Master 2 Thesis proposal

Academic year 2023-24

Ultrafast Terahertz Spectroscopy of Solid-State Materials

Institution : Institut de Physique de Rennes, University of Rennes/CNRS

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Keywords: *Terahertz, Ultrafast, Spectroscopy, Phase Transition, Pump-Probe Methodology, Ferroelectric Materials*

Description:

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.

In parallel, it is now possible to generate intense THz pulses (10-12s, 400kV/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 project will focus on lead-free prototype ferroelectric material, KTa1−xNbxO3 (KTN), where the paraelectric-toferroelectric ordering temperature can be tuned by appropriate Niobium doping. We foresee to use intense electromagnetic pulses in the THz range both as external probe and as an external perturbation. In a first stage, the candidate will use the setup to probe the changes to the THz absorption in both the paraelectric and the ferroelectric phase and learn basic knowledge about THz-physics and TDS. In a second step, if allowed by time, the very same THz pulse will be used to strongly excite matter and drive optically the macroscopic phase transition. The candidate should have some knowledge regarding optical properties of solids and optics/photonics. Basic skills in experimental physics are very welcome. In addition, notion of solid-state physics will be also appreciated.

The candidate will be working on a cutting-edge THz setup able to provide pulsed electric fields as high as 400kV/cm with 1 picosecond duration (10-12s). She/he will be trained in the use of very intense and ultrafast lasers as well as time-resolved spectroscopy. Basic skills in programming are very welcome as the setup is currently implemented with Python.

The Material and Light team is currently a main actor of the international French-Japanese laboratory IRL Dynacom (Tokyo University/CNRS/Rennes University: http://irl-dynacom.chem.s.u-tokyo.ac.jp) and has a worldwide recognition in the field of ultrafast science. The working environment is multicultural and international. English is the working language.

References

(1)“Optical properties of solids”, Mark Fox, *Oxford Series;*
(2)“Resonant and non-resonant control over matter and light by
intense terahertz transients”, T. Kampfrath, K. Tanaka and K. Nelson , *Nature Photonics (2013);*
(3)“Tutorial: An introductionto terahertz time domain spectroscopy (THz-TDS)”, J. Neu and C. Schmuttenmaer, *Journal of Applied Physics (2018);*
(4) S. Triebwasser, “Study of Ferroelectric Transitions of Solid-Solution Single Crystals of KNbO3 -KTaO3”, *Phys. Rev. 114, 63 (1959).*

The Team: the candidate will work inside the “Materials & Light Group” which is a research group based at the Institute of Physics of the University of Rennes including CNRS researchers. Our researches focus 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) involving French and Japanese Universities (University Tokyo, Tokyo Institute of Technology, Tohoku University). More information can be found on the website:
https://ipr.univ-rennes.fr/departement-materiaux-et-lumiere

Duration: *from* 01/02 /2024 *to* 31 /07 /2024
Gratification/salary: 570 (€/month)
PhD opportunity: Yes, funding for one PhD project is 100% secured

Interested candidate should contact :

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