Scientific Area	SA.2 Artificial Quantum Systems
Topic title	Wave packet interference experiments for the investigation of ultrafast dynamics and decoherence effects on the attosecond time scale
Main host institution	Institute of Physics, University of Freiburg www.physik.uni-freiburg.de/startdynamic-en?set_language=en
Supervisor/institution	Frank Stienkemeier, http://www.nanophysics.uni-freiburg.de/?set_language=en
Co-Supervisor/institution	Giuseppe Sansone http://www.atto.uni-freiburg.de/en/publications?set_language=en
Mentor[1]/institution	Stefan Willitsch coldions.chemie.unibas.ch/en/home/
Secondment institution	Sirah Lasertechnik http://www.sirah.com/

Topic description

Wave packet interferometry of electronic transitions using ultrafast, broadband lasers is a powerful technique to reveal the full quantum dynamics of an excited system. Coherent couplings and related decoherence and dissipation dynamics, as well as entanglement in many-body systems can be studied even down to attosecond time scales. In this project, based on our experience on wave packet interferometry and multidimensional coherent methods (L. Bruder, et al., Nat. Comm. 9, 4823 (2018), L. Bruder, et al., PCCP 21, 2276 (2019)), wave packet interferometry will be employed to study coherent couplings and related decoherence and dissipation dynamics, and, in particular to apply corresponding methods to attosecond pulses. These are created in the extreme ultraviolet and X-ray spectral range by the process of high-order harmonics generation in gases. A broadband electronic superposition of states can be achieved by irradiating atoms and molecules with such coherent broadband pulses. Quantum beating ranging from a few hundreds of attoseconds up to a few femtoseconds are expected for excitations in the extreme ultraviolet range. The observation of such beating is limited by decoherence effects, whose relevance strongly depends on the environment in which the system is placed. In particular, we will investigate the feasibility of experimental methods for the reconstruction (amplitude and phase) of the different components of an electronic wave packet created by an attosecond pulse. Using as target system helium atoms and helium clusters, we aim at investigating how the interaction with the environment affects the quantum beating between the different states and how decoherence effects depend on the size (number of atoms) of clusters.
The experimental approach for the analysis of the electronic wave packet will be based on the measurement of the photoelectron spectrum created by the single and multiple-photon ionization induced by an intense infrared pulse on the coherent quantum superposition of states (J. Mauritsson et al. Phys. Rev. Lett. **105**,053001 (2010)). Strategies for a complete read-out (amplitude and phase simultaneously) of the electronic wave packets will be developed.

Recommended applicant's profile

The applicant should be a highly motivated early stage researcher with a Master degree in Physics. A solid background in the atomic, molecular and optical physics as well as experience in laser and vacuum technology is needed.

[1] Mentor: The primary role of the mentors will be to identify and facilitate specific training objectives, advise on any problems faced by the ESR, including career matters with an external perspective and provide mediation in the case of disputes.

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