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Theory of strong-field attosecond transient absorption

METTE GAARDE, Louisiana State University

Attosecond transient absorption (ATA) has recently received a lot of attention as a powerful approach to probing ultrafast electron dynamics. In particular, a number of experimental and theoretical works have investigated the transient absorption of attosecond extreme ultraviolet (XUV) pulses in systems exposed to a moderately strong, ultrafast, infrared (IR) laser pulse. ATA is based on the inherent synchronization between an attosecond pulse and the few-cycle IR pulse used to produce it, and provides insight into the energy transfer between electromagnetic fields and matter even at the sub-femtosecond time scale. In this talk, I will first briefly present an overview of the theoretical framework we have developed to describe the IR-assisted attosecond absorption, both at the single-atom level and at the level of a macroscopic number of atoms in a gas. This framework is based on a time-dependent approach to absorption; a process which is most often described in the frequency domain. In the second part of the talk, I will present recent results, several of which were obtained in collaboration with different experimental groups: (i) the appearance of light-induced structures in the absorption spectrum of an isolated attosecond pulse, (ii) the evolution of a resonant absorption line shape that can be caused by either microscopic or macroscopic effects, and (iii) the use of a fourth-order nonlinear coupling - in the absorption of the harmonics that constitute an attosecond pulse train – to define delay zero of the overlap between the XUV and the IR pulses.