), which permits to focus the returning light onto the tip of an optical fiber (600 µm in diameter mounted on a precision linear stage). Fiber was then coupled to a gated Czerny-Turner spectrometer, model Shamrock sr-303i (303 mm focal length, f/4, 100 µm slit), fitted with an iCCD detector (1024 × 1024 pixel, 26 mm^2 pixel, intensifier diameter 25 mm). Spectrometer used a 150 grooves per mm grating. The spectral range spans from 235 nm to 828 nm. The entire system is mounted on a wheeled cart, which is easily transportable, also fitted with leveling feet for guaranteeing device stability once it is positioned in the desired location. Additionally, laser and telescope are also equipped with a pair of pneumatic leveling isolation mounts to avoid oscillations on the focusing point on the target and on the light collection point at the optical fiber. Data acquisition is carried out using offered software for imaging and spectroscopy from Andor installed in a personal computer. Data obtained are exported in appropriate format and processed using Matlab® (The Mathworks Inc., South Natick, MA, USA).

Finally, by using this standoff geometry some systematic tests have been performed. There is no doubt about the analysis potentiality of LIBS at distance. However, because the LIBS technique is able to simultaneously detect the presence of all elements and, sometimes, molecules (in the form of emitting fragments), the main issue focuses first on the decision about the presence or absence of a trace, and then the identification between explosive residues and those harmless when they are present on the surface of a support. The usual work sequence begins with several laser shots scanning a well defined surface. The system decision is based in which at least the spectrum from one laser shot leads to a positive response for the conditions imposed to each purpose. Therefore, each spectrum is individually evaluated according to a series of interconnected basic premises depending on the compound (ammonium nitrate, sodium chlorate and organic explosives) being looking for. As a general norm, premises for decision are that two of the components within the evaluated spectrum and the intensity ratio between them are included within a preset range.

Beyond the assess on detection and recognition capabilities, the influence of the surrounding ambient on the analytical signal due to the light propagation through the atmosphere has been also evaluated.

Findings have revealed that, regardless the target being interrogated, the vast majority of the contribution to the emissions related to hydrogen (H), nitrogen (N) and oxygen (O) is basically coming from the surrounding air. This is argued by the larger amount of ionized air (plasma plume volume) as compared to the ablated rate on the target. Thus, the larger the relative humidity, more sensitive the emissions associated to hydrogen are. In the same vein, it seems that the hotter the air is, the less it will ionize when ablation takes place. Nevertheless, these conclusions cannot be firm entirely since the atmospheric conditions may also alter the sample itself.

Finally, in addition to the air contribution on the LIBS signal, it has been detected that the proportionality between intensities for different emissions features varies within a series of spectra gathered from the same target. This fact is argued by the heterogeneous distribution of the trace over the support surface. As a consequence, two different traces at different levels may report the same intensity ratio. Hence, this circumstance limits the direct use of intensity ratios as threshold value for making a decision about the nature of the residue.

1.3.4. WP4. RAMAN TECHNOLOGY DEVELOPMENT

Stand-off Raman spectroscopy is a powerful tool for distant detection of a variety of interesting compounds. It provides a molecular fingerprint of intact molecules and can be applied to organic as well as inorganic materials. It is therefore no surprise that this technique is also quite interesting when it comes to remote sensing of explosives. On the other hand the challenges that one has to overcome are several and they have been studied throughout the OPTIX project. Following the project outline a pulse laser for excitation of the Raman spectrum, a telescope for collection of the Raman scattered light were used. From the telescope a fiber optic cable connected to the spectrograph which was equipped with a fast time gated iCCd camera.

Raman signals are generally very weak (only one out of 10^6-10^8 photons) due to the low probability of inelastic scattering of photons with matter. To optimize all parameters that influence signal generation and collection investigations on different aspects of the technique were performed. First, the excitation wavelength of the laser plays a crucial role on the generation of Raman photons. Generally speaking the cross section of Raman scattering is inversely proportional to the excitation wavelength of the laser used. As solid state lasers are the only option if high pulse energies are required (for LIBS), a Nd:YAG laser (EKSPLA Nanosecond E/O Q-switched Nd:YAG laser NL301HT) with a second (532 nm), third (355 nm) and fourth (266 nm) harmonic crystal were used in the experimental setup, so that the dependency of the collected signal with the excitation laser line could be observed. Whereas a simple astronomer telescope can be used to record Raman scattered light when using an 532nm excitation laser, a dedicated UV telescope is of advantage when using the 355 nm laser line and it is a must when working with the forth harmonic (266 nm). A dedicated UV telescope was thus tested and a way developed to connect this telescope most efficiently to the fiber optic cable which then taking the light to the spectrograph. In case the sample under investigation did not show self absorption in the UV range the Raman intensities increased at shorter wavelengths. However, in case the target analyte or the matrix did show self absorption no increase could be registered, in fact a lower signal was obtained. Therefore, for sake of robustness of the overall it was therefore decided to use 532 nm as laser excitation line, as it represents the best compromise between scattering efficiency and robustness also for stand-off Raman detection.

Another challenge is the discrimination of unwanted interferences of light, like daylight or fluorescence effects. This is implemented by using a pulsed laser coupled to a gated ICCD (Princeton Instruments PI-MAX:1024RB-18-FG-43, 500 ps) camera. By syncing the camera to the laser pulse with the right delay only photons with relevant information are detected on the CCD chip. This had to be optimised during several experiments, especially the right delay time with different sample distances had to be found. Fluorescence is the designated enemy of Raman spectroscopy, as when generated it is most of the time stronger and therefore masks the Raman signal. On the other hand there is a fundamental difference between the inelastic scattering and fluorescence: the earlier happens instantly whereas the latter is delayed in time. So also here discrimination of fluorescence can be achieved in some cases by timing the camera gate just right. This was also shown during the investigations undertaken during the project. Unfortunately, it turned out that the possible gating time of 500ps did allow to avoid disturbing fluorescence only in some occasions.

In the proposal stand-off detection of explosives at 20 m was the goal. Of course also stand-off Raman has to be adjusted to the distance between collection optic (telescope) and sample of interest. Again, the right delay between laser pulse and camera had to be determined and implemented into the experiments. After that qualitative and quantitative analysis of a variety of explosives on different surfaces with different confusants was conducted at 20 m distance. Additionally it was possible to increase the distance to 100 m and identify explosives also at this extended distance. For this type of experiments it was necessary to move to the Austrian Armed Forces as they could provide us with the facilities required for these experiments.

Optimisation of the stand-off Raman system also included the usage of a special developed fibre optic consisting of several smaller fibres, which at one end formed a circular area matching the projected field of view of the telescope and at the other formed a slit that provided the best coupling to the Czerny–Turner spectrograph. It was shown that a significant increase of signal can be obtained with such fibres. Another factor of interest is the beam diameter and the resulting energy density during measurement. So a comparison between a 6 mm diameter beam directly from the laser and beam diameter of 23 mm achieved with a beam expander was done. In both cases the laser power has been limited so that the power density is comparable for all measurements.

After these thorough investigations on optimisation of the Raman subsystem several measurements on different explosives and precursors on different substrates with different confusants were undertaken. These do not only provide the necessary spectral library for successful identification of dangerous and explosive materials, but allow combination with data achieved from the other subsystems to increase prediction accuracy and reduce false-negative feedbacks of the chemometrics. These analyses included anorganic compounds used for improvised explosives (e.g. NH_4NO_3) as well as professional grade explosives (e.g. PETN) on surfaces ranging from common plastic (LDPE, PA, etc) to aluminium or car parts. Confusants like soap or oil, which mostly mask the Raman signal by producing a lot of fluorescence, were also added to the mix. Table 1 summarises the combinations of experiments performed during the project.

Table 1: Overview over the investigated substances in different combinations

	$NaClO_3$	**$KClO_3$**	**NH_4NO_3**	**H_2O_2**	**PETN**	**TNT**	**DNT**	**RDX**	**EGDN**
Glass	✓	✓	✓	✓	✓	✓	✓	✓	✓
Plastic(LDPE)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Aluminium	✓	✓	✓	✓	✓	✓	✓	✓	✓
Nylon	✓	✓	✓	✓	✓	✓	✓	✓	✓
Car paint	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fuel oil	✓	✓	✓	✓	✓	✓	✓	✓	✓
Motor oil	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hand soap	✓	✓	✓	✓	✓	✓	✓	✓	✓
Soil	✓	✓	✓	✓	✓	✓	✓	✓	✓
NaCl	✓	✓	✓	✓	✓	✓	✓	✓	✓
Car wax	✓	✓	✓	✓	✓	✓	✓	✓	✓

As remote detection of explosives can generally only be performed on surfaces, the capability of the stand-off Raman to sense even the smallest amounts of dangerous compounds left by the suspect on a surfaces is of utter importance. Hence, trace amounts of several substances were analysed to estimate the limit of the applied detection method. Therefore, the sample materials were deposited on an area of 28 mm^2 on an aluminium surface. NH_4NO_3, $NaClO_3$, $KClO_3$,TNT and PETN show distinctive signals when analysing down to a few hundred µg. The LOD (limit of detection) for H_2O_2 was calculated as 0.6%.

The following figure shows representative spectra recorded using the stand alone Raman system at the Vienna University of Technology.

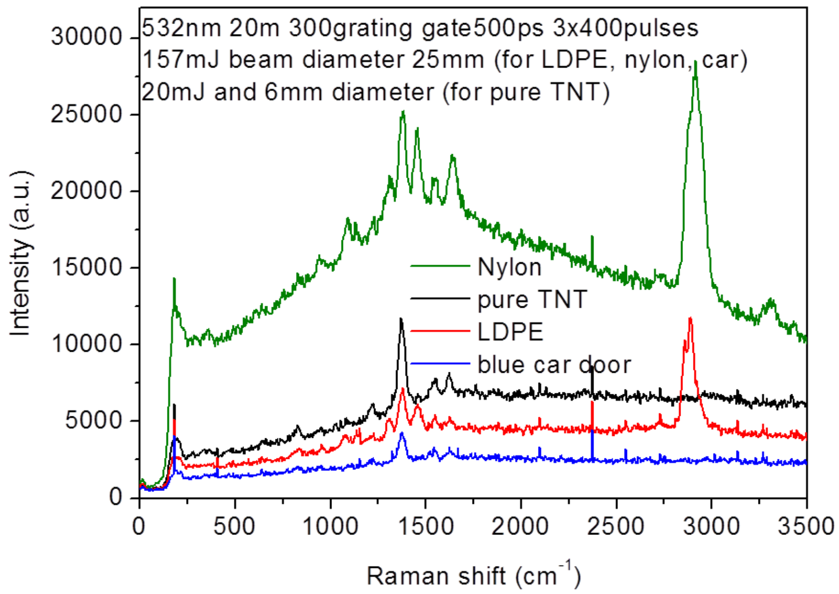


Figure 7. Characteristic standoff Raman spectra recorded with the stand alone System in Vienna.

Table 2: LODs of different explosives at 20 m distance

	LOD [mg]
DNT	0.53
$KClO_3$	0.64
$NaClO_3$	0.67
NH_4NO_3	0.14
PETN	0.57
RDX	6.15
TNT	0.65

In addition to the scheduled work outlined in the project proposal, further research activities were conducted. Emphasis was put on the development of strategies for quantitative standoff Raman scattering. Concerning this topic it was found that when the internally recorded Raman signature from ambient air (N_2) is taken as an internal standard, quantitative results could be obtained. This was shown on the example of NH_4NO_3 in NaCl as well as H_2O_2 in water. Furthermore, the fact that a pulsed laser source was used was exploited for the simultaneous analysis of two and three objects placed in a row. Time resolved detection allowed first to detect the closest object followed by the more distant ones. This was shown on the example of liquid samples with a position accuracy of only 1 cm. Such high precision was made possible by careful characterisation of the laser pulse profile as well as by applying chemometric techniques for the analysis of time resolved spectra. Finally, the concept of spatial offset Raman scattering was developed and tested for standoff distances ranging from 12 to 40 m. In this concept the focus of the telescope is kept constant but the laser spot on the sample is moved across the object. In this way a spatial offset between the position where the laser hits the sample and the position from which the Raman photons are collected can be established. In case the laser light is scattered by the container material a "light funnel" is created which expands into the object (container). Raman photons can be generated within this light funnel. Thus the bigger the spatial offset the higher will be the contribution of Raman photons generated inside the container. Spatial offset standoff Raman scattering thus allows to identify the content of different containers such as plastic bags, bottles and alike.

This summarises the work and findings of WP4 and gives an overview of the capabilities of the stand-off Raman subsystem.

1.3.5. IR TECHNOLOGY DEVELOPMENT

Detection of explosives in the mid infrared (MIR) is a challenging task because the spectral range of interest bestrides nearly the whole finger print region from 3 to 11 µm. Since explosive molecules are usually broad band absorbers which can exhibit absorption bands of several hundred nanometres, even the detection of single explosives is challenging as well. It is nearly impossible to address a whole absorption band or even the entire fingerprint region with only one laser device. During this project, a detection scheme was developed which enables indirect detection of the class of nitro based explosives by detecting the characteristic marker gases NO and NO_2. For this purpose it is necessary to separate functional NO_x groups from the original molecule. This is achieved by a technique called pulsed laser fragmentation (PLF). Utilizing a combination of PLF and subsequent fragment detection in the MIR enables to detect explosives containing functional nitro groups with only three lasers. In this project the same laser is used for PLF as for the LIBS and Raman measurements. Fragment detection is done by two quantum cascade lasers (QCLs) at 1600 and 1900 cm^{-1}. These wavelengths are superior to others because they address absorption bands of NO and NO_2 and are also nearly free of interferences with other atmospheric gases. The detection is performed in two steps: at first, the PLF beam is aimed to the sample which generates a plume of characteristic NO_x fragments in front of the sample. In the second step the beams of the probing QCLs are aimed through the plume and are back reflected on the sample surface. The back reflected radiation is collected by a telescope and focussed on a sensitive MIR detector. If NO and NO_2 molecules have been generated during PLF this is detected as absorption.

