Probing quantum vacuum nonlinearities with high-intensity lasers

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Abstract:

The quantum vacuum is characterized by the omnipresence of quantum fluctuations of the underlying theory's particle degrees of freedom (in QED: electrons/positrons and photons) in the form of virtual processes.

As electromagnetic fields couple to charged particles, the fluctuations of these virtual particles can give rise to effective nonlinear interactions among electromagnetic fields, thereby invalidating one of the cornerstones of Maxwell's classical theory of electrodynamics, namely the celebrated superposition principle for electromagnetic fields in vacuum [1]. Being of a true quantum nature and having no tree-level analogue, these violations however are typically extremely tiny and suppressed parametrically with the electron mass, making them very elusive in experiment.

The planning and commissioning of various high-intensity laser facilities worldwide just now, suggests a particularly promising route towards the first verification of QED vacuum nonlinearity in a well-controlled laboratory experiment. Aiming at performing such a discovery experiment with state-of-the-art technology, all-optical signatures of QED vacuum nonlinearity seem most promising. This class of signatures encompasses vacuum fluctuation mediated interaction processes, where both the microscopic origin of the electromagnetic fields driving the effect and the signal itself are photons.

In this talk, we in particular focus on the feasibility of an experimental verification of QED vacuum nonlinearities with state of the art technology, using x-ray free electron and optical high-intensity lasers [2-4].

[1] W. Heisenberg and H. Euler, Z. Phys. 98, 714 (1936)
[2] F. Karbstein, H. Gies, M. Reuter and M. Zepf, Phys. Rev. D 92, 071301 (2015)
[3] H. Gies, F. Karbstein and N. Seegert, Phys. Rev. D 93, 085034 (2016)
[4] F. Karbstein and C. Sundqvist, Phys. Rev. D 94, 013004 (2016)