Abstract

Ultrafast science 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 subcycle approach to quantum physics.

Following the introduction, in the first part of the talk I will make a brief overview of the femtosecond technology based on fiber lasers and demonstrate common method of electro-optic sampling, which enables subcycle probing of the optical field. Next, I will present our recent experiments on direct detection of vacuum fluctuations in the multi-THz frequency range using this technique [1-3]. Toward the subject of control, I will show that by utilizing a second nonlinear crystal and co-propagating excitation pulses, we 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 [4]. 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.

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[3] A. S. Moskalenko et al., Phys. Rev. Lett. 115, 263601 (2015).
[4] C. Riek et al., Nature 541, 376 (2017).