Laser-driven creation of high-energy ions boosts next-gen accelerators

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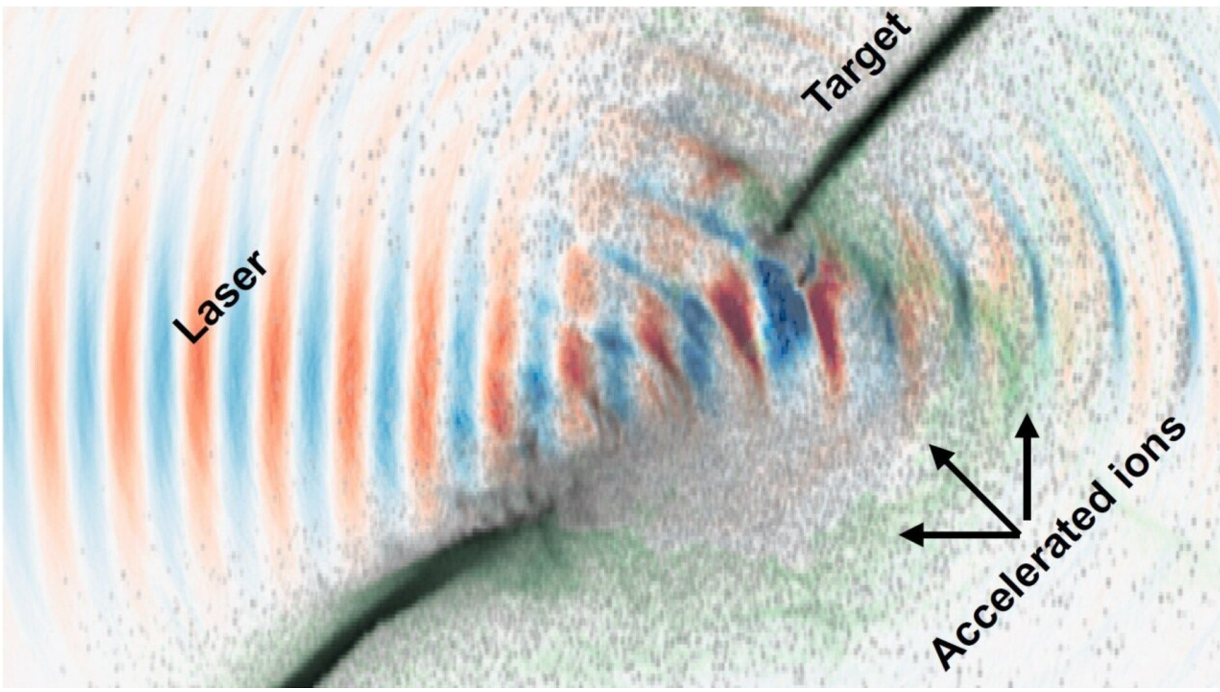

Credit: Imperial College London

A new way to create high-energy ions could speed up their applications in treating cancer and probing the fundamental nature of matter.

The new technique, created by researchers at Imperial College London with collaborators in Japan and Germany, will help deliver beams of ions that could treat cancers with high doses of more targeted radiation.

Particle accelerators use electric fields to accelerate a range of particles, such as ions. They have been developed and used for over a century, to both conduct fundamental studies and treat cancers in hospitals. Recently, new methods that involve lasers manipulating electrons in plasma have been developed, which create electric fields millions of times larger than those possible in standard machines.

These techniques allow accelerators to be much smaller and to deliver ultrashort ion beams only nanoseconds long. This is particularly useful for cancer radiotherapy, allowing targeted treatment that leaves more healthy tissue intact.

The new study, published in the journal *Light: Science & Applications*, shows how to get copious high-energy ions out of these accelerators. Co-first author Dr. Nicholas Dover, from the Department of Physics at Imperial, said, "We have made a significant leap forward in bringing these laser-driven ion sources out of the lab and towards practical applications."

Accelerating ions

The team used state-of-the-art high-power lasers at Kansai Photon Science Institute in Japan and Helmholtz-Zentrum Dresden-Rossendorf in Germany to develop the technique for accelerating ions with lasers.

The system works by firing a laser at a plasma to accelerate it and create the electric field. However, usually the plasma is opaque to light, meaning the laser only interacts with the plasma surface that it first strikes before bouncing off.

However, for very intense lasers, the target electrons are accelerated to close to the speed of light, dramatically changing the refractive index and allowing the laser to enter the now transparent target. When this happens, the laser interacts with the entire target, and is almost completely absorbed. This generates an extreme induced electric field which accelerates target ions in the laser direction.

The team showed how to optimize ion acceleration by carefully choosing a target thickness matched to the laser system parameters. This results in a target becoming transparent just at the most intense part of the laser pulse.

Dr. Dover said, "By using two independent laser systems to replicate these results, we demonstrate that our technique can be applied to any of the many existing petawatt-class femtosecond laser facilities. These lasers are rapidly being developed to improve their stability and repetition rate."

"This is ideal for delivering ultrashort pulse ion beams, which radiobiologists can use to unravel mysteries in high-dose radiobiology."

More information: Nicholas Dover et al, Enhanced ion acceleration from transparency-driven foils demonstrated at two ultraintense laser facilities, *Light: Science & Applications* (2023). DOI: 10.1038/s41377-023-01083-9. www.nature.com/articles/s41377-023-01083-9

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