Time-Domain Quantum Electrodynamics

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Abstract:
Ultrafast photonics enabled many dramatic advances in science most notably providing the ability to probe excited states of matter together with their evolution and coupling on the intrinsic timescales. It can be argued that the modern aim of ultrafast science is to use this understanding to enable dynamical control of condensed matter with light. The multi-terahertz (multi-THz, e.g. from 1 to 100 THz) band is particularly attractive for this purpose as it spans over many fundamental collective excitations in ordinary and quantum matter. Furthermore, while some information on a quantum nature of many-body interactions in condensed matter can be obtained from classical spectroscopic probes, it can be argued that it is the temporal monitor of the non-classicality of light that is poised to gain direct access to nontrivial correlations of fundamental degrees of freedom in matter. For this, an experimental ability to sample quantum THz fields should provide first steps toward a novel regime of experimental subcycle quantum physics.

Following the introduction, in the first part of the presentation I will make a brief overview of the femtosecond fiber laser technology, developed at the Univ. of Konstanz to enable ultrabroad detection of multi-THz fields. Next I will present a common method of electro-optic sampling, which enables subcycle probing of the optical field. Modifications of this method in our recent experiments enabled direct detection of vacuum fluctuations in the multi-THz frequency range [1-3]. Toward the subject of control, I will present a scheme [4], such that by utilizing a second nonlinear crystal and co-propagating excitation pulses one can locally modify the quantum statistics of the multi-THz vacuum state. Fluctuations of the modified vacuum, sampled with subcycle temporal resolution, can reveal substantial redistribution of noise above and below the bare vacuum level. The ability to detect bare and squeezed vacuum states is the foundation for a new approach to subcycle physics. Current experimental and theoretical work is underway to understand and improve the sampling of time-domain states of quantum light toward the goal of ultrafast quantum spectroscopy. I will conclude by discussing latest theoretical advances in this area.