Lasers for Safety and Security

Safety and security is one of the key areas of attention for the European Commission. To show how laser science and technology can contribute to a safer world, in this focus section we give some examples of recent safety and security related initiatives within Laserlab-Europe. In previous issues of Laserlab Forum, we already reported on a number of similar projects related to safety and security. In 2011, in a transnational access project conducted at LaserLaB Amsterdam, Spanish forensic experts were for the first time able to detect the presence of DNT, a material found in many explosive materials, through layers of non-transparent plastics. To accomplish this, they used time-resolved Raman spectroscopy, a laser technique extensively researched at LaserLaB Amsterdam, which provides 'molecular fingerprints' to identify chemical compounds. In 2014, CLF spin-out Cobalt Light Systems received the MacRobert Award, the UK's most prestigious engineering prize, for their application of Spatially Offset Raman Spectroscopy (SORS) in an airport security scanner that allows airports to remove the existing hand-luggage liquid ban. The technique identifies explosive threat materials inside containers in seconds without opening them. More recently, IOE-MUT (Warsaw, Poland) created a multifunctional lidar system for stand-off detection of biological clouds at distances up to several kilometres, which can be used as an early warning device for biological warfare. The bio-lidar system is also able to classify the type of detected species by making a comparison with a database. More generally, several partners of Laserlab-Europe have developed laser-based detection techniques that can be used to distinguish between toxic and non-toxic varieties of the same molecule, for example, and to measure pollution levels that can be considered a threat to our health and as such a safety risk as well. Finally, we should also mention the many laser techniques applied to biomedical cases that have been highlighted in Laserlab Forum over the years. Those, in a way, can also be seen as concerning issues of safety, especially when these techniques reduce the risk of dying of life-threatening diseases like cancer.

Detection of hidden objects by X-ray imaging using a laser-generated electron beam

For detection of objects through barriers such as items smuggled in a container crate or buried landmines, standard X-ray detection techniques are inadequate. In collaboration with the UK's Defence Science and Technology Laboratory, scientists from Laserlab-Europe partner the Central Laser Facility (CLF) have developed and demonstrated a new approach to probe for hidden objects or items surrounded by sand or soil.

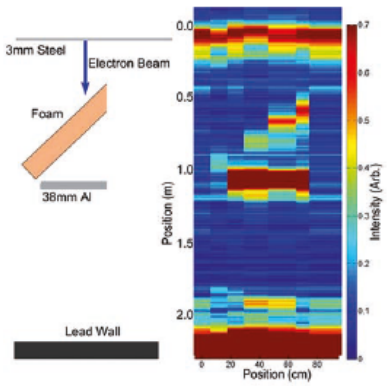
X-ray backscatter imaging is currently used in a range of technologies, from portal security, where it is used to scan airline passengers, vehicles and containers, to industrial inspection, studying the internal structure of low density materials, and applications requiring single sided imaging. Currently, the application of this technique to the detection of landmines is limited due to the surrounding sand or soil strongly attenuating the 10s to 100s of keV X-rays required for backscatter imaging.

In collaboration with the UK's Defence Science and Technology Laboratory the CLF have developed and demonstrated a new approach using a high energy 140 MeV short-pulse (<100 fs) electron beam, generated by laser-driven acceleration, to probe the sample. High energy electrons are able to penetrate to greater depths in a sample; these electrons will then produce X-rays via bremsstrahlung emission, which then backscatter and travel back through the sample before being detected. The backscattered X-ray pulses coming from deeper within the sample will take longer to reach the detectors, therefore a depth profile can be formed. Scanning across the sample allows one to generate a full 3D like image.

An experiment carried out using the Gemini laser system generated the electron beam by focusing the laser pulse in a supersonic gas jet. A variety of detector and scintillator configurations were used to measure the backscattered X-ray pulses coming from various depths within the sample, with the main challenge being the capability of the detectors to resolve pulses that hit the detector, only billionths of a second apart. Despite this extreme challenge, an X-ray backscatter image of an array of different density and atomic number items was demonstrated and is the first time a backscatter image with depth information has been acquired using a laser-driven electron beam to generate X-ray emission in the imaging target itself.

Although this research is in its very early stages, it is hoped that it will ultimately lead to a deployable system that can be used to help detect buried or hidden objects such as landmines or contraband.

