## §29. Density Limit of ICRF Sustained Plasma

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The performance of the ICRF heating was better in the higher range of electron density in LHD. The stored energy of 240 kJ was achieved at the electron density of 1.5 x $10^{19}$ $m^{-3}$ by applying the ICRF power of 2.4 MW. Plasma was initiated by ECH, and heated and sustained only by ICRF pulse. The stored energy was increased almost linearly as the electron density increasing up to 1.5 x $10^{19}$ $m^{-3}$ with fixed ICRF power.

However this tendency was saturated and degraded at the higher density range. In NBI plasma, this saturation was occurred at the much higher density range of several times at the same power level. This density limit of ICRF was gradually increased by the antenna conditionings during the initial phase of experimental period. Therefore this phenomenon is seemed to relate with the plasma-wall interaction at the plasma peripheral region or at the neighborhood of the antennas. Further wall conditioning like the boronization may be effective in getting the higher performance.

In Fig.1, the stored energy of ICRF sustained plasma are plotted by changing the electron density. The increase of stored energy at the range of less than 1.5 x $10^{19}$ $m^{-3}$ is due to the improvements of the energy confinement of LHD and also of the antenna coupling to the plasma as increasing the plasma density.[1] There is the saturation at the higher density range. This tendency is quite different with the NBI heating of the same power level. Figure 2 shows the stored energy of NBI heated plasma on the wider density range. In the low density range, the performances of the plasma of ICRF and NBI were not so different, however at the higher density range of over 2 x $10^{19}m^{-3}$, there is an apparent difference between these heatings.

The density limits of these heating methods are compared with the scaling laws of helical devices. In Fig.3, the obtained electron density in ICRF is shown by changing the heating power. Dashed line is the scaling law of helical devices derived from the medium size helical devices. Data of NBI heating with gas-puff mode of Fig.2 well agree with the values of the scaling. The data of ICRF have small value of around half of the scaling law.

One of the explanations of this difference is that: NBI mainly heats electrons but ICRF heats ions. The minority ions heated by ICRF have large pitch angle and some particles have large shifted orbits from the magnetic surfaces. These cause the higher plasma-wall interactions in ICRF plasma. From the observations on the large tokamaks, it can be expected that the ICRF performances will be largely improved by the advanced wall conditionings using boron coating or others. Wall coating is scheduled on the experimental period in 2001 in LHD.

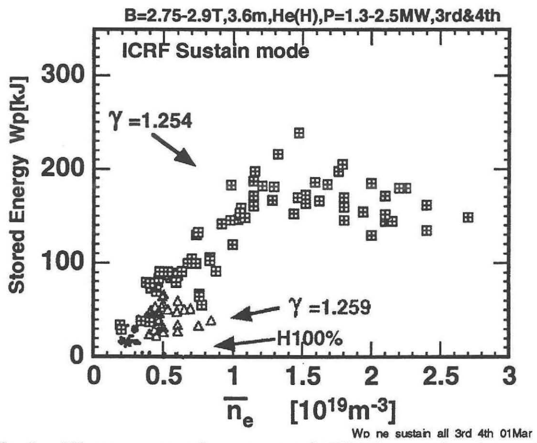


Fig.1 Plasma stored energy of ICRF sustained mode is shown for plasma density. (Boxes and triangles: He plasma with H minority ion with different coil pitch parameters γ, Closed circles: H 100% plasma )

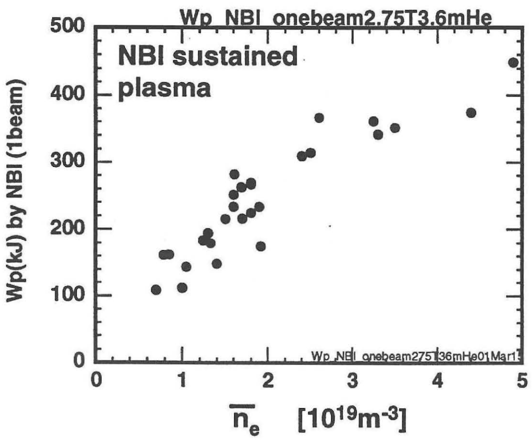


Fig.2 Plasma stored energy of NBI sustained mode is shown for wide density range. NBI power was 1.5MW and gas puff fueling was used.

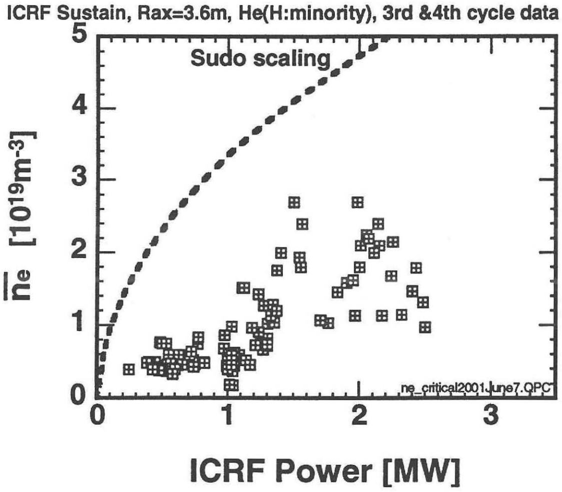


Fig.3 Electron density of ICRF sustained plasma is shown by changing the ICRF power. Dashed line is critical density of scaling law (by Sudo) of helical devices of medium size.

**Reference**

[1] T. Mutoh, et al., Journal of Plasma and Fusion Research, **77** (2001) 495