Probing Strong Field QED in beam-plasma collisions

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Strong Field Quantum Electro-Dynamics (SFQED) is a regime where charged particules experience very strong electro-magnetic (EM) fields leading to extreme quantum phenomena like Breit Wheeler pair generation or polarization of quantum vacuum [1]. The presence of quantum effects in these light-matter interactions becomes non negligible when the electric field experienced by charged particle in its rest frame is of the order of magnitude of the Schwinger field $E_{\text{Schwinger}} = 1.8 \times 10^{23}\,\text{V/m}$. This regime is still barely explored from an experimental point of view due to the need of extreme values of EM fields.

Several setups were proposed to reach such high values of EM fields : collision of two high-intensity laser pulses, collision of a laser pulse and an electron beam [2] and recently, collision between two highly compressed and focused electron beams [3]. In this last scenario, one uses the fact that each electron beam is a source of high EM fields. While the beam doesn't experience its own self fields, during the collision electrons from the first beam experience EM fields from the second beam and vice versa.

Here we propose a new concept to probe SFQED where a beam collides with a high-density plasma. The beam self fields are reflected and interact with the incoming beam as if the beam was experiencing fields coming from an "image" beam. This setup is particularly easy to implement experimentally since we only need one beam saving us from aligning two micrometer-scale beams. We demonstrate that we may be able to reach EM fields exceeding $E_{\text{Schwinger}}$ in the electron rest frame, thus creating copious amount of electron-positrons pairs that could be measured experimentally. We discuss several physical processes taking place during the beam-plasma collision such as field ionisation when starting from a solid state, plasma transparency when the bunch length is too small, excitation of a blowout cavity in the bulk of the plasma for overdense electron beams, and the influence of the beam shape on reflected fields.

References

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