Researchers uncover a new obstacle to effective accelerator beams

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High-energy ion beams—laser-like beams of atomic particles fired through accelerators—have applications that range from inertial confinement fusion to the production of superhot extreme states of matter that are thought to exist in the core of giant planets like Jupiter and that researchers are eager to study. These positively charged ion beams must be neutralized by negatively charged electrons to keep them sharply focused. However, researchers have found many obstacles to the neutralization process.

Featured Article

At the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL), scientists have discovered a surprising new obstacle that reduces the neutralization of ion beam pulses. The findings, reported in Physics of Plasmas and promoted as a Featured Article, provide new insight into a source of the problem and indicate how to prevent it.

The discovery proposes an explanation for the poor rate of neutralization first observed in experiments at the Lawrence Berkeley National Laboratory back in 2002. The problem has remained unexplained prior to the development of codes capable of simulating the processes involved.

Physicist Chaohui Lan, a visiting scientist from the China Academy of Engineering Physics, uncovered the cause while performing computer simulations of electron dynamics with PPPL physicist Igor Kaganovich, deputy head of the PPPL Theory and Computation Department. Their research on Princeton University computers explored the injection of electrons from a thin filament into the beam pulse to neutralize it for effective focusing and transport. Results showed that the process reduced neutralization when compared with passing the beam through plasma ¬— the charged state of matter composed of free ions and electrons.

Charged islands

"In these simulations I found something unusual," said Lan, lead author of the Physics of Plasmas paper that Kaganovich coauthored. "I called them 'charged islands' that could not be further neutralized by injected electrons."

What Lan had stumbled on was formation of "electrostatic solitary waves" (ESW), a type of stable electron-excited wave that previous studies of neutralization had not reported. Such waves can reach several centimeters in length and move back and forth from the edges of the ion beam pulse, affecting electron motion and reducing neutralization. The waves interact weakly with one another and in some cases disrupt and impart energy to the electrons, causing them to escape the beam and further reduce the neutralization.

To minimize the problem, the new findings suggest widening the filament that injects the electrons into the beam to improve the rate of neutralization. "That broadens the distribution of electrons," says Kaganovich, "and lessens the excitation of the waves." Moreover, he adds, the model developed at PPPL should help researchers study and understand the mechanisms behind the excitation of these waves to aid in controlling them.

More information: C. Lan et al, Electrostatic solitary waves in ion beam neutralization, *Physics of Plasmas* (2019). DOI: 10.1063/1.5093760

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