Laser Wakefield Acceleration of Electrons Demonstrated

When most of us think of particle accelerators we think of a huge machine. But there is a push to develop more compact, cost-effective particle accelerators for high-energy physics, and research groups around the world have been working toward this end. One group has now demonstrated a way to excite electrons so that these compact sources may be more practical.

French researchers from the Centre National De La Recherche Scientifique (CNRS), the Commissariat A L'Energie Atomique (CEA), and a U.K. researcher from Blackett Laboratory have accelerated electrons injected in a plasma wave generated by a laser wakefield mechanism. "The significance of this is that it opens a way for using femtosecond lasers for acceleration of electrons in a plasma," says Chan Joshi, a professor in UCLA's electrical engineering department, who specializes in plasma physics and quantum electronics.

The researchers sent a short laser pulse (400 fs, 1.06 μm, Ti:Sapphire *Continued on page 10*

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oscillator with Nd:Glass amplifiers) through a low-density, fully ionized helium gas, at about 0.1–1 Torr, which excites waves of positive- and negative-charged regions, and generates a high electric field. The phenomenon, which has been demonstrated before, is named laser wakefield because of the "wake-like" waves that result. In 1996, two groups—one at the Univ. of Texas and the other at Ecole Polytechnique in France—optically measured the laser wakefield effect.

Although the effect has been demonstrated, acceleration had not occurred until the recent experiment. The CNRS group focused the laser on the gas, and at the same time injected a 3-MV electron beam into the plasma. The electron particle then rode the plasma waves and increased in velocity. The result was an electric field of 1.5 GV/m, and an energy gain as high as 1.6 MeV.

While the energy gain is not nearly as high as what is produced in larger accelerators such as CERN (at about 80 GeV electrons) on the France/Switzerland border, Francois Amiranoff (Laboratoire pour l'Utilisation des Lasers Intenses) says that this latest development is a positive step toward generating acceleration with lasers and plasmas. "We cannot say that this will someday replace present-day accelerators, but we have demonstrated the principle with wakefield. We now need to learn how to guide these high-intensity laser pulses over distances of 10–20 cm. If we can do that we could easily get GV energies with present-day lasers."

This field began over 15 years ago, and currently there are several schemes using lasers for accelerating electrons in a plasma, including "beat-wave" (where two laser beams are sent through low-density plasma) and "self-modulated laser wakefield" (where one laser beam is sent through a high-intensity plasma). But now that proof-of-principal has been demonstrated for the laser wakefield, talk of future applications may intensify.

"With the very high energies we hope to someday achieve, the main application will be in particle physics at moderate energies (MeV to GeV)," says Amiranoff. ◆