MAS20-2020-000063

Abstract for an Invited Paper
for the MAS20 Meeting of
the American Physical Society

Exploring the quantum vacuum with super-intense laser pulses[1]

WENDELL T. HILL, III, University of Maryland, College Park

Multi-petawatt laser pulses of short duration have placed us at the threshold of a new era where novel experimental investigations of nonlinear aspects of electrodynamics – quantum electrodynamics (QED) – will be possible. Fundamental tests of QED from the photon side and its intimate coupling to the quantum vacuum are on the horizon. The very essence of the vacuum is pleached with a fundamental tenet of quantum physics – quantum fluctuation – virtual particles and antiparticles (e.g., electron-positron pairs) fluctuating into and out of existence. Quantitative measurements of virtual particles not only will challenge calculations from the 1930s, they will set strenuous limits for add-ons to the Standard Model. Photons are unique probes in that they are uncharged and their Bosonic nature allows unlimited numbers of them to be collocated within an arbitrarily-small volume, at least classically. Quantum mechanics makes a different prediction. As the intensity increases, the linear response of light propagating in a physical vacuum, as Maxwell equations demand, gives way to a nonlinear response. Post-Maxwellian theories, such as QED, allow virtual pairs to mediate an interaction between photons that can be viewed, to some extent, as light propagating through material. At high enough intensity the quantum vacuum will break down, inducing real pairs to emerge. The critical intensity (I_{cr}) for breakdown, the so-called Schwinger limit, is $\simeq 2 \times 10^{29}$ W/cm^2. Even though I_{cr} is beyond current technology, there are fundamental features of the quantum vacuum that can be explored at substantially lower intensities. In this talk we will explore some of these ideas, focusing on the new physics that can be learned, and the tools and conditions required.

[1] National Science Foundation