Catching tokamak fastballs: Controlling runaway electrons

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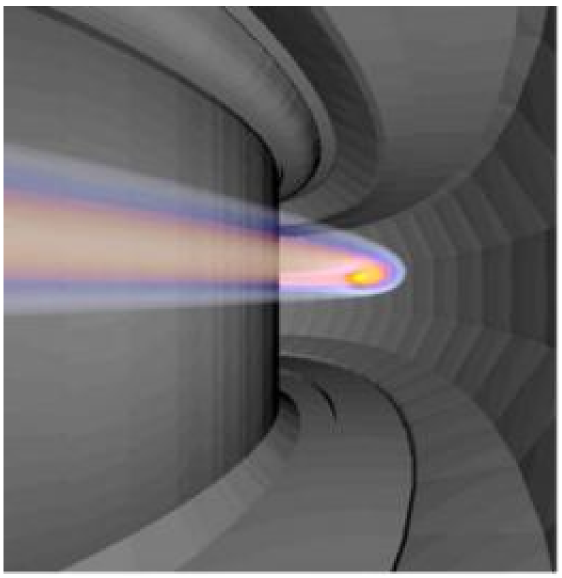

A computer-generated 3-D view shows runaway electrons in DIII-D based on high speed 2-D images of synchrotron emission from electrons traveling near the speed of light inside the tokamak. Credit: N.W. Eidietis and M.R. Wade, General Atomics

a leading design concept for producing nuclear fusion energy—can, under certain rare fault conditions, produce beams of very energetic "runaway" electrons that have the potential to damage interior surfaces of the device. In the event of such a fault, a tokamak-based nuclear fusion power plant will have to employ protection systems to prevent any damage. Now, scientists at the DIII-D National Fusion Facility have demonstrated a new method for controlling these high-energy electrons.

This work, reported at the 53rd APS Division of Plasma Physics conference, could help overcome a significant challenge to designing tokamak-based fusion power plants.

In a tokamak, enormous electrical current (up to many millions of amperes) is driven through a donut-shaped ring of plasma to contain this ionized gas at the extreme temperatures (100 million °C) required for nuclear fusion. Significant system faults may cause a tokamak discharge to rapidly terminate, or "disrupt," losing its entire plasma current in a few hundredths of a second. The rapid drop in current during a disruption can accelerate electrons in the plasma to near the speed of light, forming a beam of high-energy runaway electrons.

By purposely causing a rapid drop in plasma current in the DIII-D tokamak, scientists at General Atomics in San Diego are producing 300,000 Ampere beams of runaway electrons and learning how to control them. Plasma physicist Nick Eidietis and his coworkers apply rapid pre-programmed changes in magnetic control coils to move the runaway electron beam away from interior surfaces so that automatic feedback control can keep them from slamming into interior surfaces. Magnetic field measurements and images from high-speed cameras allow scientists to determine their location and spatial structure.

Having established control, the team is exploring two methods for dissipating the runaway electron beam before it can do any harm. If ample time is available, the electron beam current is slowly reduced using the magnetic control coils. If time is of the essence, the second method injects large quantities of noble gases such as argon, neon, or xenon, into the beam to more rapidly dissipate the energy of the electrons. Both methods lead to a much more benign interaction with interior surfaces.

Runaway electron beams are of particular importance for the design of the ITER tokamak presently under construction in France. Designed to produce up to 500 MW of fusion power, ITER will be many times larger than existing tokamaks and thus capable of producing much higher runaway electron currents during a disruption than seen in the DIII-D experiment.

"One of our next steps will be to adjust our control system to simulate the characteristics of the ITER system to evaluate the feasibility of this approach to catching and controlling runaway electrons," said Dr. Eidietis.

According to Dr. Dave Hill, Deputy Director of the DIII-D National Fusion Program, "This is an exciting research result which we look forward to successfully testing in future larger fusion experiments such as ITER."

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