Towards Solid-Density Electron Beams, Extremely Dense Gamma-Ray Pulses and Strong-Field QED in Beam-Plasma Interaction

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When an electron beam impinges onto an overdense plasma, the beam self fields are reflected at the plasma surface. The interaction of the beam with the reflected fields, also called near field transition radiation, can result in several key processes: the beam experiences a strong focusing effect and emits dense pulses of gamma rays through an inverse Compton scattering (ICS) process with the transition radiation. For high-energy high-density beams, this interaction can reach strong-field QED conditions, where the electric field experienced in the beam rest frame exceeds the Schwinger critical field $E_{\text{Schwinger}} = 1.8\times10^{23}$ V/m. Such beam-plasma collisions offer a promising path to probe strong-field QED in controlled conditions, with an automatic overlap between the beam and the fields, free of the jitter inherent to multi-beam schemes. We will show, through theory and simulations, that this single-beam setup [1] can achieve interaction conditions similar to those envisioned in beam-beam collisions [2], but in a much simpler and more controllable way.

On the experimental side, with the current beam parameters of the FACET-II facility at SLAC, we are studying this interaction when passing through multiple thin plasma layers of solid density, which strongly reinforce the effect and allow to self-focus the beam and thus to emit brighter gamma rays, with conversion efficiencies exceeding 10% [3]. This is the purpose of the E332 experiment [1]at the SLAC National Accelerator Laboratory. During the beam-plasma interaction, the beam is focused each time it passes through a vacuum-plasma boundary leading to an increase of beam final divergence, a shift of the waist and a smaller beam size. We will present the latest experimental results by looking at the modified beam parameters after the interaction of the 10-GeV electron beam with a specifically-designed multifoil target that acts as multiple thin plasma layers. We furthermore report on simulations of realistic electron beam and plasma configurations for FACET-II that give rise to focusing of electron bunches that we compare to the experimental data. Finally, we will discuss how the beam-multifoil interaction can be leveraged to self-focus the beam to solid density and to provide a first laserless investigation of strong-field QED.

References

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