Research Highlights

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Subject Category: Plasma physics

Riding the plasma wave

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Abstract

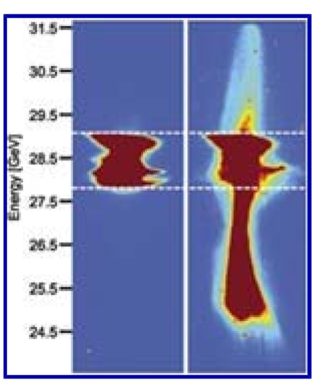
A new record has been set for the acceleration of particles in a plasma wakefield — an energy gain of more than 2.7 GeV in a 10-cm-long device.

Pushing the energy frontier is not easy. But plasmas, which are capable of generating large focusing and accelerating fields, might offer a solution. Beam–plasma and laser–plasma tests have shown promising results, and more recently beam-driven wakefield accelerators have been used to demonstrate acceleration and focusing of both electrons and positrons in metre-length plasma modules. The latest research, carried out by Mark Hogan and colleagues[1] (#B1) at the Stanford Linear Accelerator (SLAC) and reported in *Physical Review Letters*, goes even further and marks a crucial step along the path towards future high-energy machines.

The team have developed a plasma-wakefield accelerator based on a highly focused, ultrarelativistic electron beam from the SLAC linac. The beam, in bunches of more than 10^{10} electrons of energy 28.5 GeV, is used to generate a plasma inside a lithium vapour, and then to drive a large wave within that plasma. If the resulting plasma is sufficiently dense, a critical 'blowout' regime is reached in which the plasma electrons are expelled from the beam volume, leaving behind a pure ion column. These electrons return one-half plasma period later and congregate behind the main body of the driving electron bunch, creating a large-amplitude plasma wakefield that accelerates particles at the rear of the pack.

The transverse profile and the energy spread of the beam before and after the plasma are monitored, and the acceleration and focusing achieved is impressive. Particles at the rear of the bunch are accelerated to an energy about 2.7 GeV larger than their incoming energy (Fig. 1). This corresponds to an accelerating gradient of 37 GeV m^{-1} — more than a thousand times that in conventional linacs. (#f1)

Figure 1: Electron acceleration in a plasma wakefield. (/nphys/journal/vaop/nprelaunch/fig_tab/nphys102_F1.html)



(/nphys/journal/vaop/nprelaunch/fig_tab/nphys102_F1.html)

Before acceleration (left), the energy distribution of electrons from the linac beam is centred on 28.5 GeV. But the beam creates a plasma whose wakefield subsequently accelerates some of the electrons up to higher energies (right).

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Further advantages are that the accelerator signature is reproducible from shot to shot and the bunch length and current distributions can be optimized for a variety of vapour/plasma densities by tweaking parameters in the main linac. Such field-ionized plasma production does not suffer from the timing, lifetime or alignment issues that plague other plasma techniques.

References

1. Hogan, M. J. *et al*. Multi-GeV energy gain in a plasma-wakefield accelerator. *Phys. Rev. Lett.* **95**, 054802 doi:10.1103/PhysRevLett.95.054802 (2005) | **Article** (http://dx.doi.org/10.1103%2FPhysRevLett.95.054802) |