In the first part of the project a prototype was developed which can be merged with the rest of the OPTIX prototype. The IR prototype mostly consists of two QCLs with driver electronics, a detector, a lock in amplifier, and a data acquisition device (DAC). QCL drivers, lock in amplifier, and DAC were centralized into one 19 inch rack mount which represents the controlling device of the IR prototype. All other components of the IR prototype, such as QCLs and detector, are connected to and controlled by this device. The device itself is connected to a personnel computer via USB interface. Initially, it was intended to overlay the beams of the YAG laser and the QCLs and to use the same path for all beams. But during the development of the OPTIX prototype it emerged, that optics which are in principle suitable for wavelengths in the VIS and MIR as well, exhibit strong attenuation in the VIS which hindered appropriate operation of LIBS. For this reason the consortium decided to continue work with two independent systems, one for LIBS and Raman and one for MIR. In order to enable easy operation, software was developed which enables fully automated measurement of NO and NO_2 with the IR prototype.

After the development of the IR prototype was finished laboratory tests were performed to study the fragmentation process. To do so, tests in an absorption cell were carried out using RDX, TNT, and PETN sample pellets. The beams of the probing QCLs were aimed lengthwise through an absorption cell with a length of 38 cm. Sample pellets were placed in the middle of the cell behind another window. The fragmentation laser was focused onto the sample pellet through this window. Before fragmentation, the cell was evacuated to a pressure of p=10 mbar. Due to increased broadening of absorption lines with increasing pressure, working at low pressures facilitates measurement and data analysis and therefore this was exploited in the initial phase even though later practical operation has to be performed under atmospheric conditions. After fragmentation for one minute the probing QCLs were scanned. The results are shown in Figure 8. Characteristic extinction spectra of NO and NO_2 could be measured for all samples. The strongest signal was obtained with the PETN sample with a fragmentation pulse energy of E=87 mJ. For data analysis, the heights of the extinction peaks of NO and NO_2 were plotted against each other in a two dimensional coordinate system. Since NO_2 exhibits three peaks within the scanned spectral range, the strongest one in the middle was chosen for analysis. The analysis plot is shown in the lower right of figure Figure 8. As can be seen, the data points related to an explosive are forming clusters. Although these clusters overlap to some extent, this means that discrimination of different explosives is possible in principle.

funnel

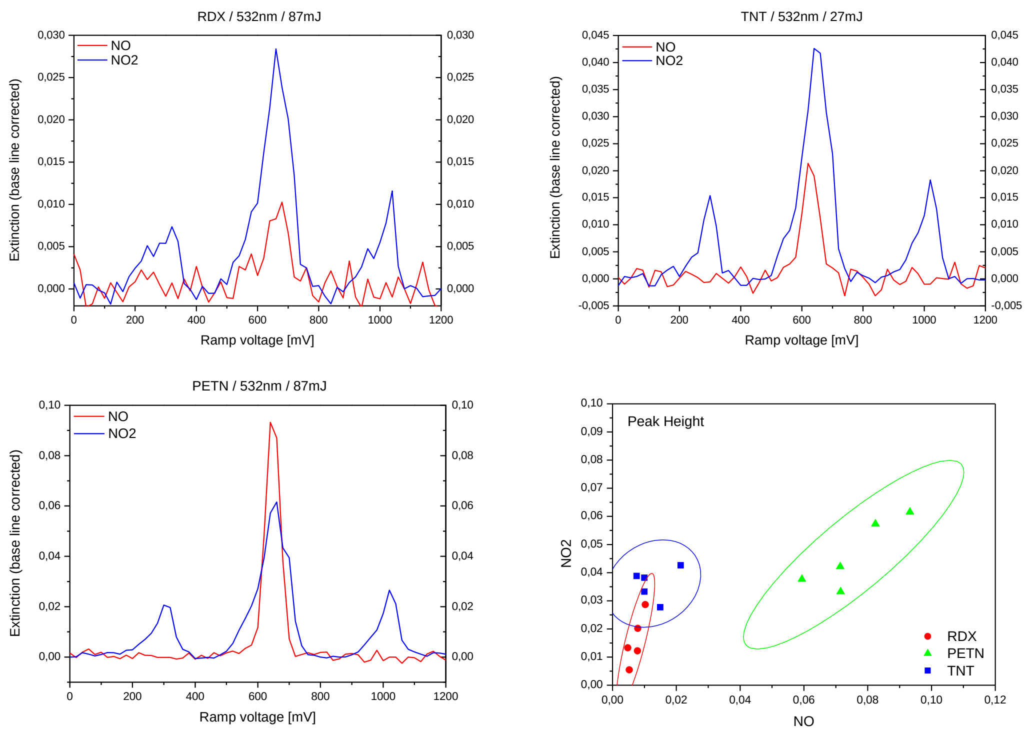


Figure 8. Cell measurements of fragmentation products of RDX, TNT, and PETN in transmission configuration.

The fragmentation tests also showed that the application of the 532 mn fragmentation laser strongly affects the samples and changes their surfaces from slight discolouration up to ablation. In realistic conditions, i.e., in stand off configuration where the sample reflects the QCL probing beams, changing surfaces complicate absorption measurements because it is nearly impossible to discriminate whether a decrease in the detected intensity results from absorption due to the presence of NO_x or from changes in the sample surface. Furthermore, most sample materials exhibit a very weak reflectivity, i.e., only a very small amount of the applied probing beam energy is reflected and available for detection and analysis, leading to poor signal/noise ratio. These drawbacks hindered the detection of explosive samples in stand off configuration. Nevertheless, the capability to detect the characteristic gases NO and NO_2 was successfully demonstrated. To do so, a beaker containing nitric acid was placed in front of a reflecting object. By adding copper to the nitric acid, measurable amounts of NO and NO_2 were produced. In Figure 9. The measured spectra are compared with simulations of the target gases. As can be seen, both spectra show good agreement with the simulations. By adapting the simulations to the measured spectra concentrations of 3700 ppm and 150 ppm could be estimated for NO and NO_2 respectively.

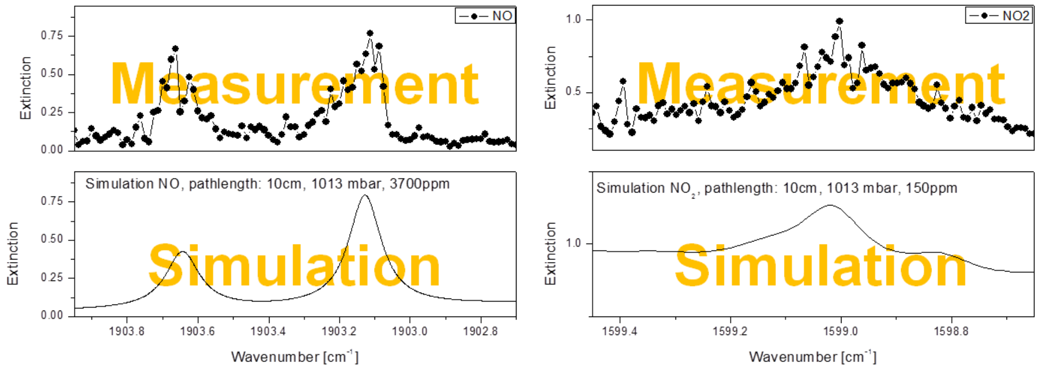


Figure 9. Stand off measurement of NO and NO2 by the chemical reaction of copper with nitric acid over a distance of 20 m.

Although detection of realistic explosive samples could not be demonstrated yet in stand off configuration, the application of fragmentation wavelengths in the UV spectral region and more powerful QCLs for probing in order to optimize the fragmentation process and to obtain better signal/noise ratios enables this technique to complement other techniques for explosive detection.

1.3.6. WP6. ENABLING TECHNOLOGIES DEVELOPMENT

1.3.6.1.Chemometrics.

The chemometrics methods developed for the OPTIX prototype encompass a wide variety of filters aimed to enhance the signal quality which are applicable to each of the three technologies (LIBS, IR and Raman) as well as specialized identification methods that take the unique characteristics of each technology into account.

LIBS spectra supply atomic information, and tests have shown that the expected variability of LIBS measurements is very high, making identification of single shot experiments challenging. Based on the atomic characteristics of LIBS measurements, the identification scheme uses fixed positions within each measurement to determine if an explosive substance is present or not. Since background characteristics heavily influence the contributions of signals and are – again, due to the atomic nature of LIBS – indiscernible from the desired signal, each background material needs to have its own reference database. These databases are represented as support vector machines (SVM) that must be trained with appropriate reference measurements of explosives and non-explosive materials on the specific background. The trained SVMs can then be stored and used to classify unknown measurements which have the same background material. Initial tests have verified that Raman spectroscopy can be applied to identify background material allowing the fitting SVM to be used for high sensitivity LIBS trace detection.

Table 3: Interval ranges used for LIBS SVM explosive detection

Name	nanometer Range
cyanide	(387.7, 388.7)
aluminum	(396.6, 397.2)
kalium	(404.3, 405.0)
C_2	(516.1, 516.8)
natrium_1	(568.1, 568.6)
natrium_2	(568.6, 569.2)
hydrogenAlpha	(654.5, 657.5)
nitrogen	(746.2, 747.1)
oxygen_O	(776.6, 777.0)
sulfur	(920.5, 921.5)
unknown1	(422.5, 423.0)
unknown2	(766.0, 766.6)
unknown3	(769.5, 770.0)

Raman spectroscopy is less sensitive than LIBS but is non-destructive, allowing multiple sampling, and supplies molecular information of measured substances. Molecular information is more diverse than atomic information, and thus background materials are not as critical as in case of LIBS. Fluorescence and other background effects are eliminated in measurements by adaptive filters specially developed for the OPTIX project. Identification of

Raman measurements is based on prototype references that are extracted from reference spectra of pure explosive materials. These prototype references contain information about expected signal positions and relative intensities of the explosive materials, and are compared to pre-processed unknown measurements in order to identify explosives. The identification has proven to be effective under realistic conditions in tests carried out by FOI. An interesting result of realistic testing is the observation that the detail level of prototype references is a major factor influencing the identification effectiveness. Interestingly, very detailed references containing information of major and minor signals are often less suitable for the identification of realistic standoff measurements as much of the detail visible under laboratory conditions is lost and only major signal contributions are visible. Reducing the detail within measurement certainly increases the risk of confusing two or more compounds which are molecularly similar like e. g. $NaClO_3$ and $KClO_3$. To find the optimal level of detail used for references, larger test series with a wide variety of explosives, and especially a wide variety of non-explosives, is needed.

Standoff measurements using IR could not yet achieve the quality needed for the detection of explosives, therefore the development of IR identification did not proceed past rudimentary methods and could not be tested on a relevant number of spectra.

The chemometrics software developed for the OPTIX prototype is based on Mircosoft .NET written in c#. The filter and identification routines are designed to require non-specialized hard or software, and for future development it is possible to change the hardware from a standard PC to embedded systems using digital signal processors by porting the source code to the desired environment.

1.3.6.2. Laser development

1.3.6.2.1. Laser base.

Laser base was designed to accept all laser sources and combining optics. According to project objectives, the three-laser laser source was created, assembled and partially tested.

The base of OPTIX laser source is powerful nanosecond NL310 type laser specifically modified to extend flash lamps life-time and simplify exploitation and service. The pre-installation for two quantum cascade lasers emitting in NIR range was incorporated into the nanosecond laser body. Special optics was incorporated for IR and ns laser beams. The pre-installation for accepting beam transportation optics beam arm was manufactured too.

Optical lay-out of the system is presented in Figure 10.

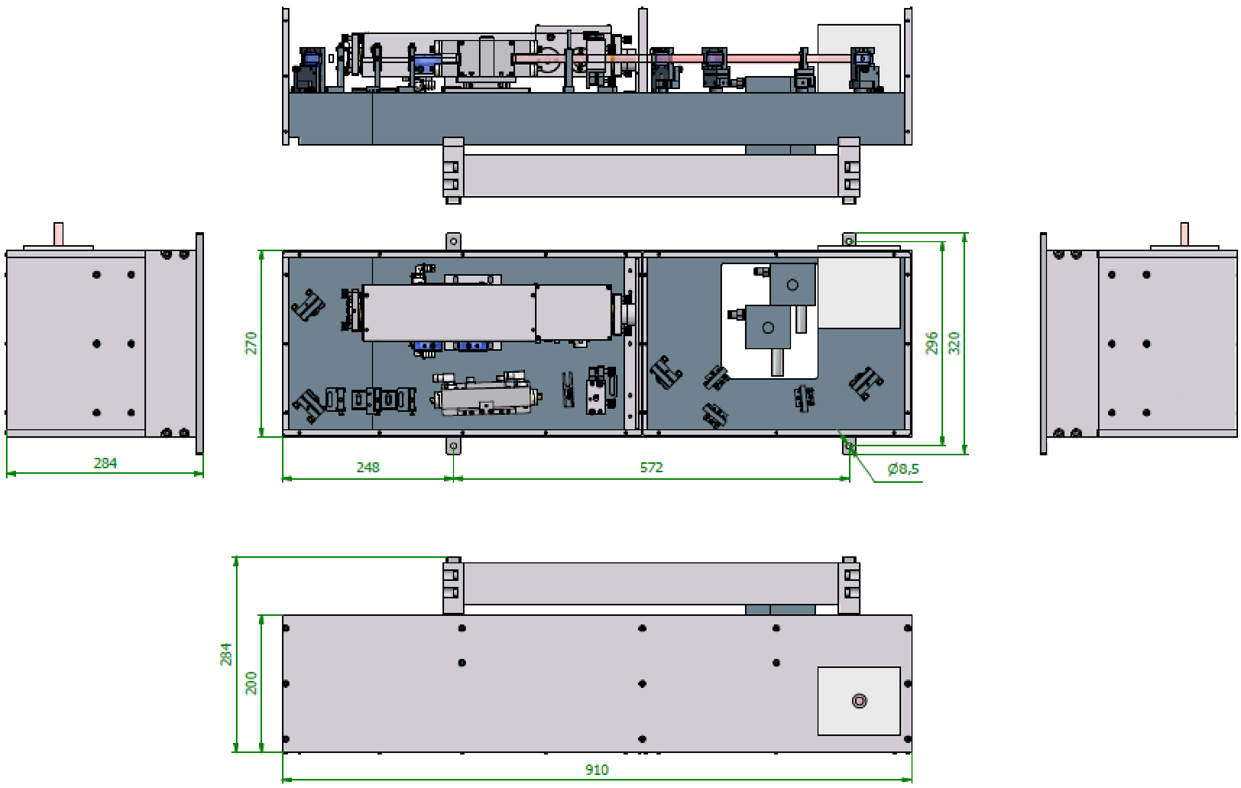


Figure 10. The three laser source mechanical lay-out

Laser consists of two compartments. Sealed master oscillator and power amplifier with the second harmonics generator occupy the first compartment. The second compartment is QCL and beam combining optics one. In this compartment, pre-installation for beam transportation optics is made.

