§6. Study of Wave Physics in High Beta Plasmas

Takase, Y., Ejiri, A., Ono, Y., Yamada, T., Nagashima, Y., Adachi, Y., Tojo, H., Masuda, T., Oosako, T., Yamaguchi, T., Matsuzawa, H., Kobayashi, H., Yamada, K., Kurashina, H., Hayashi, H. (Frontier Sci., Univ. Tokyo),
Sasaki, M., An, B.I. (Sci., Univ. Tokyo),
Nishino, N. (Eng., Hiroshima Univ.),
Mitarai, O. (Eng., Kyushu Tokai Univ.),
Fukuyama, A. (Eng., Kyoto Univ.),
Maekawa, T., Tanaka, H. (En. Sci., Kyoto Univ.),
Hanada, K., Idei, H. (RIAM, Kyushu Univ.),
Mutoh, T., Kumazawa, R., Seki, T., Saito, K., Kasahara, H., Kawahata, K., Tanaka, K., Tokuzawa, T.

The purpose of this collaboration is to develop an RF heating method to produce high beta plasmas, which is a common issue in spherical tokamaks (ST) and helical systems. In particular, electron heating and current drive by Landau damping and transit time damping of the high harmonic fast wave (HHFW) are explored. The development of heating scenarios is carried out on both LHD and the TST-2 spherical tokamak at the University of Tokyo, with R = 0.38 m, a = 0.25 m (R/a = 1.5) and RF power of up to 400 kW at 21MHz. TST-2 has the advantages of ample experimental time and flexibility with short turn-around time for hardware modifications.

A successful measurement of the HHFW by a fast visible light diagnostic was made on TST-2. In the past, although detection of the scattered wave around the HHFW pump frequency was made successfully by a system using a photodiode, the pump wave itself was not separated from electromagnetic noise. The replacement of the photodiode with a photomultiplier tube (PMT), which is less susceptible to electromagnetic noise, has enabled detection of the HHFW pump wave. However, the system with a PMT does not have a sufficient dynamic range to detect the sideband wave produced by parametric decay instability (PDI). A new system using a hybrid photodetector (HPD), which has the combined advantages of the PMT and the avalanche photodiode (APD), is being developed.

PDI data obtained by electrostatic probes indicated that the low frequency ion-cyclotron quasimode (ICQM) has electrostatic characteristics, and that the HHFW pump wave has a relatively long correlation length. Previouly unknown PDI components were discovered in the frequency spectra measured by magnetic probes (Fig. 1). Since the frequency difference from the pump wave frequency increases proportionally to the toroidal magnetic field B_ϕ, these may be generated by PDI involving cyclotron motions of molecular or impurity ions. Although several suggestive results are obtained, no definitive conclusion can be drawn on the causal relationship between PDI and deterioration of heating. On TST-2, waves are measured by many diagnostics, including the fast visible light diagnostic, magnetic probes, electrostatic probes, and microwave reflectometer. Correlation analyses of different physics variables measured by these diagnostics were performed. The floating potentials measured by probes separated by 4 mm poloidally have very high correlation and the phase shift is very small. In particular, at the pump frequency the correlation was nearly one and the phase shift was nearly zero. In contrast, the correlation between the magnetic probe signal and the floting potential was very weak during the first half of RF pulse. During the second half of RF pulse, the correlation increases and the phase shift becomes constant. The correlation between the ion saturation current and the floating potential was intermediate, and the phase shift was finite.

In ST, a major issue is non-inductive plasma production and sustainment without the use of the central solenoid. ST plasma formation by ECH is already demonstrated in many STs including TST-2, but there are several candidates for the physical mechanism of current formation. TST-2 has demonstrated for the first time that the high-β_p ST plasma produced by ECH can be sustained by RF power (21 MHz) alone. This result indicates strongly that the current is not produced by non-inductive current drive but by pressure gradient. It was found that RF-sustained plasma is more susceptible to termination by MHD instability compared to EC-sustained plasma. The fluctuation level in RF-sustained plasma is higher than in EC-sustained plasma even when the plasma current is being maintained, but increases rapidly in frequency ranges of 0-1 kHz and 5-10 kHz prior to a plasma collapse.

Further plasma current ramp-up experiments using waves in the lower hybrid frequency range are being planned on TST-2. These experiments require higher fields (~ 0.3 T). Since ECH (2.45 GHz) pre-ionization is not effective at these fields, a hot-cathode electron source for providing a plasma in front of the antenna is being developed. Testing of four 200 MHz transmitters were completed at a power level of 100 kW each. The output powers of two transmitters are combined and fed into a loop antenna. Two loop antennas will be used for initial experiments..

The 21 MHz RF system used on TST-2 until now will be used for HHFW heating experiments on the UTST device. New transmission lines to UTST and a new antenna for UTST were fabricated, and initial experiments have begun.

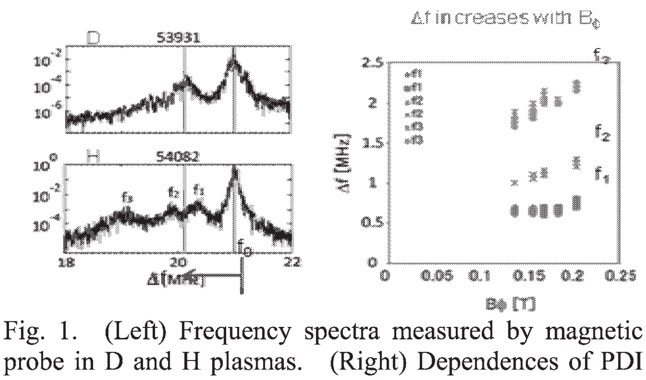

Fig. 1. (Left) Frequency spectra measured by magnetic probe in D and H plasmas. (Right) Dependences of PDI peak frequencies relative to the HHFW pump frequency on the toroidal magnetic field.