# Observation of whistler wave instability driven by temperature anisotropy of energetic electrons on EXL-50 spherical torus


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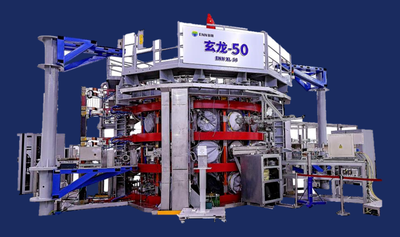




**Abstract** Whistler waves driven by temperature anisotropy energetic electrons are observed in electron cyclotron wave (ECW) steady state plasmas on XuanLong-50 (EXL-50) spherical torus. The whistler waves have multiple frequency bands which are proportional to the Alfvén velocity. Increasing of the bulk electron density or decreasing of the energetic electron temperature anisotropy reduces the intensity of the whistler wave and decreases the loss of energetic electrons. Moreover, the small disruption of plasma caused by whistler waves is also observed, probably as aF result of whistler wave affecting the equilibrium profile. Furthermore, the interaction of whistler waves with low frequency acoustic waves has been observed. These provide a novel experimental way to study wave-particle interactions and whistler wave control of runway electrons on future fusion devices.


## 1. XuanLong-50 spherical torus and resonance condition

※ XuanLong-50 spherical torus (EXL-50) does not have central solenoid

※ EXL-50 uses three sets of electron cyclotron wave (ECW) systems (28 GHz) to heat the plasma, start-up and ramp-up plasma current ($T_{\perp e} > T_{\parallel e}$).

※ Energetic electrons contribute the main plasma current (**Bump on tail**)

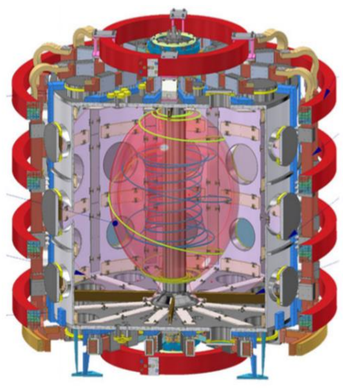


Figure1. The schematic diagram of EXL-50

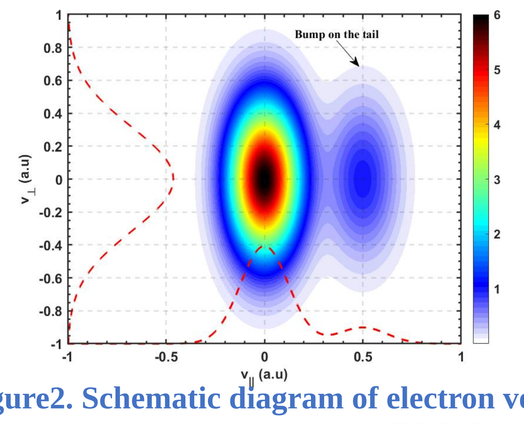



Figure2. Schematic diagram of electron velocity distribution function on EXL-50.

※ Electron-wave coupling can be expressed as

$$\omega - k_\parallel v_\parallel - k_\perp v_d - l\omega_{ce}/\gamma = 0 \quad (1)$$

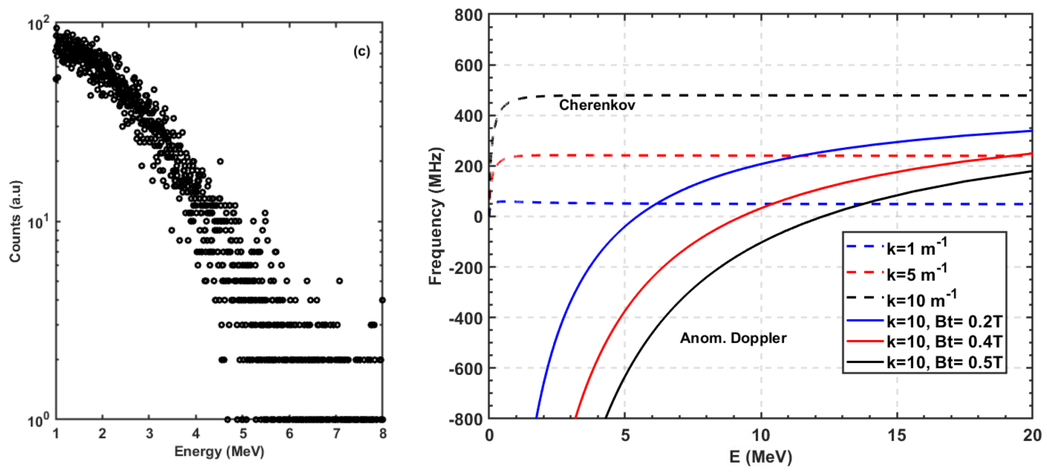



Figure3. Hard X-ray spectrum (left) and calculated resonance curves for different k and Bt (right)

## 2 High-frequency magnetic probe

※ A high-frequency magnetic probe (HFP) is developed on EXL-50 to measure high-frequency magnetic field fluctuation

※ **1-200 MHz** magnetic field fluctuation will be measured by the high-frequency magnetic diagnostic.

