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LAWRENCE LIVERMORE NATIONAL LABORATORY

LASER PRODUCED RELATIVISTIC ELECTRON-POSITRON PAIR PLASMA JET

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High-flux jets of positrons with temperatures of MeV have recently been produced in experiments at high-intensity laser facilities at Lawrence Livermore National Laboratory and the Laboratory for Laser Energetics [1-2]. These experiments may lead to the production of relativistic electron-positron "pair" plasmas, enabling direct laboratory experiments on a state of matter otherwise found only in exotic astrophysical systems such as active galaxies, quasars, gamma ray bursts and black holes – or shortly after the Big Bang. This breakthrough experiment opens up a major area of high-energy-density laboratory plasma astrophysics identified in recent assessments: "Because of the unity mass ratio, pair plasmas behave differently from electron-ion plasmas in many respects. It is extremely desirable to study pair plasmas in the laboratory, both for the fundamental physics and for astrophysical applications." [3].

Illuminating a millimeter-scale gold target with a high-intensity (>10^18 Watts/cm^2) laser pulse creates a quasi-monoenergetic conical jet of electrons and positrons with a ~20 degree divergence angle [2]. The jet particles have energies up to 20 MeV and a thermal temperature of ~1 MeV. About 0.1% of the laser energy is converted to positrons. The particle energies and divergence angles are controlled by varying the laser and target conditions. This new positron source exploits unique capabilities of energetic short-pulse lasers. Experiments to date have used 100 - 1000 J lasers and simple gold disks to produce positron jets. Upcoming experiments will use new, multi-kilojoule, short-pulse laser systems such as Omega EP and NIF ARC, and more advanced target designs to optimize the relativistic pair production. These experiments should create the first relativistic high-density pair plasmas in the laboratory [4] - a completely novel system enabling detailed study of some of the most exotic and energetic systems in the universe.

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[1] Chen, Hui, *et al.*, Phy. Rev. Lett. **102**, 105001 (2009)
[2] Chen, Hui, *et al.*, Phy. Rev. Lett. **105**, 015003 (2010)
[3] Rosner, R. *et al.*, "Research Opportunities in Plasma Astrophysics" (http://www.ppl.gov/conferences/2010/WOPA). Also see Betti, R., *et al.* "Advancing the Science of High Energy Density Laboratory Plasmas", (http://www.science.doe.gov/ofes/FESAC-HEDLP-REPORT.pdf, 2009)
[4] Chen, Hui, *et al.*, High Energy Density Physics, in press (2011)