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Numerical investigation of high-energy photon emission in double-layer targets with particle-in-cell codes

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High-energy photon emission can occur during the interaction of ultra-intense ($> 10^{18}$ W/cm^2) lasers with plasma obtained from the ionization of a suitable target. This emission of electromagnetic radiation follows the generation of relativistic electrons during the interaction itself. Indeed, relativistic electrons can produce high-energy photons (keV-MeV energy range) thanks mainly to two processes. One is synchrotron-like emission mediated by the electromagnetic fields present in the plasma and named Non-linear Inverse Compton Scattering (NICS) when electrons scatter off an ultra-intense ($\gg 10^{18}$ W/cm^2) laser pulse [[1]]. The other is bremsstrahlung emission, mediated by the atoms and ions inside the target [[2]]. Studying these phenomena is of great interest to have a complete picture of laser-plasma interaction and develop laser-based high-energy photon sources for applications. Accurate tools to study laser-driven high-energy photon emission are Particle-In-Cell (PIC) methods coupled with Monte Carlo (MC) modules to simulate photon emission [[3], [4]]. The open-source PIC code SMILEI [[5]] offers an MC package of this kind to simulate NICS, while a module for bremsstrahlung simulation is not yet available in this code. This contribution presents the results of simulation aimed to investigate NICS and bremsstrahlung emission in the case of laser interaction with a double-layer target (DLT) made of a low-density nanostructured carbon foam deposited on a thin solid substrate. DLTs can enhance the production of fast electrons with their nanostructured layer [[6]] and, thus, are interesting for boosting the consequent photon emission processes. An extensive set of 2D simulations to explore NICS in DLT has been performed with SMILEI. In particular, after a preliminary benchmark with other PIC codes capable of simulating NICS (EPOCH [[7]], WarpX [[8]], and PIConGPU [[9]]), SMILEI has been used to study the properties of this emission and assess the role of the target. The results show the relevance of the DLT and its capability to tune the emission, making DLTs worthy of investigation in future experimental campaigns. To support the possible development of a bremsstrahlung module in SMILEI, the modelling of this emission in laser-plasma scenarios can be further investigated. To this scope, this contribution presents the rationale of different simulation approaches for bremsstrahlung based on currently available open-source tools and applied to DLTs. These approaches consist in using the bremsstrahlung package in the PIC code EPOCH and coupling PIC codes, including SMILEI, with the MC code GEANT4 [[10]]. Although these simulation tools present some open problems that a future SMILEI implementation could solve, their results show that DLTs can enhance the high-energy bremsstrahlung emission compared to a single solid layer and enable control of the emission itself.

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