1.3.6.2.2.Master oscillator.

Master oscillator is designed as a rigid closed body machined from a single aluminium piece. It contains the master oscillator cavity and Pockels cell driver with HV power supply. The master oscillator cavity assembly includes the master oscillator chamber, cavity mirrors, Q-switch, thin-film polarizer and Q-switch electronics. The master oscillator chamber contains one flash lamp used to optically pump the Nd:YAG rod. The flash lamp and Nd:YAG rod are surrounded by a diffuse reflector employed to increase the pump efficiency. Principle of operation of master oscillator is described in laser user manual..

Taking into account the exploitation environment and complicated conditions, the master oscillator was designed with sealed optical beam path. To prevent contamination of optical part of the laser even during field service, new laser chamber design was done. The laser chamber of new design is made of two parts. One containing Nd:YAG active element is sealed in optical beam compartment. Another one with flash lamp can be separated from rod compartment and taken out from laser body for flash lamp replacement. That means that laser service can be performed in field conditions without danger of optical part contamination. As the master oscillator operation stability is the main factor for full laser system stability, exploitation of laser becomes easier.

The new laser external view is presented in Figure 11.

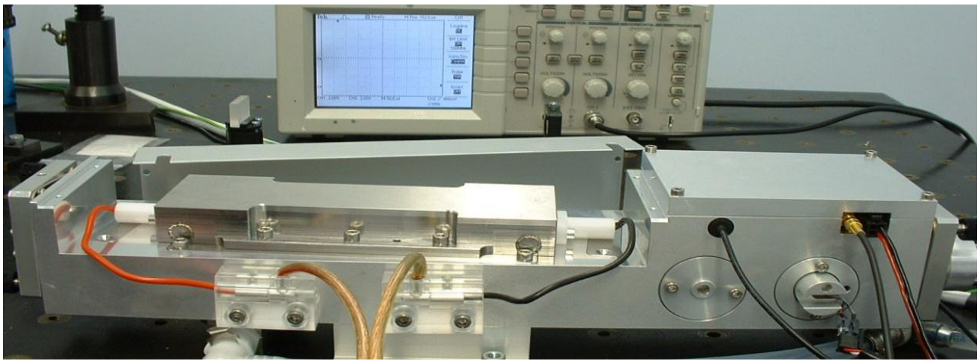


Figure 11. New master oscillator external view. (Laser chamber compartment cover is off)

1.3.6.2.3.Flash lamp replacement.

The design of master oscillator allows flash lamp replacement without opening the cavity. In such way, the cavity is protected from contamination.

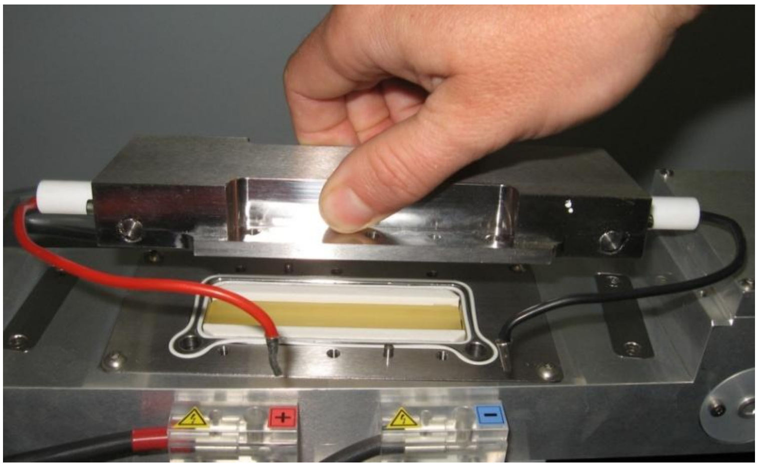


Figure 12. Flash lamp replacement is easy due to split design of the laser chamber

1.3.6.2.4.Life time tests.

Another important aspect of laser exploitation is operation time between services. The main consumable in flash lamp pumped lasers are the flash lamps. To prolong their service time, a new flash lamp was designed. The life time tests were performed with master oscillator running at full output power for several weeks. Test results are illustrated by diagram in Figure 13.

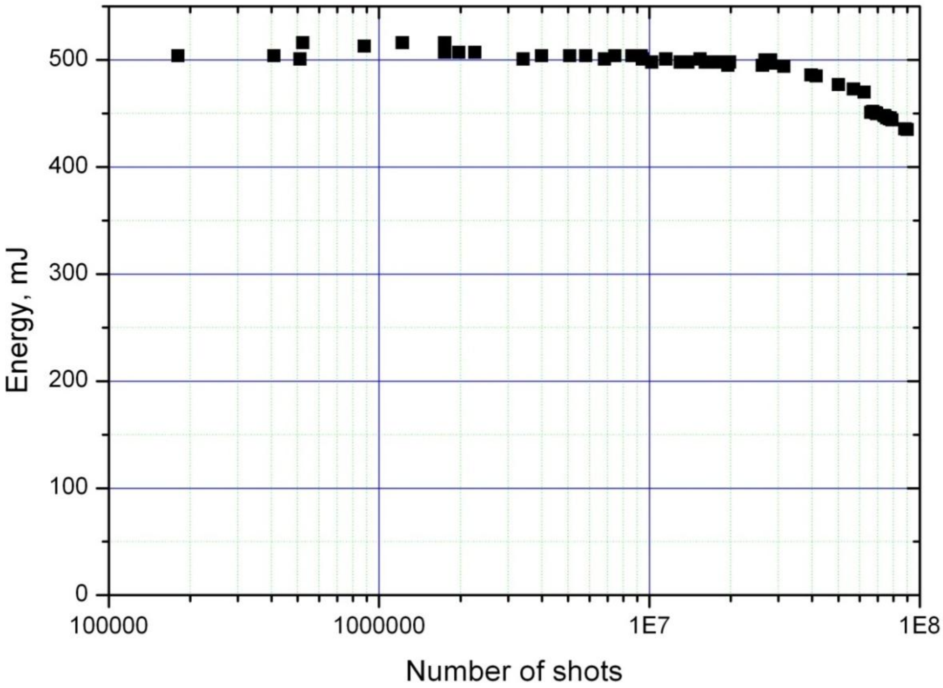


Figure 13. Life time tests of master oscillator flash lamp

It can be seen that new laser and flash lamp design lets achieve very good results. Flash lamp easily achieves 80 mln. shots while degrading output power by only 10%.

1.3.6.2.5.Laser optical layout

The NL310 laser developed for OPTIX project comprises: master oscillator, power amplifier, the second harmonics generator (SHG) and separate compartment for quantum cascade lasers (QCL). Optical layout of the laser is presented in Figure 14.

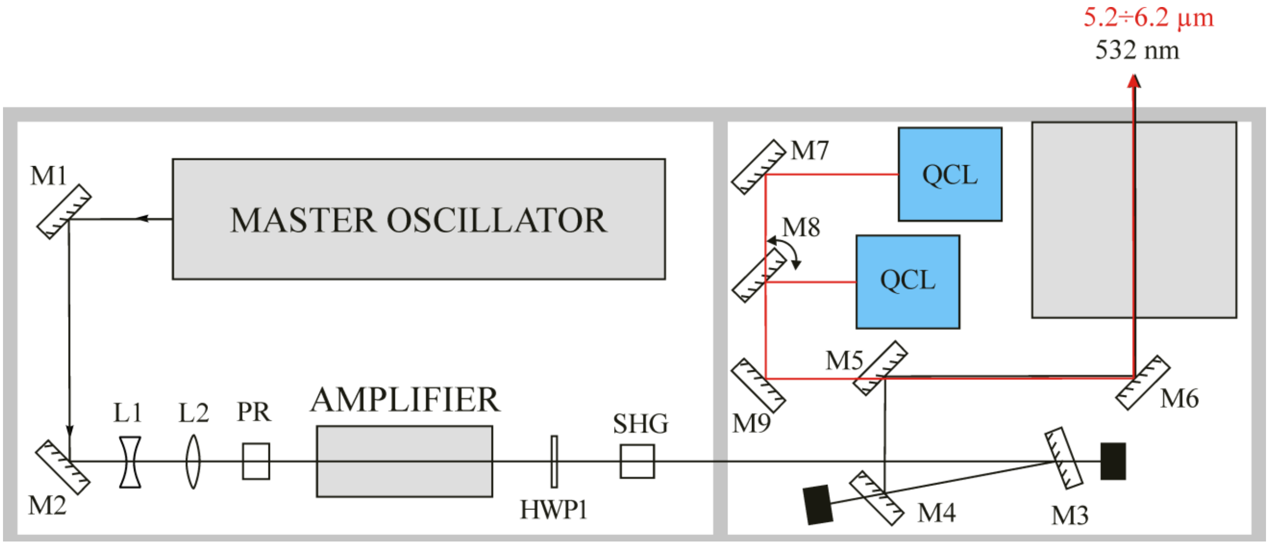


Figure 14. Optical layout of NL310 series laser head

The specifications according to requirements of the preliminary system design coming out of the work package 2 are presented in Table 4.

Table 4

Parameter	Value
Wavelength, *nm*	532
Pulse duration, *ns*	4–6
Max. pulse energy, *mJ*	700
Pulse energy stability (st. dev.), %	1.5
Maximum repetition rate, *Hz*	10
Optical pulse jitter, *ns*	0.5
Linewidth at 1064 nm, cm^{-1}	< 1
Beam profile	'hat top' in near and near Gaussian in far fields
Beam diameter, *mm*	~12
Beam divergence, *mrad*	< 0.5
M^2	< 2
Water consumption (max 20 °C), *l/min* (for water-water cooling models only)	< 10
Power consumption, *kVA* (208-240 V AC; 1-phase; 50/60 Hz)	≤ 2.5
Dimensions, *mm*	
laser head	910×200×284
power supply	600×555×660

1.3.6.2.6.Laser System powering group.

The flash lamp power supply, cooling unit and laser control circuitry are mounted in a single power supply cabinet. The umbilical connecting the laser head to the power supply cabinet contains flash lamp power cables. The laser head is also connected with the power supply cabinet by cooling water pipes, Q-switch triggering and power cables. The cabinet contains the necessary components to power-up and cool the laser heads. It is directly connected to the mains power supply. Each individual subsystem is then connected to the mains through a bus at the bottom of the cabinet.

All the units of powering/cooling group are modular and built to fit the standard 19-inch enclosures. These modules can be easily mounted into Indra-made cabinet

The power supply cabinet MR9 accommodates the following: control Unit located at the top of the cabinet. It performs the following functions:

- Controls the timing of the laser firing sequence;

- Allows the laser to either be controlled manually by control pad or operate in an external control mode;
- Monitors the integrity of interlock loop, and shuts the laser down in case the loop is broken;
- Distributes the power for the electronics in the laser head.

Power supply PS5053: Charges up the capacitor banks that are then discharged through the flash lamps.

Cooling unit PS1245CO: The cooling unit is a < 2.0 kW water/air heat exchanger. The unit is assembled with a 5 µm particle filter and a de-ionizer cartridge.

The front view of powering/cooling cabinet is presented in Figure 15

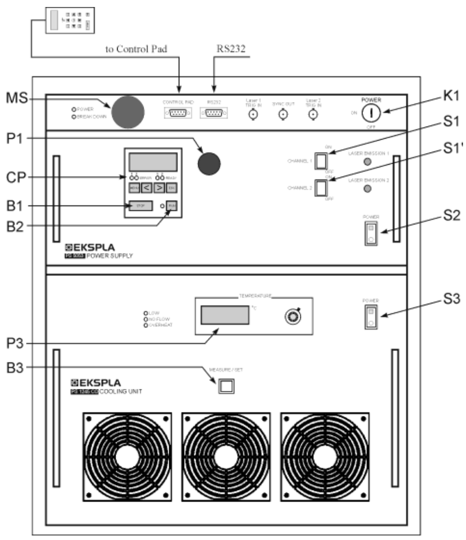


Figure 15. Front view of power supply cabinet.

There are a number of controls at the front of power supply, cooling unit and control unit which are thoroughly described in laser user manual . In this report, we skip this description due to its volume.

1.3.6.2.7.Synchropulse for OPTIX system.

According to preliminary design requirements elaborated in working package 2, the laser has to provide a synchronization pulse for full OPTIX system operation. This synchronization pulse is available from the front of the power supply (Figure 15). Pulse parameters as follows:

OUT –	BNC socket provides synchronization pulse linked with the second channel controlled from the remote control pad, with the following characteristics:	
	amplitude	>4 V @ 50 Ω
	rise time	50 ns
	duration	>5 µs
	jitter in respect to optical pulse:	±0.5 ns (internal triggering)
		±125 ns (external triggering)

This trigger signal and actual laser output pulses are linked by Q-switch synchronisation pulse. It can be controlled in time with respect to Pockels cell triggering pulse. Pockels cell triggering pulse in turn is synchronized with optical pulse quite precisely ($\pm$0.5 ns). Delay can be easily adjusted by means of control pad connected to control unit. In delay menu (precise description will be provided in laser manual) of control pad the delay between the output sync pulse at OUT connector located on the front panel of the power supply cabinet and the Q-switch triggering moment is set. This delay may be tuned in the range from –8 ms to +8 ms by 0.125 μs steps. The negative value means that sync pulse at the OUT is preceding the laser optical pulse. As discussed in technical management group, this range of delays is sufficient for all system synchronization.

1.3.6.2.8.Mechanical assembly.

Laser mechanical assembly is made on the casted aluminium frame with aluminium enclosures. The laser is divided into two compartments: one which is sealed contains master oscillator, power amplifier and the second harmonics generator (fig. 9). The amplifier consists of beam expanding telescope of lenses L1 & L2, 90° polarization rotator PR for depolarization reduction and amplifier laser chamber. Two flash lamps and Nd:YAG rod are mounted in a water-cooled chamber with efficient diffusive reflector.

