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

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The goal of this collaboration is to study experimentally the generation of plasma and the ramp-up of the plasma current by radiofrequency (RF) waves in spherical tokamaks (STs), under collaboration among Japanese universities (University of Tokyo, Kyoto University, Kyushu University) and NIFS. Two ST devices are used for this purpose, TST-2 at the University of Tokyo ($R$ = 0.38 m, $a$ = 0.25 m) with RF capabilities at frequencies 2.45 GHz (5 kW), 8.2 GHz (10 kW), 21 MHz (400 kW) and 200 MHz (400 kW), and LATE at Kyoto University ($R$ = 0.265 m, $a$ = 0.20 m) with 2.45 GHz (100 kW) and 5 GHz (100 kW). The two ST devices have both common equipments (such as magnetic diagnostics, interferometer, X-ray diagnostics, electrostatic probes) and complementary equipments (such as Thomson scattering at TST-2, ion beam probe at LATE, etc.). The Network-type Collaboration of NIFS enables attempts to develop understanding of universal physics efficiently by integrating the results obtained on the two complementary devices, instead of working independently on each device as in the past. The accomplishments during the fiscal year 2012 are described below.

i) Hard X-ray measurements on TST-2

Soft X-ray and low-energy hard X-ray spectral measurements have been performed with a Si(Li) detector, and high-energy hard X-ray spectral measurements have been performed with NaI scintillators and photomultipliers on TST-2 up to now. X-ray spectral measurements in the intermediate energy range were attempted on TST-2 with CdTe detectors being used on LATE. After noise elimination and calibration, it was demonstrated that spectral measurements under TST-2 conditions are possible. Preparations are under way to measure RF start-up plasmas on TST-2 with CdTe detectors purchased for use on TST-2.

ii) Microwave interferometers on LATE

Four microwave interferometers viewing the plasma along four different chords have been in use on LATE. Two more chords of interferometers were needed, but the cost of new systems prevented installation of additional chords. The TST-2 group proposed adding two new chords inexpensively by making use of PIN switches. This upgrade has been completed and experiments are now being performed using 6 chords of interferometers.

iii) Ion termperature measurement on LATE

RF waves that are used for non-inductive plasma current drive and plasma current ramp-up in ST, such as the electron cyclotron wave (ECW), electron Bernstein wave (EBW), and lower hybrid wave (LHW), are absorbed by electrons, so normally ion heating is not expected. However, in when the high-harmonic fast wave (HHFW) is injected into an OH plasma in TST-2, ion heating was observed. This is believed to be due to waves produced non-linearly by parametric decay instability (PDI). The ion temperature has not been measured in LATE, so the high-resolution visible spectrometer used in TST-2 was transported to LATE to measure the ion temperature. The measured ion temperature (shown in Fig. 1) was much higher than expected.

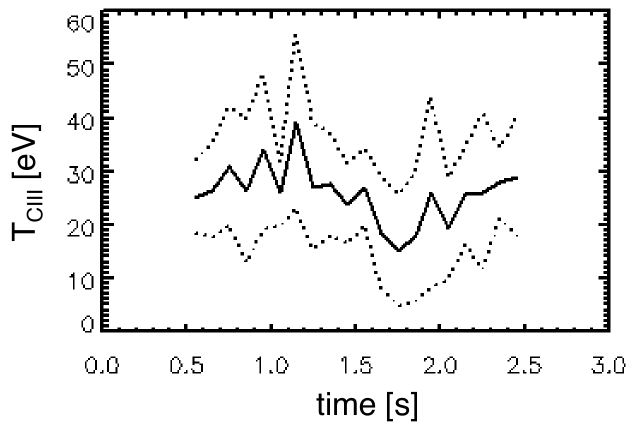


Fig. 1. Time evolution the Carbon ion temperature measured by Doppler broadening of the CIII line (464.7 nm) in LATE. The dotted lines indicate the range of ±1σ.

iv) Development of Electrostatic RF Probe

A new electrostatic RF probe for measuring RF waves is being developed between Kyushu University and the University of Tokyo. The eventual goal is to measure the wavevector of the RF wave using an array of electrostatic RF probes. A prototype electrostatic RF probe was tested.

Plasma current start-up experiments using the dielectric-loaded waveguide antenna were performed on TST-2. Non-inductive plasma current start-up to 10 kA was demonstrated using 40 kA of LHW power. The current drive figure of merit ($\eta_{CD} = I_p n_e R/P_{RF}$ ) of this antenna was higher than that obtained using the combline antenna, which is designed to excite a travelling fast wave. The best current drive efficiency was obtained in the case in which the $n_{||}$ (= $ck_{||}/\omega$) spectrum of the excited LHW was peaked around 9 and the toroidal field was higher than in previous experiments (0.2 T). There was a stronger X-ray emission in this case, which suggests that the fast electrons produced by LHW plays an important role in driving the plasma current.