Laserlab V
JRA2

Advanced Laser-based Techniques for
Imaging and Spectroscopy in material science
and biomedicine (ALTIS)

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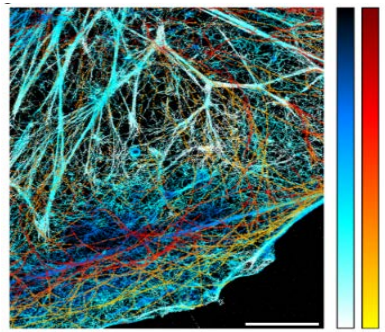
Science and Technology Facilities Council

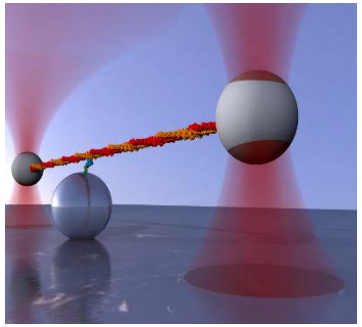
central laser facility

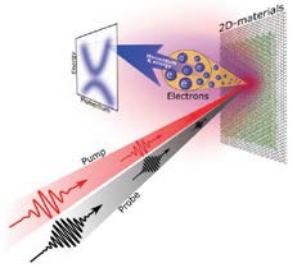
ALTIS

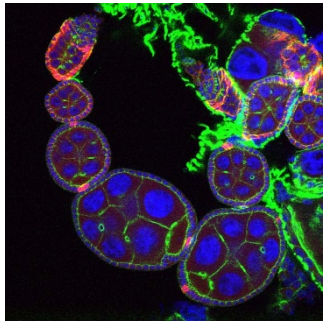
Advanced **L**aser-based **T**echniques for **I**maging and **S**pectroscopy

- Addressing the needs of new and innovative workstations, methodologies
- Platforms for advanced **imaging and spectroscopy.**
- Applications in (for example) ***biomedicine***, ***bio- and nanomaterials*** and ***environmental*** *science*.
- 20 partners in 4 interconnected objectives in 9 focused tasks.









ALTIS - OBJECTIVES

1
Advanced Nano, Microscopic Imaging and Spectroscopy

- detection, characterization and imaging of biological samples
- single molecule (nanometers) to single cells or small cell populations (microns)
- label free to minimise perturbation to function

2
Advanced Meso- and Macroscopic Imaging and Spectroscopy

- analysis of large biological samples, from tissues to whole organs and animals
- improving spatial and temporal resolution in techniques such as light-sheet microscopy & optical tomography
- address the challenge to translate laser-based techniques to the clinics

3
Ultrafast Spectroscopy from THz to XUV

- ultrafast, pump-probe instrumentation and techniques
- broad range of frequencies - attoseconds to femtoseconds
- electronic and vibrational coherent multidimensional spectroscopy
- as/fs XUV spectroscopy XUV materials and gases

4
Advanced spectroscopic methods for atmospheric pollutants and microplastics

- addressing air and water pollution
- accurate scientific methods to evaluate the impact of polluting gases, metals and microplastics
- different, complementary, laser spectroscopic techniques

THE PARTNERS

1
Advanced Nano, Microscopic Imaging and Spectroscopy

Task 1.1 *STFC-CLF*, CNRS -ISMO*
Increase single molecule imaging in terms of multiplexing or 3D localization

Task 1.2 LENS*, LLAMS, CNRS – ISMO, ILC, INFLPR, VULRC
Platforms for imaging, detection and manipulation of biological samples at the molecular and cellular scale

Task 1.3 LENS*, LLAMS, CNRS – ISMO, ILC, INFLPR, VULRC
Label-free spectroscopy and imaging

2
Advanced Meso- and Macroscopic Imaging and Spectroscopy

Task 2.1 *CUSBO*, ULF-FORTH, ICFO, LENS, VULRC, CNRS-ISMO, CLL, MUT-IOE*
High-resolution imaging of intact biological samples