Figure 16. NL310 laser rear view.
Connectors for cooling tubes, power cable umbilical and control socket are visible

Harmonics generation is performed in DKDP nonlinear crystal placed in oven for thermal stabilization and service prolongation as the nonlinear crystal is hydroscopic. Prior to the harmonics crystal, a half-wave retardation plate HWP1 orients the beam to the appropriate polarization for harmonics generation. The crystal is mounted on adjustable support. The heaters are kept on at all times, even when the system is in stand-by mode (power key-switch is in OFF position [K1] on the Cabinet); this protects the crystals against atmospheric humidity. The holders are equipped with LED indicators that flash when the temperature inside the holder has reached the set value.

Enhancements made after feedback from UMA and Indra:

After exploitation at UMA facilities and at Indra it was found that after standing-by laser need too long time to reach thermal equilibrium. To make this time shorter the direct access to second harmonica crystal adjustments was needed. Some minor modifications were made.

Aperture at the upper cover of laser enclose was made to provide access to harmonics crystal angle tuning. A cork for this aperture closing was made too.

The second harmonic beams is separated from fundamental radiation by dichroic mirrors M3 and M4 which are mounted in QCL compartment**.**

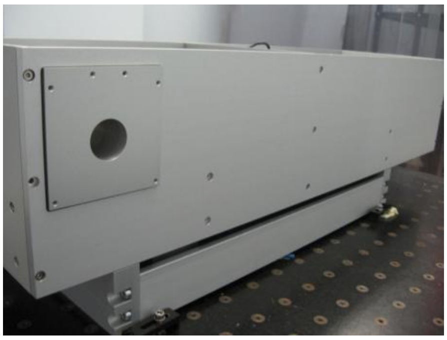


Figure 17. NL310 laser external view from beam transportation side. Pre-installation for articulated arm is visible

Figure 18. NL310 laser view with upper covers opened.

1.3.6.2.9.QCL compartment.

In QCL compartment pre installation for two QCL lasers and beam steering optics and combining beam splitter are done. QCL laser planned to mount vertically to assure access to their cooling sockets, power and control sockets and nitrogen purging sockets. In this compartment second harmonics separators and midIR IIH beams combining beam splitter were mounted. Figure 19.

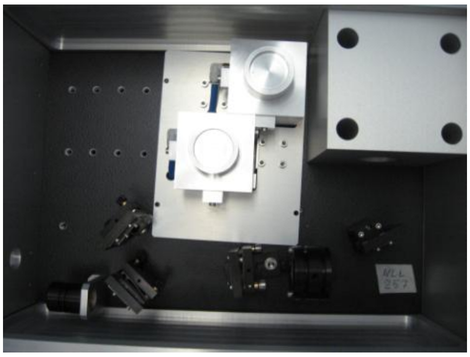


Figure 19. QCL laser and beam combining optics compartment.

In the same compartment pre installation for articulated arm is done.

Conclusions.

The laser system specification, laser base optical design and mechanical design have been fulfilled. The pre installation for QCL lasers are. The nanosecond laser tests were performed. The parameters fulfil specifications formulated by work package 2.

1.3.6.3.Spectrometer system for LIBS and Raman

The tasks performed were:

1. Development and production of optical fibers
2. Development and production of LIBS-system
    a. fast triggering
    b. 3 channels
    c. timing diagram (in cooperation with Ekspla)
3. Development and production of Raman system
    a. development of high-sensitive optical bench
    b. adaption to ICCD-camera

1.3.6.3.1.Optical Fibers

Avantes has designed and produced the following optical fibers and an interconnect:

1x FC3-IR400-1.7-ME
1x FC-IR1000-2.2-ME
1x FC-IR1000-0.5-ME
1x Fiberoptic interconnect (ME-FI-SM-MM)

During the integration and testing phase in June 2012 new fiber assemblies were designed to optimize the performance of the system for the UV part of the spectra:

FC3- UV600-2 , FC-UV1000-0.5 and a fiberoptic interconnect
FC3- UV200-2 , FC-UV600-0.5 and a fiberoptic interconnect

These different sets were tested for the LIBS setup of the system.
These components have been developed and produced according to specifications and have been used in the OPTIX prototype.

1.3.6.3.2.LIBS

For LIBS a, initially a 3 Channel spectrometer AvaSpec-3648-RM was built with the following settings:

Channel 1: Grating VC (1200 lines/mm), blaze 500nm
range 331-593nm
slit 10 µm, 1000µm height

Channel 2: Grating NC (1200 lines/mm), blaze 750nm
range 592-821nm
slit 10 µm, 1000µm height
OSF550

Channel 3: Grating NC (1200 lines/mm), blaze 750nm
range 797-983nm
slit 10 µm, 1000µm height
OSF600

The required application specific software for fast triggering was designed and tested.

This feature is implemented in the optical benches control.

The spectrometer configuration was then changed, because the initial timing control showed problems with the 532nm excitation peak of the laser being in the middle of the spectrum to be evaluated, and a new backthinned CCD-detector type was tested, S-11555 of Hamamatsu, in combination with a Replaceable slit spectrometer design. This detector showed problems with gated timing and unwanted light sensitivity of the shift register. Eventually the spectrometers were replaced by 3 spectrometers with Sony ILX554B detectors, AvaSpec-2048-RM which showed good results for both timing and integration time.

To have a proper adjustment between excitation source and detector (laser and spectrometer) Ekspla and Avantes have created a timing diagram.

1.3.6.3.3.RAMAN

For the RAMAN system we developed:

1. Channel spectrometer AvaSpec-ICCD
2. Grating NC (1200 lines/mm), blaze 500nm
3. range 534-620nm (200cm-1 to 3300cm-1)
4. resolution 5-7 cm-1 FWHM
5. slit 25 µm, 1000µm height
6. DCL-UV/VIS detector Collection lens

Gating capability of the spectrometer (delay laser shot to acquisition):

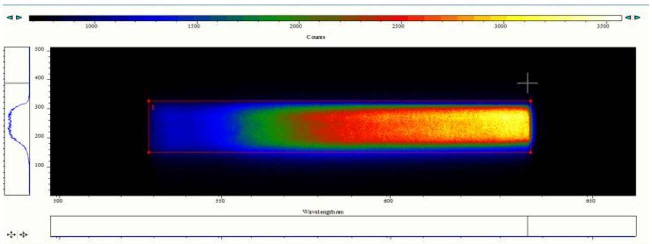
7. 0 ns to < 150 ns in steps of 21 ns

Integration time of detector:

8. 10-100ns in steps of 10 ns

We have selected to implement an Andor iStar ICCD camera DH740-18F-63.
This device is integrated into the newly designed High Sensitivity optical bench design.

- The overall performance of the optical bench was as expected. We did encounter some issues and therefore had to design some improvements for
  - stray light
  - thickness first mirror
  - alignment technique mirrors
- These issues have all been addressed and have been tested in the final model.
- Wavelength range: 527-637 nm
- Resolution: (FWHM) 0,7 nm @ 546 nm:
- Stray light: 0,12 %
- S/N: 1.000x
- Sensitivity: 1.200 x (compared to reference Avaspec)



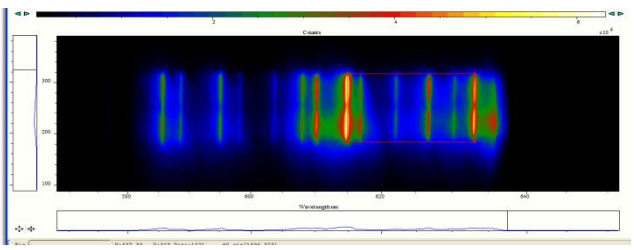
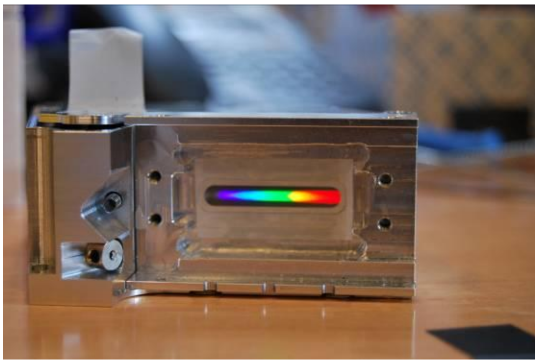


Figure 20. Figures depicting the simulation of sensitivity and spectral distribution of High Sensitivity Bench

The prototype of High Sensitivity optical bench, which is designed to have maximum use of the numeric aperture of the optical fibers (n.a. = 0.22), is produced and built according to our design specifications. (See photo's below)



We have obtained a resolution of minimum 0.3 [nm] to an average of 0.4 [nm] with a standard Sony linear detector array. This result is close to the first specifications as required in D2.

			Fwhm	
wavelength	620	[Nm]	0,3	[Nm]
wave number	16129,0	[cm-1]	7.8	[cm-1]

1.3.6.4.Optical subsystem

The aim of this activity is to achieve the design, construction and testing of the necessary optical sub-assemblies to allow the analysis of a samples at standoff distances by the three selected optical spectroscopies (LIBS, Raman and IR) maximizing the use of common optical elements for the three technologies.

The approach of this activity follows:

- Design of the optical layout of the system, consisting of:

- A beam expander to allow focussing the laser at the target surface with differnt spots for each technology
- A collection telescope to collect tha light comming from the sample
- Three separated optical paths to drive light comming out form the telescope to the detector selected for each technology (nemely the optical fibers for LIBS and Raman and the detector window for IR).
- A beam steering unit to make the emission coaxial with the collection (allowing an easy adaptation to different working distances)
- An articulated optical arm connecting the laser head with the beam expander allowing the movement of the telescope during scanning while maintaining the proper alignement between emission and conllection.

- Specification and procurement of the articulated optical arm: Initially the optical arm was designed and manufactured to mange all waveleghts foreseen in the project (532nm, 1024 nm and 5200-6300nm). This initial prototype showe problems to witestand the full prower of the NdYag laser at 532 nm.
  After the consortium decission of not to integrate the IR technology into the prototype, the articulated optical arm mirrors where optimized for 532 nm

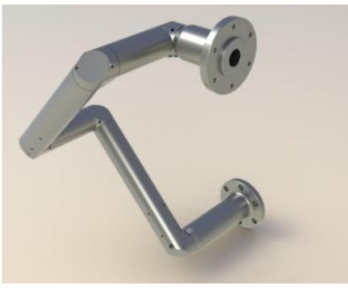


Figure 21. Articulated Optical arm for the OPTIX prototype.

- Design, procurement, assembly and laboratory alignment of the opto-mechanical elements for the motorised laser delivery system, beam expander, to meet the required laser spot size for each of the core technologies.

  During the design of the emission block it was found that it was not possible to simultaneous focus the photo fragmentation laser and the QCL in the required spot size due to the limited availability of optical materials capable of transmitting 532 nm. and QCL lasers. This led to introduce changes into the preliminary optical layout of the system to include a removable lens that will be inserted into the optical path only for photo fragmentation.

  After the decision to integrate only LIBS and Raman the beam expander was redesigned to optimize the performace for those technologies.

  During the project several optimizations where perfomed to increase the cuality of the plasma produced for LIBS technology.

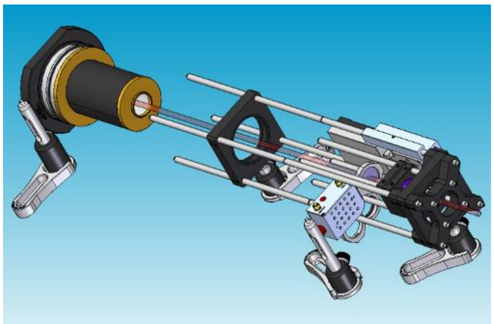


Figure 22. 3D model of the laser delivery system (Beam expander).

- Detailed design, procurement and construction of the opto-mechanical components of the collection block to meet the requirements of each of the core technologies (LIBS, Raman, IR).
  The design was made making as much as possible use of commercial commponents to achieve the flexibility to adapt the prototype to the need that may appear during experimentation.
  A commercial telescope was modified and adated to the prototype. Standard lenses and mounts where used whenever it was possible. Custom elements where designed and manufactured as needed

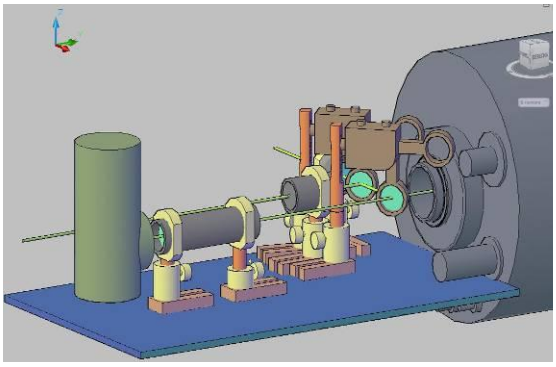


Figure 23. 3D model of the collection block. Procurement and customization of the commercial telescope to adapt to OPTIX prototype requirements.

The following results have been achieved:

- Availability of the collection block (Modified commercial telescope, and specific optical paths for the collection of light coming from the sample into the three different detectors). Fully automated selection of the technology to be use was possible.

- Assembly and laboratory alignment of the beam expander.

- Design and construction of the mechanics to accommodate the motorized beam expander.

1.3.7. WP7. INTEGRATION

The objective of this activity is to build-up the final system capable of performing standoff analysis based on Raman, LIBS and IR spectroscopy. The outcomes of the work package follows:

- LIBS and Raman techniques has been integrated in the final OPTIX prototype together with the enabling technologies (laser, spectrometer, chemometrics). OPTIX prototype has been developed following the specifications on work package 2.
- The prototype was prepared for the installation of the IR technology, but finally it was decided to keep IR spectroscopy is an independent prototype.

In the integration of OPTIX prototype the following activities has been executed:

- Definition and agreement with EKSPLA of the mechanical interface between the laser and the optical arm and manufacturing of the necessary parts.
- Definition of the mechanical interfaces between the optical arm and the beam expander.
- Definition of the mechanical interface between the telescope and the laser delivery system.
- Definition of the timing diagram between the laser and the LIBS spectrometer to meet the requirements stated on the system specification.

