Studies of non-inductive tokamak plasma start-up with various lower hybrid current drive scenarios

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Fully non-inductive operation of a tokamak allows for removal of the central solenoid, which may lead to a compact economical fusion reactor. Fully non-inductive tokamak plasma start-up using lower-hybrid (LH) current drive has been studied on the TST-2 spherical tokamak. Start-up up to about a quarter of the Ohmically driven plasma current has been achieved fully non-inductively using LH waves launched from the outer-midplane side and the top side of the plasma [1].

For the conventional outer-midplane launch scenario, numerical simulations showed that absorption was weak. Experimentally, uncontrolled density increase has been observed during the rf pulse possibly due to weak absorption and increased LH wave interactions in the scrape-off-layer (SOL). For the top launch scenario, strong absorption was predicted due to the parallel refractive index upshift characteristics. Density control was also observed to be much better for the top launcher compared to the outer-midplane launcher. However, strong thick-target x-ray radiation was observed during the top launcher pulse. This is thought to indicate that LH waves drive radially outward fast electron diffusion that leads to large fast electron losses at the limiters [2]. In both these scenarios, numerical simulations showed that LH waves were absorbed only near the edge of the plasma, limiting the current drive efficiency.

A new off-midplane LH launcher was recently developed and installed (Fig. 1) to achieve good absorption nearer the magnetic axis [3]. The LH waves launched from the outer-off-midplane side were predicted to propagate through the magnetic axis due to refraction. The initial parallel refractive index was chosen to be relatively high (~13) so that the LH waves could interact with the cold core electrons in the tens of eV range.

The new LH launcher is a capacitively coupled combline antenna with seven straps and 90 degrees phasing between the straps [3]. Only the two elements at the ends are connected to the transmission line. In vacuum, the power fed from the input port comes out of the output port connected to a dummy load. In the presence of a plasma, some of the power is radiated into the plasma as LH waves. Since reflection is always low, the LH system is quite resilient to changes in plasma conditions.

Using the new off-midplane LH launcher, tokamak configuration was successfully generated. The plasma generated by the off-midplane launcher had on-axis electron temperature twice as high as the previous two antennas. Density control was also better with the off-midplane launcher. This may be due to better core absorption and reduced LH wave interactions with the SOL plasma. At the same time, x-ray radiation was observed to be much lower during the off-midplane launcher pulse compared to the top launcher pulse. This indicates that LH wave driven fast electron losses were successfully reduced.

This work was supported by JSPS KAKENHI Grant Numbers 22K03573 and 21226021, NIFS Collaboration Research Programs NIFS20KUTR155 and Japan/US Cooperation in Fusion Research and Development. Work at General Atomics was supported by US DoE contract DE-AC03-97ER-54411.

References

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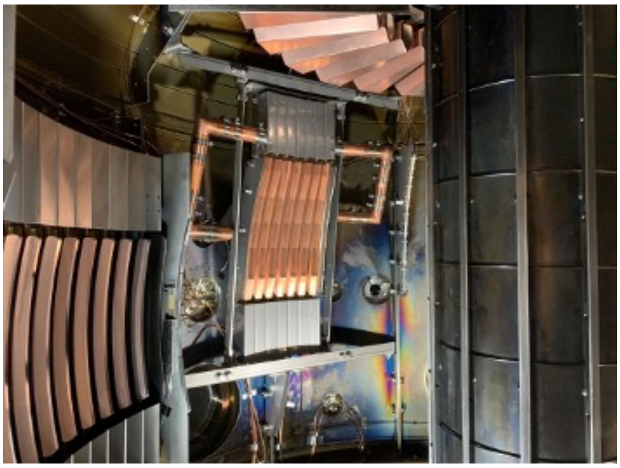

Figure 1. The newly installed off-midplane launcher (center) with the previously installed midplane launcher (left) and top launcher (top).