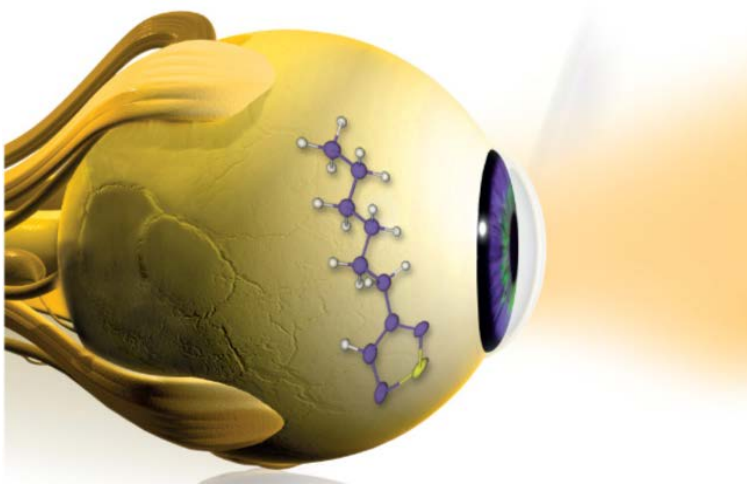
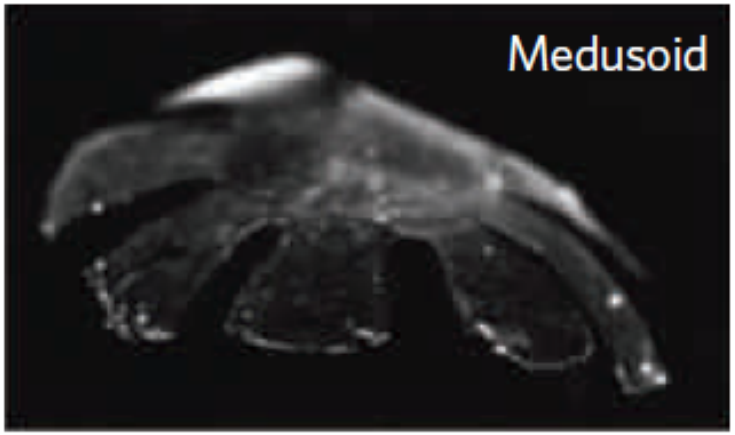
RL 1 - Ultrashort light pulse generation and applications to the study of ultrafast phenomena in the matter

- **Organic actuators for living cell opto-stimulation towards artificial retina and soft robotics**
- **X-ray spectroscopy of ultrafast dynamics in molecules and materials**
- **Label-free vibrational microscopy with ultrashort pulses to study the origin of diseases (e.g. tumors) in cells and tissues**
- **Attosecond electron dynamics: from atoms to complex systems**
- **Light-driven ultrafast processes for energy conversion systems: from biomolecules to complex systems**
- **Femtosecond spectroscopy for investigation of novel materials for light harvesting and photonics**
- **Photonics and ultrafast processes in low-dimensional materials**

Organic actuators for living cell opto stimulation towards artificial retina and soft robotics





Nature Biotechnol. **30,** 792 (2012).

The overarching goal of this activity is to induce light sensitivity in living cells, tissues or organism in order to control their physiology by light. Specific objects are:

- understanding of the coupling mechanisms that transduce light into a bio chemical signal;
- fabrication of light actuators and their characterization by spectroscopy and electrochemistry;
- exploitation of light actuators in cell lines or thin muscular films.

