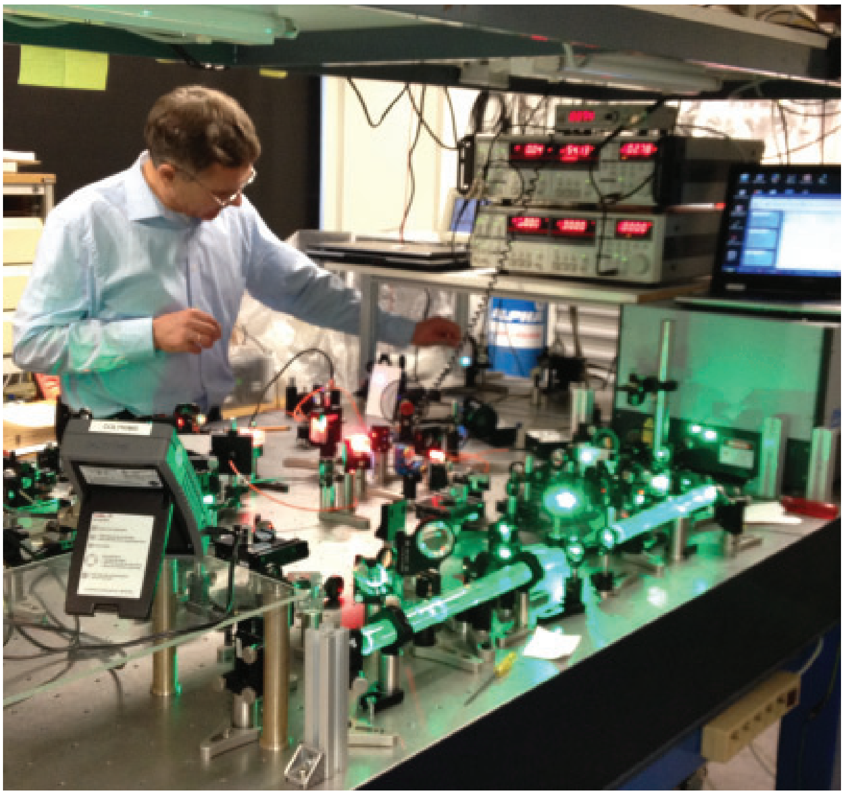
Laser igniting laser in the sky

The technology of light…

The Coherently-enhanced Raman One-beam Standoff Spectroscopic TRacing of Airborne Pollutants (CROSS TRAP) project is a specific targeted research project funded in the Future and Emerging Technologies funding scheme by the 7th Framework Programme of the EU. The goal of the project is to develop a novel laser remote sensing technique for probing air at a distance for hazardous gas-phase substances, which, unlike solid particles, are much harder to detect at low concentrations.

This EU project is coordinated by the Photonics Institute of the Vienna University of Technology and includes seven other partners: academic research groups at the Ruprecht-Karls University of Heidelberg (Germany), Politecnico di Milano (Italy), Bilkent University (Turkey), and the International Laser Centre of the Moscow State University (Russia) and hi-tech companies – Menlo Systems GmbH (Germany), Light Conversion (Lithuania) and Covesion (UK).

The project envisages a versatile method for standoff chemical identification of trace amounts of airborne pollutants that can be fingerprinted using their characteristic vibrational Raman spectral signatures. The core idea of the proposal is to enable a standoff, laser-ignited, coherent source of radiation shining in the exact reverse direction with respect to an outgoing laser beam. This coherent backward beam will interact in gas with a time-delayed second probe laser beam, providing a backward propagating signal that is then detected at the laser source using a LIDAR-type apparatus. The radical advantage, as compared to traditional incoherent light probing techniques, is in the so-called coherent enhancement of the signal, which implies that light waves oscillate in synch rather than randomly to form an intense sharp laser-like beam.



‘The goal of the project is to develop a novel laser remote sensing technique for probing air at a distance for hazardous gas-phase substances, which, unlike solid particles, are much harder to detect at low concentrations.’

