New twists in the diffraction of intense laser light

January 12 2016

A discovery by University of Strathclyde researchers could have a major impact on advancing smaller, cheaper, laser-driven particle accelerators – and their potential applications.

The research found that the diffraction of ultra-intense laser light passing through a thin foil could be used to control charged particle motion. This new observation in the fundamental physics of intense laser-plasma interactions could have a wide-reaching impact in medicine, industry and security.

The findings of the research, published in leading physics journal *Nature Physics*, has demonstrated that the interaction of the high intensity laser pulse with the foil target creates a localised region (termed a relativistic plasma aperture) at the peak of the laser intensity which is transparent to the laser light. Manipulating the diffraction of the light through the aperture enables control of the particle motion.

The research, a collaboration with the Central Laser Facility and Queen's University Belfast, is led by the University of Strathclyde's Professor Paul McKenna. He said: "The development of compact laser-driven particle accelerators and high-energy radiation sources relies on controlling the motion of plasma electrons displaced by the intense laser fields.

"Our discovery that diffraction via a self-induced plasma aperture not only controls this motion but also drives the production of twisting plasma structures opens a new pathway to controlling charged particle dynamics. The results have immediate application in the development of laser-driven ion sources and can potentially be used to model astrophysical phenomena such as helical field structures in jets originating from the rotation of black hole accretion disks.

"The plasma electrons are accelerated to close to the speed of light, gaining mass due to Einstein's mass-energy conservation principle. This effect can make a region of an opaque foil transparent, creating a relativistic plasma aperture, and in the process induce diffraction of the laser light – similar to how normal light waves diffract though a pin-hole. Unlike normal diffraction however, the plasma aperture adapts in response to the laser light, enabling control of the plasma electron motion."

The researchers found that, by changing the polarisation of the light beam, the electron beam structure could be made to rotate at variable rotational frequencies dependent on the degree of ellipticity of the laser polarisation.

This leads to spiral-shaped, or twisted, plasma structures being produced. 3D simulations and modelling by the team showed that helical magnetic fields induced using this concept could potentially be used in laboratory investigations of similar field structures in astrophysical jets.

More information: Bruno Gonzalez-Izquierdo et al. Optically controlled dense current structures driven by relativistic plasma aperture-induced diffraction, *Nature Physics* (2016). DOI: 10.1038/nphys3613

Provided by University of Strathclyde, Glasgow