§54. Scenario Discussion and Development Study for Sustainment of Steady State ST Plasma Configuration

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Electron Bernstein wave heating and plasma-current dive (EBWH and EBWCD) is one of attractive candidates of heating and current drive method to sustain the steady-state plasma in the spherical tokamak (ST). The Q-shu University Experiment with Steady State Spherical Tokamak (QUEST) was proposed at Kyushu University, and the QUEST tokamak has been constructed. The establishment of steady-state current drive method is a key issue to study plasma-wall interaction phenomena in the steady-state QUEST plasma. In the EBWH and EBWCD, some mode conversions from the electron cyclotron (electromagnetic) wave to the electron Bernstein (electrostatic) wave are required. In the X-B mode conversion scenario, the incident X-mode wave meets the R-cutoff, and converts to the B-mode. In the O-X-B mode conversion, the incident O-mode wave is reflected at the O-cutoff, and propagates as X-mode wave, then, the X-mode wave converts to the B-mode wave. The density gradient at the conversion into the B-mode wave is a key parameter to attain high conversion efficiency from the X/O-mode wave to the B-mode wave. Even mixture modes of the X/O-mode are required, depending the density gradient. In addition to the launching mode, the launching angle is also an essential parameter to achieve the high conversion efficiency. In the X-B mode conversion, the beam is injected in perpendicular to the magnetic field of the tokamak, while the beam is obliquely injected to the plasma with an optimum angle in the O-X-B mode conversion. In order to conduct the experiments, the launching mode, *i.e* the launching polarization, and the launching angle should be controlled to attain the high conversion efficiency.

The antenna for the EBWH/EBWCD experiments in the QUEST should ensure the controllability of the launching polarization and angle. In the 32nd IRMMW-THz conference, the field profiles radiated from designed prototype antenna were reported [1]. The fields were evaluated from the Kirchhoff and HFSS codes. The prototype antenna had rather large side- lobe components.

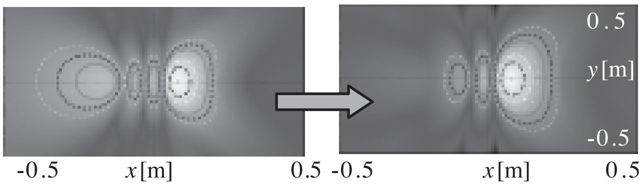

Fig.1: Radiation field patterns from prototype and new designed antennae.

In order to reduce the side-lobe components, the antenna structure is modified in this study. Figure 1 shows the improvement of the field patterns radiated from phased-array antennae at the propagating z=0.1m position. The radiated beam was obliquely steered with the reduced side-lobe component.

In the steady-state operation, the heat generation due to the high power transmission should be properly removed at the antenna component by the forced cooling. The heat generation comes from the surface magnetic field or current at the component inner-wall. Figure 2 shows the surface magnetic field at the orthomode transducer (OMT) calculated with the HFSS code. In order to excite the launching mode, the OMT was used to mix two orthogonal electric field components with intensity and phase differences in the antenna system. The forced cooling at the transducer is analyzed with the HFSS/e-Physics code.

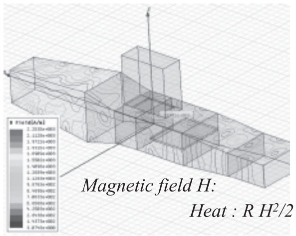

Fig.2: Heart analysis of OMT with HFSS/e-Physics code

In the steady-state operation in the QUEST, it is planned to sustain the rather low plasma current of 20kA in the lower density region as a first step. In the lower density and/or its lower gradient case, the O-X-B scenario is suitable for the EBWH/CD with a high conversion efficiency to the B-wave. The incident O-mode launched from the low -field/density side can be converted to the X-mode if the beam is injected with an appropriate angle oblique to the magnetic field. The wave propagation and absorption of the B-wave after the O-X-B mode conversion is evaluated using the TASK/WR ray tracing code. The dispersion relations for O/X/B-modes are described with non-relativistic hot plasma expressions without cold and electrostatic approximations. The geometrical coordinates are taken as a simple tokamak configuration with circular poloidal cross-sections. The profiles of electron density and temperature, and plasma current are assumed to be parabolic. Figure 3(a) shows a ray-trajectory evaluated in the O-X-B conversion scenario. The evolutions of the refractive indices in perpendicular and parallel to the magnetic field are also shown in Fig3 (b). The launched O-mode is converted into X/B-modes at the O-mode cutoff and upper hybrid resonance.

[1] H. Idei, *et al*. The 32nd International Conference on Infrared, Millimeter and TeraHertz waves.

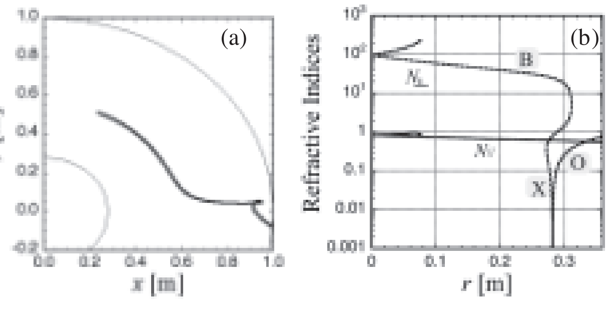

Fig.3: Ray trajectory and evolution of refractive indices in the O-X-B scenario calculated by the TASK/WR code.