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Near QED-regime of laser–plasma interaction

Liangliang Ji

Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai 201800, China

Laser-plasma interaction in the near QED-regime (10^{22}-10^{25}W/cm^2) exhibits exotic features other than relativity. While this regime is not yet accessible in laboratories at the moment, particle-in-cell (PIC) simulation provides the most powerful tool to explore the new physics therein. We did full three-dimensional PIC simulations to systematically investigate the interaction process at such extreme intensities and found that radiation of electrons in the laser field fundamentally changes the particle dynamics. First, electrons transfer a significant fraction of their energy to radiation, producing MeV Gamma-photons at a very high efficiency. Thus the laser energy absorption channel is notably tuned in a way that electrons get less portion of energy from the laser while photons obtain more, as the laser intensity rises. Second, electrons experience strong feedbacks due to radiation reaction (RR) force. We show that the RR force could be strong enough to compensate for the expelling laser ponderomotive force so that electrons can be trapped inside the laser pulse instead of being scattered off. This anomalous trapping mechanism leads to a dense plasma bunch confined within the most intense region of the laser beam, resulting in an observable effect in potential experiments in the near future. Further, thoese confined electrons fiercely emit gamma-photons at efficiencies up to 35%. Therefore laser-plasma interaction in this regime automatically becomes an ultra-bright gamma-ray source-a crucial approach for several key disciplines, e.g., nuclear photonics, vacuum QED effects etc. The possibility to observe RR effect at 10^{22}W/cm^2 intensity level will also be discussed.

References

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Figure 1. Electrons are trapped within the laser pulse due to radiation reaction (RR) from the gamma-photon emission. Their trajectories inside an extremely strong laser field are shown in blue (no RR) and red (with RR).