Attosecond electron dynamics in solids and tunneling junctions

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Attosecond science is based on the control of electron motion by the sub-optical-cycle field waveform of intense ultrashort laser pulses. In our lab, we apply the waveform control to investigate signatures of many-body electron dynamics of bulk solids, nanostructures and molecules on ultrafast time scales. In a first experiment, we show that excitons can play an important role in high-harmonic generation (HHG), the hallmark effect of attosecond science. In a thin GaN crystal, we find that the laser field induces a ponderomotive motion of the electron-hole pair, shifting the energy of excitonic states and causing resonances to appear in HHG. The resonances are accompanied by attosecond time delays. Our work opens up a new route to observe and control ultrafast bound-state dynamics and many-body effects in solids. In a second research avenue, we integrate a conventional scanning tunneling microscope (STM) with an ultrafast femtosecond laser. We demonstrate attosecond control of the electric current in the nanoscale STM tunneling junction using the waveform of the laser field. We also introduce a strong-field model which explains the physics of ultrafast STM currents. Our innovation promises simultaneous ångström and attosecond observations of plasmonic dynamics and ultrafast many-body phenomena in organic molecules.