Efficient Gamma-Ray Generation by a Single-Cycle Tightly-Focused Laser

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The availability of multi-petawatt lasers offers, in principle, new possibilities for investigating various effects [Nakamura 2012, Ridgers 2012, Lezhnin 2018], including ɣ-photon and electron-positron pair generation. Approximately two decades ago, the λ^3 regime was envisioned by G. Mourou *et al.* [Mourou 2002, where a single-cycle laser pulse is focused down to the diffraction limit level. At the λ^3 regime, one can obtain the maximum intensity that a laser of a certain power can offer. In [Hadjisolomou 2021, Hadjisolomou 2022], we develop a computational method where a near-single-cycle laser pulse is focused by an $f1/3$ parabola to a spherical-like volume of sub-wavelength diameter and then bonded into particle-in-cell simulations. In the simulations, the laser interacted with a mass-limited foil, where a multi-parametric scan of the interaction includes the foil thickness and electron number density, resulting in obtaining the optimal parameters for γ-photon generation. Other variables were the laser power and the laser polarisation, revealing that for γ-photon generation in the λ^3 regime, the radial laser polarisation is optimal, versus the azimuthal polarisation that strongly suppresses the ɣ-photon yield. The power-scaling for radial polarisation leads to a scaling law, where the effect of electron-positron generation is also indicated. As a final step, the results from our PIC simulations are used in Monte-Carlo simulations [Kolenaty 2022], where the interaction of laser-generated particles with high-Z targets used as a secondary target is revealed. The Monte-Carlo simulations suggest the generation of an even higher number of electron-positron pairs than what initially PIC predicts, along with the generation of unstable nuclei originating from photonuclear interactions.