Task 2.2 *LLAMS*, LLC, CLL, ICFO, CUSBO, ULLC, USZ*
Translational research: from biophotonics to clinical use

3
Ultrafast Spectroscopy from THz to XUV

Task 3.1 *CUSBO*, LLC, LLAMS, LACUS, LENS, CALT, CNRS-ISMO*
Coherent multidimensional spectroscopic tools and methods

Task 3.2 *LIDYL*, ULF-FORTH, CNRS-ISMO, MPQ-MPG*
Workstations for spatially/angularly resolved attosecond spectroscopy

Task 3.3 *STFC-CLF*, MPQ, CUSBO, CALT, FELIX*
Optical setups for condensed matter spectroscopy in the XUV

4
Advanced spectroscopic methods for atmospheric pollutants and microplastics

Task 4.1 *LLAMS*, LLC, CALT, FELIX, ILC, ULLC*
Advanced spectroscopic methods for atmospheric pollutants and microplastics

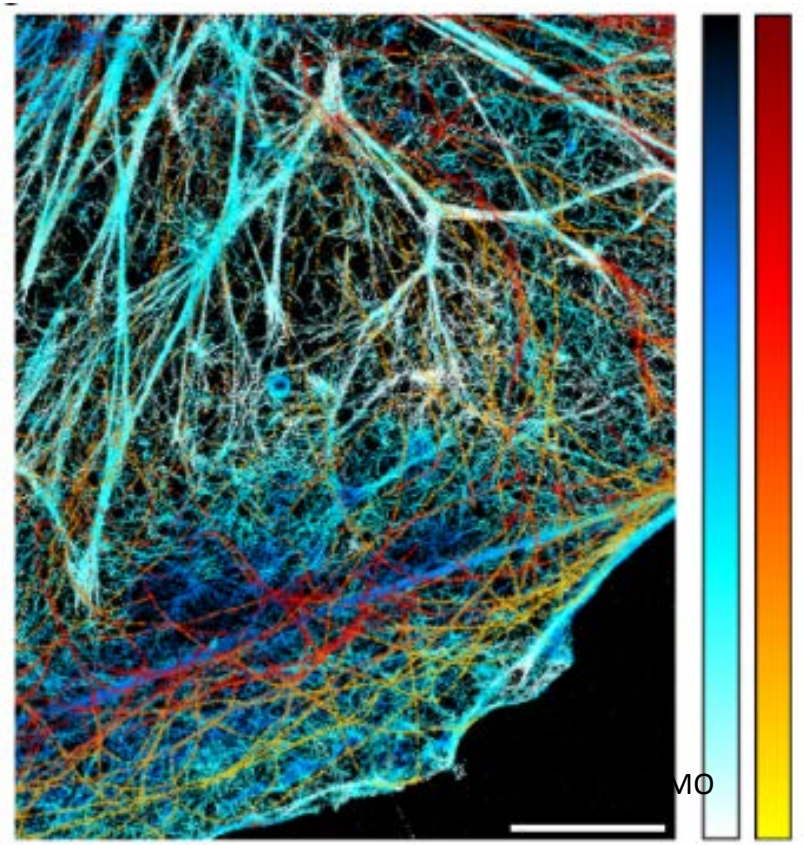
Task 1.1 *Increase single molecule imaging in terms of multiplexing or 3D localization*

STFC-CLF, CNRS -ISMO*

Merging fast 3D adaptive optics (AO) control with DAISY

Dual-view **A**stigmatic **I**maging with **S**upercritical Angle Fluorescence **Y**ield imaging

- 3D localisation ~1 micron above coverslip
- down to 15 nm axial resolution (minimal resolution loss in X and Y)
- new optical strategies and fluorescent reporter control
- Fast response (10 ms) transmissive addressable AO device for fast 3D imaging



SME Collaborations

Adaptica (www.adaptica.com) deformable mirror technology.

