Superconducting tokamaks are standing tall

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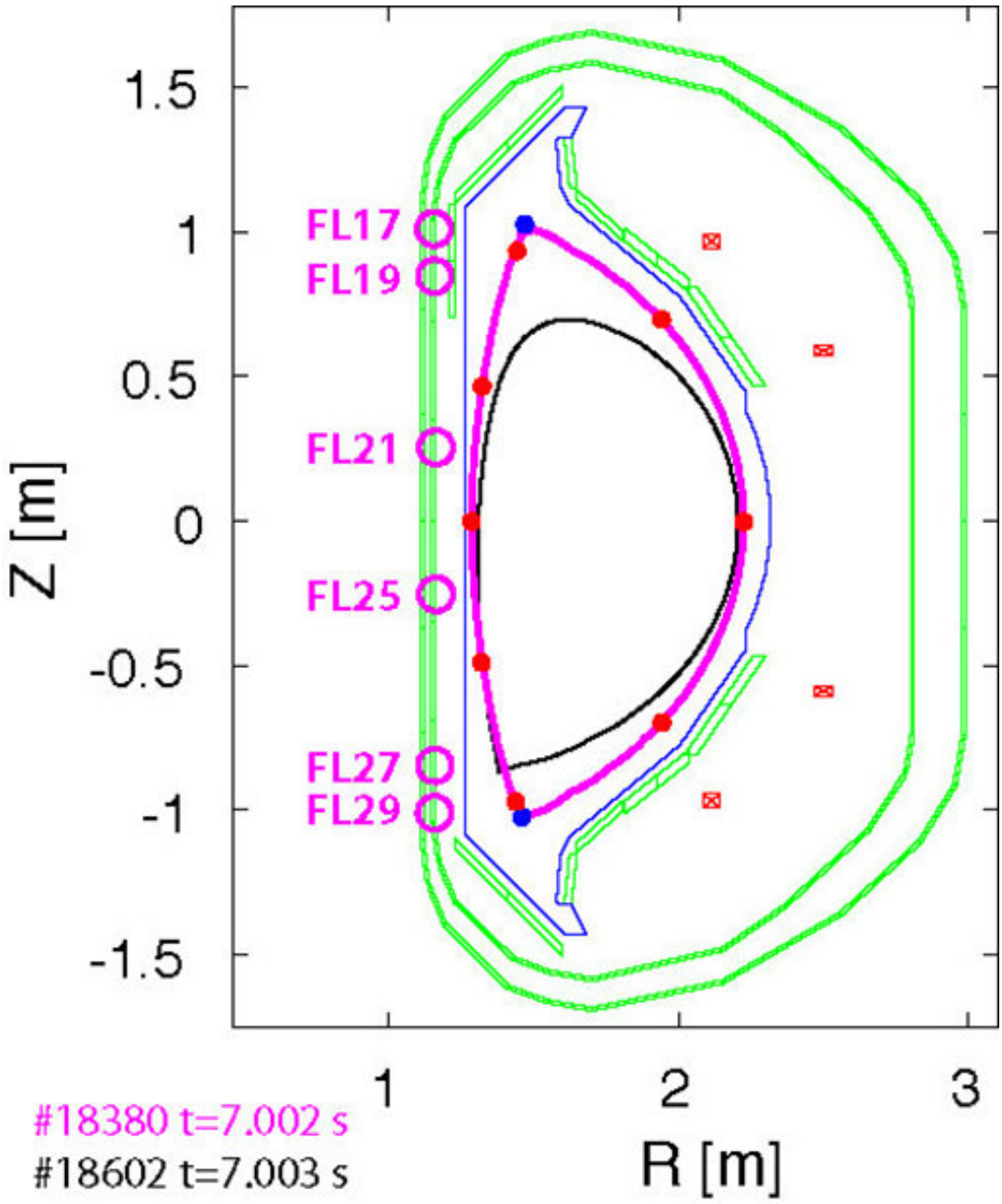

Cross-section of the KSTAR tokamak showing select hardware components of the vertical control system: new magnetic flux loops (magenta circles) used to infer the vertical position of the plasma and vertical magnetic field coils (red squares) that control the position. A new algorithm sustained a stable plasma discharge #18380 (magenta) that was significantly taller than discharges such as #18602 (black) that used an earlier algorithm and suffered vertical oscillations. The double vacuum vessel wall (green) and plasma first wall (blue) are also shown. Credit: Nick Eidietis, General Atomics

A persistent problem has dogged the largest fusion device in South Korea. The Korean Superconducting Tokamak Advanced Research (KSTAR) device has run successfully since 2008. However, controlling the vertical position of the ultra-hot plasma has proven difficult. Stable control of the vertical position allows precise shaping and positioning of the plasma boundary, vital to a reactor's performance. Now, a team led by Princeton Plasma Physics Laboratory has sharply improved the ability to control the vertical position. The result? The new control algorithm stabilizes the plasma position for record tall plasmas in KSTAR that exceed even the KSTAR design specifications.

The new scheme will enable the KSTAR team to study plasma conditions very similar to those that will be created in the ITER tokamak, using the same configuration of plasma diagnostics and superconducting magnetic field coils. The ITER tokamak is an international project being assembled in France. The new scheme will allow the KSTAR project to realize one its key roles in the international fusion research effort: contribute techniques for successful steady-state physics operation of ITER. The new capability also supports the main mission of the KSTAR project. That mission is to establish the scientific and technological bases for an attractive fusion reactor as a future energy source.

The shape of the plasma boundary in fusion energy experiments, such as KSTAR and ITER, must be carefully controlled to achieve the plasma temperatures and densities required to access and sustain fusion burn. As plasma shapes become taller, or more "elongated," larger plasma currents can be sustained leading to increased fusion power output, but the requirements for stable control of the vertical position become more stringent. Compared to conventional tokamaks that use magnetic field coils made from copper and located close to the plasma surface, the magnetic field coils in superconducting tokamaks are fewer in number and are located further away to accommodate coil cooling and radiation shielding systems. This coil configuration tends to couple plasma control loops that are largely decoupled in conventional tokamaks. The new digital control algorithm developed in the KSTAR plasma control system integrates multiple control schemes to effectively decouple the vertical position control from other control loops used to maintain the plasma current, plasma shape, and radial position.

More information: D. Mueller, S. Hahn, N. Eidietis, J.G. Bak, J. Barr, M.D. Boyer, D.A. Humphreys, Y. In, Y.M. Jeon, H.S. Kim, M. Lanctot, and M. Walker, "Improvement of vertical stabilization on KSTAR." APS Division of Plasma Physics Meeting, abstract NO4.011. Milwaukee, Wisconsin (2017).

N.W. Eidietis, J. Barr, S.H. Hahn, D.A. Humphreys, Y.K. In, Y.M. Jeon, M. Lanctot, D. Mueller, and M. Walker, "Control advances for achieving the ITER baseline scenario on KSTAR." APS Division of Plasma Physics Meeting, abstract NO4.010. Milwaukee, Wisconsin (2017).

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