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Observation of ELM-free improved energy confinement mode of hot ion plasmas in KSTAR

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In recent years, the stationary long pulse operation of hot ion temperature plasmas of 10~15keV has been highlighted in KSTAR. This remarkable achievement was accomplished by operating the plasma in quite low density with sufficient neutral beam heating. By preventing the plasma from H-mode transition, we could make an improvement of energy confinement as much as in H-mode, while keeping the particle confinement in L-mode without ELM crashes. In addition, a further improvement can be made by changing the magnetic configuration to unfavorable ion grad-B drift one. This new improved confinement mode, analogous to so-called I-mode [1], is discussed in this presentation.

In this improved mode, the most remarkable outcome is the extremely high ion temperature together with strong toroidal plasma rotation. The large increase of core ion temperature seems to be linked with strong stabilization of sawteeth instability with no internal transport barrier. Therefore, adding central ECH usually leads to sawteeth crash resulting in breaking down high Ti state.

Magnetic configuration change made additional improvement on energy confinement. By controlling the X-point toward unfavorable ion grad-B drift direction, the overall performances are improved more than 30~50% additionally. This high confinement discharge shows a clear pedestal structure on edge profiles, while the density was remained in L-mode level. Interestingly, a sort of weakly-coherent-mode (WCM) is observed in low frequency (~20kHz) unlike those in other I-mode discharges [1].

For reliable access and robust sustainment of I-mode, several control recipes relying on different physics basis have been developed and utilized at various conditions. I-mode can be activated either by changing the magnetic configuration to unfavorable ion grad-B drift direction or by controlling the heating power above a threshold under the same magnetic configuration. Since the sawtooth stabilization turns out to be one of key elements for stable I-mode operation without any mode-locking, an elaborate early-neutral-beam scenario or q_{min} control was developed and applied successfully. Also, an edge-localized magnetic perturbation (E-RMP) is shown to be an effective tool to make I-mode access more robust. As a result, the operation regime of I-mode is effectively expanded in view of heating power and plasma density. Furthermore, an integrated operation scenario combining both L-to-I and I-to-H transitions in a sequence was able to explore extremely high beta plasma operation even with limited heating powers. As a summary, we discuss the potential possibility of this I-mode as an alternative advanced scenario for future devices.

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References

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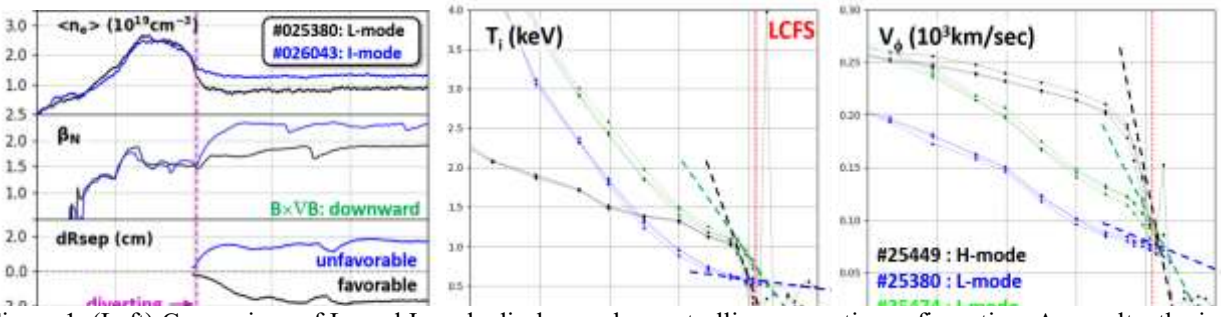

Figure 1. (Left) Comparison of L- and I-mode discharges by controlling magnetic configuration. As results, the ion temperature (middle) and toroidal rotation (right) profiles are shown for H-, L-, and I-modes, respectively