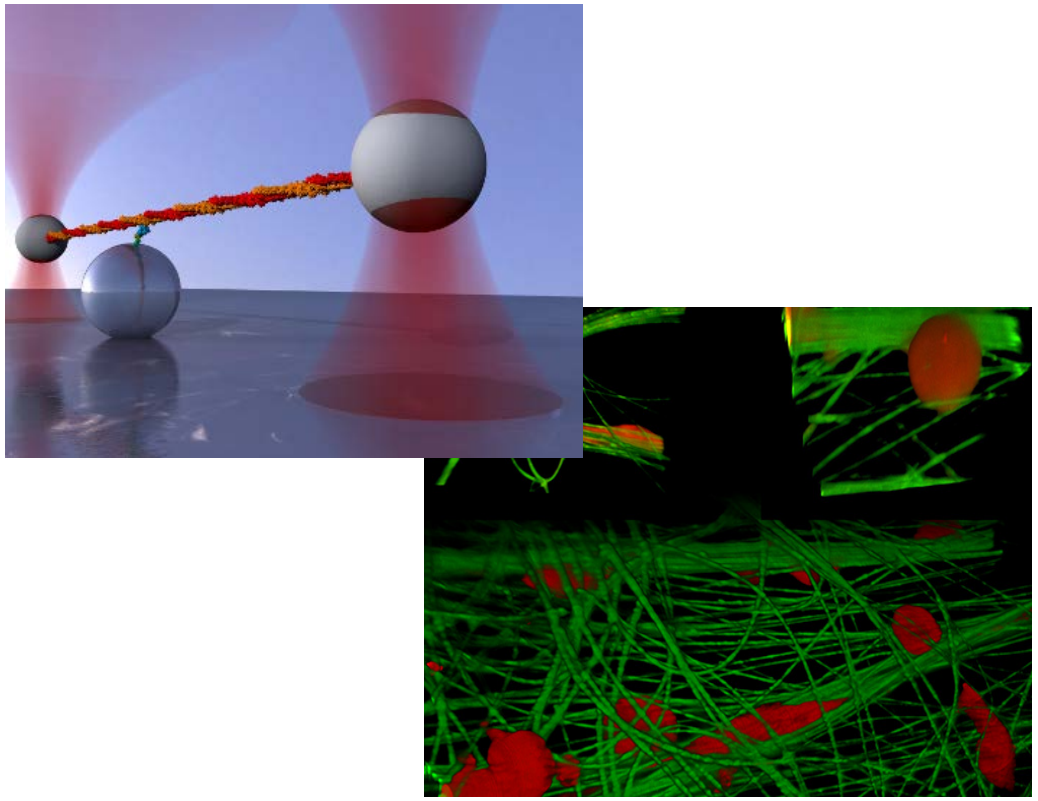
Abbelight (www.abbelight.com) that has a license on the patent for DAISY imaging, and is supportive in terms of software developments.

Task 1.2 *Platforms for imaging, detection and manipulation of biological samples at the molecular and cellular scale*

LENS*, LLAMS, CNRS –ISMO, ILC, INFLPR, VULRC + Nanoscience Centre (NSC Finland) subcontractor

Innovate platforms to manipulate and image single cells.

