SLAC NATIONAL ACCELERATOR LABORATORY

Science Highlight
Accelerating Particles with Plasma

Scientists have shown that a promising technique for accelerating electrons on waves of plasma is efficient enough to power a new generation of shorter, more economical accelerators. This could greatly expand their use in areas such as medicine, national security, industry and high-energy physics research.

A Milestone in Plasma Wakefield Acceleration

With this achievement, researchers hit a milestone in demonstrating the practicality of plasma wakefield acceleration, a technique in which electrons gain energy by essentially surfing on a wave of electrons within an ionized gas.

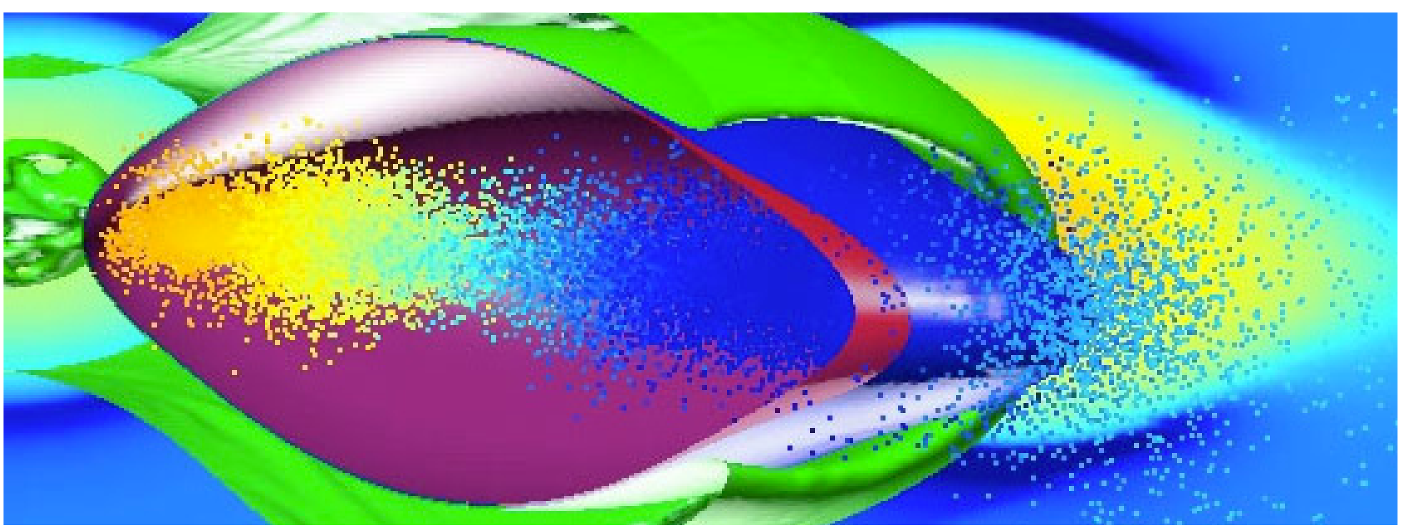
Using SLAC's Facility for Advanced Accelerator Experimental Tests (FACET), they boosted bunches of electrons to energies 400 to 500 times higher than they could reach traveling the same distance in a conventional accelerator.

Just as important, energy was transferred to the electrons much more efficiently than in previous experiments. This crucial combination of energy and efficiency had never been reached before. The results were published in *Nature*.

"Many of the practical aspects of an accelerator are determined by how quickly the particles can be accelerated," said SLAC accelerator physicist Mike Litos, lead author of the paper. "To put these results in context, we have now shown that we could use this technique to accelerate an electron beam to the same energies achieved in the 2-mile-long SLAC linear accelerator in less than 20 feet."

Surfing on a Wave of Electrons

Plasma wakefields have been of interest to accelerator physicists for 35 years as one of the more promising ways to drive the smaller, cheaper accelerators of the future. In a 2007 paper, researchers announced they had accelerated electrons in the tail end of a long electron bunch from 42 billion electronvolts to 85 billion electronvolts, causing a great deal of excitement in the scientific community.



