RL 2 – Solid state lasers and photonic devices for integrated systems

- Theoretical photonics
- Optical metrology and laser gas sensing
- Innovative infrared laser systems
- Spectroscopy of gases and liquids
- Broadband direct comb spectroscopy
- Integrated quantum photonics
- Integrated optofluidic devices

Responsible of the line: prof. Paolo Laporta – **paolo.laporta@polimi.it**

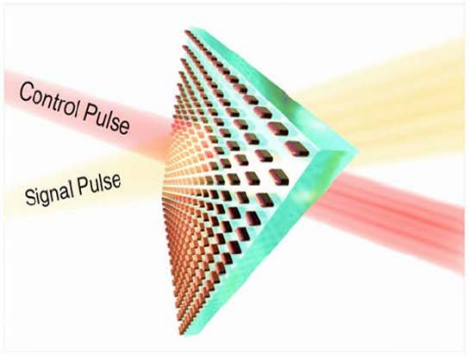
THEORETICAL PHOTONICS
Nanostructures, metasurfaces, parity-time and topological photonics

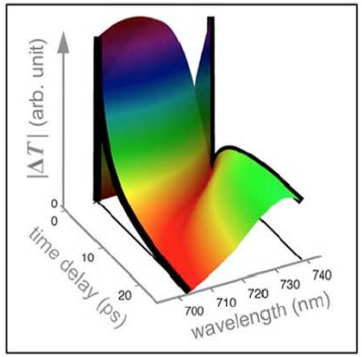
Activities

- **Linear and nonlinear ultrafast properties of metal-dielectric nanostructures:** Modeling ultrafast response of metal-dielectric materials, design of innovative nanosystems for ultra-fast optical switching

- **Optical metasurfaces:** New ways for light manipulation at the nanoscale based on scattering in synthetic optical meta-surfaces

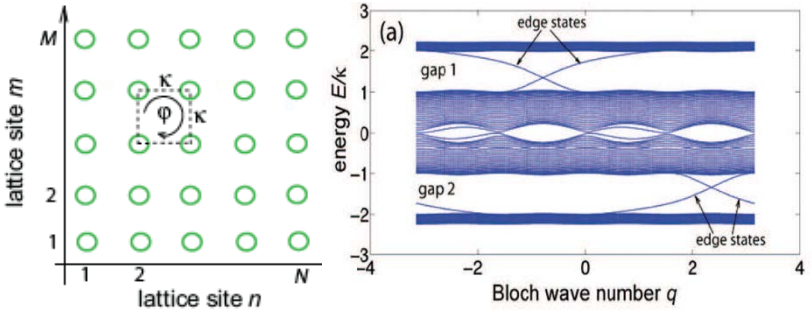
- **Parity-time and topological photonics:** The forefront routes for molding the flow of photons in synthetic media inspired by concepts of quantum physics and topological phases of matter





$$\frac{dE_n}{dt} = (1 - i\alpha)Z_n E_n - \gamma E_n - i\sum_{\sigma \neq 0} \kappa_\sigma E_{n+\sigma},$$

$$T\frac{dZ_n}{dt} = p - Z_n - (1 + 2Z_n)|E_n|^2,$$



Ms Thesis titles

1) ***Metasurfaces for all-optical modulators***
2) ***Fano resonances and topological insulator lasers***

Requirements: strong theoretical skillness, knowledge of advanced topics in quantum physics and optics, MatLab, numerical methods

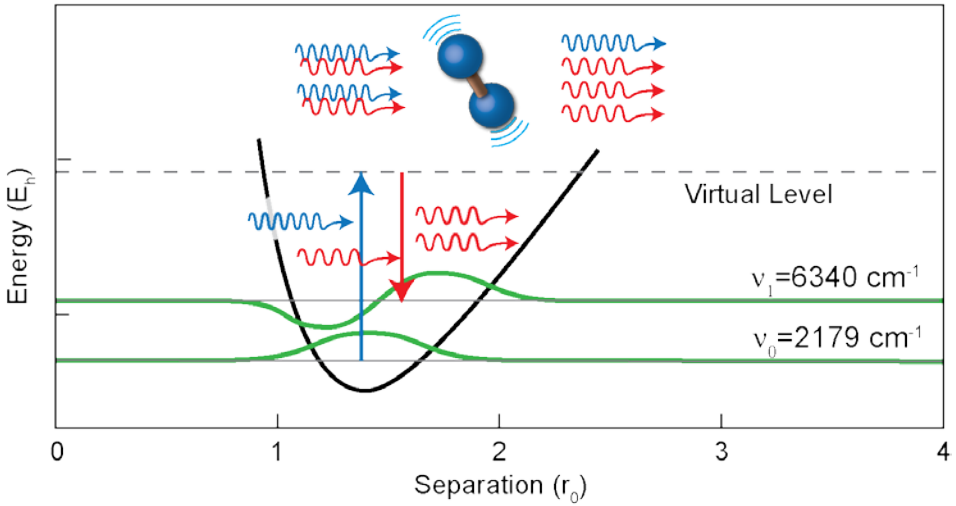
Contact: prof. Giuseppe Della Valle – giuseppe.dellavalle@polimi.it

