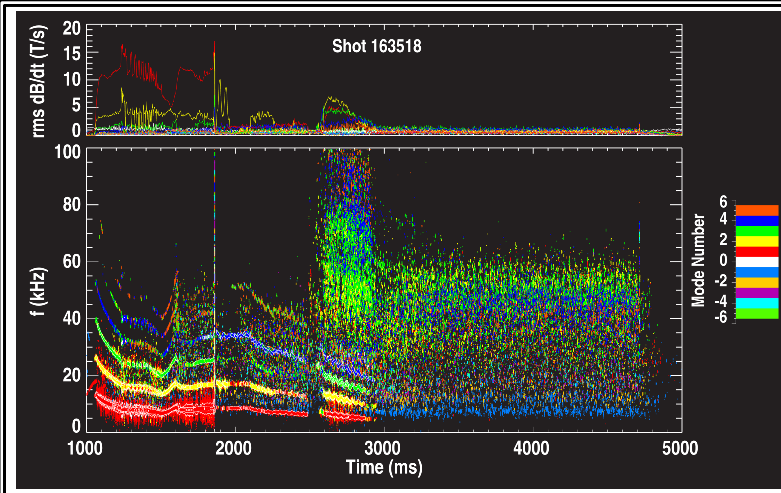
News advisory -- for immediate release
Nov. 16, 2015

The thrill of discovery: An improved edge plasma for large, ITER-scale fusion energy devices

DIII-D researchers find new low-torque solution with high-energy confinement

SAVANNAH, GA (Nov. 16) – Deep inside the careful process of solving the mysteries of fusion energy, this was a rare moment of *wow*.

General Atomics physicist Keith Burrell had spent that summer day in the San Diego high-tech control room of the DIII-D National Fusion Facility, the nation's largest fusion-energy device, leading an experimental team conducting experiments on fusion plasma hotter than the sun. They were chasing a tantalizing observation that they had seen the year before, where the pressure of the edge of their fusion plasma spontaneously increased by 60%. This time, they were excited to find that the more stable, improved conditions lasted as long as the plasma could be maintained with the hardware they had. This meant that this improved edge could be used in future reactor scale devices to solve a major problem standing in the way of achieving energy production from nuclear fusion.



***The thrill of discovery** : Physicists at DIII-D find how to control instabilities while achieving 60% more electron pedestal pressure and confinement and over 40% more global energy increases, important for fueling large tokamaks such as ITER. Image by K. Burrell, DIII-D*

The *wow* moment came, Dr. Burrell explained, because the long lasting, improved edge conditions were immediately obvious in the raw data plots. In most of his experience in plasma physics, advances are usually incremental, growing out of lengthy and meticulous analysis. But this experiment proved a rare moment of discovery right in the control room in real time.

He will be discussing his team's findings at the 57th Association of Plasma Physics, Division of Plasma Physics in Savannah 9:30 a.m., Nov. 20.

The new discovery solves a problem at the heart of fusion energy development. To light a fusion fire using hydrogen isotopes requires temperatures hotter than the core of the sun. No material can withstand those temperatures; at those temperatures, even atoms are pulled apart and the electrons and the nuclei move around as separate entities. How on earth, then, can you confine a fusion plasma? The answer used in tokamaks like DIII-D is to use immaterial magnetic fields to hold the plasma off of the walls of the container. The challenge is that a magnetized plasma has many ways of developing instabilities that can cause a rapid loss of energy. The particular one that Dr. Burrell's team was concerned with is called the Edge Localized Mode (ELM), which causes the edge of the plasma to peel off, allowing the particles to run along the edge magnetic field and smash into the wall. The problem is that the ELM causes a large loss of energy in a short time. Fusion engineers can design surfaces to take the average heat load. However, in ITER and future fusion reactors, the pulsed load from the ELMs would be so large that the plasma facing surfaces would be damaged.

(From P-1)

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Dr. Burrell and his team believe the key lies in their seemingly paradoxical discovery, that increasing the loss of the edge plasma by using smaller microscale instabilities that can limit the edge conditions that stop ELMs instabilities from occurring. In the **Fig. 1 illustration,** measurements of the oscillating magnetic fields from those microinstabilities are shown in the blue to green colors. In essence, the microinstabilities produce a continuous smooth heat load that engineers require while eliminating the pulsed load due to ELMs.

