UMR UR1-CNRS 6251

PhD thesis hosted at the Institute of Physics of Rennes (IPR)

Title:

Ultrafast Terahertz Spectroscopy of Multi-Functional Materials

PhD supervisors:

Niels Keller (CNRS research director); Roman Bertoni (Assistant Professor)

Scientific Overview and Project :

The Material & Light department, inside the Institute of Physics of Rennes (IPR), has a worldwide recognition in the field of ultrafast photo-induced effect in condensed matter and more particularly photo-induced phase transition (PIPT) [1,2]. This new field of research make use of light as new control parameter in order to tune the physical properties of material. For instance, it is possible to induce a metal to insulator transition or to demagnetize a ferromagnet under light irradiation [3]. Recently, the range of optical pulses used to probe and control material properties as reached the terahertz range (10^{-12}s, 300 µm) [4]. From that perspective, current laser-based technology allows to map in real time the variation of electromagnetic fields corresponding to optical frequencies lying in the Terahertz range. It translates the more conventional Fourier Spectroscopy (spectral dimension) into the time-domain with the so-call time domain spectroscopy (TDS) where oscillations of electromagnetic field are directly recorded [5]. In parallel, it is now possible to generate intense THz pulses (10^{-12}s, 400 kV/cm) at laboratory scale and use it to interrogate solid-state materials or modify their properties. By doing so, it is possible to directly access low energy collective excitations. Depending on the resonantly excited degree of freedoms one should be able to directly observed magnons (spin's wave of the electron) or phonons (lattice vibrations).
This thesis targets to study rare-earth iron-based oxide materials (orthoferrites) for future information technologies in the THz domain. We foresee to use intense electromagnetic pulses in the THz range both as external probe and as an external perturbation to study these materials. It has been shown by optical pump-probe studies that antiferromagnetic iron-based perovskite systems possess magnetization dynamics in the THz frequency domain. For instance, one key challenge is the control of a phase transition allowing to manipulate either the magnetization dynamics or the terahertz absorption of the material. Throughout this project thesis one selected orthoferrite material exhibiting several intrinsic magnetic phase transitions will be studied. One key idea is to induce with phase transition dynamically through an optical near-infrared or a terahertz pump pulse and to monitor the resulting dynamics.

Supervision:

This PhD thesis will be supervised by Roman Bertoni (Assistant Professor) and Niels Keller (CNRS Director) with experimental support from Nicolas Godin (Engineer). The candidate will be deeply involved in the femtosecond laser lab built by the material and light team. Daily work involves strong interactions with all team members working in the laser lab.

Required skills and knowledge:

Candidates must have deep knowledge in optics and solids-state physics. Also, a strong background in optical spectroscopy and the related experimental techniques is recommended. Good skills in programing, interfacing, data treatment and analysis (if possible by using Python) are strongly appreciated. English is the working language in the team. The PhD candidate will be strongly encouraged to present the scientific results in national and international conferences.

Employment conditions:

The contracts retirement contributions and give right include full social security coverage and unemployment benefits. PhD students have no teaching obligations at University of Rennes. Rennes is a medium size French city less 1h30 train ride from Paris and 1h from the sea coast, offering a relaxing lifestyle with many cultural and sport activities.

The Team:

The candidate will work inside the “Materials and Light Department” at the Institute of Physics of the University of Rennes. Our research is focused on ultrafast out-of-equilibrium phenomena in materials and molecules using optical and X-ray techniques with femtosecond to picosecond time resolution. The team is now part of a newly establish International Research Laboratory (IRL-DYNACOM) involving French and Japanese Universities (University Tokyo, Tohoku University).

More information can be found on the website:

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

How to apply:

Interested candidates should send a single pdf file with:
1. a cover letter
2. CV
Application should be made through the following portal:
https://amethis.doctorat-bretagneloire.fr/amethis-client/prd/consulter/offre/542

Contact:

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References:

[1] M. Hervé, et al. "Ultrafast and persistent photoinduced phase transition at room temperature monitored by streaming powder diffraction" *Nature Communications* (2024).
[2] Y. Tokura, "Photoinduced phase transition: a tool for generating a hidden state of matter" *Journal of the Physical Society of Japan* (2006).
[3], A. V. Kimel, et al. "Ultrafast non-thermal control of magnetization by instantaneous photomagnetic pulses" *Nature* (2005).
[4] T. Kampfrath, et al. "Resonant and non-resonant control over matter and light by intense terahertz transients" *Nature Photonics* (2013).
[5] J. Neu, et al. "Tutorial: An introduction to terahertz time domain spectroscopy (THz-TDS) " *Journal of Applied Physics* (2018).