OPTICAL METROLOGY and LASER GAS SENSING

Spectroscopy for fundamental physics, environment and combustion

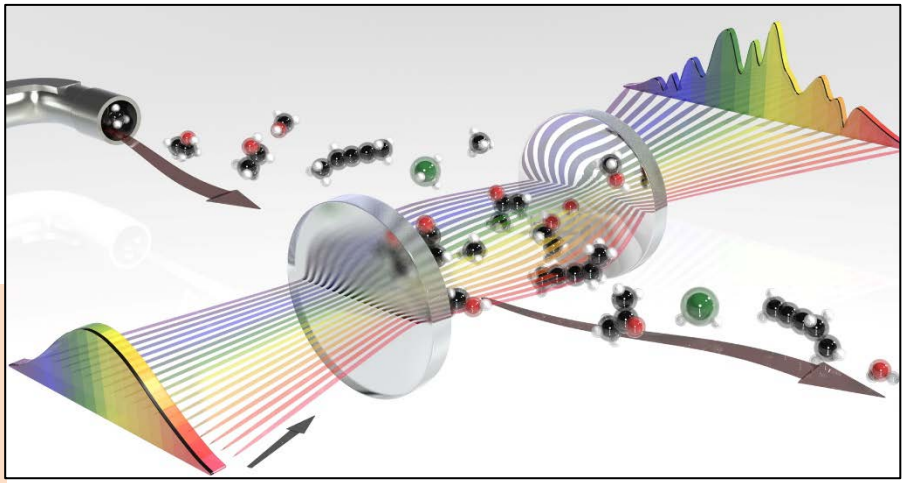
Activities

- **Fundamental physics via molecular hydrogen metrology:** ultra-accurate coherent Raman spectroscopy of H_2 for comparison against quantum mechanical models
- **Chemical kinetic studies in combustion processes:** detection of chemicals in the gas phase at **high temporal resolution** via dual-comb spectroscopy
- **Environmental monitoring and breath analysis:** development of optical spectrometers based on ultra-high finesse resonators for multi-species gas detection at **parts-per-billion** sensitivity



Ms Thesis titles

1) ***Ultimate precision molecular hydrogen metrology***
2) ***Dual-comb spectroscopy for time-resolved gas sensing***
3) ***Cavity-enhanced spectroscopy for trace gas sensing***