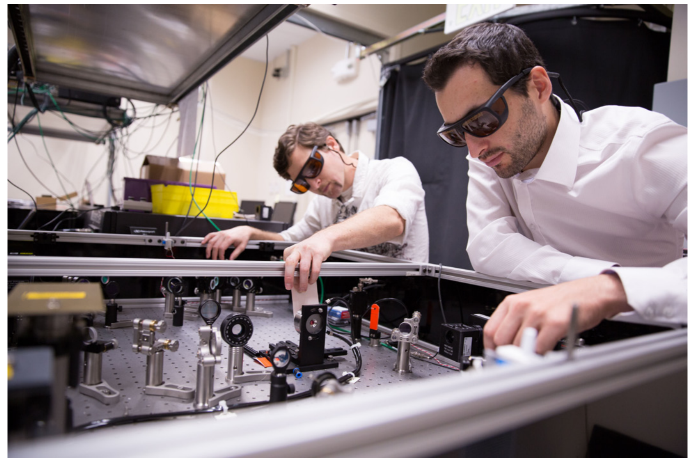
This simulation depicts two electron bunches – containing 5 billion to 6 billion electrons each – that were accelerated by laser generated plasma inside an oven of hot lithium gas during experiments at SLAC.

SLAC National Accelerator Laboratory
2575 Sand Hill Road
Menlo Park, CA 94025–7015

slac.stanford.edu

However, fewer than 1 billion of the 18 billion electrons in the pulse actually gained energy and they had a wide spread of energies, making them unsuitable for experiments.

In this experiment, researchers from SLAC and the University of California, Los Angeles, sent pairs of electron bunches containing 5 billion to 6 billion electrons each into a laser-generated column of plasma inside an oven of hot lithium gas. The first bunch in each pair was the drive bunch; it blasted all the free electrons away from the lithium atoms, leaving the positively charged lithium nuclei behind – a configuration known as the "blowout regime." The blasted electrons then fell back in behind the second bunch of electrons, known as the trailing bunch, forming a "plasma wake" that propelled the trailing bunch to higher energy.

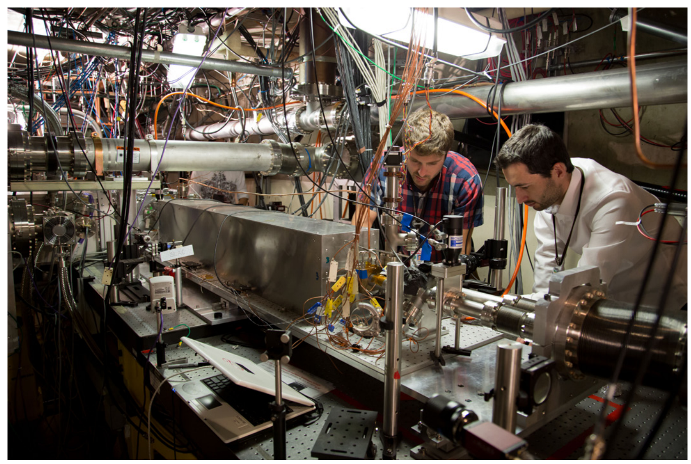


SLAC researchers use a laser table at FACET to create a plasma used for accelerating electrons to high energies in a very short distance.

An Efficient, Viable Technology

Previous experiments had demonstrated multi-bunch acceleration, but the team at SLAC was the first to reach the high energies of the blowout regime, where maximum energy gains at maximum efficiencies can be found. Of equal importance, the accelerated electrons wound up with a relatively small energy spread.

"Reaching the blowout regime with a two-bunch configuration has enabled us to increase the acceleration efficiency to a maximum of 50 percent – high enough to really show that plasma wakefield acceleration is a viable technology for future accelerators," said Mark Hogan, SLAC accelerator physicist and one of the principal investigators of the experiment.



SLAC researchers monitor pairs of electron bunches sent into a plasma inside an oven of hot lithium gas at FACET.

The plasma source used in the experiment was developed by a team of scientists led by Chandrashekhar Joshi, director of the Neptune Facility for Advanced Accelerator Research at UCLA. The UCLA and SLAC groups have been at the forefront of research on plasma wakefield acceleration for more than a decade.

Citation: M. Litos et al., Nature, 6 November 2014 (10.1038/nature13882)

For More Information

SLAC Office of Communications
communications@slac.stanford.edu

104599-01-2015