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Understanding and Laser Control of Fano Resonances and Absorption in the Time Domain

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Quantum states and resonances associated with transitions between them are among the most fundamental elements of physics and chemistry. It is thus crucial to comprehensively understand states and resonances, not only in their (traditional) energy representation, but also from a time-domain perspective. This is especially important for time-dependent interactions such as atoms exposed to weak or intense laser fields. Here, I will present an experiment on the time-domain measurement and laser control of atomic resonances in helium atoms. Using extreme-ultraviolet (XUV) attosecond-pulsed light from high-harmonic generation (HHG), we were able to study Fano resonances arising in the double-excitation of both He electrons after absorption of a single XUV photon. The XUV absorption spectrum was recorded after the passage of the broadband HHG pulse through a He medium, as a function of time delay and intensity of a synchronized and coherently-locked near-visible (VIS) laser pulse. The modification of the original Fano absorption profiles during the interaction with the VIS laser pulse could be understood by considering a single time-domain phase control operation. As a result, the Fano resonance and the defining asymmetry (q) parameter could be mapped into a phase of the dipole response. This understanding also allows to create resonant amplification of light without inversion by a short-pulsed (impulsive) control operation, thus complementing the traditional dressed-state picture of electromagnetically-induced transparency. The same physical mechanism not only allows to measure quantum-state resolved phase changes of individual doubly-excited states in the control of two-electron wave packets, but also paves a route towards frequency combs at x-ray frequencies for precision spectroscopy of highly-charged ions.