EXM2783

NON-INDUCTIVE PLASA START-UP USING ELECTRON BERNSTEIN WAVE MODE-CONVERTED FROM ELECTRON CYCLOTRON WAVE LAUNCHED FROM HIGH-FIELD SIDE ON SPERICAL TOKAMAK, QUEST

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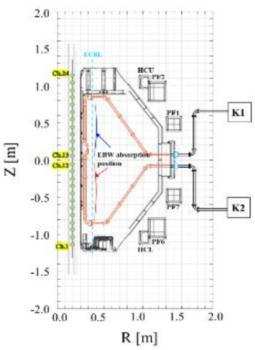
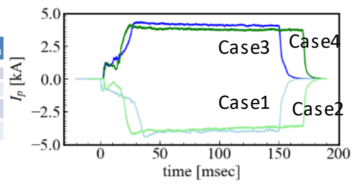
Conclusion

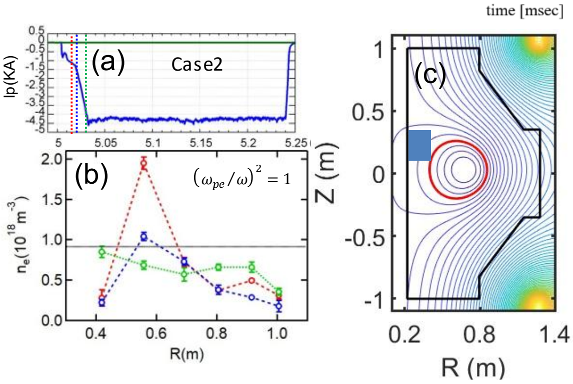
In QUEST, the experiments were performed to plasma start-up with ECW X-mode using the dedicated antenna for the HFS launch. The ECW was propagating to the LFS and passing through the 1st ECR layer, because the ECW absorption was predicted to be slight in the high n_e region such as $(\omega_{pe}/\omega)^2 > 1$. The passed ECW approached the UHR, was converted into the EBW. The EBW was effectively absorbed near 1st ECR layer and drove I_p, resulting in the formation a CFS. The clear evidence of EBWCD could be obtained by changing B_T and B_R directions. Four magnetic configurations were conducted to confirm the EBWCD effect. The direction of the driven current is reversed depending on the directions of B_T and B_R, which is characteristic of EBWCD, not ECCD or pressure-driven current. The results were qualitatively agreed with the ray-tracing calculation. The B_R scan with the horizontal field coil were performed. The results indicated that the B_R control was useful to obtain the smooth plasma start-up. In conclusion, EBWCD played an important role in plasma start-up in the ECW X-mode HFS launch. The most notable feature of the HFS launch was the formation of CFS, but the CFS has never been realized in the LFS launch with the same magnetic field configuration. This indicated that the HFS launch played an essential role in effective mode conversion into EBW and the EBWCD sufficiently functioned in the CFS formation. In particular, the observed engineering current drive efficiency even in the OFS condition was comparable to that expected in future fusion pilot plants.



QUEST experiments

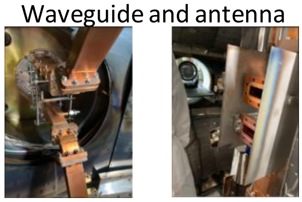
	B_T	B_V	I_P	Top	Bottom
Case 1	CCW	CCW	CW	Eq	Anti
Case 2	CW	CCW	CW	Anti	Eq
Case 3	CW	CW	CCW	Anti	Eq
Case 4	CCW	CW	CCW	Eq	Anti





