Plasma research shows promise for future compact accelerators

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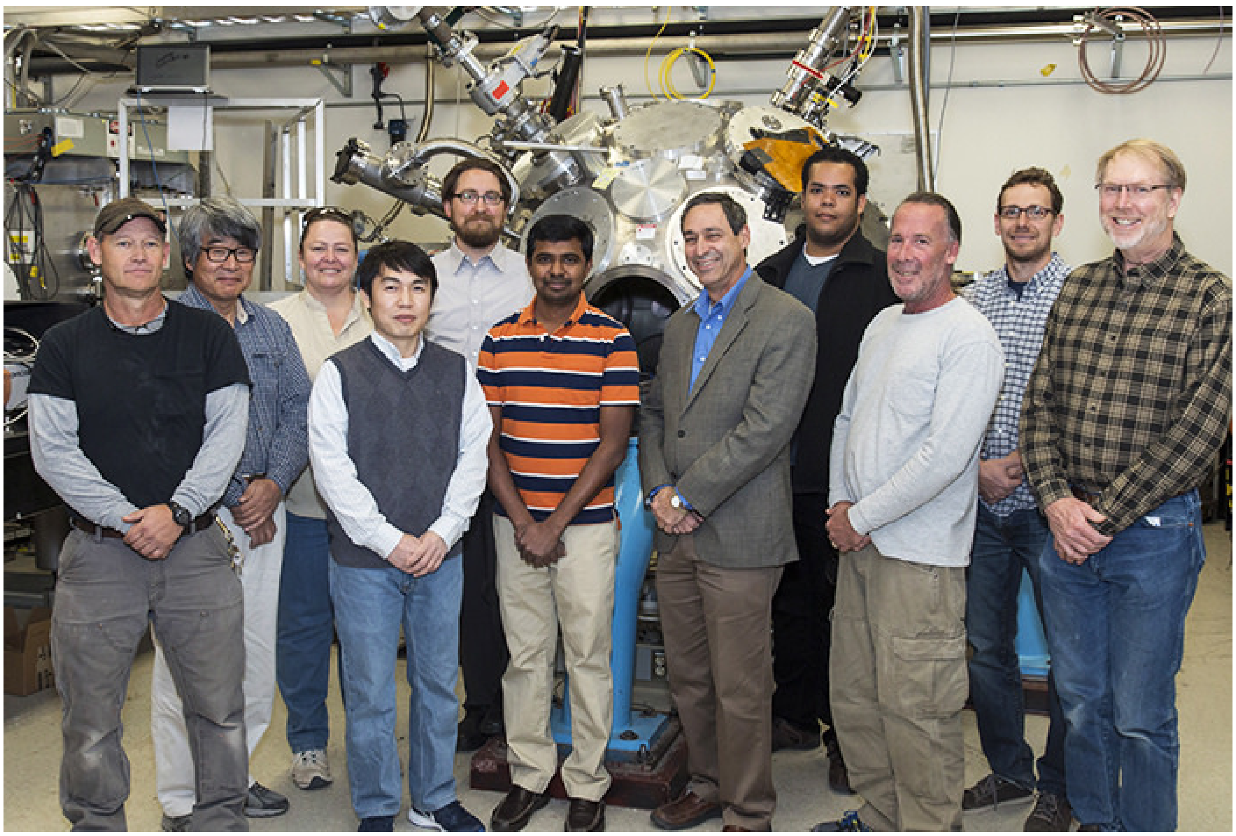

The team in front of the Trident Target Chamber. Back, from left: Tom Shimada, Sha-Marie Reid, Adam Sefkow, Miguel Santiago, and Chris Hamilton. Front, from left: Russ Mortensen, Chengkun Huang, Sasi Palaniyappan, Juan Fernandez, Cort Gautier and Randy Johnson.

A transformative breakthrough in controlling ion beams allows small-scale laser-plasma accelerators to deliver unprecedented power densities. That development offers benefits in a wide range of applications, including nuclear fusion experiments, cancer treatments, and security scans to detect smuggled nuclear materials.

"In our research, plasma uses the energy stored in its electromagnetic fields to self-organize itself in such a way to reduce the energy-spread of the laser-plasma ion accelerator," said Sasikumar Palaniyappan of Los Alamos National Laboratory's Plasma Physics group. "In the past, most of the attempts to solve this problem required active plasma control, which is difficult."

Laser-plasma accelerators shoot a high-energy laser into a cloud of plasma, releasing a beam of ions, or electrically charged particles, in a fraction of the distance required by conventional accelerators. The laser generates electromagnetic fields in the plasma.

Using a computer simulation called Vector-Particle-In-Cell (VPIC), the Laboratory's team of physicists and computational scientists developed a scheme that enlists the electromagnetic fields so the beam essentially contains itself, reducing the energy spread, making the beam more efficient, and concentrating more energy on its target.

"Our simulation shows that a gigantic magnetic field carried by the relativistic electron jet from laser-plasma interaction facilitates the generation of a slow space charge wave, which synchronizes the ions with the electrons and shapes the ion beam spectrum," said team member Chengkun Huang, of the Laboratory's Theoretical Division.

The magnetic field is about one hundred times stronger than the world record achieved in a magnet. The team confirmed the simulation through experiments on the Trident laser at the Laboratory.

High-energy ion beams from plasma accelerators can be used for ion fast-ignition in nuclear fusion, but overcoming the loss of power resulting from large energy spread has remained a challenge despite a decade-plus effort. The breakthrough by Palaniyappan and his team addresses this problem and may contribute to improved next-generation particle accelerators. Other applications of the compact, high-energy tabletop laser plasma accelerators include scanning devices that can spot hidden nuclear materials and various radiotherapy treatments for cancer.

The Los Alamos discovery will also benefit basic science, since the more powerful ion beams can flash-heat materials to create warm, dense matter similar to that found in stars and planetary cores, enabling the laboratory study of matter in this state.

The research article "Efficient quasi-monoenergetic ion beams from laser-driven relativistic plasmas" was published Dec. 11 in *Nature Communications*.

More information: Sasi Palaniyappan et al. Efficient quasi-monoenergetic ion beams from laser-driven relativistic plasmas, *Nature Communications* (2015). DOI: 10.1038/ncomms10170

Provided by Los Alamos National Laboratory

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