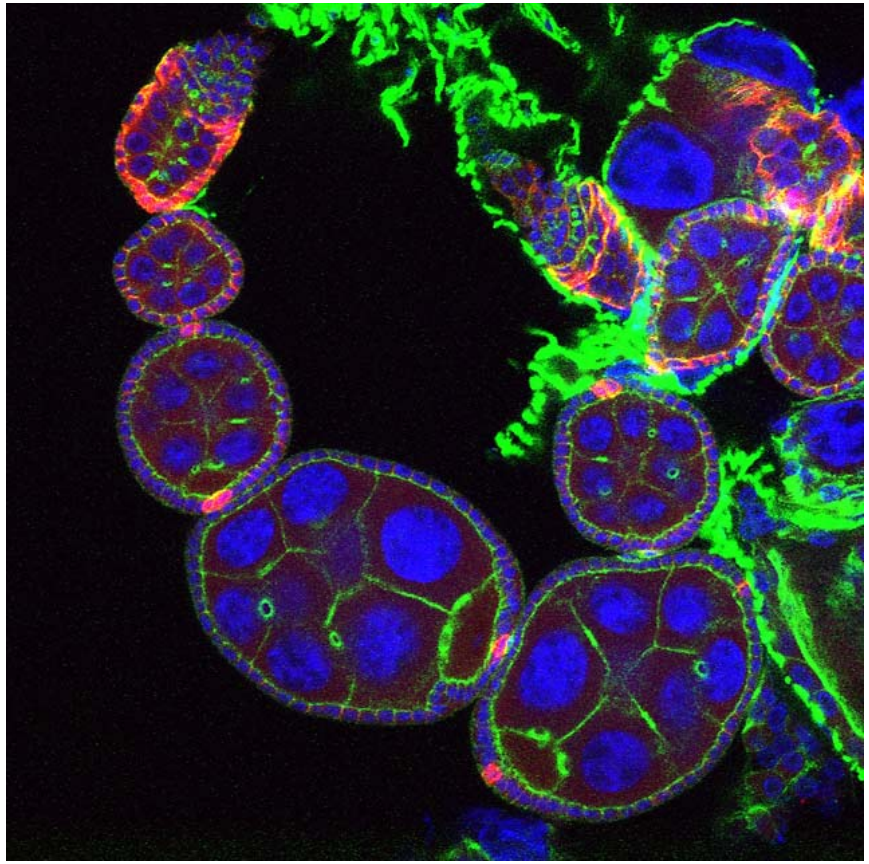
- Pushing the limits in mechanobiology, electrophysiology and sub-cell organisations
- Tweezers and acoustic force to manipulate polymers
- Complementary and combinatory approaches to sub diffraction 3D microscopy - SIM, STORM/PALM, AFM - spatial organisation, mechanical, topical and electric properties
- Potential changes and Ca^{2+} fluxes monitored and controlled by FRET force sensors and photo-cages



SME Collaborations
Abbelight (www.abbelight.com)
Femtika (www.femtika.lt) sample registration between the super-resolved image and the AFM image
LUMICKS (www.lumicks.com) acoustic force and optical tweezers in combination with fluorescence instrumentation

Task 1.3 *Label-free spectroscopy and imaging*

ILC*, ULF-FORTH, LENS, CALT, CLL, ULLC + IPHT Jena (Germany)



Creating optical fingerprint database for label free spectroscopy and imaging

- Spectroscopic features (auto-fluorescence, Raman, SRS, CARS, SHG etc) of molecular, cellular and tissue samples
- Made available on open-source engines with associated analytical packages
- Collecting and finding correlations between signals and molecular and physiological changes
- Exchange of reference samples between partners

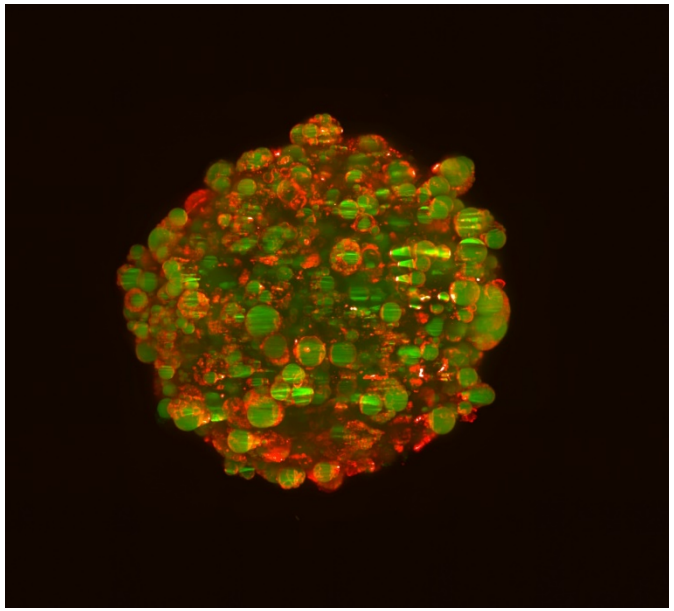
SME collaborations:
LaserLeap SA non-invasive skin diagnostics to facilitate translation of the developed knowledge base to clinical settings.
Becker&Hickl (www.becker-hickl.com), leader in TCSPC instrumentation design and applications, to increase potential of world-wide impact of the developed database.
Light4Tech (www.l4t.it) helping with integration and prototyping of new devices.

