§6. 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 for heating and current drive by the high-harmonic fast wave (HHFW). In addition, four transmitters with output powers of 100 kW each 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 (LHW). The preparation for 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 2009. An output power of 100 kW into the dummy load was achieved from each of the four 200 MHz transmitters.

As shown in Fig. 1, the output powers of two transmitters are presently connected to the two-strap loop antenna, previously used for the 21 MHz HHFW heating experiment. In FY 2009, electronic circuits including high reflection interlock and grid voltage keying pulse were prepared. High power phase shifter breakdown failures were identified to be due to metal powder accumulation on teflon discs supporting the center conductor. These were disassembled and cleaned. Impedance matching was achieved by double-stub tuners attached to each half of the two-strap antenna. RF powers exceeding 100 kW can now be delivered into the plasma through this antenna.

Although preliminary experiments will be performed using the two-strap loop antenna, this antenna cannot excite a uni-directional travelling wave necessary for current drive experiments. 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 was modified for use on TST-2. The TST-2 combline antenna consists of an array of eleven-element quarter-wave resonant loops coupled by mutual inductance (Fig. 2). The advantage of the combline antenna is that only the edge element needs to be excited externally. 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 feeder lines to the edge elements were designed and fabricated. This antenna will be installed in early FY2010, and plasma current ramp-up experiments will begin soon thereafter.

[1] Y. Takase, “ST Research in Japan (invited),” MAST Research Forum (Culham, UK, Sept. 2009).
[2] Y. Takase, “RF Start-up, Heating and Current Drive Studies on TST-2 and UTST (invited),” 15th International Workshop on Spherical Tori 2009 (Madison, USA, Oct. 2009).
[3] Y. Takase, et al., “RF Experiments on TST-2,” 51st Annual Meeting of the Division of Plasma Physics, American Physical Society (Atlanta, USA, Nov. 2009).

Fig. 1. Photograph showing the coaxial transmission lines to deliver RF power from 200 MHz transmitters installed on the mezzanine level to the two-strap loop antenna installed inside the TST-2 vacuum vessel.

Fig. 2. The TST-2 eleven-element combline antenna. 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.