Comparison between low field side and high field side injections for EBW conversion in QUEST

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Introduction

Spherical tokamaks like QUEST [1] have limited center stack space, therefore non-inductive heating methods like RF heating are of interest. However, a plasma density cutoff limit exists in the RF electron cyclotron resonance (ECR) heating. Electron Bernstein wave (EBW), an electrostatic wave, can overcome this limit, which makes it of interest in this work. High field side (HFS) injection of X-mode via the use of a mirror polarizer is known for its efficient EBW conversion [2,3]. However, QUEST's RF frequency (8.2 GHz) dictates the use of an oversized mirror polarizer. To overcome this problem, waveguides are used to transmit the RF power from low field side (LFS) to HFS. This work targets efficient EBW excitation, clear EBW current drive (EBWCD) and over-dense plasma.

GENRAY ray tracing results

GENRAY ray tracing [4] was used to confirm that the HFS X-mode wave has access to the upper hybrid resonance layer (UHRL). GENRAY confirmed that to excite EBW and drive plasma current, either an injection tilt, or a vertical displacement of the antenna from the mid-plane is required as shown in Fig. 1.

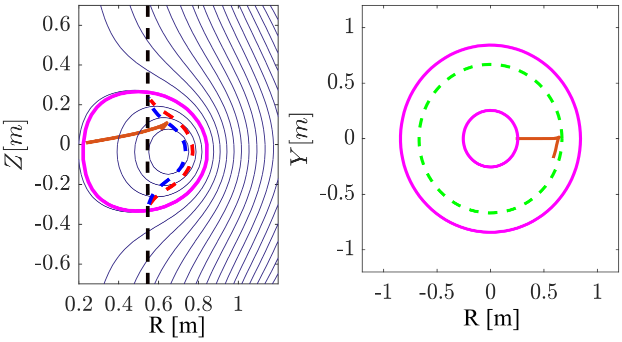

Fig. 1 (Left: Poloidal view) Dashed blue is UHRL, dashed red is R-cutoff, dashed black is ECR layer, (Right: Toroidal view) dashed green is magnetic axis

HFS experimental design

In the proposed system (shown in fig. 2) waveguide must traverse ECR layer inducing waveguide breakdown. To avoid the breakdown, waveguides are filled with SF_6 gas and a sapphire vacuum window is placed past the ECR layer. Two 8.2 GHz klystrons, of RF power of 15 kW each, are connected to both HFS and LFS systems via a waveguide switch.

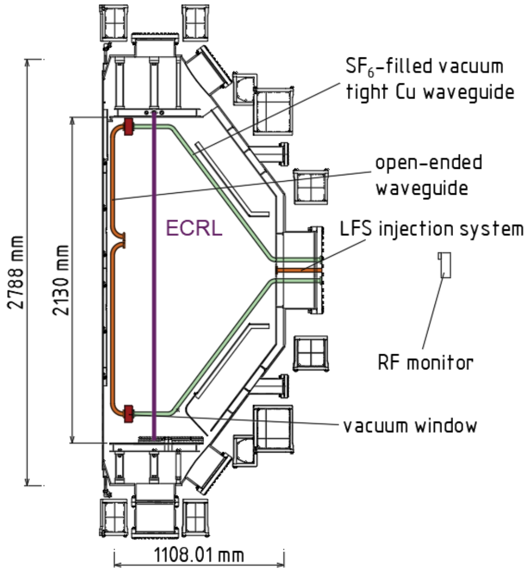

Fig. 2 HFS schematic where K1 and K2 are Klystrons 1 and 2, PC is Phase Controller

Results

HFS was compared to LFS, and fast-camera, Hα and AXUV show that HFS radiation is higher than LFS radiation. Over-dense plasma of 1.5×10^{18} m^{-3} was measured with a Langmuir probe as well as an interferometer as compared to 8×10^{17} m^{-3} in LFS. However, EBWCD was not achieved due to lack of closed flux surface.

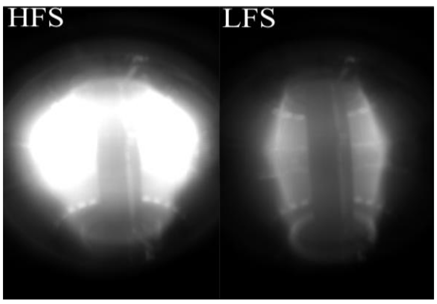

Fig. 3 Fast camera results of HFS vs LFS

Summary

HFS injection of 8.2 GHz X-mode for EBW conversion in QUEST surpassed LFS's cutoff density resulting in over-dense plasma, but EBWCD is yet to be confirmed.

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