Discovery of a new confinement state for plasma

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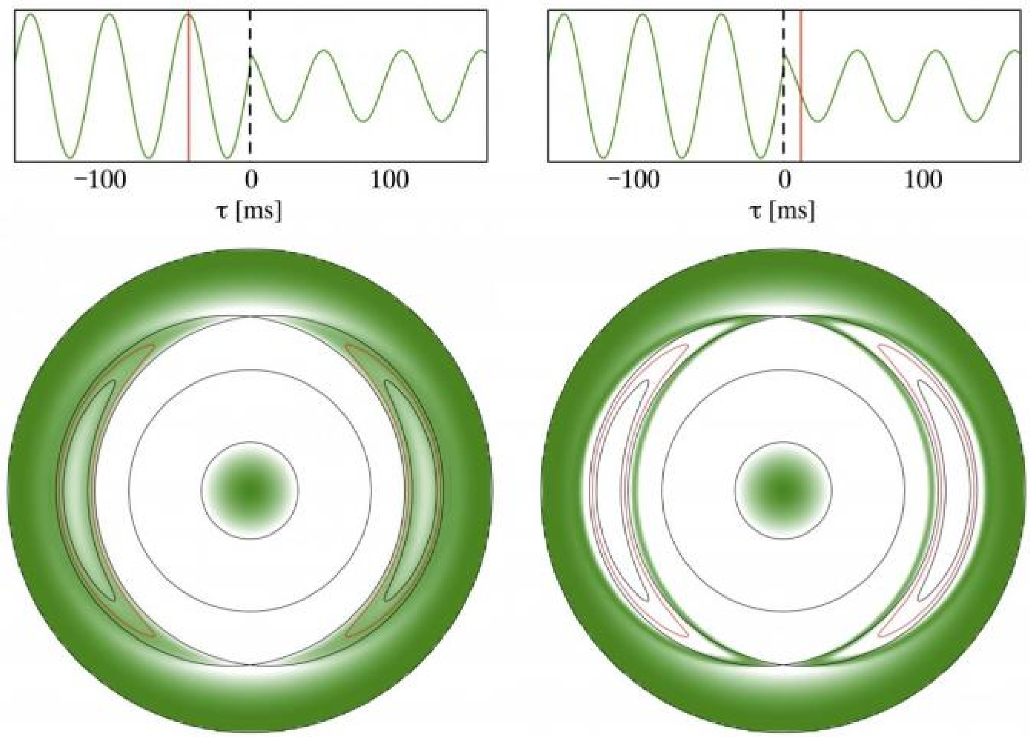

Figure 1 indicates by green colors the amplitude of the temperature variation due to the momentary heating inside and outside the magnetic island at the time slice indicated by red lines. The dashed lines indicate the timing when the confinement performance (adiabaticity) changes. When the confinement performance (adiabaticity) is bad (left : tau 0), the invasion of temperature variations into the inner part of the magnetic island is suppressed and there are no temperature variations inside the magnetic island. (The area inside the magnetic island remains white.).

The National Institutes of Natural Sciences National Institute for Fusion Science applied the "Momentary Heating Propagation Method" to the DIII-D tokamak device operated for the United States Office of Science, Department of Energy, by the General Atomics and made the important discovery of a new plasma confinement state. This discovery was introduced in the November 4, 2015, issue of *Scientific Reports*, a journal of the British science journal Nature group, in an article titled "Self-regulated oscillation of transport and topology of magnetic islands in toroidal plasmas."

Seeking to achieve fusion energy, research on high-temperature and high-density plasma confinement by magnetic fields is being conducted around the world. In a magnetically confined plasma, as the core temperature of the plasma increases, the flow of disturbed plasma called turbulence emerges. Turbulence does not stop at the place of its generation, and moves circumferentially like a surge of waves.

In magnetically confined plasmas twofold confinement areas called magnetic islands exist. In these areas there is no temperature gradient that results in the source of turbulence. For that reason turbulence generated outside the magnetic island where a temperature gradient exists enters into the magnetic island, and the confinement state inside the magnetic island will be determined depending upon the intensity of turbulence. In future fusion plasma, too, it will be extremely important to improve the magnetic island's confinement state. Further, even in solar plasmas, it has been indicated from solar flare emissions that magnetic islands may exist. Thus, research on turbulence in magnetic islands is an extremely important topic.

Professor Katsumi Ida, Assistant professor Tatsuya Kobayashi, and the LHD experiment group, together with Professor Shigeru Inagaki at Kyushu University, have, together with Dr. T. Evans, a DIII-D senior researcher, discovered for the first time in the world a new confinement state inside a magnetic island by applying the "momentary heating propagation method" to the DIII-D plasma. The "momentary heating propagation method" allows the plasma confinement performance (adiabaticity) to be diagnosed from the amplitude of temperature variations and the propagation speed caused by the momentary heating.

This discovery, because it is essential for improving the confinement of the fusion reactor plasma, will be an important compass pointing in the direction of future fusion research. Further, the ripple effects in academic research, too, will be great.

In cases with good confinement performance (high adiabaticity) in the magnetic island, the propagation of heat that seeks to enter from outside slows, and at the same time variations in temperature become smaller. Accordingly, by momentary heating of the plasma, and by diagnosing the amplitude of temperature variations and the propagation speed ("momentary heating propagation method") we learn details of the confinement performance. Previously, experiments in LHD found "that confinement performance inside the magnetic island is good (the adiabaticity was 7 times greater than outside)". This time, in the DIII-D plasma, a "particularly superlative magnetic island" was discovered. Moreover, the self-regulated oscillations were also discovered between two different adiabaticity states, the "good state (adiabaticity is 5 times greater)" and "an even more superlative state (adiabaticity is 40 times greater)."

Accompanying the self-regulated oscillation, we observed for the first time, a state in which temperature variations were transferred in the magnetic island and one in which temperature variations were small with repeatedly alternating cycle. This discovery of the self-regulated oscillation means that there is variety in the performance of plasma confinement (adiabaticity). This discovery provides new guiding principles for producing a magnetic island with good confinement condition, and will greatly contribute to fusion research. Further, this newly discovered mechanism may also be significant for interpreting space and solar physics effects, and we anticipate the wide circulation of these results academic research.

These research results were published in the British academic science journal *Scientific Reports* (online edition) of the Nature group on November 4, 2015, and is widely available.

More information: K. Ida et al. Self-regulated oscillation of transport and topology of magnetic islands in toroidal plasmas, *Scientific Reports* (2015). DOI: 10.1038/srep16165

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