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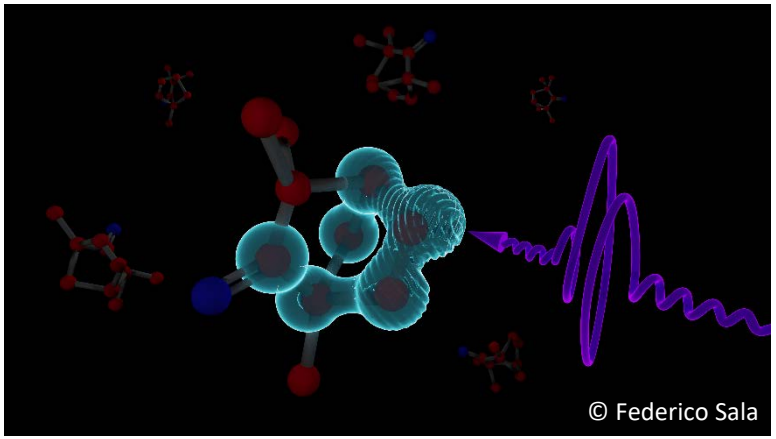
X-ray spectroscopy of ultrafast dynamics in molecules and materials

www.udyni.eu



Attosecond soft-X spectroscopy

- Soft-X attosecond pulses (300 – 550 eV) in a chip
- Soft-X spectroscopy of 2D topological materials and perovskites
- Electron dynamics in biomolecules (collaboration with FERMI Free Electron Laser)

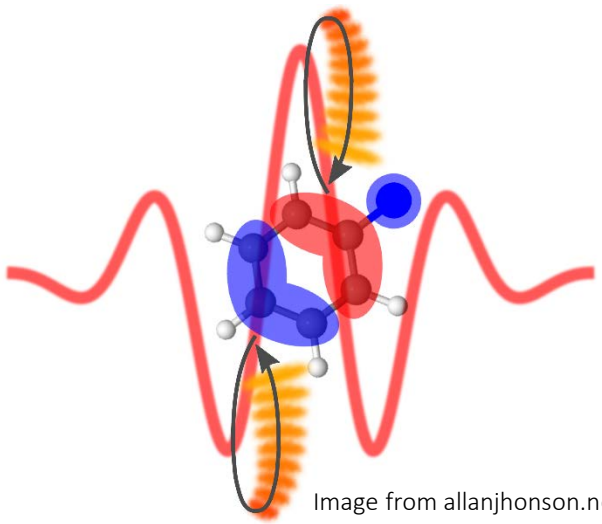


Image from allanjhonson.net

Attosecond HHG Spectroscopy

- Probing structure and carrier dynamics by High-order Harmonics Generation (HHG)
- Molecular imaging by polarization-resolved HHG in biomolecules
- Investigation of exciton dynamics in topological materials

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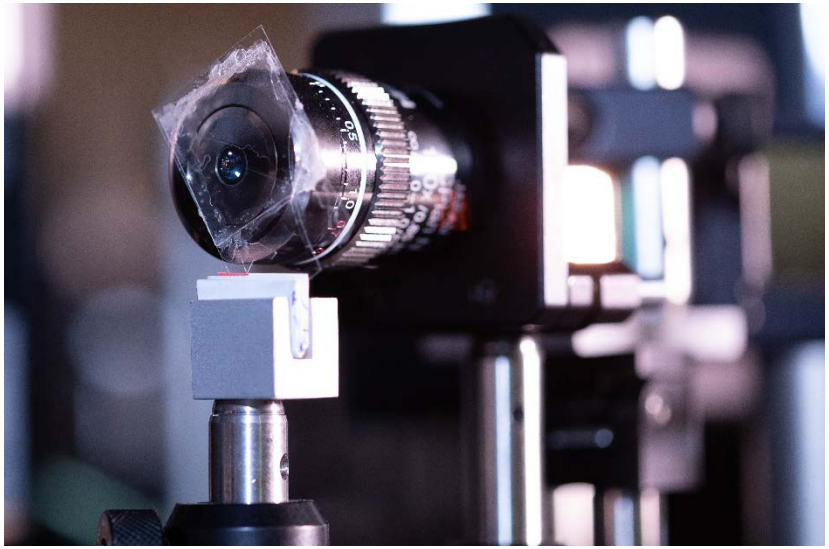
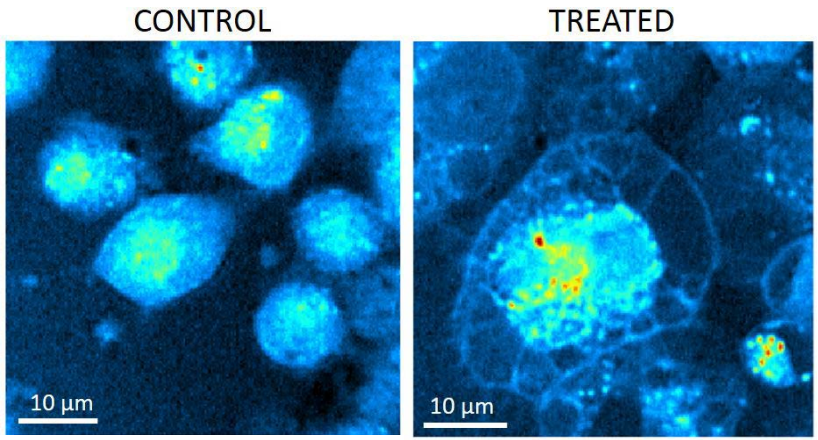
Dr. Caterina Vozzi caterina.vozzi@polimi.it

