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Electron-Positron Jets Created by Ultra-Intense Lasers

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For decades, positrons could only be produced in the laboratory using either radioactive sources or electron accelerators. Recently, it has been shown that ultra-intense laser pulses ($I\lambda^2 > 10^{19}$ W$\cdot\mu$m^2/cm^2) incident on solid targets can also provide copious positrons ($\sim 10^{10}$) via pair production.[1] While time-integrated energy spectra of the positrons have been experimentally observed, the exact character of the relativistic positron-electron (e^+-e^-) beam is only now becoming clear. The detailed physics behind the generation and acceleration of the positrons will be presented. Particle-in-cell simulations using the hybrid code Lsp[2] of the entire process, from laser-generated electrons to positrons ejected from the solid target, compare favorably to observed energy distributions. Using this benchmark as a base, the actual spatial-temporal energy and density profiles of the ejected positron (and electron) beam are investigated, where space charge is found to be an important effect in determining the properties of this "jet." In particular, this jet is found to consist of a leading, dense electron bunch that is immediately followed by a nearly charge-neutral e^+-e^- beam. In addition to exploring the exciting possibility of using this source to create e^+-e^- plasmas, injection of this jet into a low-density plasma behind the target reveals a strong plasma wakefield effect that dominates the beam-plasma interaction. This, in turn, suggests ways to use this jet as a source of positrons for small-scale laser wakefield accelerator research. This work was performed in collaboration with H. Chen, A.J. Link, and D.R. Welch under the auspices of the U.S. DOE under Contract DE-AC52-07NA27344 and LDRD 10-ERD-044.

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[2] D.R. Welch, et. al, Phys. Plasmas **13**, 063105 (2006).