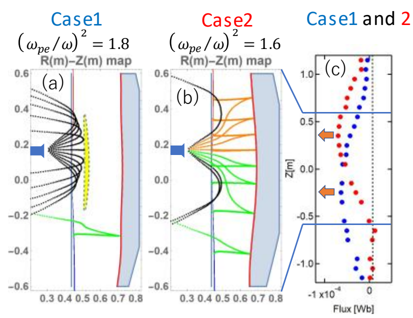
The time evolution of I_P in the case that the equilibrium I_P region located in the bottom area (B_T CW), is plotted in the diagram (a). Three lines denote the timing of n_e measurement with Thomson scattering. The measured n_e profiles are plotted in the diagram (b). The line color corresponds to the time indicated in the diagram (a). A horizontal line represents $(\omega_{pe}/\omega)^2 = 1$, where ω_{pe} and ω denote plasma frequency and injected ECW frequency, respectively. Magnetic flux surface reconstructed by an equilibrium code at 5.05s is shown in the diagram (c). The red circle shows the LCFS. An antenna cover shown in Fig. 2 was positioned at R=0.4m.

Waveguide and antenna



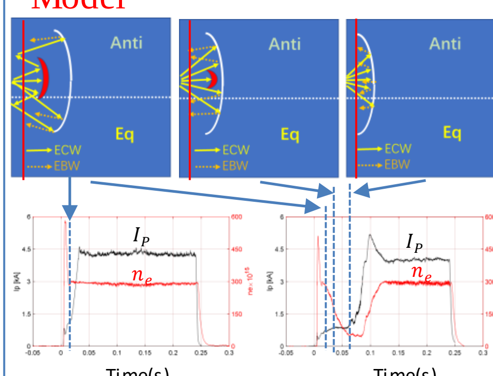
Left: A photograph of the dedicated waveguides and the flange from the vacuum side of the vacuum vessel of QUEST. Right: A photograph of the dedicated antennas and antenna covers. The covers were made of tungsten

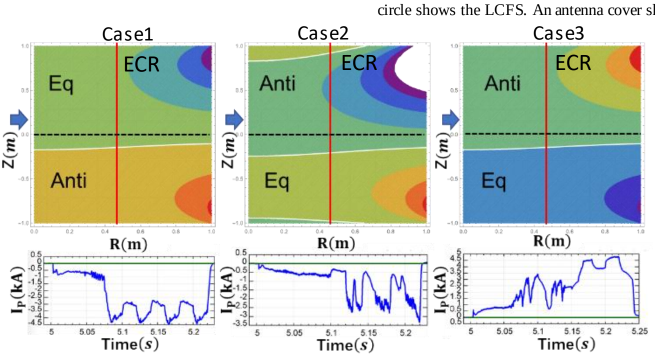
Model Calculation



(a) Typical conditions for EBW for the case of $(\omega_{pe}/\omega)^2 \cong 1.8$ B_T CCW for N_ϕ=0.1 at the head of the antenna (see the blue mark) are illustrated on a R-Z map. Vertical blue and red lines denote 1st ECR and UHR. The yellow region indicates L-cutoff for N_ϕ=0.1. Red and blue regions show EBW deposition regions to drive equilibrium I_P (red) and anti-equilibrium I_P (blue). The black rays are ECW reflected by L-cutoff and a green ray indicates a reflected ECW at the center stack. The mode-converted EBW is absorbed at the vicinity of 1st ECR layer. (b) Typical conditions for $(\omega_{pe}/\omega)^2 \cong 1.6$. The orange and green rays show wave trajectory to drive equilibrium I_P and anti-equilibrium I_P, respectively. (c) I_P induced magnetic flux (red B_T CCW: blue B_T CW) on the center stack measured with flux loops as a function of Z position. The left-directed arrow denotes equilibrium I_P direction.

Model





The B_R conditions for various B_T and I_P direction on the map of R=0~1.0m (vertical axis) and Z=-1~1m (horizontal axis). The white lines denote $B_R = 0$ boundary. Time evolutions of I_P are also plotted. "Eq" and "Anti" region in the diagram denotes EBWCD region for equilibrium and anti-equilibrium. The dotted line indicates the midplane. The B_R structure was modified by the error field from the toroidal coil. The ECR layer was located at the vertical red line. The ECW power was modulated from 40kW to 20kW three times from 5.1s. It should be noted that the injection antenna was located at the top side marked by a blue arrow in each diagram.

EBW Characteristics

$$N_\parallel \cong N_\phi/R + N_R\, B_R/B$$