Attosecond physics – opportunities and challenges

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The natural time scale of electronic dynamics in atoms, molecules and solids is attoseconds. On this time scale, the propagation of electronic wavepackets and the "beating" of the coherent superposition of electronic eigenstates takes place. Electronic and atomic collisions physics, the central theme of the ICPEAC conference series, represents, in fact, one of the earliest explorations of attosecond dynamics. As recognized since the early days of quantum physics, the Coulomb field of a charged particle passing by an atom provides an ultrashort atto- to femtosecond half-cycle electromagnetic pulse.

Only with recent advances in ultrafast laser technologies featuring phase controlled few-cycle strong-field near infrared pulses as well as XUV pulses of attosecond close duration, the interplay and interrelation between photonic and collisional interactions with matter has begun to be explored in unprecedented detail. Moreover, with the availability of such electromagnetic "designer" pulses, the field of attosecond dynamics has dramatically expanded its scope well beyond the confines of collision physics. The dream of watching electronic dynamics, charge transfer, bond breaking and making, or electron ejection in real time is becoming reality even though many major challenges still lie ahead to fully realize this dream. Such attosecond chronoscopy allows a novel look at a wide range of fundamental photophysical and photochemical processes in the time domain, including Auger and autoionization processes, photoemission from atoms, molecules and surfaces, completing conventional energy-domain spectroscopy. Attosecond chronoscopy raises fundamental conceptual and theoretical questions as which novel information becomes accessible and which dynamical processes can be controlled and steered.

In this talk, we will focus on a few prototypical cases ranging from photoemission and non-linear response of rare gas atoms to the observation and control of electronic motion in nanoscale structures and in condensed matter.