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

Department Materials and Light

Title:

Study of ultrafast photo-induced phenomena near critical points in molecular materials

PhD supervisor: Roman Bertoni (Assistant Professor)

Funding: ANR project hosted at University Rennes 1

Scientific Overview:

The material & light team inside the Institute of Physics of Rennes has a worldwide recognition in the field of ultrafast photo-induced phase transition. This new field of research makes 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. Spectacular results such as light-induced superconductivity or generation of transient ferroelectric phase under ultrafast optical photo-excitation were demonstrated. In order to optimize the control granted by the light field, it is mandatory to understand the microscopic effects into play. Those out-of-equilibrium phenomena involve fundamentals couplings between the different quantum degrees of freedom (electrons, lattice, spins, orbitals).

Time resolved measurements are truly suited for the study of mechanisms involved in the formation of new photo-induced states. More precisely, optical spectroscopy is a dedicated technique because electromagnetic waves in the visible and infrared range are in resonance with numerous internal degrees of freedom of solid-state materials. The advanced of laser delivering intense ultrashort pulses of femtosecond duration allow to monitor fundamental electronic and structural dynamics on their relevant timescale.

For a long time, the study of photo-induced phase transition was restricted to the sole use of temperature as external control parameter. Recent studies have demonstrated the possibility to add the use of hydrostatic pressure to explore the phase diagram of material. The idea is to look for parts of the phase diagram near critical points where gigantic photo-response may occur. This PhD project follows this new line of research where several control parameters (Temperature, Pressure and Light) will be used to generate new multifunctional states potentially hidden at thermal equilibrium.

Project:

This PhD project aims to develop a new experimental setup combining a High Pressure He gas cell with the existing femtosecond laser platform. The candidate will intensively use several setups of femtosecond optical spectroscopy implemented in the material and light team. Those setups are able to deliver ultrashort laser pulse of around 100 fs while covering a spectral range spanning from UV (250 nm) to far infrared (15 µm). All the experiments are based on the so-called pump-probe techniques where two light pulses are used to impact and monitor the system respectively. The main task of the candidate will be to perform ultrafast optical spectroscopy of molecular conductors inside the High Pressure cell (0-7 kabrs) in different spectral ranges.

This PhD project involves the use and expertise of several optical spectroscopic techniques such as transient absorption spectroscopy, supercontinuum spectroscopy (white light) and time-resolved infrared measurements. The candidate should develop a strong knowledge in the field of photo-induced phase transition and ultrafast photo-induced phenomena in condensed matter. In addition, we will master all the cutting-edge techniques involve in those fields of research. In addition, complementary measurements involving X-ray diffraction and static optical spectroscopy are needed to characterize the sample. The PhD candidate will be strongly encouraged to present the scientific results in national and international conferences.

Supervision:

This PhD thesis will be supervised by Roman Bertoni (Assistant Professor) with strong 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 will involve strong interactions with all team members working in the laser lab and sharing of knowledge. Nicolas Godin is an expert in charge of all developments involving sample environment (Temperature, Pressure) and laser spectroscopy. Roman Bertoni has a strong expertise in femtosecond optical spectroscopy and ultrafast techniques in general. He was also involved in the supervision of numerous students in the laser lab.

Required skills and knowledge:

Candidates must have knowledge in solid state physics and theory of phase transition. Candidates must have background in optical spectroscopy and the related experimental techniques. Good skills in programing, interfacing and data treatment and analysis (if possible with Python) are strongly appreciated. English is the working language in the team.

This PhD project is developped in the frame of the new International Research Laboratory DYNACOM supervised by Pr. Ohkoshi of the Tokyo University and Pr. Collet of University Rennes 1. Stays in Japan to visit Japanese colleagues' experts in the field of Photo-Induced Phase Transition are foreseen.

References:

[1] E.Collet, et al, ***Science*** ,300 (5619), 2003

[2] R.Bertoni, et al, ***Nature Materials***, 15 (6), 2016

[3] M.Mitrano, et al, ***Nature***, 530 (7591) 2016

[4] AH.Zewail, ***J. Chem. Phys. A***, 2000

[5] A.Cantaluppi, et al, ***Nature Physics***, 14 (8), 2018

[6] R.Bertoni, et al, ***Angewandte Chemie***, 128 (30), 2012

[7] R.Bertoni, et al, ***Account of Chemical Research***, 48 (3), 2015