Theoretical modeling of ultra-short pulse laser interaction with condensed matter

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Compared to continuous lasers, ultra-fast pulsed laser systems damage targets by localized effects before the heated electrons produced during the interaction have time to diffuse away. Optical and transport properties of dielectrics and semiconductors determine their applicability to laser optics and devices such as photodetectors, transistors, and light emitters. Therefore, it is of great importance to describe the microscopic processes taking place when these materials interact with an intense laser field. The governing microscopic processes occur within the time scale of the laser pulse so that the appropriate dynamical models have to explicitly account for them. We conduct theoretical investigation of the many laser breakdown effects in solid dielectric and semiconductor materials irradiated by high power, ultra-short laser pulses.

We derive a quantum kinetic theory for laser-induced breakdown in dielectric and semiconductor materials based on a generalized Boltzmann-type equation, including energy-drift and free-carrier absorption, anti-diffusion effects, interband excitation, Coulomb scattering, Auger recombination, thermal exchange with the lattice, *etc*. Higher intensities effects such as enhancement of ionization by transient bandgap renormalization and multiphoton and tunneling ionization are also considered.

The created model numerically predicts semiconductor material breakdown using computational codes parameterized by the incident laser pulse, including pulse width and peak intensity, and by the properties of the target materials, including band-gap, mobility, initial lattice temperature, dielectric constant, and effective mass of electrons. The energy spectra of the electron distribution function and the time dependence of the electron density are calculated to illustrate how different laser and material parameters influence the conduction electron dynamics. The electron distribution is used to evaluate average electron energy and temperature.