Lecco Laboratories

cosmos_lab_

Cosmos Lab

Cosmos website

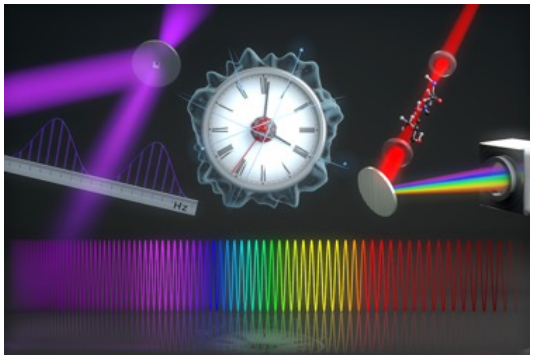
Chrome website

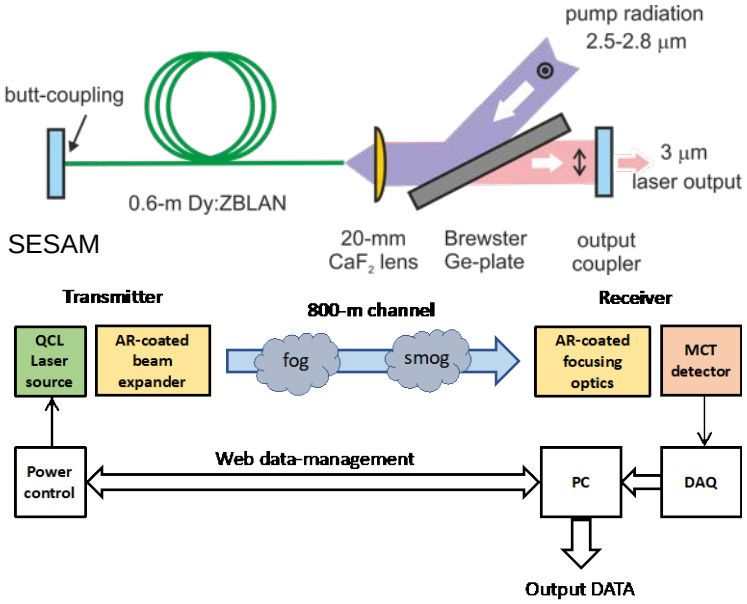
Contact: prof. Marco Marangoni – marco.marangoni@polimi.it

INNOVATIVE INFRARED LASER SYSTEMS
Synthesis of novel light sources for precision measurements

Activities

- **Ultrafast laser systems:** Design, realization, and characterization of femtosecond laser systems in the near and mid-infrared spectral region
- **Near-IR & Mid-IR optical frequency combs:** Development and characterization of optical frequency comb synthesizers in the “molecular fingerprint” spectral region from 1 to 5 μm
- **Novel low-noise lasers:** Development and characterization of high spectral purity and frequency stabilized lasers in the near and mid-IR spectral regions





Ms Thesis titles

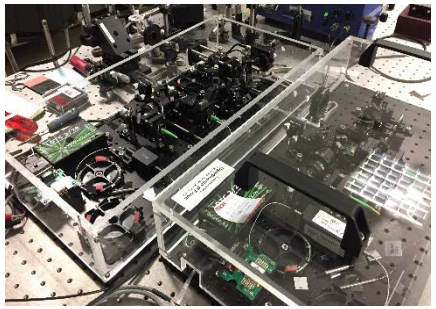
1) Femtosecond Dy-ZBLAN fiber laser at 3 μm
2) Mid-IR optical frequency comb based on fs Cr:ZnSe laser system
3) Free-space optical communication link at 10 μm
4) Single-frequency fiber laser at 2 μm for quantum optics

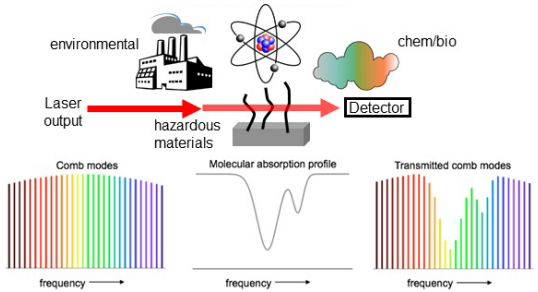
Contact: prof. Gianluca Galzerano – gianluca.galzerano@polimi.it

SPECTROSCOPY OF GASES AND LIQUIDS
Comb spectrometers for gas analysis and chemometrics of liquids

Activities

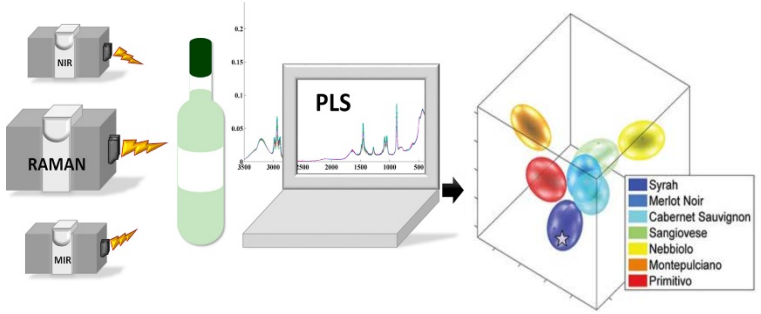
- **Fiber-format optical frequency comb:** Desing and implementation of fiber-format optical frequency comb sources for precision spectroscopy
- **Precision spectroscopy of gases and liquids:** Development of ultra-sensitive setups for detection of trace compounds and contaminants in gases and liquids
- **Spectral processing:** Advanced processing of spectral data for classification and chemometrics of components in gases and liquids





