Probing relativistic astrophysical shocks by extreme-intensity lasers

M. Lobet[1], C. Ruyer[1], A. Debayle[1], E. d'Humières[2], M. Grech[3], M. Lemoine[4], L. Gremillet[1]
[1]*CEA, DAM, DIF, F-91297 Arpajon, France*
[2]*CELIA, UMR 5107, Université de Bordeaux-CNRS-CEA, 33405 Talence, France*
[3]*LULI, UMR 7605, CNRS-CEA-Ecole Polytechnique-Université Paris VI, Ecole Polytechnique, 91128 Palaiseau, France*
[4]*Institut d'Astrophysique de Paris, CNRS, UPMC, 98 bis boulevard Arago, F-75014 Paris, France*

Collisionless shocks between counter-streaming astrophysical flows are the subject of extensive research [1]. Laser experiments on such phenomena will allow to benchmark numerical predictions [2], yet their realization remains highly challenging [3]. This is particularly so for the study of electron-positron (e^--e^+) instabilities due to the difficulty of creating dense enough pair plasmas. Current investigations rely on pair production in thick high-Z targets via the Bethe-Heitler annihilation of Bremsstrahlung photons [4]. Nonetheless, recent works have pointed out the possibility to generate dense electron-positron plasma jets via quantum electrodynamic (QED) processes mediated by ultra-intense (>10^{23} W.cm^{-2}) laser pulses [5].

Here, we explore a colliding-plasma concept exploiting the extreme fields envisioned on future short-pulse, large-scale (~100kJ, 60fs) laser facilities [6]. Using QED-particle-in-cell simulations, we present the first self-consistent study of the collective interaction between two laser-produced ultra-relativistic e^--e^+ jets, a configuration similar to that occurring in termination shocks of pulsar winds [7]. Filamentation instabilities are found to build up a >2×10^6T magnetostatic barrier, able to thermalize a significant fraction of the bulk jet energy and trigger a short-lived (<50fs) collisionless shock. The associated gamma-ray generation and subsequent ion-ion collision are analyzed in detail.

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