§4. RF Plasma Generation and Current Ramp-up Experiments on Spherical Tokamaks

Takase, Y., Ejiri, A., Tsujii, N., Wakatsuki, T., Kakuda, H., Sonehara, M., Shinya, T., Furui, H. (Frontier Sci./Sci., Univ. Tokyo), Maekawa, T., Tanaka, H., Uchida, M. (Energy Sci., Kyoto Univ.), Nagashima, Y. (RIAM, Kyushu Univ.), Kasahara, H., Mutoh, T., Seki, T., Saito, K., Shimpo, F., Nomura, G.

The purpose of this research is to investigate experimentally the physics of spherical tokamak plasma formation and plasma current ramp-up using radiofrequency (RF) waves as network collaboration among Univ. Tokyo, Kyoto Univ., Kyushu Univ. and NIFS. The TST-2 device at the Univ. Tokyo (R = 0.38 m, a = 0.25 m, with RF powers at 2.45 GHz [5kW], 8.2 GHz [10kW], 21 MHz [400kW], and 200 MHz [400kW]) and the LATE device at Kyoto Univ. (R = 0.265m, a = 0.20m, with RF powers at 2.45 GHz [100 kW] and 5 GHz [100 kW]) are used. These two devices have both common facility (such as magnetic diagnostics, interferometer, X-ray diagnostics, electrostatic probes) and complementary facility (such as Thomson scattering and ion Doppler spectroscopy at TST-2, ion beam probe at LATE). Compared to advancing research independently on each device, it becomes possible to make more efficient progress towards developing understanding of universal physics by unifying the results obtained on both devices using complementary methods, utilizing the network collaboration framework. This research is a continuation of collaboration started in fiscal year 2012 (FY2012).

Waves used for plasma formation, plasma current ramp-up and sustainment are electron cyclotron wave, electron Bernstein wave, and lower hybrid wave, all of which are absorbed by electrons. Therefore, direct ion heating by these waves are not expected. However, it is possible for ions to be heated through other processes such as nonlinear wave-particle interactions. Measurements in low density (order of 10^{17} m^{-3}) RF generated plasmas are very difficult, but the ion temperature was measured successfully in LATE plasmas in FY2012 using the high resolution spectrometer transported from the Univ. Tokyo. In FY2013, toroidal and poloidal flows as well as the ion temperature were measured successfully in TST-2 plasmas using a newly developed mechanism to switch between toroidal and poloidal sightlines (Fig. 1). Similar measurements are planned for LATE. In LATE, first results of electrostatic potential measurements are being obtained. It would become possible to characterize the equilibrium of RF generated plasmas combining the results of potential and flow measurements.

Three kinds of probes are being developed collaboratively by Univ. Tokyo and Kyushu Univ. The electrostatic RF probe has a high impedance resistor attached immediately behind the probe electrode to eliminate the effect of cable capacitance which becomes important at high frequencies. An array of such probes are being used to measure the wavevector of the electrostatic lower hybrid wave. The turbulence probe consisting of a Mach probe and a three-axis magnetic probe was developed to measure the Reynolds stress and the Maxwell stress directly. It was found that the poloidal flow and the radial derivative of the Reynolds stress have similar radial profiles (Fig. 2). The Rogowski probe consisting of a Rogowski coil and a three-axis magnetic probe was developed to measure the local current density. The magnetic field pick-up on the Rogowski coil signal was eliminated successfully, and the radial profile of current density was measured successfully in inductively formed (OH) plasmas.

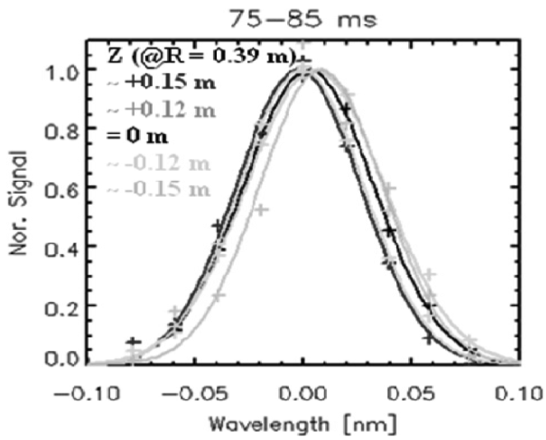

Fig. 1. Spectra of the 464.7 nm CIII line measured by the high resolution spectrometer in TST-2 RF plasmas formed and sustained by 15 kW of LHW power (I_p = 6.4 kA). Sightlines viewing the plasma poloidal cross section upward (blue, light blue) and downward (green, orange). T_i ~ 5 eV, v_{pol} ~ 3km/s.

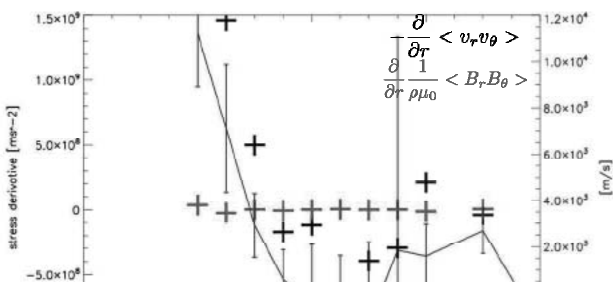

Fig. 2. Radial profiles of the poloidal flow velocity and the stress derivatives. Similar profiles were observed for the poloidal flow (blue) and the radial derivative of the Reynolds stress (black), while the radial derivative of the Maxwell stress (red) is negligible.