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Abstract for an Invited Paper
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High harmonic spectroscopy and time-resolved holography with photoelectrons

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I will describe recent applications of high harmonic generation for tracking attosecond dynamics of electrons and holes in molecules, and our hopes to use photo-electron spectra for the same purpose. Interaction of intense infrared laser light with atoms and molecules leads to rich dynamics which presents unique combination of quantum and classical physics, ripe with unusual opportunities for imaging dynamics of electrons and nuclei at the time-scale from about 100 attoseconds to a few femtoseconds. As the infrared laser field strips an electron from an atom or a molecule, the electron starts to oscillate in the laser field. Energy E of these oscillations scales linearly with laser intensity I and quadratically with wavelength λ and can easily exceed 100 eV for typical experimental conditions. Re-encounter of the electron with the parent ion during such oscillations leads to several effects, including (i) high harmonic generation, which results from recombination of the returning electron with hole left in the ion, and (ii) electron parent-ion diffraction and electron holography, which results from electron-parent ion scattering. These processes encode spatial and temporal information about the parent ion. Spatial resolution can be better than an angstrom, courtesy of the electron de-Broglie wavelength. Temporal resolution can exceed 100 attoseconds, thanks to the dependence of the returning electron energy on the instant of its return: this energy changes from almost zero to the maximum value in less than half of the laser cycle T (T=2.6 fsec for λ=800 nm). I will first introduce the basic ideas underlying time-resolved electron holography and show recent proof-of-principle experimental results. The bulk of this talk will focus on high harmonic spectroscopy. The properties of high harmonic radiation - amplitude, phase, and polarization - encode detailed information about attosecond to few-femtosecond motion of electrons and light nuclei in the molecule. Experimental challenge is to completely characterize the emitted radiation, measuring not only light intensity but also phase and polarization. Theoretical challenge is to interpret the experimental data, taking into account highly nonlinear, non-perturbative nature of laser-induced dynamics. I will illustrate the potential of the technique by showing several examples of successful joint experimental and theoretical efforts, which gave us sometimes unexpected insight into core rearrangement during strong-field ionization. I will also show results of using high harmonic generation to time-resolve electron tunnelling from atoms and molecules.