Label-free vibrational microscopy with ultrashort pulses to study the origin of diseases (e.g. tumors) in cells and tissues





- **Multi-discipline**: ultrafast optics, multimodal label-free microscopy (coherent Raman, fluorescence, second-harmonic generation)
- **Artificial Intelligence** (deep learning) photonics applications (noise reduction, feature extraction, image analysis)
- **Biological applications** (cell metabolism, tissue mapping, tumor identification) with biologists and medical doctors.
- www.fisi.polimi.it/en/teaching/students/thesis_available/54196

See also:
- www.vibra.polimi.it,
- www.crimson-project.eu/
- https://youtu.be/FEpd0qQWrZY

Contacts: Prof. Dario Polli dario.polli@polimi.it
Prof. Giulio Cerullo giulio.cerullo@polimi.it

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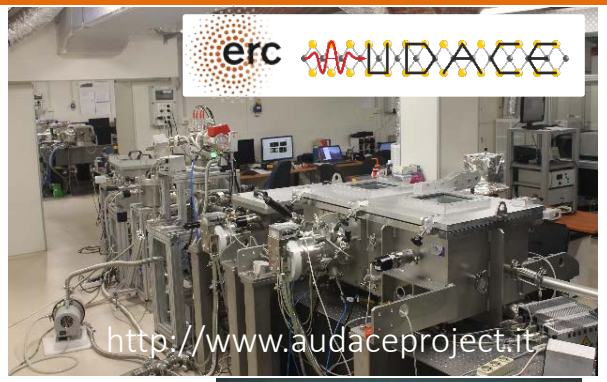
Attosecond electron dynamics: from atoms to complex systems

ATTOSECOND RESEARCH CENTER

http://attosecond.fisi.polimi.it

Investigation of light-matter interaction with the shortest light pulses

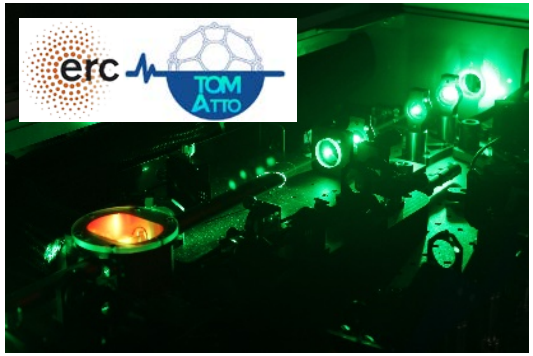


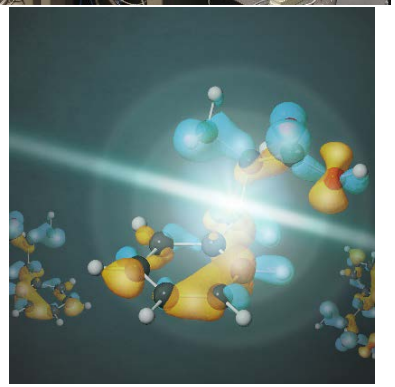
Attosecond dynamics in solids

- Sub-femtosecond carrier dynamics in bulk semiconductors
- Ultrafast exciton dynamics in 2D materials

www.fisi.polimi.it/it/didattica/studenti/tesi_disponibili/54182

Attosecond electron dynamics: from atoms to biomolecules





- Investigation of electron motion in atoms, molecules and optoelectronic materials

