§11. Heating and Current Drive Experiments on the TST-2 Spherical Tokamak

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This research is carried out as collaboration among several universities and NIFS. The purpose of this collaborative research is to perform heating and current drive experiments using radiofrequency (RF) waves on a spherical tokamak (ST) plasma, with the eventual objective of developing innovative methods for plasma start-up and steady-state sustainment.

The TST-2 spherical tokamak at the University of Tokyo is presently the largest ST device in Japan, with $R = 0.38$ m and $a = 0.25$ m (aspect ratio $R/a = 1.5$). It has already achieved toroidal magnetic fields of up to 0.3 T and plasma currents of up to 0.14 MA. RF power of up to 400 kW in the frequency range 10–30 MHz is available for this experiment. In addition, transmitters at 200 MHz, previously used on the JFT-2M tokamak, have been transferred from JAEA.

During Fiscal Year 2005, two RF transmitters were brought to operation at a frequency of 21 MHz and an output power of 200 kW each. Heating experiments using the high harmonic fast wave (HHFW) have resumed after relocation of TST-2 to the Kashiwa Campus of the University of Tokyo, and initial results were obtained.

The preparation of RF transmitters for TST-2 was carried out by collaboration between the University of Tokyo RF group and the ICRF group of NIFS. Improvements and RF power testing were initiated in Fiscal Year 2004. During Fiscal Year 2005, full-power testing of the final power amplifiers, improvement of the control system (including the implementation of protection circuits), development of a tuning algorithm, adjustments of the matching circuits and transmission lines, and high power testing of the antenna were performed successfully.

Previously, while TST-2 was located on the Hongo Campus, only one transmitter was used for a short pulse (1ms or less). At the Kashiwa Campus, two transmitters were installed with a full set of power supplies. This has enabled operation at the full power of 400 kW using both transmitters, and for longer pulses (about 10 ms, sufficiently longer than the energy confinement time).

While TST-2 was at the Hongo Campus, an antenna consisting of two elements (current straps, each with width 10 cm, height 60 cm) was used to excite the HHFW. The RF currents flowing on the two current straps are out of phase. This antenna had a fixed spacing between the two current straps (18° center to center), and the Faraday shield orientation was horizontal. The antenna was upgraded to enable excitation of different toroidal mode numbers (and therefore, the wavenumber parallel to the magnetic field, which is important for determining wave absorption) by varying the distance between the two current straps. Since the excitation of the slow wave at the plasma periphery can lead to increased edge electric fields and RF sheath voltages, and consequently generation of impurities, the Faraday shield was modified to follow the average inclination of the magnetic field for typical operation (about 30° from horizontal) in order to short out the electric field parallel to the magnetic field lines. The separation between the two current straps can be adjusted so that the dominant toroidal mode number is 4, 6, or 10, which should be absorbed strongly by electrons with temperatures of around 70 eV to 400 eV.

In the HHFW heating experiments performed during Fiscal Year 2005, high power RF injection (greater than 300 kW) was achieved, and initial indications of electron heating, such as increased soft X-ray emission intensity, were observed.

In order to understand wave physics, it is very important to measure the wave excited in the plasma directly. A diagnostic to measure the wave in the plasma interior using microwave reflectometry is being developed on TST-2. It is indispensable to take diffraction effects into account in order to evaluate the experimental data quantitatively. Imaging optics have been designed and fabricated based on wave calculations taking this effect into account, and its performance was tested. The phase of the reflected wave from the plasma was measured when 100 kW of RF power was injected, and the density fluctuation amplitude obtained from its variation, and the RF electric field amplitude were evaluated. The upper limit on the RF electric field amplitude was about 1 kV/m, consistent with that obtained by an order estimate. An example of reflectometer data is shown in Fig. 1. The radial structure, obtained by sweeping the incident microwave frequency, is qualitatively consistent with the result of a full-wave calculation. . However, a further noise reduction is required for a more quantitative comparison.

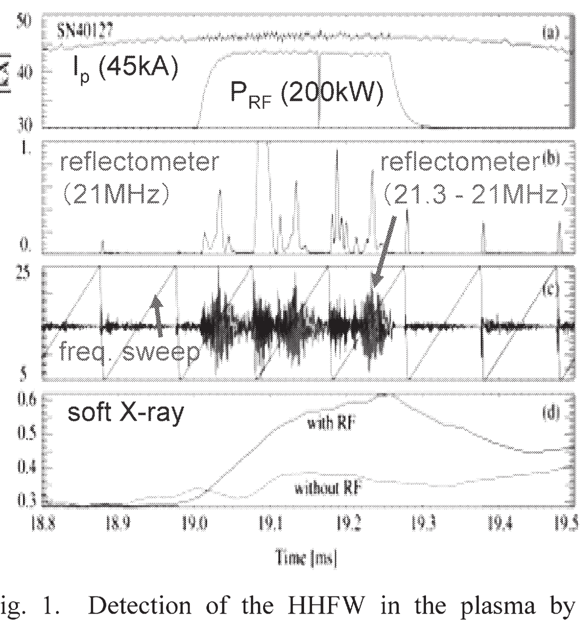

Fig. 1. Detection of the HHFW in the plasma by a reflectometer.