Optimal Channel for Creating Dense Pair Plasmas with Multi-PW Lasers

C P Ridgers[1]

[1] *Department of Physics, York Plasma Institute, University of York, York, UK. Contact Phone: +447908776980*
Contact Email: chritopher.ridgers@york.ac.uk

Relativistic electron-positron (pair) plasmas are ubiquitous in the environments of extreme astrophysical objects but have proven difficult to create at sufficient density that they exhibit collective effects in the laboratory. High-intensity lasers provide an ideal platform for creating dense relativistic pair plasmas due to the strong accelerating electromagnetic fields. These fields cause electrons in the plasma to radiate >MeV photons, which can convert into electron-positron pairs in the strong fields in the plasma. The strong field gradients mean that these processes can occur in a compact spatial region and in a very short time leading to a high-density pair plasma. The optimal channel for creating a dense pair plasma is known at intensities achievable by current PW high power/intensity laser pulses (10^{21} W/cm^2) – the plasma electrons emit >MeV photons by bremsstrahlung on collision with ions, and these photons create pairs in the electric field around these ions (or un-ionised atoms in the target) by the Bethe-Heitler process. At intensities achievable by >10 PW lasers (>10^{24} W/cm^2), the optimal channel is photon emission by nonlinear Compton scattering of plasma electrons in the laser's electromagnetic fields followed by multiphoton Breit-Wheeler pair production in these fields. We will show that over a wide range of intensities achievable by upcoming multi (1-10) PW lasers (10^{22}–10^{24} W/cm^2), however, a new channel is optimal: >MeV photons from nonlinear Compton scattering producing pairs via the Bethe-Heitler process. Due to the decreased mean-free path of this process compared to bremsstrahlung-Bethe-Heitler, this channel can lead to pair plasmas >10 times denser than currently achievable and should be the experimental approach of choice for generating dense plasmas with multi-PW lasers.