The accelerator revolution

University of Oxford physicists and their collaborators have injected an intense laser pulse, with fleetingly more power than the combined output of all the power stations on Earth, into a plasma to create a new generation of tabletop-sized particle accelerators.

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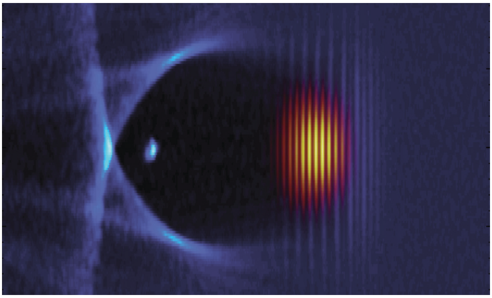

Image: N. Bourgeois

Particle accelerators are found today in many different settings, from the sources of X-rays and therapeutic particle beams used in hospitals, to the atom-smashing machines at CERN. These machines accelerate a stream of charged particles through an electric field oscillating in time at radiofrequencies. The longer the journey, the more energy the particle gains, so the Large Hadron Collider (LHC) at CERN, for instance, hurls particles round a 27km circumference circular tunnel.

Laser physicists led by Professor Simon Hooker at the University of Oxford are among a handful of research groups worldwide that are developing a new kind of accelerator, using plasma and lasers to create an extremely strong electric field and thus attain high particle energies in very short distances. A plasma is an electrically neutral gas containing a sea of positive ions and negative electrons. If an intense laser pulse of 1018 W/cm^2 is injected into the plasma, it pushes the electrons away as it propagates, setting up a density wave behind the laser pulse in much the same way as a wake follows a boat travelling across water. A strong electric field of 100 Gigavolts per metre is created between the peaks and troughs of this wave. This is a thousand times bigger than the accelerating fields used in the LHC, so the accelerator length can become a thousand times shorter without reducing the particle energy.

Oxford physicists and their collaborators at the Lawrence Berkeley National Laboratory in the US have recently generated electron beams with energies of up to 1 GeV – an energy equivalent to accelerating the electrons across one billion volts and typical of that used in today's synchrotrons and free-electron lasers – in an acceleration stage of just 3 cm. A vital contribution to this achievement was the development by Professor Hooker and his team of a 'plasma channel' to guide the laser pulse – which has a diameter smaller than a human hair – and keep it focused over several centimetres. The Oxford–LBNL success merited coverage in *The Economist* and an excellence award from the American Physical Society.

These new accelerators will be able to fit onto a tabletop (with most of that space being taken up by the laser!) and replace the 100 m machines in current use with cheaper equipment that can be more widely available. The Oxford team also hopes to use these laser-driven electron beams to drive very compact sources of tuneable X-rays. It is anticipated that the X-ray pulses produced will be only a few femtoseconds long; this opens up the exciting possibility of observing for the first time the unfolding of physical, chemical and biological processes at the molecular and atomic level.

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