Task 2.1 *High-resolution imaging of intact biological samples*

CUSBO, ULF-FORTH, ICFO, LENS, VULRC, CNRS-ISMO, CLL, MUT-IOE*

Broadening the applicability of instruments in the bio- and medical fields

- Improving capabilities, adopting novel photonic technologies and sample preparation.
- Technology exchange - eg photo-generated micromechanical components
- Knowledge exchange - eg Light Sheet Microscopy – better views, faster and denser
- Correlative imaging and integrated approaches - LSFM, Single molecule, Coherence Tomography Soft X-Ray Contact
- Wave shaping and spectral tuning to probe large opaque material, for fast flow imaging



SME collaboration:
Femtika (www.femtika.lt) for the production of custom made micro-optical components and micromechanical sample holders.

Task 2.2 *Translational research: from biophotonics to clinical use*

LLAMS, LLC, CLL, ICFO, CUSBO, ULLC, USZ*

Translational research transforms scientific findings to clinical applications

- cooperate in development of time-domain (time-of flight) and CW Diffuse Correlation Spectroscopy.
- techniques clinically tested on human skin
- early detection of biomarkers for cancer and neuronal injuries in stroke victims
- develop portable multifunctional imaging platforms combining Optical Coherence Tomography with targeted fluorescence imaging
- teacher and student ‘exchange’ and possible joint clinical studies

SME Collaborations

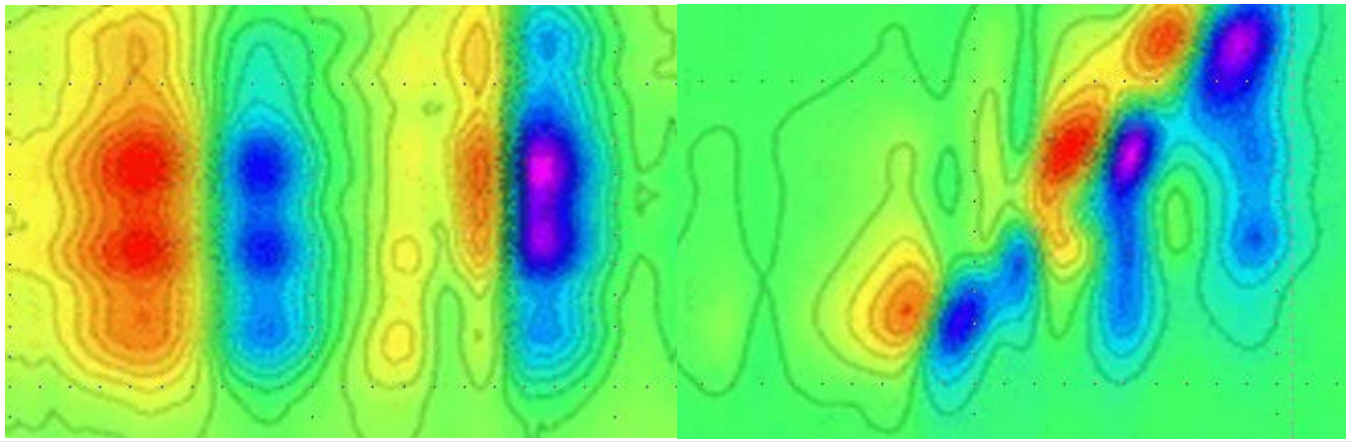
HemoPhotonics (www.hemophotonics.com) and **MPD (www.micro-photon-devices.com)** - advisors and providers/developers of components.