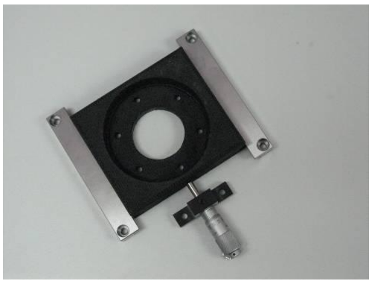


Figure 24. Parts for the interface between the laser and the optical arm

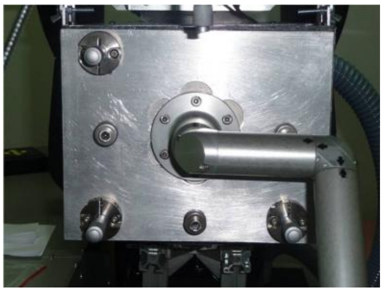


Figure 25. Detail of the interface between the optical arm.

- LIBS and Raman spectrometers as well as the Nd:YAG laser were mechanically integrated into the prototype.
- The articulated optical arm to guide the laser to the beam delivery system was integrated into the prototype.

- Mechanical integration of the optical subsystem.Both emission and collection systems were upgraded along the duration of the project to improve mechanical stability.
- The beam expander and optics for collecting LIBS and Raman were also implemented as scheduled. Different beam expanders were designed, assembled and tested by Indra along the project to improve the requirements for LIBS analysis.
- A critical step to achieve a good performance of the prototype was the optical alignment of the whole subsystem. The collimation of the telescope was improved before the alignment of the collection block. Regarding the emission block, the alignment between laser-optical arm-beam expander was also critical to achieve the best focus a 20 m. Finally, it was found that the emission and collection systems had to be perfectly aligned in order to achieve the highest LIBS and Raman signal, being the LIBS technology the most sensitive to small deviations in the alignment.

Figure 26. Final OPTIX prototype.

- Interconnection between all subsystems was also successfully completed and tested.
- Control computer and the software to control the prototype have been completed.

Figure 27. Screenshot of the final version of the User Interface of the OPTIX prototype.

– After finishing the integration phases of the OPTIX prototype, the basic performance of the prototype was checked. A summary of the results obtained after optimizing the prototype for the 532 nm laser is below:

  - The 91% of the laser power was transmitted by the beam expander.
  - The energy on sample at 20 m was around 78% of the energy at the arm output.
  - The individual technologies LIBS and Raman were tested to verify that the OPTIX platform was capable to acquire spectra at standoff distance of 20 m.
  - Capabnility of the prototype to scan a surface at 20 m without degradation of the singal acquired was verified

  The figures below show some sample spectra acquired with the prototype before sending it to University of Malaga for optimization of the individual technologies

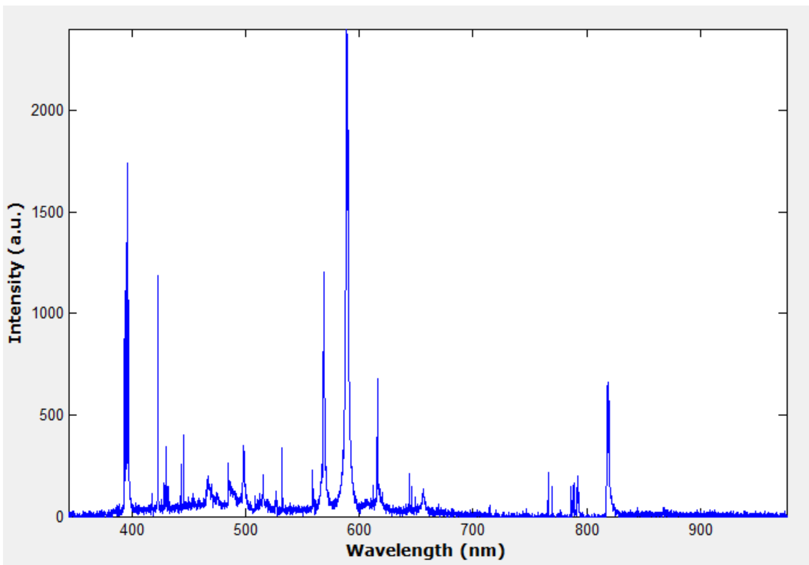


Figure 28. Aluminum LIBS spectrum acquired with AvaSpec2048 installed on the prototype just before delivering OPTIX platform to UMA.

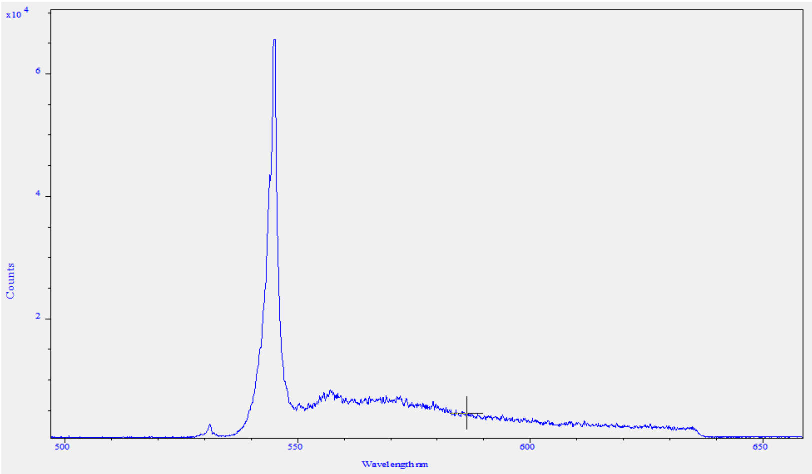


Figure 29. RAMAN spectrum acquired with the prototype just before delivering OPTIX platform to UMA with single shot acquisition over a sulphur pellet.

1.3.8. WP8. TEST AND EVALUATION

The OPTIX prototype has been tested at four different levels during the execution of the project:

- Engineering testing during integration phase. Test devoted to verify the general performance of the prototype in laboratory conditions using samples not necessarily related to the intended application of OPTIX
- Laboratory testing of the individual technologies. Test performed on the integrated prototype in less controlled laboratory conditions to fine tuning the individual technologies
- Real environment performance tests to verify the performance of the integrated prototype en near to real environments in outdoor conditions
- Final optimised OPTIX prototype testing. To give the final users the possibility to test the performance of the prototype after final optimization

Laboratory testing of individual technologies

1) LIBS

In addition to the analysis of different analytes on varying backgrounds the influence of environmental parameters, such as temperature and humidity, were evaluated under controlled laboratory conditions at the University of Malaga (D8.1). However, due to the constraints in laser energy and the focusing optical train, it was not possible to perform a significant parameterisation of the experimental variables. Ablation thresholds for the vast majority of materials (mainly the backgrounds), considered for the OPTIX project, were only reached with the maximum laser energy and an optimised focus.
LIBS is a feasible technique for the stand-off detection of trace explosives. Although data have only demonstrated the capabilities to recognise residues left on the surfaces of supports from a closed list, but equivalent performance is expected when a larger range of products is tested. Nevertheless, thorough additional investigations on explosives detection

in different environments should be performed in order to guarantee the complete acceptability of LIBS to operate under fully realistic conditions.

- organic explosive traces can be detect when left on the surfaces of inorganic supports
- discrimination of some residues necessitates powerful chemometric algorithms
- humidity and temperature may alter performance, but large signal variability prevents definitive conclusions
- scattering distorts laser energy at the target, thus influencing plasma light collection

2) Raman spectroscopy

To establish the performance of the OPTIX prototype Raman subsystem, the Limit Of Detection (LOD) of two threat materials was determined and compared with the respective values obtained with a stand-off Raman system built in Vienna. TUWIEN performed this task at the FOI premises (D8.1), applying pure sample material on aluminium backgrounds in such a way that the laser beam excited the entire analyte. The inorganic threat material potassium chlorate ($KClO_3$) yielded a LOD of 5.61 mg whereas the analysis of the organic explosive pentaerytritol tetranitrate (PETN) resulted in a LOD of 5.92 mg. The Viennese comparison results were 0.64 mg and 0.57 mg, respectively. This substantial difference can partly be explained by a broken optical arm which was only repaired by the according manufacturer after the real environment evaluation at the FOI. Because of the broken optical arm, the beam directing path was kept unchanged after a preliminary optimisation.

3) Infrared absorption

Depending on the sample composition, a fragmentation laser causes the emission of different amounts of NO and NO_2. The according infrared absorption of NO and NO_2 is detected via two Quantum Cascade Lasers (QCLs). The resulting ratio can indicate the presence of certain explosives. Due to technical difficulties, the IR subunit was not integrated in the OPTIX prototype. Nevertheless, a separately built IR setup was developed and tested by the University of Clausthal (D8.1). The test activities have shown that the background material widely influences the intensity level of measured back-reflected and backscattered light and therefore the reachable detection limit. With the lasers used during the tests it was not possible to measure NO and NO_2 after the fragmentation of real samples due to the insufficient signal/noise ratio (SNR). It is anticipated, that increased laser power would enhance the SNR and therefore enable the detection of lower concentrations. Even a change of the fragmentation laser wavelength from 532 nm to the UV can increase the amounts of NO_x during fragmentation since photofragmentation is more effective in the UV.

Apart from that, pulsed laser fragmentation and subsequent IR measurement of NO and NO_2 has been tested under optimised conditions in the laboratory and works properly. Furthermore, the IR technology has proved its capability to detect concentrations of NO and NO_2 of 3700 to 150 ppm located at 20 m distance, which were generated by the chemical reaction of copper and nitric acid.

Real environment performance

To evaluate the OPTIX prototype performance under realistic outdoor conditions, a three-stage test series was conducted at the FOI, ranging from bulk testing over background evaluation to scenario based testing (D8.2).

1 **Bulk testing**: big amounts of the following three material classes were analysed:

a) Chemically pure substances in big amounts acted as reference measurements.
b) Commercially available compounds such as C4 plastic explosives and dynamite were tested.
c) Home-made explosives: fertilisers, weed killers, oil, sugar and the Breivik recipe were used.

2 **Background testing:** The influence of background materials on the system performance was evaluated using varying amounts of six different substance mixtures – including two benign samples – on different metals, a car door, plastics as well as a rucksack.

3 **Scenario based testing:** A "terrorist" prepared a chlorate based bomb under household conditions. The contaminated materials (paper towel, door with finger prints, bomb container, rucksack for transport) were analysed via OPTIX prototype and a chemical analysis was performed to quantify the contamination.

Result: For the challenging realistic scenarios the OPTIX performance is not yet sufficient. Whereas Raman spectroscopy is limited by fluorescence, LIBS is less specific and requires a stronger laser. Beside the technical improvement of the existing prototype new concepts for explosive detection were proposed based on the acquired experience.

Final optimised OPTIX prototype

After the realignment of the optical, articulated arm, the prototype was optimised at Indra, leading to an increased Raman performance.

Together with GUCI the performance from the end-user perspective was evaluated in Valdemoro (D8.3). At 16 m (limited by the test site) bulk explosives, substrates and traces were investigated.

- The false positives detected when the objects were analysed by LIBS could be due to the manual selection of the substrate and the reduced working distance of 16 m. Further experimentation would have to be carried out in order to develop a robust algorithm to classify any substrate automatically and to make the analysis substrate independent.

- The influence of analytical conditions on LIBS (e.g. working distance, appropriate focus of the laser, environmental conditions, etc.) shall be reduced to allow the operational deployment of a system based on LIBS analysis.

- LIBS traces analysis is strongly influenced by the substrate and the environmental conditions; previous knowledge of the sample is required for the analysis

- Even substances beyond the defined project list were tested, showing the need to extend the database for real application.

In current development status LODs are not low enough to fulfil the requirements of bomb squads.

1.4. Potential impact, dissemination activities and exploitation of results

1.4.1. Potential impact

OPTIX is a capability project based on the research, development and adaptation of LIBS, RAMAN and IR technologies for the standoff detection and identification of explosives. As requested in the topic SEC-2007-1.3-01 of the Security call of the 7th Framework Program of the EC.

Since the very beginning of the project, it is well known that there is no "*silver bullet"* or single technology that will address the detection of explosives, less from a distance in all possible scenarios and OPTIX is not the final answer to the standoff detection of explosives request.

Nevertheless, the project has generated a valuable knowledge showing some of the possibilities and challenges of using optical technologies for standoff detection of explosives and giving the end users a good opportunity to understand what the technology can offer today and may offer in the future.

The knowledge generated in OPTIX is not only applicable for the detection of explosives (or even security application) and can be useful in other fields, like industrial process control, environmental monitoring of forensic applications, just to mention a few of them.

From the scientific point of view, the academic partners involved in OPTIX have been very active disseminating and promoting project results: over 10 scientific papers related to project foreground has been published, a PhD thesis have been produced related to the project, over 55 articles of OPTIX has been published in mass media all over Europe. Project coordinator has been interviewed twice in radio programmes in Spain. The project has participated in more than 25 conferences, where a presentation has been showed.

The SMEs involved in OPTIX, EKSPLA and AVANTES, has brought new products to the market and improved other existing products with the developments and knowledge gained in the project framework. This has increased their competitiveness in the market, reinforcing the European Industry in the areas of lasers and sensors:

Although the perfomance achieved with the OPTIX prototype is not enoght for the itended aplication by bomb squad, the knowledge generated during the project allwos to identify possible improvements on the approach that has been collected in D.1.2 and has provided a valuable experience on the collaboration of Industry, academy and End User from the very initial steps of a technological development.