Ms Thesis titles

1) ***Dual-comb CARS detection of hazardous chemicals in drinkable water***
2) ***Stand-off detection of anthrax spores by single-beam CARS spectroscopy***



Contact: prof. Nicola Coluccelli – nicola.coluccelli@polimi.it

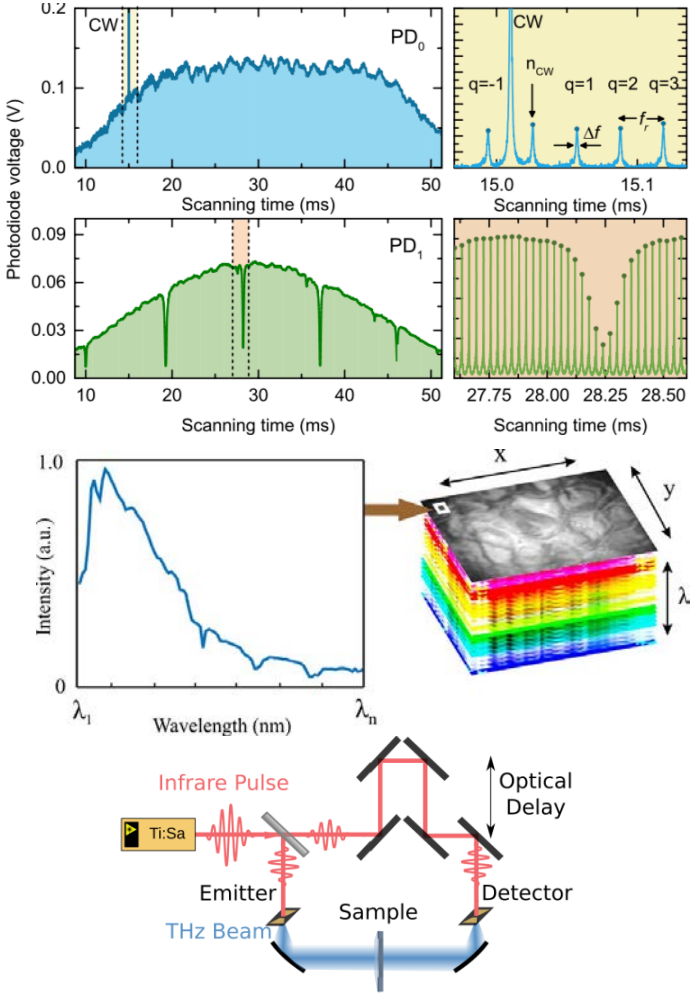
BROADBAND DIRECT COMB SPECTROSCOPY
Novel spectro-imaging methods for material characterization

Activities

- **Novel broadband spectroscopic methods:** Development of fast and broadband spectroscopic methods exploiting the unique properties of the optical frequency combs as probe sources
- **Hyperspectral imaging in the near- and mid-ir regions:** Implementation of innovative spectral imaging methods based on the direct use of optical frequency comb synthesizers
- **Time domain and FTIR spectroscopic methods:** Development of TDS in the THz region and implementation of FTIR spectrometers based on optical frequency comb sources

Ms Thesis titles

1) ***Broad-band direct-comb-spectroscopy in the near- and mid-infrared spectral regions for atmospheric remote sensing***
2) ***Direct-comb hyperspectral imaging in the near- and mid-infrared spectral regions for biological tissue analysis***
3) ***Time-domain-spectro-imaging in the THz region***

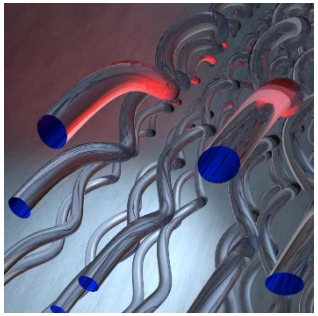


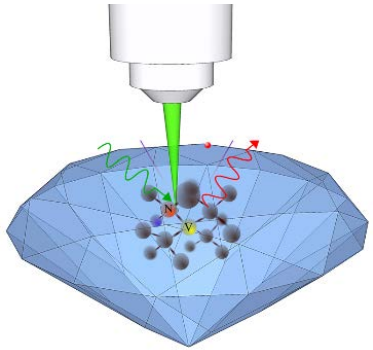
Contact: prof. Alessio Gambetta – alessio.gambetta@polimi.it

