First demonstration of new laser-driven accelerator technology

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A team of UK scientists has used, for the first time, an extremely short-pulse laser to accelerate high-energy electrons over an incredibly short distance. Current accelerators can be hundreds of metres long, this is just a millimetre long.

Earlier laser-driven accelerators were inefficient, accelerating the electrons to a wide range of energies. But scientists who wish to use these electron beams to research materials science – such as the structure of viruses and moon rock – need the electrons to have the same energy. The team of scientists, led by Imperial College London and including scientists from the CCLRC Rutherford Appleton Laboratory, the University of Strathclyde and University of California, Los Angeles, has shown for the first time that a laser-driven accelerator can produce a beam of electrons with a narrow range of energies. The results of this experiment will be published in Nature on 30 September 2004.

The experiment was performed at the CCLRC Rutherford Appleton Laboratory near Oxford using the Astra laser. This major breakthrough represents a step towards a new technology which promises to be much cheaper and more compact than the conventional approach and in the future could allow individual universities to afford these accelerators instead of relying on large national laboratories.

Currently there are a few large-scale accelerators around the world, such as CERN - the European laboratory for high energy physics research in Geneva, which is about 10 km across. As scientists try and probe the universe at smaller and smaller scales they need higher energy beams – the current accelerator technology means that the only way to achieve this is to make even bigger accelerators. "Scientists all accept that before long we'll need a completely new approach to producing the beams of particles required for next generation light sources and high energy physics research. In this experiment we've proved that compact, high power lasers can offer a viable new technology," says Stuart Mangles, one of the researchers from Imperial College London.

Professor Karl Krushelnick from Imperial College London led the team of researchers and explains that though this result is scientifically very significant, it is only the start of further research. "The next step is to increase the energy of the electrons from these laser-driven accelerators – either by increasing the length of the accelerator or by increasing the laser power. We're still some way off producing a beam of electrons that could be useful for X-ray radiation sources and high energy physics but we're all really excited by this major step forwards".

The initial concept of laser Wakefield accelerators was first discussed 25 years ago. It has only been in the last 10 years that the technology has enabled the theory to be realized. Laser Wakefield accelerators were first proposed in 1979 by Toshi Tajima and John Dawson in a famous paper in Physical Review Letters. When an intense laser pulse is focused into a region of gas (helium in these experiments) it ionizes the gas, turning it into a plasma, and can set up a wave travelling behind the pulse at very nearly the speed of light. "This plasma-wave generates a very large electric field that is more than 100 times greater than the electric field of conventional accelerators, and this accelerates the electrons much like surfers are carried along on a wave at a beach," explains Chris Murphy, another member of the research team based at the Rutherford Appleton Laboratory.

Previous experiments have relied on these plasma waves breaking (just like when a wave breaks on a beach) to produce large numbers of energetic electrons but this wavebreaking process has always produced an unwanted large energy spread. By carefully controlling the laser and plasma parameters the Imperial College team has shown that it is possible to use wavebreaking to produce beams of electrons with a narrow energy spread. That's why electrons are accelerated to 70MeV in this experiment over a length of just 0.6mm, compared with many metres in a conventional accelerator.

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