1.4.2. Main dissemination activities

Many dissemination activities have been executed during the project lifetime. This dissemination activities objective was to promote the project results to the scientific community and to the broad audience. The main dissemination activities are:

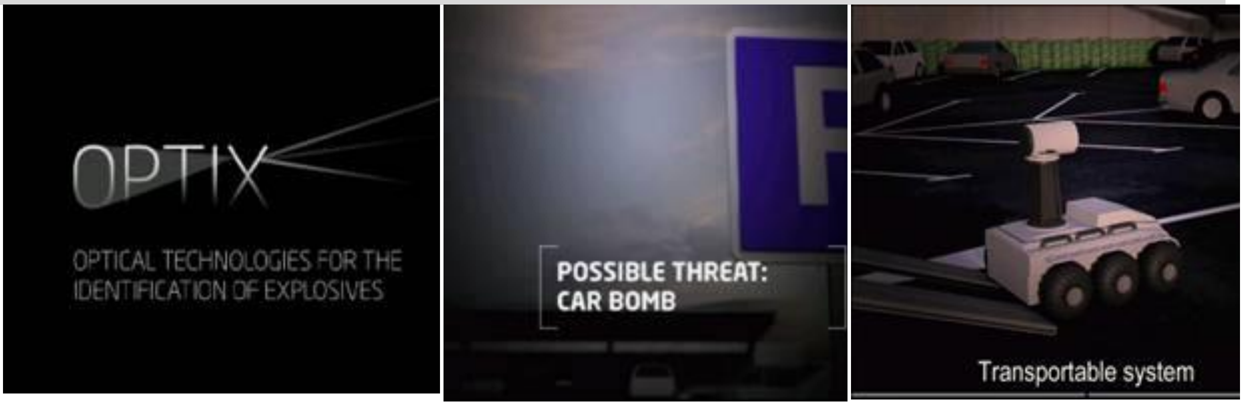
- Articles publication in mass media.
- Scientific papers publication.
- Project website creation.
- Project presentation in conferences.
- Project posters and leaflets creation.
- A 3 D animation has been developed were the performance of the prototype against a bomb threat is reflected.
- Project newsletter distribution among the scientific and end users community.

Some details of those main activities are presented bellow:

3D animation

A 3D animation was created during the first stage of the project to serve as a dissemination material that could be used along the project to better understand the goals that were to be achieved in the project.

3D ANIMATION SCENE SEQUENCE



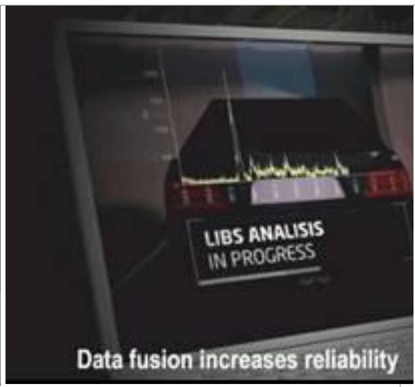
Threat of a possible car bomb is detected in a parking. Security forces bring OPTIX transportable system to the parking.

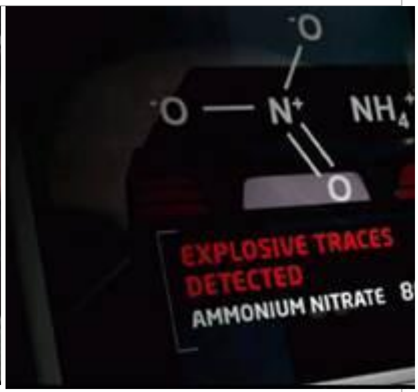

OPTIX prototype is operated remotely. OPTIX system starts scanning areas where traces of explosives could be. First scan the door of the car. As is shown in the laptop none explosives has been found.

3D ANIMATION SCENE SEQUENCE		
		
OPTIX system analyses another suspicious car. Raman, LIBS and IR technologies can be used sequentially or alternatively.		
		

As seen in the vignette above, OPTIX system has detected one common substance in the explosives. In order to find possible proofs that could evidence the existence of explosives, the system continuous scanning the steering wheel.

3D ANIMATION SCENE SEQUENCE





Data fusion process starts from the data collected from the three technologies: LIBS, Raman and IR. OPTIX system explosive traces has detected.

Figure 30. 3D animation scene sequence

<u>Printed materials: posters</u>

Along the life time of the project, some posters have been created in order to disseminate the project goals in several events around the world. The detail of events where the posters has been shown are listed in table A2 of this document.

Some examples of the posters presented in such events are depicted in the following figures (for detailed information refer to D9.6 Dissemination Materials).

Figure 31. (From Upper left to bottom right)
OPTIX poster in Security Research Conference 09 (SRC 09) in Stockholm (Sweden).
OPTIX poster in Euro-Atlantic Security Conference in Stockholm (Sweden).
OPTIX poster in "Detection Conference 2009 Symposium and Workshop" in San Diego Microelectronic Meeting (USA).
OPTIX poster in STRAW project workshop Madrid (Spain), in Security Research Conference (SRC'10)/Oostende (Belgium) and in the CBRNE Conference in Madrid (Spain)

Project presentation

OPTIX partners have attended several conferences and seminars related to the field of research of OPTIX and they have shown a presentation of the project.

The detail of events where a presentation related to OPTIX has been shown are listed in table A2 of this document. The presentations are available in the four releases of dissemination plans submitted to the EC (D9.2 to D9.5).

Scientific papers and lectures

Several scientific papers have been published during the project, all of them are listed in table A1 of this document.

Mass Media

Along the life of the project, over 55 articles of OPTIX have been published in mass media. All of them has been included in table A2 of this document.

1.4.3. Exploitation of results

Actions foreseen for exploitation of results

Academic exploitation

Research areas of interest

One of the research developments within the OPTIX project that may be of interest to the wider analysis community may be the use of pulsed lasers for stand-off Raman spectroscopy, allowing 3D information to be collected. This could be of interest in process analysis as more detailed information of what is happening in a reactor could be obtained without the need to remove samples for analysis.

Courses and seminars identified by TUWIEN

Regarding courses or seminars that could be organised, stand-off Raman is a small but growing field and it is anticipated that there will be dedicated sessions at the forthcoming ICAVS (international conference on advanced vibrational spectroscopy) conferences in Kobe in 2013 and Vienna in 2015.

Several scientific publications have been published by partners as it has been detailed in deliverables D9.5 and D9.6.

Regarding expertise/consultancy TU Wien can offer experience and knowledge of stand-off Raman for any further projects related to OPTIX that might arise.

Finally, a product related to the OPTIX prototype that could be offered could be a process analyser, as mentioned in Section 3 and earlier in this section. For process analysis the information from all 3 techniques, along with the integrated chemometrics routines for identification of changes within the reactor, would provide a great deal of information regarding the state of the reactor contents. The increased speed of measurement and the sensitivity afforded by the new detector/spectrograph combinations would be beneficial in providing continuous monitoring of the reactor and a fast response to any changes within. This process could easily be automated. Additionally, the use of gated detectors to select the portion of returning light that is analysed (as shown for the Raman system at TU Wien) could facilitate continuous measurement of different regions of a reactor without the need for removal of samples for analysis.

All sciences using spectroscopic techniques can benefit from using tuneable ns lasers. Advertising in Web pages of the company and representatives, taking part in exhibitions, conferences are performed to inform potential customers about new laser technologies.

Industrial exploitation

Patents

Ekspla was applied for European patent. .After experts made patentability investigation there are indications of the positive patenting results.

TU Wien applied for a patent dealing with spatial offset stand off Raman spectroscopy. This application was made in Austria with a follow-up PCT application.

- Bernhard Lendl, Bernhard Zachhuber, Christoph Gasser, “Apparatus for examining an object and methods for detecting light scattered in an object”
  Austrian Pat. Appl. [Pre-Grant] (2012), AT 511512 A1 20121215

- Bernhard Lendl, Bernhard Zachhuber, Christoph Gasser, „Apparatus for examining an object and methods for detecting light scattered in an object
  PCT Int. Appl. (2012), WO 2012159138 A1 20121129.

Consultancy offering and solutions related to OPTIX project.

On the basis of gained experience Ekspla can propose optical design of multi-wavelength laser systems. Ekspla is providing these services at the moment.

On the basis of gained experience Ekspla can propose custom nanosecond laser design.

Using the new technology can design and manufacture custom power supplies for flash-lamp pumped lasers.

Products that could be developed related to OPTIX project.

LIBS spectrometer - the software is the key component of any LIBS system, and algorithms created in OPTIX project can be effective in this application.

RAMAN lidar – Using UV wavelength pulses of nanosecond laser, beam transmission and detection telescopes and micro spectrometer with intensified CCD camera could be used for air constituent’s tracking and monitoring.

Chemometrics developed for OPTIX could be used on portable field systems for chemical analysis.

Non-commercial exploitation:

OPTIX system could be integrated in the future in a system of systems for the prevention of terrorist attacks with IED. (Integration project or Demonstration projects- phase 2 of the FP7).

Technologies developed in OPTIX project have a potential use on forensic investigation of the scene of an explosion.

IR technology

The wavelength for pulsed laser fragmentation (PLF) has been abridged to 532nm to simplify the integration with the LIBS and RAMAN technologies. The investigation of other wavelengths (especially in the UV spectral region) is envisaged.

Raman technology

The fundaments developed in the area of stand off Raman spectroscopy are used for follow up projects which aim at different applications in the area of industrial process monitoring (corrosion detection) as well as environmental analysis.

1.5. Project website

A public project website was developed by the project coordinator (Indra) before month 7 of the project. This represented deliverable D9.1 Web site and project presentation. The web url is: www.fp7-optix.eu.

OPTIX website contents are:

- ✓ ***OPTIX in a nutshell.*** A brief description of the project.
- ✓ ***Partners.*** A description of OPTIX members.
- ✓ ***Project overview.*** Project objectives, technologies description and the targeted future system.
- ✓ ***Meetings.*** In this section the list of meetings is shown.
- ✓ ***Workshops.*** Information about workshops with end users.
- ✓ ***Public Documents.*** Documents related to the project can be downloaded, such as a project leaflet, press release and public deliverables.
- ✓ ***Published papers.*** The papers published in the project are reflected.
- ✓ ***Scientific papers.*** The scientific papers published in the project are reflected.
- ✓ ***Links.*** Links related to the project, such as liaisons with other projects is included in the section.
- ✓ ***Contact.*** Project coordinator contact details.
- ✓ ***Search.*** Search tool.

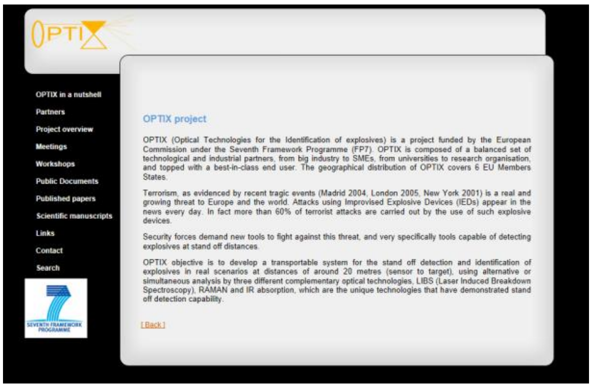


Figure 32. Website

1.5.1. Contact details

The person of contact associated to this project is:

F. Javier Hernández Crespo

fjhernandez@indra.e

2. Use and dissemination of foreground

2.1. Section A

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	*Detection of Explosives using Pulsed Laser Fragmentation and MIR Spectroscopy*	*Mario Mordmueller (TUC)*	*Encyclopedia of Analytical Chemistry*	*17 DEC 2012*	*John Wiley & Sons, Ltd.*	*UK*	*2012*			*no*

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
2	*Chapter 24: Application of Quantum Cascade Lasers for Safety and Security*	*Ulrike Willer, Mario Mordmüller, Wolfgang Schade* *(TUC)*	*The Wonder of Nanotechnology: Present and future of Optoelectronics Quantum Devices and their applications for Environment , Health, Security, and Energy*		*SPIE*		*2013, final editing phase*			*no*
3	*Conference*	*Ulrike Willer* *(TUC)*	*LACSEA: Quantum Cascade Lasers for the Detection of Hazardous Materials*	*February 3, 2010*	*San Diego, CA, USA*	*scientific*	*50*	*international*		
4	*Conference*	*Ulrike Willer* *(TUC)*	*MIOMD-XI:* *The use of quantum cascade lasers for the detection of hazardous materials*	*September 6, 2012*	*Chicago IL, USA*	*scientific*	*80*	*international*		

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
5	*Fundamentals of stand-off Raman scattering spectroscopy for explosive fingerprinting*	*Laserna J.J. (UMA)*	*JOURNAL OF RAMAN SPECTROSCOPY*	*JAN 2013*	*WILEY-BLACKWELL*	*NJ USA*	*Volume: 44 Issue: 1*	*121-130*		*no*
6	*Adaptive approach for variable noise suppression on laser-induced breakdown spectroscopy responses using stationary wavelet transform*	*Laserna J.J. (UMA)*	*ANALYTICA CHIMICA ACTA*	*NOV 19 2012*	*ELSEVIER SCIENCE BV*	*AMSTERDAM, NETHERLANDS*	*Volume: 754*	*8-19*		*no*

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
7	*New Raman-Laser-Induced Breakdown Spectroscopy Identity of Explosives Using Parametric Data Fusion on an Integrated Sensing Platform*	*Laserna J.J. (UMA)*	*ANALYTICAL CHEMISTRY*	*AUG 15 2011*	*AMER CHEMICAL SOC*	*WASHINGTON, DC*	*Volume: 83 Issue: 16*	*6275-6285*		*no*
8	*Standoff detection of explosives: critical comparison for ensuing options on Raman spectroscopy-LIBS sensor fusion*	*Laserna J.J. (UMA)*	*ANALYTICAL AND BIOANALYTICAL CHEMISTRY*	*JUL 2011*	*SPRINGER HEIDELBERG*	*HEIDELBERG, GERMANY*	*Volume: 400 Issue: 10*	*3353-3365*		*no*

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
9	*New challenges and insights in the detection and spectral identification of organic explosives by laser induced breakdown spectroscopy*	*Laserna J.J. (UMA)*	*SPECTROCHIMICA ACTA PART B-ATOMIC SPECTROSCOPY*	*JAN 2011*	*PERGAMON-ELSEVIER SCIENCE LTD*	*OXFORD, ENGLAND*	*Volume: 66 Issue: 1*	*12-20*		*no*
10	*The development of fieldable laser-induced breakdown spectrometer: No limits on the horizon*	*Laserna J.J. (UMA)*	*SPECTROCHIMICA ACTA PART B-ATOMIC SPECTROSCOPY*	*DEC 2010*	*PERGAMON-ELSEVIER SCIENCE LTD*	*OXFORD, ENGLAND*	*Volume: 65 Issue: 12*	*975-990*		*no*

