Electron-Positron-Photon Cascades in Strong Electromagnetic Fields and Matter: A Path Toward Laboratory Pair Plasma Production

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The creation of relativistic electron-positron pair plasmas in the laboratory is a long-standing objective in high-energy-density physics, with direct implications for extreme plasma astrophysics [1]. Electromagnetic (EM) cascades are among the most promising pathways toward this goal. This talk will review recent theoretical progress in our understanding of these cascades.

I will first discuss EM avalanches, also known as self-sustained cascades, which are particularly interesting for pair plasma production as they give rise to an exponentially growing number of produced pairs. I will first focus on the recent analytical framework we have developed to estimate the growth rate of such cascades [2]. The conditions needed to trigger avalanches at multi-petawatt laser facilities will be discussed, in particular regarding the minimum laser intensity required to trigger an avalanche [3].

I will then discuss EM showers developing from the interaction of high-energy electron beams with either ultra-high intensity laser pulses or matter. I will present the analytical framework recently developed [4] to treat showers in strong background EM fields and show how it can be extended to account for EM showers in matter [5]. The divergence, density, and characteristic dimensions of the pair jets escaping a slab of material irradiated by a GeV electron beam will be discussed, and a simple criterion for pair plasma production is derived as a function of the electron beam properties.

All analytical predictions will be thoroughly benchmarked against particle-in-cell simulations with SMILEI [6] or Monte-Carlo simulations with Geant4.

References

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