David Neely (CLF)



Left: A diagram of the set-up of the array of test objects. Right: Example of an X-ray backscatter image of the object array shown left. An array of objects including 38 mm thick aluminium and 0.14 m thick insulation foam are shown. For more details see: R. Deas et al., J. X-ray Science and Technology 23, 791-7, 2015.

Laser lightning protection

French Laserlab-Europe partner LOA will lead a new FET-OPEN programme called Laser Lightning Rod, aimed at developing a new type of lightning protection. The goal of Laser Lightning Rod is to investigate and develop a new type of lightning protection based on the use of upward lightning discharges initiated by a high-repetition-rate, multi-terawatt laser.

The feasibility of the novel technique is based on recent research providing new insights into the mechanism responsible for the guiding of electrical discharges by laser filaments, as well as on cutting-edge high-power laser technology, and the availability of the uniquely suitable Säntis lightning measurement station in Northeastern Switzerland, located at an altitude of 2500 metres.

Because of the optical Kerr effect, a terawatt ultrashort laser pulse propagating in air will self-organise into thin light channels called filaments. This process results in long-range propagation of a pulse with multi GW/cm² peak intensity. Due to ionisation, a plasma track and a low-density channel are left in the wake of the pulse.

Such long-lived low density channels form a preferential path for lightning precursors, as has been demonstrated in laboratory experiments where guiding of electric discharges has been obtained over distances of 4 metres. Using a powerful kHz laser in conjunction with a new type of focusing system should allow the formation of a long and permanent low-density channel able to initiate upward lightning discharges in real conditions.

LOA will collaborate with Swiss institutions of higher education Université de Genève, École polytechnique fédérale de Lausanne (EPFL), and Haute Ecole Spécilisée de Suisse occidentale (Hes-so), as well as laser company Trumpf Scientific Lasers, and aircraft manufacturer Airbus GI. The Laser Lightning Rod programme has a budget of 3.9 million euros.

Aurélien Houard (LOA)

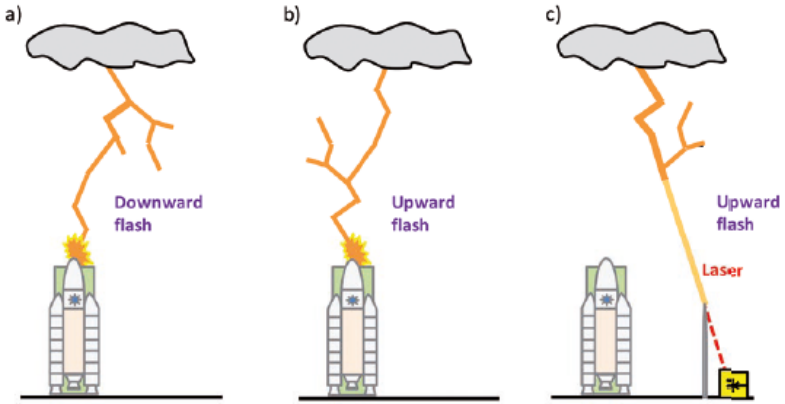
Laser speed gun velocimeter with integrated camera

Since Poland joined the EU, the country has seen a rapid increase in the number of modern, double belt highways. This, together with increasing demand among drivers for indisputable prove of their traffic offense, led to an urgent need for new methods of measuring speed of the vehicles. Accordingly, the Institute of Optoelectronics (IOE) of the Military University of Technology (MUT) in Warsaw developed a handheld laser speed gun velocimeter for law enforcement on public roads.

Widely used Doppler radar devices are becoming obsolete because they do not allow precise beam aiming. The answer to that problem is a pulsed laser diode. Combined with the right optics it can generate a narrow light beam with milliradian divergence, sufficient for accurate targeting.

As a result of joint work of IOE MUT and the ZURAD company from Ostrów Mazowiecka, a prototype named 'Rapid Laser' was built based on lidar technology. IOE took the role of R&D department and ZURAD – the future manufacturer of the device – contributed its experience in the law enforcement market.

The presented device is based on a 905 nm semiconductor pulsed laser diode. The energy of the emitted pulse



In the Laser Lightning Rod project, upward lightning flashes will be initiated by a high-repetition-rate, multi-terawatt laser, directing lightning away from vulnerable objects.