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# Effect of ion temperature on detached plasma formation using a linear divertor simulator TPDsheet-U

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The divertor is subject to damage by high heat flow particles emitted from the core plasma. Therefore, it is considered to reduce the heat load on the divertor plates by introducing neutral gas to generate a detached plasma. In the divertor of future DEMO-class devices, further reduction of the heat load is required, and simulation experiments of advanced divertors employing a divergent magnetic field configuration, such as the Super X divertor, are in progress. Therefore, basic research on heat load reduction in detached plasma is being actively conducted in small linear divertor simulators.

However, the ion temperature of the plasma produced by most linear divertors is as low as ～3 eV, which is significantly different from the ion temperature of the divertor plasma of large devices such as the International Thermonuclear Experimental Reactor (ITER), which is ～10-20 eV. Therefore, the effect of ion temperature on detached plasma generation has been an open question in basic research using linear divertor simulators. In addition, the process of detached plasma generation in the divergent field configuration used in advanced divertors has also been mainly studied by simulation, and few basic experiments have been conducted.

The objective of this study is to investigate the generation process of detached plasma with respect to ion temperature by ion cyclotron resonance (ICR) heating of high-density sheet plasma generated in a linear divertor simulator (TPDsheet-U). The sheet plasma used here is a boundary plasma, and compared to ordinary cylindrical plasma, it is thought that radiofrequency waves from the outside can penetrate the plasma more easily and efficiently heat the ions.

In this experiment, RF power in the ion cyclotron frequency band (1.0-1.3 MHz) was applied to a dense hydrogen sheet plasma ($n_e$～$10^{19}$ $m^{-3}$, $T_e$～10eV) and the energy of the heated plasma was measured using a magnetic loop coil for the ICR heating effect. Detached plasma formation such as electron density, electron temperature, and Hγ/Hα were analyzed using Langmuir probes and visible spectroscopy, respectively. As a result, it was observed for the first time that the electron temperature of the detached plasma increased and the Balmer series emission intensity ratio decreased when the ion temperature was increased by applying a resonance frequency $\omega_{RF}$, which is about 1.2 times the ion cyclotron frequency $\omega_{ci}$ of the hydrogen ions. This suggests that increasing the ion temperature causes a transition from detached plasma to attached plasma.

Figure1 shows the energy relaxation time ratio ($T_e$=10eV) versus ion temperature and plasma density for $T_e > T_i$, the temperature relaxation time $\tau_{ei}$ is much smaller than the particle confinement time $\tau_p$, so Te decreases and the electron energy loss increases. On the other hand, electron energy is transferred to ions, and ion energy is lost through charge exchange. As a result, radiative recombination and three-body recombination (EIR) occur. Conversely, for $T_e \leq T_i$, as the ion temperature increases, the temperature relaxation time $\tau_{ei}$ is equal to or greater than the particle confinement time $\tau_p$, and energy is transferred from the ion to the electron in the opposite direction. Therefore, the electron temperature does not decrease sufficiently, and the formation of detached plasma is suppressed.

References
[1] Okada, Naonori, et al. "Effects of ion temperature on detached plasma formation using a linear divertor simulator TPDsheet-U." Fusion Engineering and Design 192 (2023) 113596.

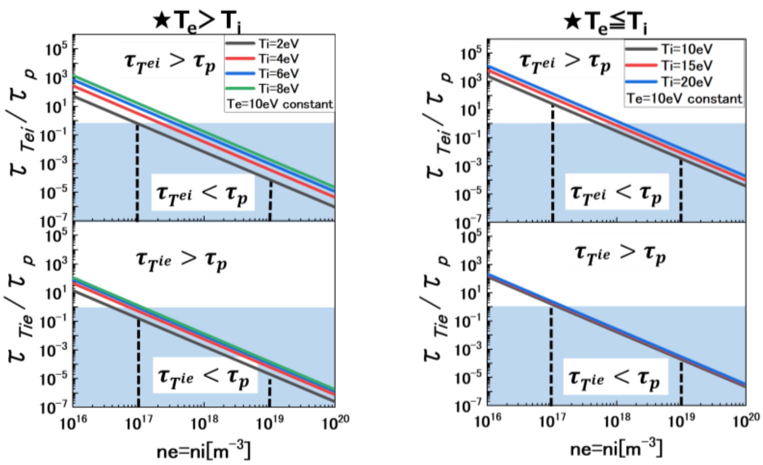


**Figure 1** Dependence of temperature relaxation time on plasma density.