UNL Department of Physics and Astronomy presents:

Precision Measurement of the Quantum Vacuum with Multi-Petawatt Lasers

PRESENTED BY
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ABSTRACT

Multi-petawatt laser pulses of short duration have placed us at the threshold of a new era where novel experimental investigations of quantum aspects of electrodynamics – quantum electrodynamics (QED) – will be possible. Tests of QED involving nonlinear photon-photon interactions, and the intimate coupling between nonlinear QED and the quantum vacuum, which have never been possible are on the horizon. The very essence of the vacuum is entangled 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 the linearity of Maxwell equations suggests that their Bosonic nature would allow unlimited numbers of them to be co-located within arbitrarily small volumes. Classically, this can be realized by raising the peak intensity of a focused laser pulse through a combination of increasing the pulse energy and decreasing its duration. Quantum mechanics makes a different prediction as the intensity increases, however. The linear response gives way to a nonlinear behavior. Higher-order field terms of post-Maxwellian theories, such as QED and Born-Infeld, allow virtual matter-anti-matter pairs to mediate an interaction between photons that can be viewed, to some extent, as light propagating through material. At high enough intensities the quantum vacuum is predicted to break down into real matter-antimatter pairs. The critical intensity (I_{cr}) for breakdown, the so-called Schwinger limit, is $\simeq 4\times10^{29}$ 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. The intensity at which quantum nonlinear effects become unambiguously discernible is estimated to occur in the neighborhood of 10^{23} - 10^{25} W/cm^2. 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.

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