Observation and Control of Attosecond Electron Dynamics in Atomic and Molecular Systems

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The availability of laser pulses with a duration down to about hundred attoseconds (=10^{-16} seconds) has raised the prospect of studying the motion of electrons on the timescales where this motion occurs in nature and to study how electron motion drives structural dynamics in molecular systems. Attosecond electron wave packet interferometry will be introduced as a technique that opens a new avenue for mapping out the wave functions of atoms and molecules and for following the ultrafast dynamics of electronic wave packets.

The next step in controlling quantum phenomena is to achieve control over electronic motion. It will be shown how the sub-cycle evolution of the electric field of light can be used to control a reaction through steering of the motion of electrons. Results are presented for the dissociative ionization of deuterium molecules ($D_2 \rightarrow D^+ + D$), where asymmetric ejection of the ionic fragment reveals that light-driven intra-molecular electronic motion prior to dissociation localizes the electron on one of the two D^+ ions in a controlled way. Extension of these results to electron transfer in complex molecules suggests a new paradigm for controlling photochemistry.