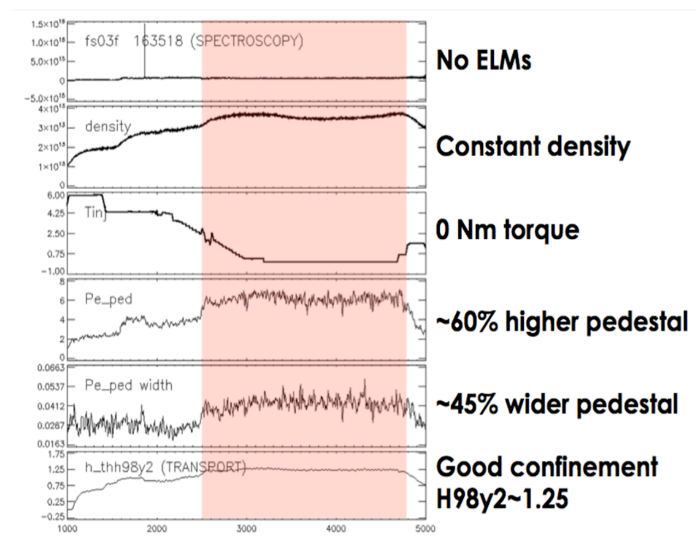

Fig. 2. Improvement of the edge plasma is shown during the shaded time. The duration of the improvement is set by hardware limitations not by any process in the plasma.

Surprise results

The elegant result from the present experiment is that the plasma does this for itself under conditions similar to those expected in future fusion reactors. The real surprise, though, is that the plasma with the microinstabilities actually has 60% better edge pressure and 40% better energy confinement.

(From P-2)
Among the plasma conditions expected in future fusion devices is low plasma rotation. In present research devices, the beams of neutral atoms injected to heat the plasma also provide a torque which makes the plasma spin. Because future reactors will be much larger and probably without neutral injection, their rotation is expected to be quite small. The new discovery by the

…team at DIII-D, which is operated by General Atomics for the Department of Energy, was made under these low rotation conditions. In fact, the low

(Continued)

rotation appears to be a key part of the recipe used to make the plasma with the improved edge conditions.
By exploiting edge turbulence in this novel manner, Dr. Burrell explained, the DIII-D team achieved outstanding tokamak performance, well above the H_{98} international tokamak energy confinement scaling. For the ITER device now being built in Caderache, France, this level is required to be above 1, which is expressed as H_{98}=1. Burrell's team reached H_{98}=1.25, thus meeting an additional confinement challenge that is usually difficult at low torque.

The new regime is triggered in double null plasmas by ramping the injected torque to zero and then maintaining it there. This lowers ExB rotation shear in the plasma edge, allowing low-k, broadband, electromagnetic turbulence to increase. The impact is that strong double-null shaping plasma raises the threshold for the ELMs instability, allowing the plasma to reach a transport limited state near but below the explosive ELM stability boundary. The resulting plasmas have burning-plasma-relevant betan=1.6-1.8 and run without the need for extra torque from 3D magnetic fields. To date, stationary conditions have been produced for 2 s or 12 energy confinement times, limited only by external hardware constraints. Stationary operation with improved pedestal conditions is highly significant for future burning plasma devices, since operation without ELMs at low rotation and good confinement is key for fusion energy production.

Fusion researchers have developed several techniques to eliminate the ELMs. Usually, these require adding extra equipment to the tokamak, which increases cost and complexity. This new discovery of the spontaneously improved edge plasma holds the promise of eliminating the ELMs without requiring this extra equipment, provided that future research shows the way to using it in reactor-grade plasmas.

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Talk: Discovery of stationary operation of Quiescent H-mode Plasmas with Net-Zero NBI Torque and High Energy Confinement on DIII-D*.

Session: YI2 Stix Award, RFP, FRC, and Post-deadline
Friday, Nov. 20, 9:30 a.m., Chatham Ballroom C.