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
11	*Simultaneous Raman spectroscopy-laser induced breakdown spectroscopy for instant standoff analysis of explosives using a mobile integrated sensor platform*	*Laserna J.J. (UMA)*	*ANALYTICAL CHEMISTRY*	*FEB 15 2010*	*AMER CHEMICAL SOC*	*WASHINGTON, DC*	*Volume: 82 Issue: 4*	*1389-1400*		*no*
12	*Simultaneous Raman-LIBS for the standoff analysis of explosive materials*	*Laserna J.J. (UMA)*	*SPECTROSCOPY EUROPE*	*JAN 1 2010*	*JOHN WILEY & SONS LTD*		*Volume: 22*	*18 - 22*		*no*
13	*The development of field-able laser-induced breakdown spectrometer: no line on the horizon*	*Laserna J.J. (UMA)*	*SPECTROCHIMICA ACTA PART B-ATOMIC SPECTROSCOPY*	*NOV 23 2010*	*PERGAMON-ELSEVIER SCIENCE LTD*	*OXFORD, ENGLAND*	*Volume: 65*	*975*		*no*

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
14	*Stand-off Raman spectrometry*	*Hobro, B. Lendl*	*TrAC*	*2009*			*Volume 28*	*1235-1242*		no
15	*Stand-off Raman Spectroscopy of Explosives*	*B. Zachhuber, G. Ramer, A.J. Hobro B. Lendl*	*SPIE*	*2010*			*7838*	*78380F-78380F-10*		No
16	*Stand-off Raman spectroscopy: a powerful technique for qualitative and quantitative analysis of inorganic and organic compounds including explosives*	*B. Zachhuber, G. Ramer, A. Hobro, E. t. H. Chrysostom, B. Lendl*	*ABC*	*2011*			*400*	*2439-2447*		No

TEMPLATE **A1:** LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
17	*Standoff Spatial Offset Raman Spectroscopy for the detection of concealed content in distant objects"*	*B. Zachhuber, C. Gasser, E. t. H. Chrysostom, B. Lendl*	*Anal. Chem.*	*2011*	*AMER CHEMICAL SOC*	*WASHINGTON, DC*	*83*	*9438-9442*		No
18	*Spatial offset stand off Raman – a distant look behind the scenes*	*B. Zachhuber, C. Gasser, A. Hobro, E. t. H. Chrysostom, B. Lendl*	*SPIE*	*2011*			*8189*	*818904-1-818904-8*		No
19	*Stand-off Spatial Offset Raman Scattering*	*Bernhard Zachhuber, Christoph Gasser, Engelene t. H. Chrysostom, Bernhard Lendl*	*in Laser Applications to Chemical, Security and Environmental Analysis*	*2011*	*(Optical Society of America*	*Washington, DC*		*LT2B.4.*		No

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
20	*Depth Profiling for the Identification of Unknown Substances and Concealed Content at Remote Distances Using Time-Resolved Stand-Off Raman Spectroscopy"*	*B. Zachhuber, C. Gasser, G. Ramer, E. t. H. Chrysostom, Bernhard Lendl*	*Appl. Spectrosc.*	*2012*			*66*	*875-881*		no
21	*Measurement with an interval: Stand-off Raman spectroscopy"*	*E. t. H. Chrysostom, B. Zachhuber, G. Ramer, B. Lendl*	*Nachrichten aus der Chemie*	*2012*			*60*	*566-568.*		no

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
1	Web	INDRA	Website url: www.fp7-optix.eu	May 2009	Online	Civil Society, Scientific Community, Industry		International
2	Video	INDRA	"Optical Technologies for the identification of explosives"	October 2009	Electronic format	Civil Society, Scientific Community, Industry		International
3	Other	INDRA	"Optical Technologies for the identification of explosives", project leaflet	May 2009	Electronic format	Civil Society, Scientific Community, Industry		International
4	Other	INDRA	Project logo	May 2009	Electronic format	Civil Society, Scientific Community, Industry		International

[1] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[2] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	***Type of activities[1]***	***Main leader***	***Title***	***Date/Period***	***Place***	***Type of audience[2]***	***Size of audience***	***Countries addressed***
5	*Workshop*	*INDRA*	*Workshop with end users for system requirements definition*	*April 2009*	*Malaga (Spain)*	*Other*		*International*
6	*Other*	*INDRA*	*"Optical Technologies for the identification of explosives", newsletter*	*January 2012*	*Online*	*Scientific Community, Industry, Other*		*International*
7	*Workshop*	*INDRA*	*Final workshop with end users for project presentation results and OPTIX prototype demonstration*	*April 2013*	*Valdemoro Madrid (Spain)*	*Scientific Community, Industry, other*		*International*
8	*Conference*	*Mario Mordmueller (TUC)*	*QCL spectroscopy for explosive agents detection*	*3 OCT 2011*	*Reno NV, USA*	*scientific*	*40*	*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
9	*Conference*	*Mario Mordmueller (TUC)*	*Detection of explosives in the MIR using Quantum Cascade Lasers*	*6 SEPT 2012*	*Baden, Austria*	*scientific*	*50*	*international*
10	*Conference*	*Ulrike Willer (TUC)*	*Pulsed laser fragmentation and subsequent infrared detection of fragments for the detection of nitrogen-based explosives*	*16 FEB 2011*	*Freiburg, Germany*	*scientific*	*80*	*international*
11	*Workshop*	*Anna Pettersson (FOI)*	*Temadag IED*	*29 August 2012*	*FOI Grindsjön, Sweden*	*scientific, police, military*	*~160*	*national, Sweden*
12	*Conference*	*INDRA , Bernhard Zachhuber (FOI)*	*HOMSEC 2013*	*March 2013*	*Feria de Madrid, Spain*	*military, police, companies*	*~4000*	*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	***Type of activities[1]***	***Main leader***	***Title***	***Date/Period***	***Place***	***Type of audience[2]***	***Size of audience***	***Countries addressed***
13	*Conference*	*Laserna J.J. (UMA)*	*Pacifichem 2010. Simultaneous Raman spectroscoy-laser-induced breakdown spectroscopy: instant standoff analysis of explosives using a Mobile integrated sensor platform*	*15 -20 December 2010*	*Honolulu, Hawaii, USA*	*scientific*	*60*	*International*
14	*Conference*	*Laserna J.J. (UMA)*	*Pacifichem 2010. LIBS spectra of organic explosives: what can be learnt from time-of-flight mass spectrometry coincidence analysis*	*15 -20 December 2010*	*Honolulu, Hawaii, USA*	*scientific*	*40*	*International*
15	*Conference*	*INDRA, FOI*	*Security Research Conference 09*	*September 2009*	*Stockholm, Sweden*	*Scientific community, industry*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	***Type of activities[1]***	***Main leader***	***Title***	***Date/Period***	***Place***	***Type of audience[2]***	***Size of audience***	***Countries addressed***
16	*Conference*	*INDRA*	*Information day 3rd call of Security 7th FP at Spanish National Contact Point-CDTI*	*July 2009*	*Madrid, Spain*	*Scientific community, industry*		*International*
17	*Presentation*	*INDRA*	*Information day 3rd call of Security 7th FP at Spanish National Contact Point-CDTI*	*July 2009*	*Madrid, Spain*	*Scientific community, industry*		*International*
18	*Conference*	*INDRA*	*STRAW project workshop (FP7 funded project)*	*March 2010*	*Madrid, Spain*	*Scientific community, industry*		*International*
19	*Poster*	*INDRA*	*OPTIX project poster in STRAW project workshop (FP7 funded project)*	*March 2010*	*Madrid, Spain*	*Scientific community, industry*		*International*
20	*Conference*	*INDRA*	*Security Research Conference (SRC'10)*	*September 2010*	*Oostende (Belgium)*	*Scientific community, industry*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
21	*Poster*	*INDRA*	*OPTIX project poster at the Security Research Conference (SRC'10)*	*September 2010*	*Oostende (Belgium)*	*Scientific community, industry*		*International*
22	*Conference*	*INDRA*	*CBRNE Conference*	*June 2010*	*Madrid (Spain)*	*Scientific community, industry*		*International*
23	*Presentation*	*INDRA*	*CBRNE Conference*	*June 2010*	*Madrid (Spain)*	*Scientific community, industry*		*International*
24	*Poster*	*INDRA*	*CBRNE Conference*	*June 2010*	*Madrid (Spain)*	*Scientific community, industry*		*International*
25	*Online conference*	*INDRA*	*"UNTAPPED MARKET POTENTIAL IN THE SECURITY SUPPLY CHAIN" webinar organised by OSMOSIS project (funded under the FP7).*	*March 20100*	*Madrid (Spain)*	*Scientific community, industry*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
26	*Presentation*	*INDRA*	*OPTIX Project presentation at "UNTAPPED MARKET POTENTIAL IN THE SECURITY SUPPLY CHAIN" webinar organised by OSMOSIS project (funded under the FP7).*	*March 20100*	*Madrid (Spain)*	*Scientific community, industry*		*International*
27	*Presentation*	*INDRA*	*Presentation of OPTIX project in HOMSEC*	*March 2013*	*Madrid (Spain)*	*Industry*		*International*
28	*Conference*	*INDRA*	*"Optical Technologies for the Identification of Explosives", CBRNE Conference in Turkey*	*June 2010*	*Turkey*	*Industry*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
29	*Poster*	*INDRA*	*"Optical Technologies for the Identification of Explosives", CBRNE Conference in Turkey.*	*June 2010*	*Turkey*	*Industry*		*International*
30	*Articles published in the popular press*	*INDRA*	*Smile, you're being spied on!*	*July 2009*		*Civil Society*		*International*
31	*Articles published in the popular press*	*UMA*	*Un grupo de la UMA trabaja en un láser para detectar explosivos*	*February 2009*		*Civil Society*		*International*
32	*Articles published in the popular press*	*INDRA*	*Optical technologies for the identification of explosives.*	*Period 1 of the project.*		*Civil Society*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
33	*Articles published in the popular press*	*INDRA*	*Indra lidera un proyecto europeo de I+D para la detección de explosivos a distancia*	*September 09*		*Civil Society*		*National (Spain)*
34	*Articles published in the popular press*	*INDRA*	*"UZUN MENZILI PATLAYICI TESPITINDI YENI YÖNTEN"*	*24.03.2010*		*Civil Society*		*International*
35	*Articles published in the popular press*	*INDRA*	*"SNIFFING OUT BOMBS"*	*APRIL 2010*		*Civil Society*		*International*
36	*Articles published in the popular press*	*INDRA*	*"CRIADO ROBO PARA DETECTAR BOMBAS A DISTANCIA"*	*02.02.2010*		*Civil Society*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
37	*Articles published in the popular press*	*INDRA*	*"INDRA LIDERA UN PROYECTO EUROPEO DE DETECCIÓN DE EXPLOSIVOS"*	*01.02.2010*		*Civil Society*		*National*
38	*Articles published in the popular press*	*INDRA*	*"NEW METHODS IN LONG DISTANCE DETECTION OF EXPLOSIVES"*	*21.03.2010*		*Civil Society*		*International*
39	*Articles published in the popular press*	*INDRA*	*"NEW METHODS IN LONG DISTANCE DETECTION OF EXPLOSIVES"*	*24.03.2010*		*Civil Society*		*International*
40	*Articles published in the popular press*	*INDRA*	*"INDRA APORTA DESDE LEÓN SU TECNOLOGÍA AL DETECTOR DE EXPLOSIVOS"*	*03.02.2010*		*Civil Society*		*National*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	***Type of activities[1]***	***Main leader***	***Title***	***Date/Period***	***Place***	***Type of audience[2]***	***Size of audience***	***Countries addressed***
41	*Articles published in the popular press*	*INDRA*	*"EL NUEVO ROBOT DETECTOR DE BOMBAS"*	*01.02.2010*		*Civil Society*		*National (Spain)*
42	*Articles published in the popular press*	*INDRA*	*"PATLAYICI TESPITINDI YENO YÖNTEM"*	*21.03.2010*		*Civil Society*		*International*
43	*Articles published in the popular press*	*INDRA*	*"DETECCIÓN ÓPTICA DE EXPLOSIVOS A DISTANCIA"*	*28.02.2010*		*Civil Society*		*National*
44	*Articles published in the popular press*	*INDRA*	*"INDRA LIDERA UN PROYECTO EUROPEO DE DETECCIÓN DE EXPLOSIVOS CON UN PRESUPUESTO DE 3,3 MILLONES DE €"*	*01.02.2010*		*Civil Society*		*National*
45	*Articles published in the popular press*	*INDRA*	*"BOMBA IMHADA OPTIK TEKNOLOJI"*	*21.03.2010*		*Civil Society*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities**[1]	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience**[2]	**Size of audience**	**Countries addressed**
46	*Articles published in the popular press*	*INDRA*	*"OPTICAL TECHNOLOGY IN BOMBA DISPOSAL"*	*21.03.2010*		*Civil Society*		*International*
47	*Articles published in the popular press*	*INDRA*	*"UN ROBOT PERMITIRÁ DETECTAR EXPLOSIVOS A 20 METROS DE DISTANCIA"*	*27.02.2010*		*Civil Society*		*National (Spain)*
48	*Articles published in the popular press*	*INDRA*	*"INDRA LIDERARÁ UN PROYECTO DE DETECCIÓN DE EXPLOSIVOS A DISTANCIA CON UN PRESUPUESTO DE 3,3 MILLONES DE EUROS"*	*03.02.2010*		*Civil Society*		*National (Spain)*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
49	*Articles published in the popular press*	*INDRA*	*"INDRA LIDERA UN PROYECTO EUROPEO DE DETECCIÓN DE EXPLOSIVOS A DISTANCIA"*	*02.02.2010*		*Civil Society*		*National (Spain)*
50	*Articles published in the popular press*	*UMA*	*Investigadores de la UMA utilizan la tecnología laser para detectar explosivos.*	*24/05/2011*		*Civil Society*		
51	*Articles published in the popular press*	*UMA*	*Javier Laserna*	*--*		*Civil Society*		*National (Spain)*
52	*Articles published in the popular press*	*UMA*	*La UMA trabaja em um proyecto europeo*	*24/05/2011*		*Civil Society*		*National (Spain)*
53	*Articles published in the popular press*	*UMA*	*Investigadores de la UMA utilizan la tecnología láser para detectar explosivos*	*24/05/2011*		*Civil Society*		*National (Spain)*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	***Type of activities[1]***	***Main leader***	***Title***	***Date/Period***	***Place***	***Type of audience[2]***	***Size of audience***	***Countries addressed***
54	*Articles published in the popular press*	*UMA*	*Investigadores de la UMA utilizan la tecnología láser para detectar explosivos*	*24/05/2011*		*Civil Society*		*National (Spain)*
55	*Articles published in the popular press*	*UMA*	*Investigadores de la UMA utilizan la tecnología láser para detectar explosivos*	*24/05/2011*		*Civil Society*		*National (Spain)*
56	*Articles published in the popular press*	*UMA*	*Investigadores de la UMA utilizan la tecnología láser para detectar explosivos*	*24/05/2011*		*Civil Society*		*National (Spain)*
57	*Articles published in the popular press*	*UMA*	*Gracias a la tecnología LIBS podemos detectar artefactos explosivos improvisados.*	*12/04/2011*		*Civil Society*		*National (Spain)*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
58	*Articles published in the popular press*	*TUWIEN*	*Sprengstoff in Sicht: Chemie-Analyse aus der Ferne*	*03/03/2012*		*Civil Society*		*National (Germany)*
59	*Articles published in the popular press*	*TUWIEN*	*Offset Raman extended to stand-off distances*	*01/03/2012*		*Civil Society*		*International*
60	*Articles published in the popular press*	*TUWIEN*	*Mit Laserlicht-Hilfe Sprengstoff entdecken*	*27/02/2012*		*Civil Society*		*International*
61	*Articles published in the popular press*	*TUWIEN*	*Finding explosives with laser beams*	*27/02/2012*		*Civil Society*		*International*
62	*Articles published in the popular press*	*TUWIEN*	*Laser beams used to detect explosives*	*27/02/2012*		*Civil Society*		*International*
63	*Articles published in the popular press*	*TUWIEN*	*Finding explosives with laser beams*	*27/02/2012*		*Civil Society*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
64	*Articles published in the popular press*	*TUWIEN*	*Using lasers to look through container walls from a distance and detect explosives*	*27/02/2012*		*Civil Society*		*International*
65	*Articles published in the popular press*	*TUWIEN*	*Laser beams help detect chemicals over long distances*	*27/02/2012*		*Civil Society*		*International*
66	*Articles published in the popular press*	*TUWIEN*	*Finding Explosives With Laser Beams*	*28/02/2012*		*Civil Society*		*International*
67	*Articles published in the popular press*	*TUWIEN*	*Laser beams could help detect explosives over long distances*	*28/02/2012*		*Civil Society*		*International*
68	*Articles published in the popular press*	*TUWIEN*	*Locating explosives with laser beams*	*27/02/2012*		*Civil Society*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
69	*Articles published in the popular press*	*TUWIEN*	*Wiener Forscher spüren Sprengstoff mit Laserlicht auf*	*27/02/2012*		*Civil Society*		*International*
70	*Articles published in the popular press*	*TUWIEN*	*Raman gegen Sprengstoff*	*28/02/2012*		*Civil Society*		*International*
71	*Articles published in the popular press*	*TUWIEN*	*Mit Laserstrahlen Sprengstoff finden*	*28/02/2012*		*Civil Society*		*International*
72	*Articles published in the popular press*	*TUWIEN*	*Mit Laserstrahlen Sprengstoff finden*	*27/02/2012*		*Civil Society*		*International*
73	*Articles published in the popular press*	*TUWIEN*	*Mit Laserstrahlen Sprengstoff finden*	*27/02/2012*		*Civil Society*		*International*
74	*Articles published in the popular press*	*TUWIEN*	*Mit Laserstrahlen Sprengstoff finden*	*27/02/2012*		*Civil Society*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	***Type of activities[1]***	***Main leader***	***Title***	***Date/Period***	***Place***	***Type of audience[2]***	***Size of audience***	***Countries addressed***
75	*Articles published in the popular press*	*TUWIEN*	*Laserstrahlen erkennen versteckten Sprengstoff*	*28/02/2102*		*Civil Society*		*International*
76	*Articles published in the popular press*	*TUWIEN*	*Neuer Laser erkennt Sprengstoff*	*28/02/2012*		*Civil Society*		*International*
77	*Articles published in the popular press*	*TUWIEN*	*Mit Laserstrahlen Sprengstoff finden*	*28/02/2012*		*Civil Society*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
78	*Articles published in the popular press*	*Avantes*	*Avantes helps fight terrorism. Avantes selected for anti-bomb device. Avantes to develop spectrometers for bomb detection.*	--		*Civil Society*		*International*
79	*Articles published in the popular press*	*Avantes*	*OPTIX hilft bei der Bekämpfung des Terrorismus.*	--		*Civil Society*		*National (Holland)*
80	*Articles published in the popular press*	*TUWIEN*	*TUWIEN has been interviewed in radio programe (of a German radio station) on the topic stand-off spatial offset Raman spectroscopy.*	--		*Civil Society*		*National (Germany)*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
81	*Articles published in the popular press*	*INDRA*	*Presentan un sistema capaz de detectar cantidades de explosivos muy pequeñas*	*25/04/2013*		*Civil Society*		*National (Spain)*
82	*Articles published in the popular press*	*AVANTES*	*Avantes maakt bommendetectie mogelijk*	*26/04/2013*		*Civil Society*		*National (Holland)*
83	*Articles published in the popular press*	*INDRA*	*Indra presenta el prototipo del sistema para la detección de explosivos Optix*	*26/04/2013*		*Civil Society*		*National (Spain)*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
84	*Articles published in the popular press*	*INDRA*	*Empresas europeas crean un sistema con láser para detectar explosivos a distancia*	*30/04/2013*		*Civil Society*		*National (Spain)*
85	*Interview*	*INDRA*	*OPTIX Project. Radio programme*	*28/04/2013*		*Civil Society*		*National (Spain)*
86	*Thesis*	*TUWIEN*	*Stand-off Raman spectroscopy for the detection of explosives, Zachhuber, B., Vienna University of Technology, Austria.*	*09/03/2012*		*Scientific Community*		*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
87	*Press release*	*AVANTES*	*Avantes maakt bommendetectie mogelijk*	*29-4-2013*	*Apeldoorn, the Netherlands(http://www.destentor.nl/regio/apeldoorn/avantes-maakt-bommendetectie-mogelijk-1.3787625)*	*Civil society*	*50.000*	*Netherlands*
88	*Press release*	*AVANTES*	*OPTIX hilft bei der Bekampfung des Terrorismus*	*May 2012*	*Germany (Laser+photonik)*	*Civil society*	*50.000*	*Germany + international*
89	*Other*	*AVANTES*	*Avantes helps fight terrorism*	*06/12/2012*	*PHOTONICS IN MILITARY AND DEFENCE" webcast*	*Industry*	*100*	*International*

