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

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The purpose of this collaborative research is to perform heating and current drive experiments using radiofrequency (RF) waves on spherical tokamak (ST) plasmas. This research aims at establishing the scientific basis for RF heating and current drive in plasmas with very high dielectric constants, 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 a major 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. TST-2 has the advantages of ample experimental time and flexibility with short turn-around time for hardware modifications. RF power of up to 400 kW in the frequency range 10–30 MHz is available, and heating and current drive experiments using the high-harmonic fast wave (HHFW) at 21 MHz are being performed using this equipment. In addition, four transmitters at 200 MHz, previously used on the JFT-2M tokamak, have been transferred from JAEA. This frequency is suitable for testing plasma current ramp-up by the lower hybrid wave.

The preparation of lower hybrid current drive and plasma current start-up experiments on TST-2 was continued by collaboration between the University of Tokyo RF group and the NIFS RF group during Fiscal Year 2008. Testing and adjustments of the 200 MHz transmitters transferred from JAEA (Fig. 1), which were started in Fiscal Year 2007, are now nearly completed.

Various diagnostics associated with the transmitters were calibrated, control and signal wiring was completed, transmission lines were installed, and power supplies were prepared for operation. Adjustments of the input and output tuning circuits were performed, and an output power of 100 kW was achieved from each of the four transmitters. The outputs of two transmitters were combined, and the outputs of the two combiners were connected to each of the two existing loop antennas. The dependence of the power combiner output on the phase difference of input powers was measured. Stub tuners are required to transform the antenna impedance to the characteristic impedance of the transmission line. Adjustments of the stub tuners were performed with vacuum load (no plasma). Preparations for the lower hybrid experiment are now nearly complete, except for control electronics such as protection circuitry for the transmitters.

Although the initial experiment will make use of the existing two-loop antenna used for the HHFW experiment up to now, lower hybrid current drive experiment requires the excitation of a uni-directional travelling wave. The combline antenna makes use of mutual coupling between adjacent loops, and is suitable for exciting a travelling wave. The combline antenna used previously on the JFT-2M tokamak has been transferred from JAEA to the University of Tokyo, and is being modified for use on TST-2 (Fig. 2). The combline antenna has the characteristics of a band-pass filter. The electric characteristics of this antenna were measured, and the band-pass characteristics were confirmed. The next step is to design and fabricate the feeder lines to the two edge elements of the eleven-element array of quarter-wave resonant loops which comprise the combline antenna.

Plasma current ramp-up experiments using the lower hybrid wave are planned to commence in 2009.

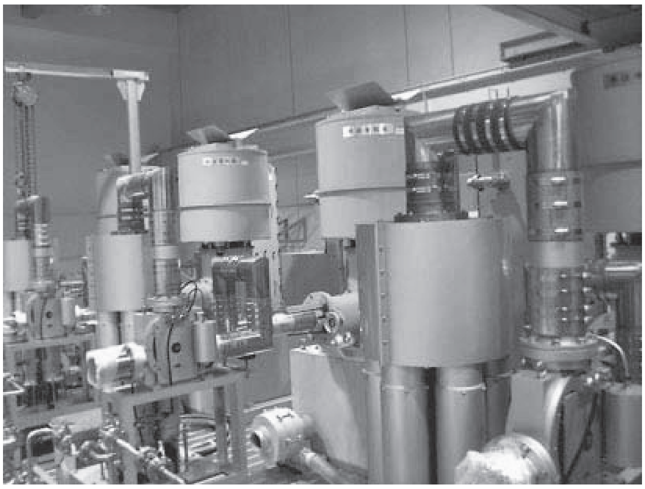

Fig. 1. Four 200 MHz transmitters and circulators transferred to the University of Tokyo from JAEA. Output power of 100 kW was achieved from each of the four transmitters.

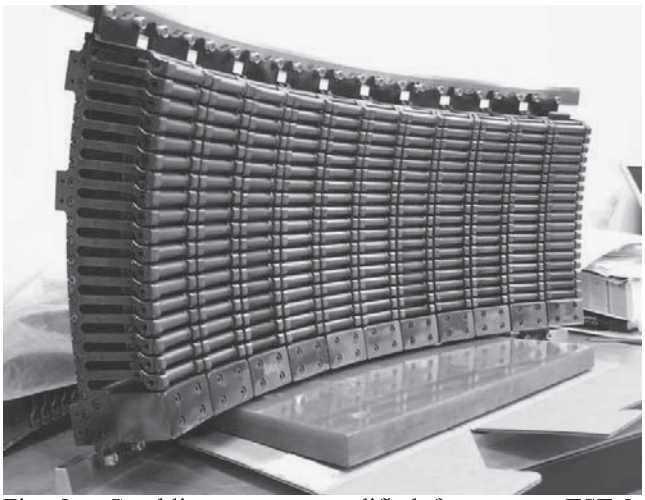

Fig. 2. Combline antenna modified for use on TST-2. The antenna is an array of eleven quarter-wave elements resonant at 200 MHz. RF power is fed to the antenna array from one end, propagates to adjacent elements by mutual inductance, and the left over power not radiated into the plasma exits from the other end of the antenna array.