Physicists conduct experiments indicating efficiency of fusion start-up technique

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Physicist Fatima Ebrahimi. Credit: Elle Starkman / PPPL Office of Communications

Physicist Fatima Ebrahimi at the U.S. Department of Energy's (DOE) Princeton Plasma Physics Laboratory (PPPL) and Princeton University has for the first time performed computer simulations indicating the efficiency of a start-up technique for doughnut-shaped fusion machines known as tokamaks. The simulations show that the technique, known as coaxial helicity injection (CHI), could also benefit tokamaks that use superconducting magnets. The research was published in March 2016, in *Nuclear Fusion*, and was supported by the DOE's Office of Science.

Physicists are interested in CHI because it could produce part of the complex web of magnetic fields that controls the superhot plasma within tokamaks. One component of that web is produced by large "D"-shaped magnets that surround the tokamak and pass through the hole in its center. The other component is produced by a central electromagnet known as a solenoid, which induces a current inside the plasma that creates another set of magnetic fields. These fields combine with the fields produced by the "D"-shaped magnets to form a twisting vortex that prevents the plasma from touching the tokamak's walls.

Future tokamaks—especially compact spherical tokamaks like NSTX-U—might not have enough room for solenoids, though. CHI could be ideal for those tokamaks because it doesn't require solenoids at all. During CHI, magnetic field lines, or loops, are inserted into the tokamak's vacuum vessel through openings in the vessel's floor. The field lines then expand to fill the vessel space, like a balloon inflating with air, until the loops undergo a process known as magnetic reconnection and snap closed. (Think of tying off that inflated balloon.) The newly formed closed field lines then induce current in the plasma.

By performing simulations, Ebrahimi found that narrowing the part of the magnetic loop that extends up into the tokamak through the floor could cause 70 percent of the field lines to close, compared with 20 to 30 percent without such narrowing. "For the first time, we see a large volume of closure during computer simulations," she said. The number of field lines that close is important because the more field lines that close, the greater the current flowing through the plasma, and the stronger the magnetic fields holding the plasma in place.

"The findings help us figure out how we can get maximum start-up current in NSTX-U," said Ebrahimi. "That is a direct application of the research. But now we also have insight into some basic physical phenomena: what are the physics behind the process of reconnection? How do the lines actually close?"

The simulations also provide a boost to the advancement of fusion energy. "Can we create and sustain a big-enough magnetic bubble in a tokamak to support a strong electric current without a solenoid?" asks Ebrahimi. "The findings indicate that 'yes, we can do it.'"

PPPL, on Princeton University's Forrestal Campus in Plainsboro, N.J., is devoted to creating new knowledge about the physics of plasmas—ultra-hot, charged gases—and to developing practical solutions for the creation of fusion energy. Results of PPPL research have ranged from a portable nuclear materials detector for anti-terrorist use to universally employed computer codes for analyzing and predicting the outcome of fusion experiments. The Laboratory is managed by the University for the U.S. Department of Energy's Office of Science, which is the largest single supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time. For more information, please visit science.energy.gov.

More information: F. Ebrahimi et al, Large-volume flux closure during plasmoid-mediated reconnection in coaxial helicity injection, *Nuclear Fusion* (2016). DOI: 10.1088/0029-5515/56/4/044002

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