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Real-time Multiscale Dynamics in Condensed Matter Impacted by Laser Pulse

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There is a remarkable development in the field of ultra-fast time-resolved measurements in solids, in which a pump laser pulse is used to prepare the system into highly excited state, while the real-time induced electronic and/or structural dynamics is tracked with subsequent probe pulses. This adds a temporal dimension on top of energy and momentum. Nowadays, laser sources are able to deliver ultra-short pulses, typically of few femtosecond duration, thereby shorter than the time scale of atomic motions. They cover diverse spectral ranges, from THz to hard X-rays. Moreover, these pulses can be very intense, possessing a macroscopic number of photons and an extremely large instantaneous electric field. We are able to act strongly and timely on the course of atomic processes in a material. The cooperative interaction in solid state may lead to positive feedback, underpinning non-linear responsiveness and threshold effect. These photo-induced phenomena may trigger a spectacular transformation of the macroscopic state and functionality of a material (from insulating to metallic, from non-magnetic to magnetic, ⋯). Several experiments have provided new insights into the transformation of diverse materials, from the melting of charge or spin order in electron correlated system to cooperative molecular switching in the solid state. Such processes are intrinsically multiscale in time and space. The real-time experiments allow to disentangle in time the complex interplay between electronic and lattice degrees of freedom ("dissecting"the Hamiltonian). The multistep nature of the dynamical picture of photoinduced transformations in solids gives a nice illustration of multiscale phenomena where the description on one scale uses information from other scales. The possibility to highly select the involved collective atomic motions, and so to trigger the dynamics coherently, makes the transformation process particularly fast and efficient ("selecting"inside the Hamiltonian). These different aspects will be discussed, as the recent opportunity to directly act by strong electric field on the motion of electrons ("modifying"the Hamiltonian).

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