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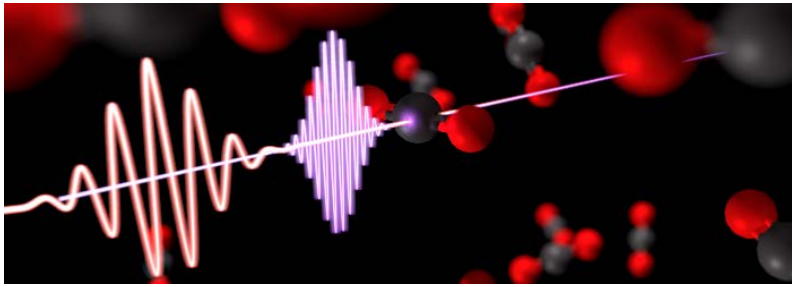
Ultrafast UV-XUV spectroscopy of DNA



- Development of a time-resolved spectroscopy setup for the investigation of ultrafast dynamics in DNA subunits

www.fisi.polimi.it/it/didattica/studenti/tesi_disponibili/57196

Contact: Prof. Mauro Nisoli – mauro.nisoli@polimi.it
Dr. Matteo Lucchini – matteo.lucchini@polimi.it

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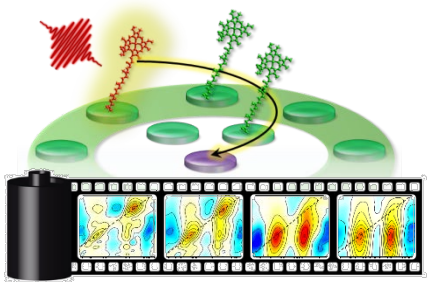
Light-driven ultrafast processes for energy conversion systems: from biomolecules to complex systems

Ultrafast movies of energy and charge transfer in Light-Harvesting Complexes



- Watching the first steps of photosynthesis by multidimensional femtosecond spectroscopies
- Dependance on the dye concentration
- Investigation of exciton dynamics in bio-inspired light-harvesting complexes

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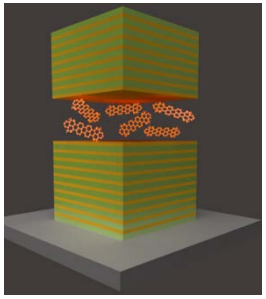
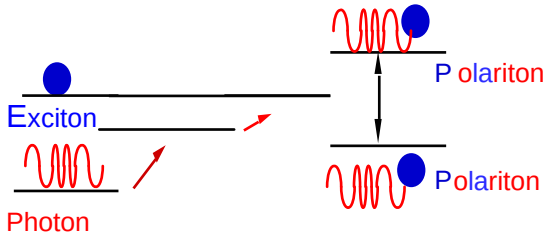
Dr. Margherita Maiuri margherita.maiuri@polimi.it

Ultrafast spectroscopy in strongly coupled organic microcavities

- Probing exciton, lower and upper polaritons (exciton-photon hybrid states) lifetimes
- Investigation of energy transfer between the electronic states



