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QED-induced opacity and dense polarized positrons and electrons generation in laser-solid interaction

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Many works have reported that dense gamma-ray photons and electron-positron pairs can be effectively generated from laser-solid interactions in the strong-field quantum electrodynamics (QED) regime with 10-PW and 100-PW laser pulses. In particular, such works with via a conventional laser-solid experimental setup that a linearly polarized laser pulse irradiates a solid target arouse significant interests, because this setup is generally adopted in current laser-solid experiments and expected to commonly use in future 100-PW laser-solid experiments aiming at various applications. Usually, the preplasma ahead of the target is ignored since the relativistic transparency and laser hole boring make a given relativistically- underdense preplasma more transparent with the enhanced laser intensity. Our QED-PIC shows that such preplasma becomes opaque when the QED effects is considered, where avalanchelike QED cascades occur and most laser energy can be converted to photons and pairs [1].

Whether the created positrons and electrons are polarized has not yet been reported, limiting their potential applications and hindering the insight investigation of 100-PW-laser solid-plasma interactions. By a recently developed QED particle-in-cell (PIC) code [2] including electron/positron spin and photon polarization effects [3], we further investigate the conventional laser-solid setup. We find [4] that once the pair yield becomes appreciable with the laser intensity reaching 10^{24} W/cm2, the pairs are obviously polarized as a function of the deflection angle. Around 30 nC positrons can acquire >30% polarization degree. The polarization can reach 60% at some energy spectra. The angle-dependent polarization is attributed to the asymmetrical laser fields formed near the plasma skin layer, where radiative spin-flip and radiation reaction play significant roles. The polarization mechanism is robust because a skin layer can be certainly formed in the conventional laser-solid setup. Therefore, generation of polarized positrons/electrons should be ubiquitous in future 100-PW-class laser-solid experiments even aiming at other applications, which suggests that electron/positron spin and photon polarization effects should be considered. Without the two effects, our simulation preliminarily shows that the positron yield will be overestimated by about 7%.

References

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