※ Significant frequency chirp is observed

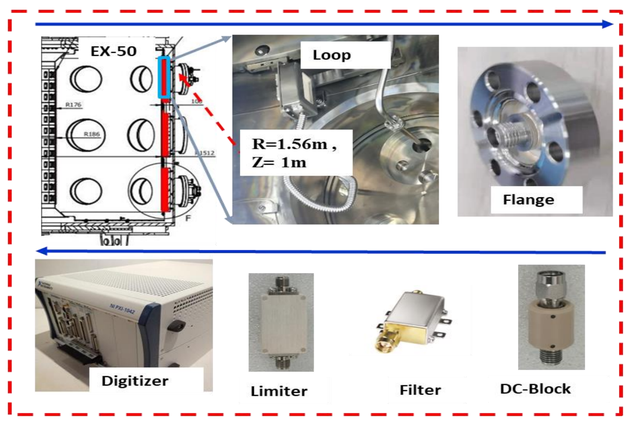



Figure4. Schematic of the hardware for HFP diagnostic (50 Ω).

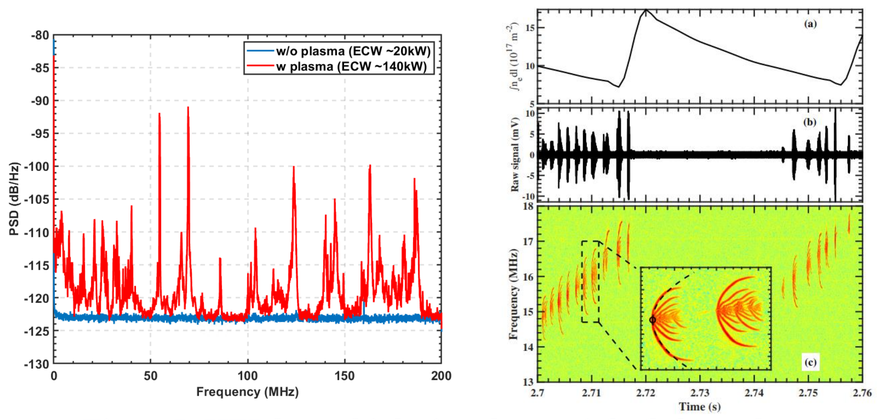



Figure5. HFP has a high signal-to satisfy (left) and observed frequency chirp (right)

## 3. Whistler wave

$$\omega_{ci} < \omega_0 \ll \omega_{ce}$$

$$\omega^2 = k^2 v_A^2 \left(1 + \frac{k_\parallel^2 c^2}{\omega_{pi}^2}\right)$$

Dispersion relation

$$\frac{T_{\perp e}}{T_{\parallel e}} - 1 > \frac{\omega}{\omega_{ce}}$$

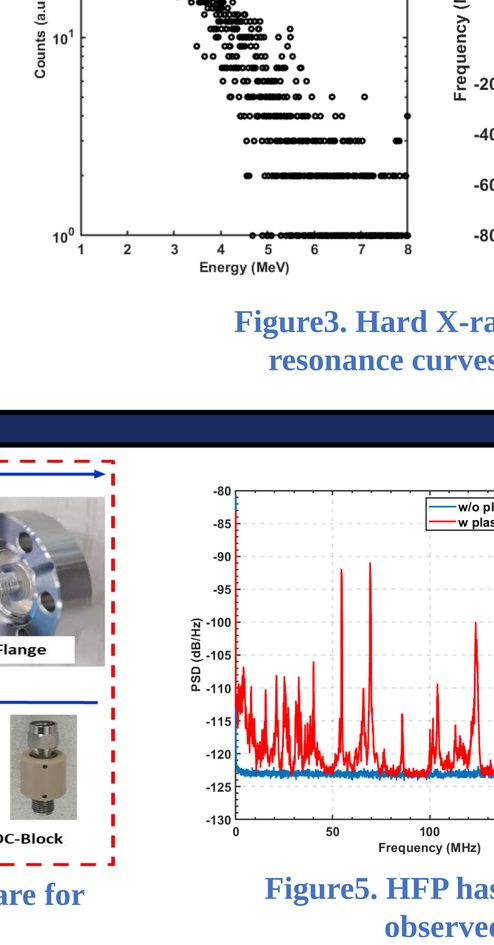
Excitation threshold







## 4. Others




※ Whistler waves may induce plasma disruption

※ Observation of nonlinear interactions of energetic particles with whistler wave and sound wave




## 5. Conclusion

※ Developed a high-frequency magnetic probe

※ Whistler wave is driven by temperature anisotropy of energetic electrons in steady state ECW plasmas

※ The frequency of the whistler wave is between 30-120 MHz, and is proportional to the Alfvén velocity

※ The whistler wave intensity is verified to be correlated with the density and $\frac{T_{\perp e}}{T_{\parallel e}}$

※ Whistler waves may induce plasma disruption

※ Nonlinear interactions between energetic particles, whistler wave and sound wave

## 6. References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