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Breaking of the ion temperature clamping in EAST electron-heated H-mode plasmas by applying neutral beam injections

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A major goal of fusion energy research is to heat and confine ionized gases (i.e. deuterium and tritium) so they fuse into heavier elements, producing significantly more power from fusion reactions than power put into the plasma for heating[1]. An essential condition for the realization of fusion reactions is to have a high fusion triple product ($n_i T_i \tau_E$), which is extremely dependent on the temperature of main ions. Therefore, it is critical to raise the ion temperature effectively in the fusion devices.

At the EAST Tokamak, the ion temperature (T_i) is observed to be clamped[2] around 1.25keV in electron-heated plasmas, even at core electron temperatures up to 10 keV (depending on the electron cyclotron resonance heating - ECRH - power and the plasma density), as shown in Fig.1. This clamping is caused by turbulence driven transport. Turbulent transport analysis shows that trapped electron mode (TEM) and electron temperature gradient (ETG) driven modes are the most unstable modes in the core of electron-heated H-mode plasmas. However, recently it was found that the T_i/T_e ratio can increase further with the fraction of the Neutral Beam Injection (NBI) power, which leads to a breaking of T_i clamping. In NBI-heating-dominant H-mode plasmas, the ion temperature gradient (ITG) driven modes become the most unstable modes. The growth rate of the ITG modes increases following the rise of the T_{i0}/T_{e0} ratio. Furthermore, a strong and broad internal transport barrier (ITB) can form at the plasma core in high-power NBI heated H-mode plasmas, which results in steep core T_e and T_i profiles, as well as a peaked n_e profile. Power balance analysis shows a weaker T_e profile stiffness at the core plasma after the formation of ITBs, where T_i clamping is broken, and the core T_i can increase further above 2 keV, which is 80% higher than the value of T_i clamping in electron-heated plasmas.

This finding proposes a possible solution to the problem of T_i clamping and demonstrates an advanced operational regime with formation of a strong and broad ITB for future fusion plasmas dominated by electron heating.

References

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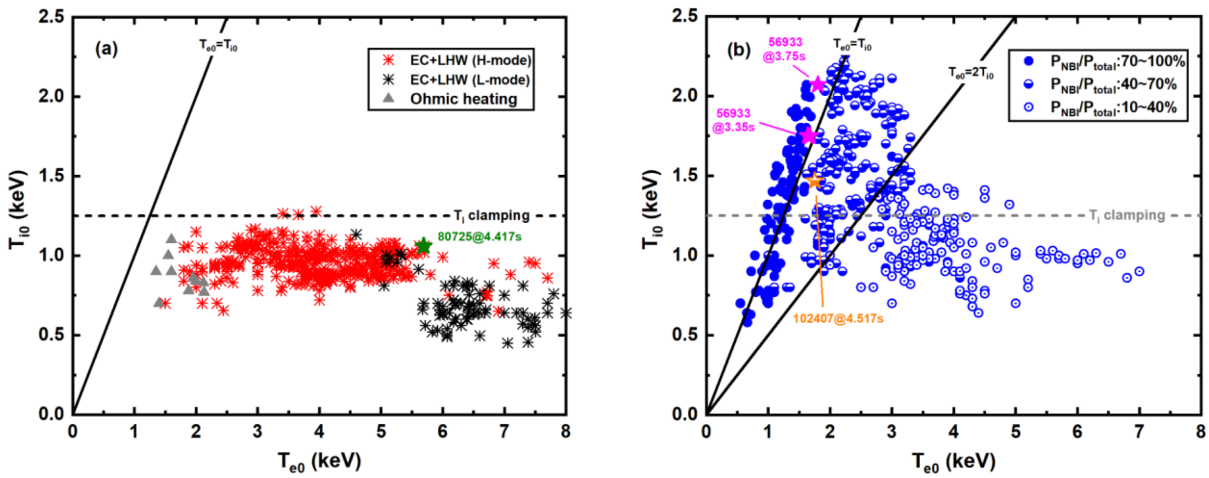

Figure 1. Variation of core electron temperature (T_{e0}) with core ion temperature (T_{i0}) at (a) electron-heated plasmas and (b) NBI heating dominant plasmas on EAST.