Photoionization dynamics in the presence of attosecond pulse trains and strong fields

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Attosecond light pulses have emerged as a powerful tool for probing fast dynamics occurring on the natural timescale of electrons. Experiments in this regime typically employ a precisely-timed combination of weak-field attosecond XUV pulses and strong-field femtosecond near-infrared (IR) laser pulses. The physics of such two-color interactions spanning widely different field strengths is quite rich and complex, even for simple electronic processes such as photo-ionization. The transient changes in the atomic and molecular structure and the quantum interferences between multiple excitation and ionization pathways determine the resulting electron dynamics.

We will present our experimental and theoretical results on the ionization dynamics in Helium atoms exposed to XUV attosecond pulse trains and moderately strong multi-cycle infrared (IR) fields. In our work, we obtain real-time measurement of the non-equilibrium structure of Helium and quantum interferences in photo-excitation pathways. The Floquet formalism is invoked to model the dressed atomic state as a manifold of Fourier components spaced by the laser frequency. We demonstrate that the ionization-yield oscillates due to interference between photo-excitation terms for various components of a given Floquet state. Phase of this interference signal is determined by the quantum phase difference between the respective transition matrix elements. We show that the intensity-dependent shifts in atomic structure modify the Floquet ionization channels and the associated interference phase. We extract this phase variation on femtosecond timescales and compare it with simulations. These results provide a comprehensive description of the two-color ionization dynamics and enable new schemes for the control of attosecond ionization and fragmentation processes in atoms and molecules.

Figure 1. (a) Spectrum of attosecond pulses relative to Helium atomic states (b) Calculated intensity dependent XUV photo-absorption cross-section (c) Measured phase of the two-color ionization process as a function of time-delay and instantaneous intensity (insets show TDSE simulation results for comparison).

1 N. Shivaram, H. Timmers, X.-M.Tong, and A. Sandhu, (Submitted)