(3) RF Heating Technologies

In the experimental campaign of 2007FY, EC and ICRF heating have made steady progress for high power and long pulse operations. The most remarkable result was the extension of the long pulse operation in the high power region exceeding 1 MW using both ICRF and ECH. In 2005FY we achieved the record of 1.6 GJ for input energy, the highest value in the world magnetic fusion devices, with the average input power of 490 kW (ICRF: 380kW, ECH: 110kW). The main target in the steady state operation in 2007FY was to achieve as long pulse sustainment as possible with the input power of more than 1 MW. It is again clarified that the input energy was not limited by heating system performance but by sudden impurity influx inside the plasma chamber.

At the long pulse operation, impurity influx of metal dusts or flakes from the wall or divertor tiles has been a major factor of plasma. Especially in the higher power operation of more than one mega watt, the impurity influx frequently caused bright sparks. After the bright sparks, plasma was usually terminated by radiation collapse. In the last year campaign, the long pulse discharge by mega watt power injection was an important task in LHD. Because the high power can sustain high density plasmas and it improves the plasma parameters such as temperature and confinement time. For this purpose, deposits and exfoliation films on the divertor tiles, vacuum vessel wall, and ICRF antennas were removed before the start of the experimental campaign. A plasma sustainment with the injection power of 1.0 MW and 800 seconds was successfully achieved. The pulse length was extended more than 1.5 times from the experiment in 2006FY at the same injection power. Repetitive hydrogen pellet injection was utilized in order to keep the ratio of hydrogen and helium ion concentration ratio. Center-peeked electron temperature profile was obtained with the repetitive pellet injection. Further investigation is required to clarify the mechanism of this temperature behavior.

The ECH antenna alignment has been checked with high power inside the vacuum vessel before the experimental campaign. The confirmation of the alignment of the injection beam made the optimization process for attaining the high electron temperature in the higher magnetic field operation.

ECH In 2007FY, a new 77 GHz gyrotron developed under the collaboration between NIFS and University of Tsukuba was installed in one of the gyrotron tank as a replacement of an old 168 GHz gyrotron. The specified power and pulse width were 1 MW/3s and 0.3MW/CW. This new gyrotron was brought to NIFS after successful demonstration at the short pulse, 1 MW operation in University of Tsukuba. The conditioning of the gyrotron was continued injecting the power into the dummy load. During the experimental campaign, the output power from this gyrotron was coupled to one of the evacuated 88.9 mm corrugated waveguide system to transmit the power into LHD. Final achievement of the gyrotron in 2007 was 800 kW, 3.6 s.

The waveguide system used for this gyrotron was modified in accordance with this upgrade of the gyrotron. O-ring vacuum seals at the miter bends are replaced by those of metal gasket for the better vacuum pressure. Copper plates with water cooling channel are installed covering the waveguide surfaces all along the transmission line. Some of the miter bends are developed and fabricated in NIFS to add the cooling channels in the miter bend block and to be accommodated with the use of metal gasket. The vacuum window at the LHD antenna is replaced by that of the CVD diamond for the higher power and longer pulse transmission capability. The connecting waveguide to this diamond window is also developed to allow the installation of the IR temperature monitor as well as the fiber optics mount for the arc sensor with minimum distortion of the corrugated waveguide.

Such upgrades on the other transmission line are planned for one more new 77 GHz gyrotron that is developed and demonstrated 1 MW short pulse operation in University of Tsukuba in 2007FY.

ICRF Long pulse operation was an important subject for ICRF heating. To prevent plasma termination caused by impurity influx, cleaning of plasma facing components was carried out during the maintenance period before the LHD experiment. Metallic deposits and exfoliation films observed on the divertor tiles, vacuum vessel wall, and the ICRF antennas were removed. The divertor tiles which were located at the high heat load section were replaced by the high performance type. Temperature increase of the new high performance tiles saturated during 1MW and 800 sec operation and the temperature was less than 100 degree. Sparks in the vacuum vessel produced from 7-I port direction was not observed. Feedback control of impedance matching system was improved. Tuning speed was increased by upgrading the motor of the pump which changes liquid level of the stub. Control system of liquid stub tuner was also improved as a whole. Performance and reliability of the impedance matching system were enhanced not only for real time control during long pulse operation but also for high power injection in short pulse operation. Water leak in vacuum was occurred at one ICRF antenna. All antennas were dismounted from LHD to improve for the experimental campaign in FY2009.

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