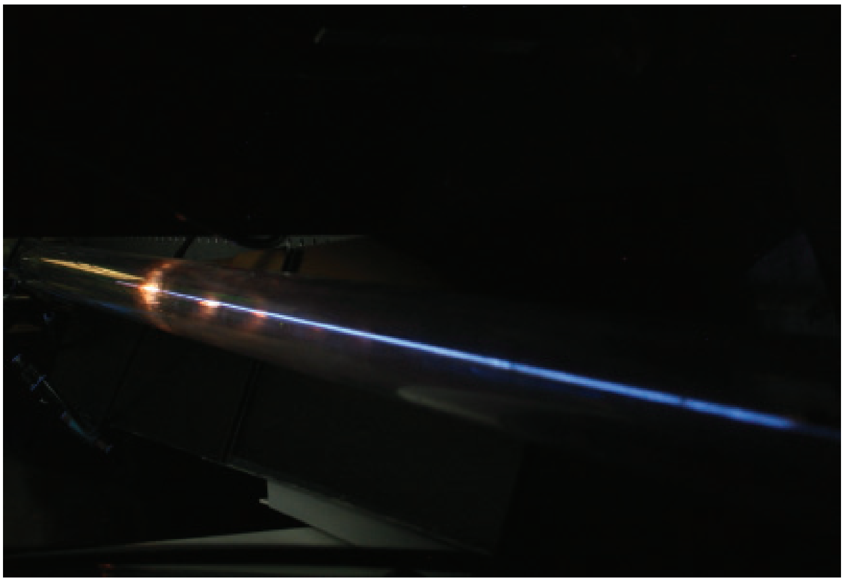
The grand technological and scientific challenge of the project is to realise such a backward propagating beam from nothing else but clear air far away from the apparatus. The solution to this seemingly intractable problem can be engineered by turning air molecules into a plasma column inside the laser beam. After the passage of the excitation laser pulse, the plasma lives on for some time, around 1 ns = 10^{-9} s, during which it continues to evolve and decay. Within a narrow range of parameters, various plasma-chemical reactions taking place during the interactions of neutral molecules, ions and electrons may briefly turn the column into a laser medium that would emit amplified spontaneous radiation from both its ends. The formation of the plasma column is a self controlled process that occurs when an intense ultrashort laser pulse, rather than diverging out at a

distance like the light from a weak laser pointer, will instead implode into a brilliant thin thread of light – the filament.

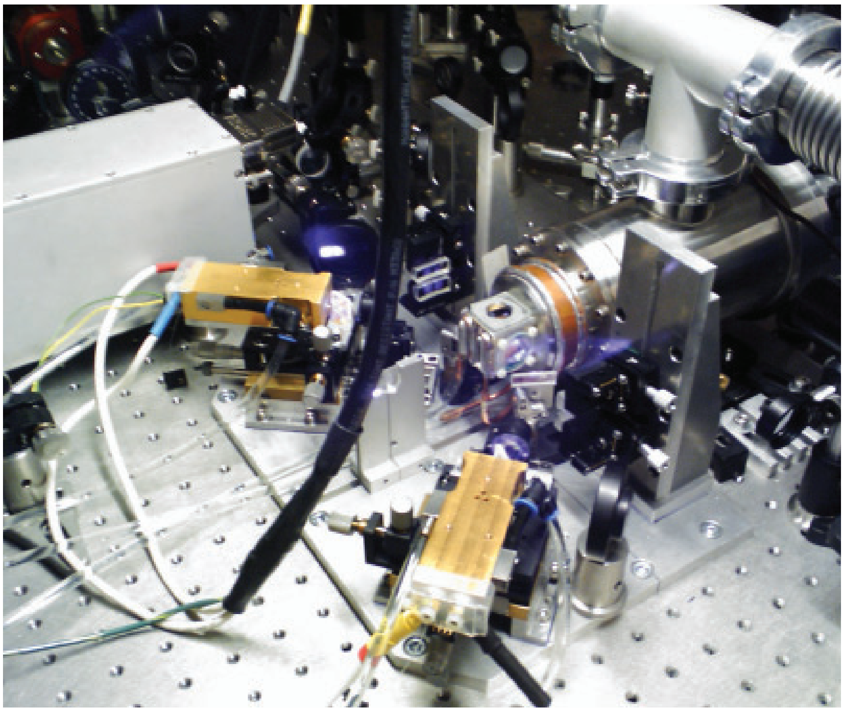
Filamentation requires high pulse peak power that must exceed a threshold value – the so-called critical power – to make the intensity dependent self focusing of the pulse in a medium able to counteract the diffractive defocusing. Furthermore, additional wavelength and pulse energy conditions apply to attain the lasing action from gas molecules.

> ‘The core idea of the proposal is to enable a standoff, laser-ignited, coherent source of radiation shining in the exact reverse direction with respect to an outgoing laser beam.’

Realisation of this project requires the development of a cutting-edge ultrashort high-power and high-energy system as well as the development of an appropriately nonlinear spectroscopic method. In cooperation with



other CROSS TRAP partners, the group in Vienna has constructed a high power laser system, providing laser pulses in the mid-infrared spectral range with only few optical cycles duration and sub-terawatt peak power. Using this unique laser source, a highly efficient UV laser from a filament in a nitrogen-argon gas mixture and in pure nitrogen gas has been demonstrated. Nanosecond and sub-nanosecond pulses of coherent UV radiation at two different wavelengths with energies of several microjoules have been generated directly from a femtosecond filament, created by high power mid-IR pulses at a distance of several meters from the laser system.



In parallel, the CROSS TRAP consortium has developed a prototype broad tuneable laser system for nonlinear Raman spectroscopy adapted to the wavelength and duration of the UV pulses generated by the ‘sky laser’. First experiments with this spectroscopic setup have demonstrated the feasibility of sensitive detection of different gas species using this new approach. The two prototypes – the sky laser and Raman spectroscopy scheme – will be merged together in late 2012 to demonstrate the full-scale capability of the proposed sensing method.

Professor Andrius Baltuska
Project Coordinator, Photonics Institute

Vienna University of Technology

Tel: +43 158 801 387 49

www.crosstrap.eu
www.cordis.europa.eu/projects/rcn/93598_en.html