Task 3.1 *Coherent multidimensional spectroscopic tools and methods*

CUSBO, LLC, LLAMS, LACUS, LENS, CALT, CNRS-ISMO + Subcontractor Laserlab-DK (Denmark)*

Bringing 2D spectroscopy to LASERLAB-EUROPE

- increase the availability and extending applications of 2D spectroscopy - THz to Deep UV
- developing suite of techniques with associated data visualisation and analysis tools
- ultra-broadband ultrashort pulses - THz to IR – visible – UV to Deep UV generated in OPAs, gases and fibres
- enhanced time resolution, frequency resolution performance, phase frequency control
- simulation packages for the TA and 2D data based on global analysis



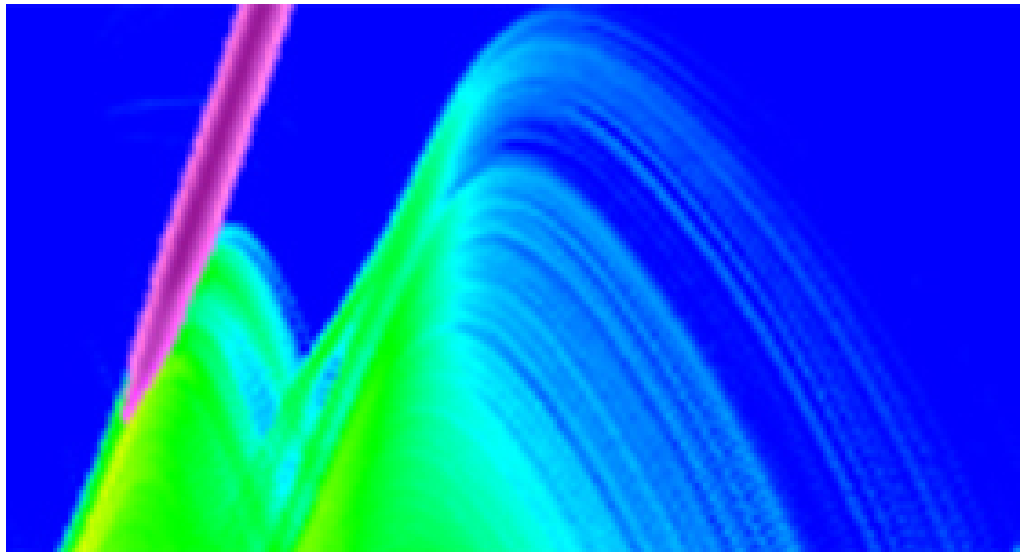
SME collaboration:
NIREOS (www.nireos.com), a spin-off company supports activities and commercial exploitation

Task 3.2 *Workstations for spatially/angularly resolved attosecond spectroscopy*

LIDYL, ULF-FORTH, CNRS-ISMO, MPQ-MPG*

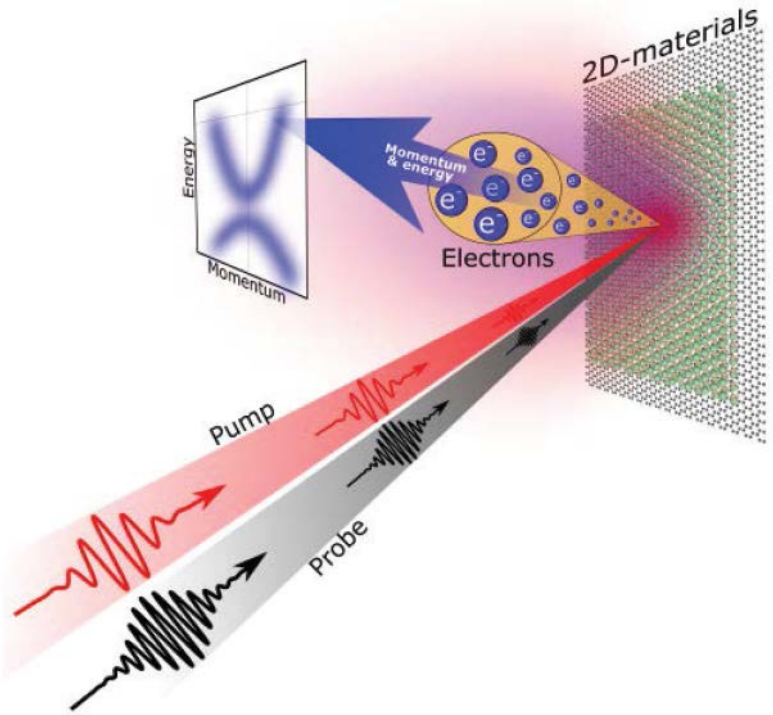
Attosecond dynamics - a concerted approach

