Scientific Area	spectroscopy on ultrafast coherent quantum dynamics
Topic title	Coherent spectroscopy of organic molecules
Main host institution	University of Freiburg: https://uni-freiburg.de/
Supervisor/institution	Frank Stienkemeier https://www.nanophysics.uni-freiburg.de/en
Co-Supervisor/institution	Klinovaja, Uni Basel, https://www.quantumtheory.unibas.ch/
Mentor[1]/institution	TBC
Secondment institution	TBC

Topic description

Coherent 2-dimensional spectroscopy and wave packet interference experiments to probe ultrafast coherent quantum dynamics on timescales down to attoseconds will be performed to characterize coherent couplings and related decoherence and dissipation dynamics, as well as entanglement in coupled molecular systems. Sequences of femtosecond laser pulses with specific carrier-envelope phase patterns will be produced to coherently excite electronic states of the sample. In an interferometric setup corresponding phase-sensitive detection is used to extract the couplings as well as the real-time dynamics. Samples will be either weakly interacting ensembles of atoms or cold cluster-isolated structures which will be produced in molecular or cluster beams at ultra-high vacuum conditions down to millikelvin temperatures. Detection will include fluorescence or ionization processes like mass-resolved ion time-of-flight spectra and photoelectron kinetic energy distributions.

Recommended applicant's profile

A PhD candidate should ideally have a strong foundation in quantum mechanics, ultrafast laser physics, condensed matter physics, and quantum optics. This field explores the control and measurement of quantum systems on ultrashort timescales, using femtosecond or atto-second pulses to study electronic and spin dynamics in atoms, molecules, and solid-state systems.

→ **Educational Background**: A Master's degree in Physics, Quantum Optics, Photonics - A solid grasp of quantum mechanics, statistical physics, electrodynamics, and nonlinear optics.

→ **Key Technical Skills**: experience with mode-locked lasers, chirped pulse amplification (CPA), and pulse shaping techniques. Familiarity with high-harmonic generation (HHG), atto-second pulse generation, and ultrafast pump-probe experiments, dispersion compensation, pulse compression, and nonlinear propagation.

→ **Quantum Coherence & Control:** Understanding coherent control techniques, Rabi oscillations, Ramsey interferometry, and light-matter interactions.

→ **Experimental & Measurement Techniques**: pump-probe spectroscopy, multidimensional coherent spectroscopy, transient absorption, and time-resolved photoemission spectroscopy

→ **Computational & Theoretical Skills:** Python, MATLAB for solving the time-dependent Schrödinger equation, density matrix evolution, and master equations.

→ **Theoretical Background**: quantum optics, many-body quantum systems, and decoherence processes

→ **Soft Skills:** analytical problem-solving skills, working in interdisciplinary collaborations.

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

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