KSTAR Controls Edge Localized Mode (ELM):
Controlling Fusion-Power Exhaust by Magnetic Field Perturbation

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Energy production by nuclear fusion reactions has long been a human dream and many researchers around the world have engaged in fusion research for many years. To enhance power efficiency, the primary objective has been to produce as much fusion in as small a volume as possible. However, we consequently encounter the problem of how we may then dissipate the exhaust power, due to the high thermal flux of the fusion products.

There have been two ways to circumvent this difficulty. One is to develop plasma facing materials which can withstand the high heat flux in severe high-flux neutron environments. Another approach is to control power dissipation by diverting or dispersing the heat flux through plasma-shape controls, without reducing fusion power gain.

In tokamak-type fusion reactors, which up to now have shown superior performance compared to other types of fusion machines, it is well known that the so-called plasma instability edge localized mode (ELM) plays an important role in power exhaust. Controlling ELMs is also one of the critical issues of controlling the power exhaust in ITER.

Since the creation of the first tokamak fusion machine (T-1) in the Soviet Union, many fusion research machines have been constructed and tested worldwide, including Japan, the US, and Europe. The recently constructed KSTAR machine, as seen in figure 1, was designed to reflect contemporary concepts in physics and also was equipped with new control knobs

KSTAR Building

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Fig. 1: Overview of KSTAR main vessel in 2011

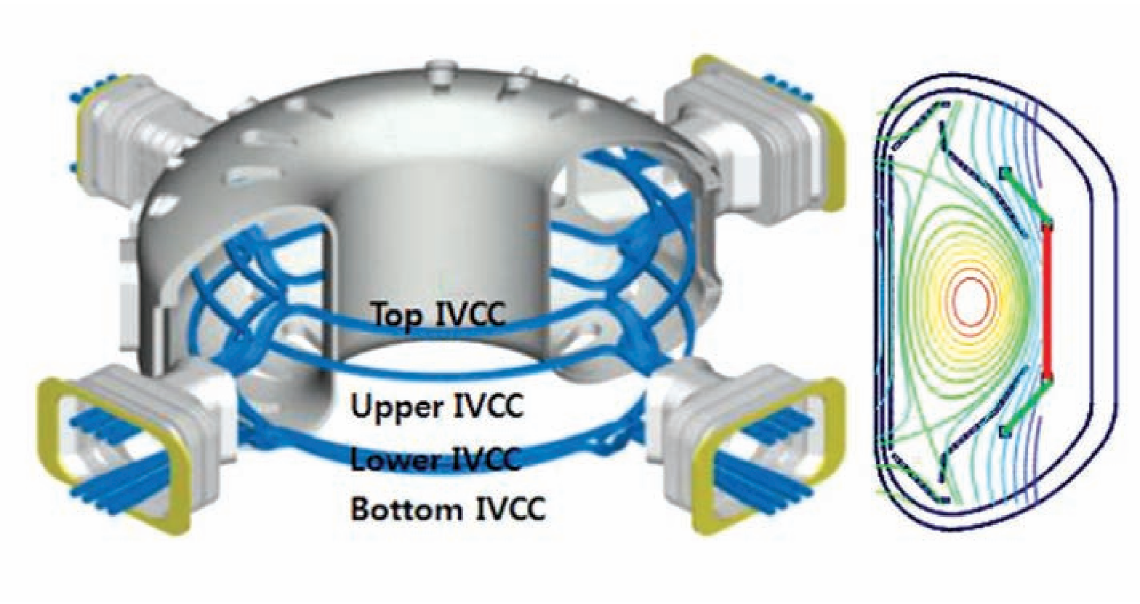

Fig. 2: In-vessel control coils in KSTAR

and diagnostics. For example, in-vessel control coils (IVCC), as seen in figure 2, support the aforementioned ideas from an engineering standpoint and a newly developed ECE-i diagnostic system supports the investigation of the internal plasma structures with 2-D images. Since KSTAR's first plasma in 2008, after over ten years of construction, KSTAR has advanced, targeting its final goal step by step through four experimental campaigns.

In the 2011 experimental campaign, by applying a toroidal n=1 mode resonant magnetic perturbation (RMP) field to the plasma boundary using IVCC, ELM suppression was first achieved in KSTAR as shown in figure 3. Before applying RMP, the regular ELM spikes in H-alpha light of the so called Type-I were observed. The type I ELM was changed to very huge spikes transiently after applying the magnetic perturbation and then the plasma finally transitioned to an ELM free or suppressed stable state. Note that a regular mode structure was set up and showed a high mode number before applying RMP but it showed an irregular or semi-chaotic structure in the ELM suppression period (4.3 s). This result suggests that a simple coil structure (n=1) rather than a complicated one (n=2 or 3) might provide ELM suppression in fusion reactors.

Additionally, ELMs were found to be mitigated by supersonic molecular beam injection (SMBI) and vertical jogging of the magnetic field in KSTAR.

Based on the obtained experimental results for power exhaust, KSTAR will pursue its original aim of fusion plasma experiments using pulses of long duration.

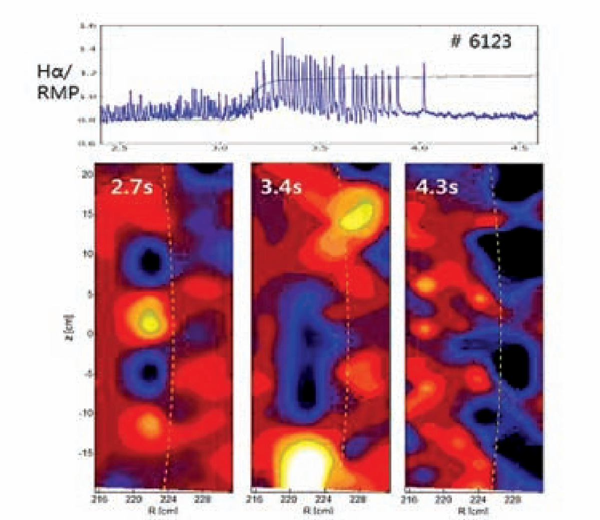

Fig. 3: Top: Time evolution of H-alpha (black line indicates RMP field). Bottom: corresponding ECE-i images(dot lines indicate LCFS)