Scientists produce shortest electron bunches ever by surfing plasma waves

October 9 2015

The shortest electron bunches ever produced have emerged in research by scientists at the University of Strathclyde.

The bunches were produced by focusing a high-power laser pulse into a supersonic helium gas jet. These 'bullets' of charged particles have a length that is one 300th of the breadth of a hair and travel at a speed close to that of light. They are also 10 times shorter than those produced from conventional accelerators.

The Strathclyde research group is leading efforts to take advantage of plasma, the ubiquitous medium that makes up most of the universe, to make the significant scientific breakthrough. The work is part of the ALPHA-X (Advanced Laser-based Accelerators towards X-rays) project, led by Professor Dino Jaroszynski of Strathclyde's Department of Physics, which aims to create the first table-top attosecond coherent X-ray source.

The study has been published in the *New Journal of Physics*.

Professor Jaroszynski said: "Plasma is completely broken down matter, which is separated into positively charged ions and very light and mobile electrons that respond easily to laser fields.

"This new research builds on the earlier pioneering results of the ALPHA-X project, in which laser-driven plasma waves are used to accelerate electrons to high energies, much in the same way as a surfer

gains momentum from a sea wave and eventually out-surfs the wave.

"It has taken 10 years from the initial ALPHA-X publication of what have become known as the "Dream Beam" papers in Nature to produce and measure these ultra-short electron bunches."

One of the challenges faced by Professor Jaroszynski and his team was to measure the duration of the very brief electron bunches from the laser wakefield accelerator. By passing the electron bunch through an ultra-thin aluminium foil, and measuring the spectrum of the light emitted from the foil as the electrons pass through it, they established that the electron bunch duration was much shorter than initially expected. The light emitted from the foil is known as Coherent Transition Radiation (CTR), which is emitted when electrons in the foil are "kicked" by the electrostatic field of the electron bunch as they pass by.

To solve the conundrum of why the electron bunches are so short, the researchers developed a new theory that explains why plasma electrons are only briefly injected into the accelerator. They showed that the electron streams crossing at the back of the accelerator 'bubble' cause a charge build-up in that region, which bumps electrons into the accelerator, in the same way that a group of skiers might suddenly find snow moguls growing in height for a brief period, diverting some skiers bunched together while the others are able to go through.

Professor Jaroszynski said: "The interaction of intense laser pulses with matter is giving rise to opportunities to investigate new physics and to develop highly compact accelerators and X-ray sources.

"The newly-published results are important for developing a new generation of compact attosecond X-ray sources which would be extremely useful for scientists and industrialists probing the structure of matter on timescales of the vibration of molecules and electron motion

in atoms and molecules. This new tool for research could have a significant impact on science."

More information: M R Islam et al. Near-threshold electron injection in the laser–plasma wakefield accelerator leading to femtosecond bunches, *New Journal of Physics* (2015). DOI: 10.1088/1367-2630/17/9/093033

Provided by University of Strathclyde, Glasgow