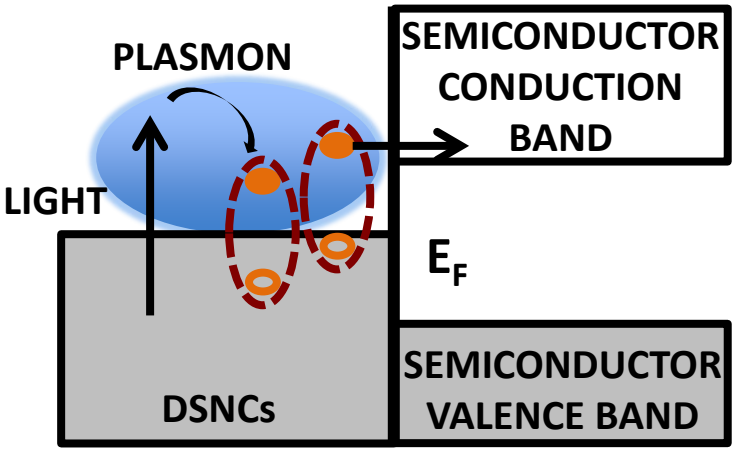


Contacts: Dr. Tersilla Virgili tersilla.virgili@polimi.it

Femtosecond spectroscopy for investigation of novel materials for light harvesting and photonics

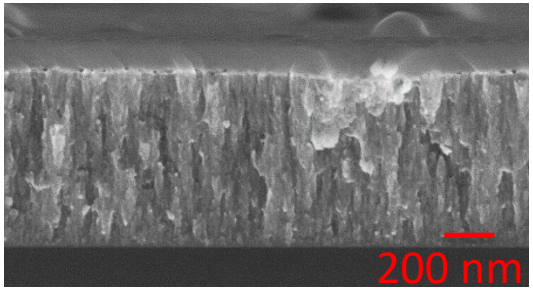
Hot electron extraction for infrared solar devices

- Fabrication of nanoheterostructures with doped semiconductor nanocrystals (DSNCs)
- Assessment with spectroscopic tools of the hot electron extraction at the materials interface
- Photocurrent measurement in infrared solar cells



Contact: Prof. Francesco Scotognella francesco.scotognella@polimi.it

Nanostructured and plasmonic materials for photonics



- Study of novel materials with engineered plasmonic properties (e.g.: TiN, Ta:TiO_2 , Au-TiO_2 , …)
- Investigation of the nonlinear ultrafast optical response
- Control of the permittivity by laser pulses

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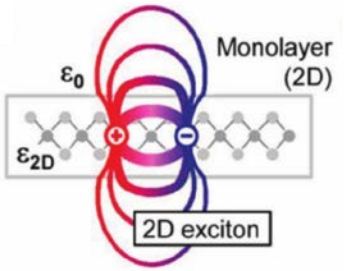
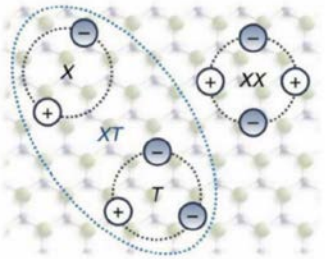
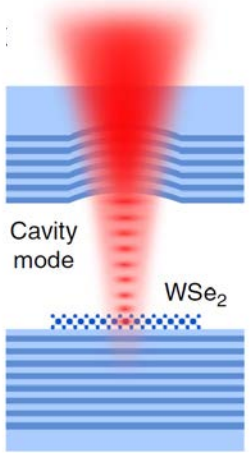
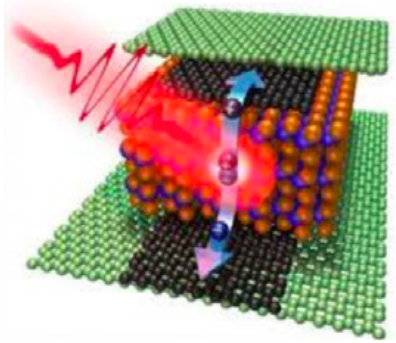
Photonics and ultrafast processes in low dimensional materials

- Photophysical processes of excitons and excitonic complexes (trions, biexcitons, electron-hole plasma, Rydberg excitons) in low dimensional transition metal dichalcogenides (TMDs).
- Exciton-polaritons in TMD based microcavities.
- Charge/exciton dynamics and spin/valley processes in TMD heterobilayers and hybrid heterostructures also based on graphene, 2D-perovskites and quantum dots.









Methods: Ultrafast optical microscopy, Reflectance contrast spectroscopy, Photoluminescence, Helicity-resolved transient absorption spectroscopy.

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