§53. Development of the Advanced Diagnostics for Steady State Operation in Spherical Tokamak QUEST

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1. QUEST

One of the important subjects in spherical tokamak (ST) researches is to demonstrate steady state operation. The QUEST (Q-shu University Experiment with Steady State Spherical Tokamak) project has been aiming at the steady state ST operation under at high wall temperature of plasma facing materials PFMs. This report will present newly developed diagnostics concerning with such subjects.

2. Real time estimation of Retained fueled particles in PFMs[1]

The plasma driven permeation flux through the nickel membrane heated at 523 K is measured in QUEST. From comparison with gas permeation it is observed that atomic hydrogen produced via plasma production strongly contribute to the permeation flux, that is, wall pumping. It is found that the total permeated fluence Q_{pdp} increases as a square root of the discharge width from 0.03 s to 1.1 s at low initial pressure and fixed RF power at ~ 4 kW. Under the various plasma conditions (RF plasma using two kinds of RF frequencies at 2.45 GHz and 8.2 GHz or combined RF+ohmic plasma) Q_{pdp} shows an offset linear relation with respect to the H_α intensity in an order of magnitude. Static gas balance experiment is performed by measuring the pressure difference Δp with and without plasma production as a function of initial pressure from 1.5×10^{-5} Torr to 1.5×10^{-4} Torr at the fixed plasma duration of 1.1 s, which is less than a characteristic diffusion time constant. It is shown that there exists a critical pressure discriminating between "wall fueling and wall pumping". Q_{pdp} increases from 1.1×10^{18} H/m^2 to 1.6×10^{18} H/m^2 with increasing initial pressure. This continuous increment in Q_{pdp} is consistent with a change in Δp from positive(meaning "wall fueling") to negative("wall pumping"). Based on the measured Δp and Q_{pdp}, pressure rise and drop due to wall fueling and pumping are deduced and the critical pressure discriminating between them is discussed.

3. Blobs mechanisms and its impact on PWI

In STs important effects of blobs are studied widely not only with respect to the physics of rapid energy transport from the core to the edge driven by edge fluctuations (peeling ballooning instabilities), but also to heat and particle load on PFMs. In order to study blob dynamics two fast cameras are designed to measure the fast flow pattern, which is one of key physical parameters to drive strong convection. Intensity weighted images by an optical filter can be used to deduce the flow pattern. Using the present fast camera recently rapid radial propagation and growth rate of the instability driven by steep gradient are studied. The slab plasma produced by cyclotron resonance heating in a simple torus is used to investigate the blob formation. By applying the vertical field, the filed lines are connected to the top and bottom plates and helical instabilities are excited depending on Bz. When the vertical pitch of the filed line, 2πRBz/Bt, is ~ 1m, strong helical instabilities driven by interchange modes are found and the frequency of blob events reaches 1-2 kHz. It is noted that the blob is accelerated at the far from the plasma source region. Reciprocated probe is set near the wall to study the blob-wall interaction.

4. Single-Side-Band Heterodyne Differential-phase Reflectometry [2]

MICROWAVE reflectometry has been widely used to measure density profile and fluctuation in the fusion-research plasma. This technique is based on a phase delay measurement of a probing-wave, propagating and reflected by a cutoff layer in the plasma. However, in large spherical tokamaks, the propagating distance becomes large at a rather small frequency range in the reflectomerty. The reflected-wave signal level is comparable to the direct coupling level between the launching and receiving antennae. New single-side-band heterodyne differential-phase reflectometry is proposed to remove the direct coupling effect.

The phase difference at between AM frequencies is detected at a diode in the AM reflectomery. The direct coupling component affects the phase detection in the reflectometry. In order to remove the coupling effect, a Single-Side-Band (SSB) heterodyne differential-phase reflectometry is proposed here. The AM frequency components at the Upper-Side-Band (USB) and Lower-Side-Band (LSB) are detected at an Image Rejection Mixer individually. The phases at the USB and LSB are detected at IQ demodulators. The phase difference in the AM frequencies is detected numerically after the phase detections. The phases are properly detected even in the rather large propagating distance range. The EBWH/CD experiment has been begun in the QUEST with the 8.2GHz system. Using the developed SSB heterodyne differential-phase reflectomerty, the phase-delays due to the *R* cutoff layers are successfully measured.

5. Design works

In collaboration with the Univ. of Tokyo Yag Thomson system is under design. In this year optical system will be tested in Univ. of Tokyo. In collaboration with Kyoto Univ. and NIFS edge current density measurement based on polarization of LiI is under design.

[1] H. Zushi, I. Takagi, et al., in preparation for submission
[2] H. Idei et al., 34th Int. Conf. on Infrared, Millimeter, and Terahertz Waves (2009)