Master 2 Internship

Title: Metal-to-insulator phase transition in Mott insulator studied by time-dependent terahertz spectroscopy

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Project:

There are numerous low-energy excitations (e.g., free carriers, phonons, magnons, Cooper pairs, etc.) in condensed matter lying in the terahertz (THz) spectral range (from 0.5 to 10 THz). Over the last two decades, ultrashort THz pulses have been used extensively, first to probe these excitations, then to directly excite and control them with the advent of more and more efficient sources in terms of intensity and duration [1]. On the other hand, modern technology requires new materials to improve both the speed and miniaturization of electronic components. As consequence, systems controllable and addressable on timescales below ~1ps, i.e. with a bandwidth in the THz range, are mandatory.

From that standpoint, Mott insulators are good candidates. They are part of the so-called strongly correlated systems corresponding to a class of materials where interactions between electrons play a key role in the appearance of ‘‘exotic’’ phases at equilibrium. This is particularly obvious when looking at the Mott transition, a metal-to-insulator transition, where each electron localizes to a single atomic site due to Coulomb’s repulsion. This Mott insulating phase, which is a cornerstone for strongly correlated materials, is present in many of them, including superconductors at high temperature. Although this transition is considered to be purely electronic, the question of a possible contribution from the electron-phonon interaction is still relevant [2]. It is worth mentioning that metal and insulator are usually good and bad reflector for THz radiations, respectively. Hence, the metal-to-insulator transition should result in a drastic change of the reflectivity or transmission in the THz frequency range.

During this Master 2 internship, we will study the metal-to-insulator transition induced by femtosecond optical or THz pulses in the V_2O_3 Mott insulator [2] to: (1) demonstrate that the metal-insulator phase transition in these materials would make it possible to achieve ultrafast photo-switches in the THz domain; (2) use two-dimensional THz spectroscopy to identify the role of phonons and electrons in this phase transition. This technique, consisting in measuring the THz response of a system excited by a pair of intense, phase-locked, THz pulses is well known for its ability to measure optical nonlinearities in the THz range as well as possible couplings between different degrees of freedom within various materials. This work will be carried out in collaboration with the team of Aline Rougier, at the ICMCB, for sample preparation, and the teams of Davide Boschetto (LOA, école Polytechnique) and Marino Marsi (LPS, Orsay), whose experience in the Mott insulator field is well known, for the study of their properties.

References:

1. T. Kampfrath et al., Nat. Photonics **7**, 680 (2013).
2. G. Lantz et al., Nat. Commun. **8**, 13917 (2017).