INTEGRATED QUANTUM PHOTONICS
by femtosecond laser micromachining

Activities

- **Reprogrammable quantum photonic processors:** Complex 3D photonic circuits, directly written by femtosecond lasers, for quantum simulation and quantum computation protocols.
- **Integrated quantum memories:** Solid-state quantum memories in waveguides directly written in doped crystals. Storage of single photons and entangled states.
- **Integrated photonic circuits for quantum communication:** Laser –written integrated sender and receiver for quantum key distribution (QKD) protocols with time-bin encoding.
- **Integrated quantum diamond photonics:** Laser writing of defects and integrated optical components in diamond for quantum sensing and magnetometry





Ms Thesis titles

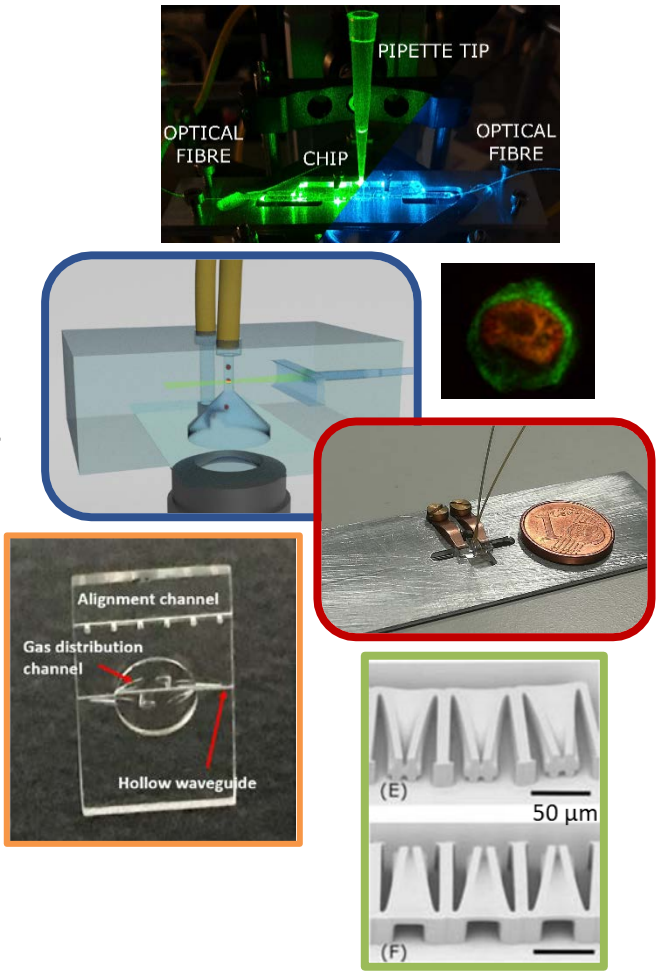
1) ***Reprogrammable photonic circuits for quantum computation and simulation***
2) ***Integrated quantum memories for solid-state quantum devices***
3) ***Integrated sender and receiver for QKD protocols with time-bin encoding***
4) ***Laser-written photonic components in diamond for quantum sensing***

Contacts: prof. R. Osellame – **roberto.osellame@polimi.it** Dr. A. Crespi – **andrea.crespi@polimi.it**
Dr. S. Eaton – **shane.eaton@gmail.com** ***(for the activity on diamond)***

INTEGRATED OPTOFLUIDIC DEVICES
by femtosecond laser micromachining

Activities

- **Optofluidics for biophotonics:** Advanced microscopy on-chip. Miniaturized and fully-automated optofluidic devices for single-cell manipulation and superresolved 3D imaging.
- **High Harmonic Generation on chip:** Engineered microchannels filled with gas for efficient on-chip generation of coherent radiation in the extreme UV and soft-X-ray region.
- **Two-photon polymerization:** Direct writing of ship-in-a-bottle devices, by photopolymerization of 3D micro/nano-structures, for innovative manipulation and sensing of biosamples.



Ms Thesis titles

1) ***Advanced microscopy in an optofluidic chip***
2) ***High Harmonic Generation on chip***
3) ***Two-photon polymerization for nanostructured biochips***

Contacts: prof. R. Osellame – roberto.osellame@polimi.it

Dr. F. Bragheri – francesca.bragheri@polimi.it Dr. R. Martinez – rebeca.martinez@polimi.it