PhD position

Ultrafast dynamics and switching of molecular materials by Terahertz/Optical pump-probe experiments.

Institut de Physique de Rennes, University of Rennes 1, France

Pump-probe ultrafast experiments allow the study of real-time dynamics at the electronic and atomic time-scale from the femtosecond to the microsecond time scale. In such experiments, the pump triggers some properties of the material, and the state of the system after a given time of evolution is read by another ultrafast short pulse. Depending on the coupling interactions of both pulses with the material under study, transient evolutions of electronic, structural, optical etc, properties can be traced out in the time-domain, allowing unique views on local and collective out of equilibrium dynamical processes.

However, the pump laser pulse generally used in the visible range contains a lot of energy that creates an hot incoherent electronic population that further indirectly couples to other degrees of freedom, such as phonons. With the advent of strong ultrashort polarized THz pulse sources, it becomes possible to directly excite collective degrees of freedom, such as polar phonons, opening the route to coherent control of electron-phonon related properties such as ferroelectricity, conductivity or magnetism [1-3]. For instance, optical excitation is known for being able to drive CT between molecules, whereas intense THz pulse can coherently drive electronic and/or atomic motions depending on selection rules and polarization.

This is particularly important in ferroelectric compounds, characterized by a spontaneous polarization that can be reversed or reoriented by an applied electric field, leading to a typical hysteresis ferroelectric loop. The para (no polarization) to ferro-electric phase transition is accompanied by the loss of the symmetry element center of inversion, that can be detected by Second Harmonic Generation (SHG), which is a very good probe of centrosymmetric to noncentrosymmetric structural change. Ferroelectricity mechanisms were usually classified as displacive or order disorder, depending whether the relative ionic displacements or the alignment of permanent dipoles build the polarization. However, it was recognized that electronic polarization was also a key mechanism for some compounds (for instance in charge transfer materials), leading to promising electronic-ferroelectricity.

This thesis aims at making use of the different timescales and responses of the motion of molecular ions and electrons to study and manipulate molecular compounds of interest, in the context of ferroelectricity and photo-induced phase transitions. In particular, the THz pulses (few-cycles) will be used as probe (Time Domain Spectroscopy), or pump coherent soft polar phonon modes. Most of the experiments will be performed at the Department Materials & Light at the IPR on our ultrafast laser facility. Complementary experiments will be performed at large facilities (synchrotron and X-FEL) or in the laboratory of partners in Japan, Europe or USA.

Keywords : Molecular materials, Ferroelectricity, Terahertz, Ultrafast Time-resolved Pump-Probe experiments, Second Harmonic Generation.

References :

[1] T. Kampfrath, K. Tanaka, and K. A. Nelson., Resonant and nonresonant control over matter and light by intense terahertz transients, Nature Photonics, (2013), 7:680

[2] Liu, M et al, "Terahertz-field-induced insulator-to-metal transition in vanadium dioxide metamaterial" Nature, 487 (2012), 345-348

[3] Morimoto, T.et al.. "Terahertz-Field-Induced Large Macroscopic Polarization and Domain-Wall Dynamics in an Organic Molecular Dielectric." *Phys. Rev Let* 118, (2017) , 107602.

[4] Ishihara, S.. "Electronic Ferroelectricity in Molecular Organic Crystals." *J. of Phys.: Cond. Mat.* 26, (2014): 493201.

Context :

The successful candidate will work in the Materials and Light laboratory at the Institute of Physics of University of Rennes I.

The group is leading a French-Japanese International Laboratory[1]. Professor Tanaka (Kyoto University), world expert in intense THz pulses, will be involved through collaboration in this project.

Our team is young and dynamic, a third being foreign, English is the working language.

The scholarships include full social security coverage and a net salary of ~1.4 k€. Students have no teaching obligations. If interested, successful candidate can apply to a teaching assistant position during the first or second year of PhD. The University offers French courses for foreigners and hosts an international Erasmus Mundus program.

The student should obtain their PhD degree within the 3 years of the financial support (before Oct 2022).

Rennes is a medium size French city less 1.5 hour train ride from Paris, offering a relaxing lifestyle with many cultural and sport activities.

Requirements:

- M.Sc. degree in physics
- Good understanding of Physics
- Good experimental and computing skills
- Good team player
- Prior hands-on experience with laser spectroscopy or nonlinear optics will be a strong asset

Timeline:

- April 2019 — announcement of the position
- April - May 2019 — candidate pre-selection.
- June 2019 — selected candidates interviews
- End of June 2019 — selection of candidate awarded position

Selected Publications of the group:

- Phys. Rev. Lett. 105, 246101 (2010)
- Nature Photonics 7, 215 (2013)
- Phys. Rev. Lett. 113, 227402 (2014)
- Chem Science, 8, 4978 (2017)
- Nature Communications, 8, 15342 (2017)

Interested candidates are encouraged to contact (before end of may):

Dr Christophe Odin (christophe.odin@univ-rennes1.fr)

Dr Marco Cammarata (marco.cammarata@univ-rennes1.fr)

Curriculum Vitae, motivation letter, university marks and manuscripts (master thesis, experimental reports, etc) might be joined to the email

Further information:

https://ipr.univ-rennes1.fr/en/materials-and-light-departement

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1 http://www.chem.s.u-tokyo.ac.jp/users/lia_im-led/index-e.html