- Ultrafast molecular dynamics probed by attosecond XUV CEP stable IR to UV sources
- Long term timing and phase stability crucial – different/complementary schemes will be studied and compared
- Methods to characterise attosecond pulses – even down to a single shot
- Combining photo-electron with photo-ion detection in correlative measurements



Task 3.3 *Optical setups for condensed matter spectroscopy in the XUV*

STFC-CLF, MPQ, CUSBO, CALT, FELIX*



Time Resolved X-Ray – better quality, better tunability

- develop new user-friendly tools for time-resolved measurements on solid targets.
- improved capability in terms of both data quality and of pump and probe tunability
- towards attosecond transient reflection and absorption spectroscopy - flexible incident angles and rotations
- evaluating and developing new attosecond 100 kHz sources

Task 4.1 *Advanced spectroscopic methods for atmospheric pollutants and microplastics*

LLAMS, LLC, CALT, FELIX, ILC, ULLC*

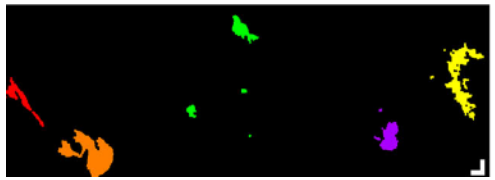
Addressing the need for new laser spectroscopic workstations and methods

GASES:- Targeting greenhouse and ozone depleting gases from hydrocarbon release, biomass burning,…..

- Complementary non-linear optical techniques for combustion diagnostics and environmental analysis
- Species sensitive rotational and vibrational spectroscopies
- Remote and miniature sensing.
- **Cross-calibration - pollutant exchange for intercomparison and validation for future access projects**

PLASTICS:- Identifying plastics in the environment, foods dust…..

- Type specific identification of microplastics using non-linear Raman spectroscopies
- Type specific identification of microplastics using IR photonics and analysing structures by IR/Mass-Spec
- Natural auto-fluorescence as a measure of the response of algae to pollution
- **Cross-calibration - microplastic exchange for intercomparison and validation for future access projects**



SME collaboration:

Optics11 (www.optics11.com) photoacoustic spectroscopy work (in-kind) with expertise and free equipment loan.

THE PARTNERS

LLC	Lund Laser Centre	Sweden
LIDYL	Laboratoire Interactions, Dynamiques et Lasers	France
CNRS-ISMO	Institut des Sciences Moléculaires d'Orsay	France
LACUS	Lausanne Centre for Ultrafast Science	Switzerland
ULF-FORTH	Foundation for Research and Technology-Hellas	Greece
ICFO	The Institute of Photonic Sciences	Spain
CALT	Centre for Advanced Laser Techniques	Croatia
ILC	International Laser Centre	Slovakia
INFLPR	National Inst. for Laser, Plasma and Radiation Physics	Romania
LENS	European Laboratory for Non-Linear Spectroscopy	Italy
MPQ	Max Planck Institute of Quantum Optics	Germany
MUT-IOE	Military University of Tech, Inst. of Optoelectronics	Poland
CUSBO	Centre for Ultrafast Science and Biomedical Optics	Italy
FELIX		Netherlands
CLL	Coimbra Laser Lab	Portugal
STFC-CLF	Central Laser Facility	UK
ULLC	Laser Centre of the University of Latvia	Latvia
USZ	Dept. Physics, University of Szeged	Hungary
LLAMS	LaserLab Amsterdam	Netherlands
VULRC	Laser Research Centre	Lithuania