Laser Driven Accelerators

By combining high-intensity lasers and plasmas, the promise of low cost, tabletop particle accelerators for use in hospitals and industry, is one step closer.

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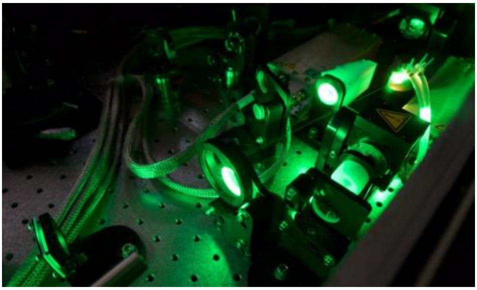

Amplifier for generating terawatt laser pulses (R Shalloo)

When we think of particle accelerators, we tend to think of the Large Hadron Collider at CERN, which is the largest machine ever built at 27 km in circumference. But of the more than 30,000 particle accelerators in operation worldwide today, fewer than 10% are used for scientific research and only 1% specifically in high energy particle physics.

Particle accelerators have been used to investigate new fuel sources and study holy relics - but the vast majority are used in medicine and industry. In medicine, accelerators are used for the diagnosis and treatment of cancer, to produce high quality beams of X-rays, and for advanced medical imaging. In industry, accelerators are an integral part of processing a broad range of products, from treating foodstuffs for increased shelf life to microelectronics inside smartphones. In fact, it is estimated that every year accelerators treat over £350 billion worth of products. But almost all of the accelerators used for these applications rely on technology developed nearly a century ago.

Scientists around the world are now working to develop new “laser wakefield” accelerators, powered by the interaction of very intense laser pulses and plasmas. An intense laser pulse is fired into a gas, which ionizes it to form a mixture of negatively charged electrons and positively charged ions, at temperatures approaching a million degrees. As the laser pulse travels through the plasma it pushes the plasma electrons out of its way, setting up a "plasma wake" behind it, which sets up huge electric fields, equivalent to a voltage difference of 10 million volts across the diameter of a human hair. These intense fields can be used to accelerate charged particles to high energies in a distance hundreds to thousands of times smaller than in a conventional particle accelerators, dramatically shrinking the size and cost.

Laser-plasma accelerators have already been used to generate electron beams with similar energies to that used in synchrotron light sources - like the Diamond Light Source near Oxford, but in an accelerator stage only a few centimetres long, rather than in a stadium-sized machine. However, the lasers used could only fire a few times per second, severely limiting the applications of these compact accelerators.

Laser physicists led by Prof Simon Hooker at Oxford, have invented a new technique, called the "multiple-pulse laser wakefield accelerator", which could increase the repetition rate of laser-plasma accelerators by a factor of a thousand. The idea is to drive the plasma wake with a train of lower energy laser pulses. The concept has been demonstrated experimentally and future work will be aimed at generating electron beams and working with experts in laser physics to develop an architecture for a new generation of table top, laser-driven accelerators with properties useful for real-world applications.

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