Real-time investigation of electron and phonon dynamics in bidimensional systems

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This seminar will be devoted to the investigation of electron and phonon dynamics along with their mutual interaction using the so-called pump-probe techniques. The characteristic time scale of these dynamics ranges in the order of femtosecond to picosecond. Therefore, a time resolution of the order of several femtoseconds is required to follow the evolution and the temporal behavior of atomic movements and their interaction with the electronic environment. In this perspective, pump-probe techniques are based on the use of two very short pulses, where one pulse is used to excite the sample and the other one to probe it. The probed signal is then detected as function of the pump-probe time delay. This general scheme can be used in a variety of settings. For example, the probe pulse could be a laser pulse of any wavelength, or an electron or X-ray pulse in order to detect a diffraction pattern for each time delay. Using a combination of several pump-probe configurations allows a deep understanding of the dynamics that take place in the sample as well as of the relaxation channels of the excess energy due to the pump pulse. More generally, these methods allow to understand the interactions between the different degrees of freedom of a crystal as electron, phonon and spin. Part of this seminar will be therefore devoted to the explanation and comparison of different pump-probe schemes, and the way in which a configuration must be chosen with respect to the desired investigation.

We have applied this technique to several types of materials, ranging from standard semiconductor to superconductors and nanostructures. In the second part of the seminar, we will focus particularly on electron and phonon dynamics in bidimensional materials. Actually, bidimensional systems have raised a lot of attention for the investigation of the underlying fundamental physics, as well as for potential applications related to nanotechnologies. We will discuss in more details two types of samples: graphene and $LaVS_3$. Graphene is a prototype for layered materials, and its investigation paves the way of a general understanding of the dynamics in bidimensional systems. On the other side, $LaVS_3$ is a member of the misfit layered chalcogenide family constituted by an alternate stack of LaS and VS_2 layers, characterized by the fact that the ratio between the size of the two elementary cells along one crystallographic direction is irrational. This leads to incommensurability and it opens the possibility of exploring the dynamics in case of aperiodicity along the aforementioned crystallographic direction. Moreover, in this investigation we will show some very recent results, which suggest the appearing of a photoinduced metal-insulator phase transition.