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
90	Presentation	AVANTES	Development of a Mobile spectrometer standoff system for detection and identification of Explosives	April-2008	Photonics Congress , Utrecht, Netherlands	Industry	100	Netherlands
91	Security Congress	AVANTES	Development of a Mobile spectrometer standoff system for detection and identification of Explosives	June-2008	Rotterdam, Netherlands	Industry	100	Netherlands
92	Other	AVANTES	Development of a Mobile spectrometer standoff system for detection and identification of Explosives	May-09	Laser and detection Systems Seminar Tel-Aviv, Israel	Industry	100	Israel and international

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
93	Video	AVANTES	OPTIX	2010	The Dutch Ministry of Economic Affairs publish a promotional video about OPTIX project Den Haag	Civil society		Netherlands
94	Press release	AVANTES	Avantes helps fight terrorism Avantes selected for anti-bomb device Avantes to develop spectrometers for bomb detection	29/08/2011	Eerbeek, the Netherlands	Civil society	50.000	International

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	**Type of activities[1]**	**Main leader**	**Title**	**Date/Period**	**Place**	**Type of audience[2]**	**Size of audience**	**Countries addressed**
95	*Conferences*	*EKSPLA*	*"The dissemination of the ideas of business and science cooperation" organised by Lithuanian Business Employers' Confederation*	*November 2008*	*Vilnius, Lithuania*	*Industry*		*International*
96	*Conferences*	*EKSPLA*	*Permanent Representation of Lithuania to the European Union*	January-09	Brussels, Belgium	*Industry*		*International*
97	*Conferences*	*EKSPLA*	Participation at the FP7 ICT-Theme Information and Networking Event in Vilnius	*June 2009*	Vilnius, Lithuania	*Industry, scientific comunity*		*National*

2.2. Section B

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[1]:	**Confidential** **Click on YES/NO**	**Foreseen embargo date** **dd/mm/yyyy**	**Application reference(s) (e.g. EP123456)**	**Subject or title of application**	**Applicant (s) (as on the application)**
Patent	No		AT 511512 A1 20121215	Apparatus for examining an object and methods for detecting light scattered in an object	Bernhard Zachhuber, Christoph Gasser, Bernhard Lendl
Patent	No		PCT Int. Appl. (2012), WO 2012159138 A1 20121129.	Apparatus for examining an object and methods for detecting light scattered in an object	Bernhard Zachhuber, Christoph Gasser, Bernhard Lendl
Patent	No		EP12197321	"Method of controlling the current of a flash lamp"	A.Michailovas, D.Jakubauskas, Grigoraitis
Patent	No		LT2011103 LT	"Method of controlling the current of a flash lamp"	A.Michailovas, D.Jakubauskas, V.Grigoraitis

[1] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

Part B2:

Type of Exploitable Foreground[1]	Descriptionof exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[2]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	*New High Sensitivity optical bench for Raman Spectroscopy.*	*No*		*High sensitivity spectrometer*	*Fluorescence, Raman spectroscopy for Scientific Market*	*Released in 2012*	*No*	*Avantes*
Commercial exploitation of R&D results	*High energy laser for the integrated OPTIX platform.* *Flash-lamp power supply with enhanced simmer current source and control algorithm* *for nanosecond laser.*	*No*		*High energy laser*	*Scientific market, industrial market*	*Introduced to market in 2010*		*Ekspla*

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[2] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Type of Exploitable Foreground[1]	Descriptionof exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[2]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	*Apparatus for examining an object and methods for detecting light scattered in an object*	*No*		*Apparatus for examining an object and methods for detecting light scattered in an object*				

3. Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	218037
Title of Project:	OPTICAL TECHNOLOGIES FOR THE IDENTIFICATION OF EXPLOSIVES
Name and Title of Coordinator:	INDRA SISTEMAS S.A.
B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***NO***
2. Please indicate whether your project involved any of the following issues (tick box) :	***NO***
RESEARCH ON HUMANS	
• Did the project involve children?	NO
• Did the project involve patients?	NO
• Did the project involve persons not able to give consent?	NO
• Did the project involve adult healthy volunteers?	NO
• Did the project involve Human genetic material?	NO
• Did the project involve Human biological samples?	NO
• Did the project involve Human data collection?	NO

RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	NO
• Did the project involve Human Foetal Tissue / Cells?	NO
• Did the project involve Human Embryonic Stem Cells (hESCs)?	NO
• Did the project on human Embryonic Stem Cells involve cells in culture?	NO
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	NO
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	NO
• Did the project involve tracking the location or observation of people?	NO
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	NO
• Were those animals transgenic small laboratory animals?	NO
• Were those animals transgenic farm animals?	NO
• Were those animals cloned farm animals?	NO
• Were those animals non-human primates?	NO
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	**NO**
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	**NO**
DUAL USE	
• Research having direct military use	YES(1)
• Research having the potential for terrorist abuse	NO

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	**0**	4
Work package leaders	**1**	5
Experienced researchers (i.e. PhD holders)	**7**	17
PhD Students	**0**	8
Other	**6**	41

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**2**
Of which, indicate the number of men:	1

(1) The technology cannot be use for development of weapons. The main use of OPTIX technology in the military field is essentially the same use as in the civil applications (detection of hidden explosive artifacts), as the terrorist threat affects to civil population but also to European Armies deployed in peace keeping missions.

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?	○ ●	Yes No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
❑	Design and implement an equal opportunity policy	○	○	○	○	○
❑	Set targets to achieve a gender balance in the workforce	○	○	○	○	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
❑	Actions to improve work-life balance	○	○	○	○	○
○	Other:					

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

● No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

- ● Yes- please specify

  TUWIEN: yes continued interaction with our students
- ○ No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

- ○ Yes- please specify
- ● No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

- ● Main discipline[1]: 1.3, 1.2 and 1.1
- ● Associated discipline[1]: 2.2
- ● Associated discipline[1]: 2.3

[1] Insert number from list below (Frascati Manual).

G	Engaging with Civil society and policy makers		
11a	**Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	○ ●	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ● No
- ○ Yes- in determining what research should be performed
- ○ Yes - in implementing the research
- ○ Yes, in communicating /disseminating / using the results of the project

11c	**In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?**	○ ●	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ● Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ● No

13b If Yes, in which fields?

Agriculture		Energy		Human rights	
Audiovisual and Media		Enlargement		Information Society	
Budget		Enterprise		Institutional affairs	
Competition		Environment		Internal Market	
Consumers		External Relations		Justice, freedom and security	
Culture		External Trade		Public Health	
Customs		Fisheries and Maritime Affairs		Regional Policy	
Development Economic and Monetary Affairs		Food Safety		Research and Innovation	
Education, Training, Youth		Foreign and Security Policy		Space	
Employment and Social Affairs		Fraud		Taxation	
		Humanitarian aid		Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ○ European level
- ○ International level

H Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals?	**23**
To how many of these is open access[1] provided?	**2**
How many of these are published in open access journals?	**1**
How many of these are published in open repositories?	**1**
To how many of these is open access not provided?	**12**
Please check all applicable reasons for not providing open access:	
☑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[2]: ……………	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**2**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	
	Registered design	
	Other	

[1] Open Access is defined as free of charge access for anyone via Internet.

[2] For instance: classification for security project.

17. How many spin-off companies were created / are planned as a direct result of the project?	**None**
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	❑	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	☑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
Difficult to estimate / not possible to quantify	❑

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ● No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ● No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

☑	Press Release	☑	Coverage in specialist press
❑	Media briefing	☑	Coverage in general (non-specialist) press
☑	TV coverage / report	☑	Coverage in national press
☑	Radio coverage / report	☑	Coverage in international press
☑	Brochures /posters / flyers	☑	Website for the general public / internet
☑	DVD /Film /Multimedia	☑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

☑	Language of the coordinator	☑	English
☑	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]