Contribution ID: **70** Type: **Oral**

Nonlinear degradation of O-X-B in MAST Upgrade

Friday, 24 June 2022 11:50 (20 minutes)

Spherical tokamaks are often operated in a highly overdense regime, which means that their core is unavailable to ECRH at several of the lowest harmonics. However, a mode coupling scheme known as O-X-B[1] may enable the use of high power microwaves for heating and current drive in such plasmas. The O-X-B scheme couples electromagnetic waves from e.g. a gyrotron to electrostatic waves known as electron Bernstein waves (EBWs) which can propagate without a high density cutoff and are strongly damped at the electron cyclotron resonances. The use of EBWs is considered a key enabling technology at MAST Upgrade which has acquired two 28/34.8 GHz gyrotrons chosen specifically for O-X-B instead of regular ECRH. Although the mode coupling scheme is promising at low power densities[2], a number of nonlinear effects may degrade its performance when unprecedented gyrotron power levels are used for O-X-B operation. Parametric decay instabilities (PDIs) and stochastic electron heating (SEH) are considered likely nonlinear loss mechanisms in upcoming MAST Upgrade EBW experiments. Even though the conversion rate of O-X-B is favorable at low power, it may scale unfavorably with power above a nonlinear threshold.

In this contribution, we investigate PDIs and SEH in the vicinity of the upper hybrid layer where EBWs are excited. The UH layer is of particular interest due in part to the wave amplification that occurs in that part of the plasma. Based on the wave amplification, we estimate a threshold for SEH to set in, causing the gyrating electron motion to be warped and become stochastic by the large amplitude electric field of the EBWs. We also consider the possibility of generating EBW shifted in frequency through PDIs, which may in turn be observed outside the plasma, by considering the PDI selection rules. The results are compared to particle-in-cell simulations, exploring changes in frequency spectra and plasma temperature as the gyrotron power density is varied.

It is found that both nonlinear effects are likely to interfere with O-X-B in MAST Upgrade at the power levels the gyrotrons are able to deliver. Whilst the SEH can cause substantial wave damping to occur in an undesired region of the plasma, some of the frequencies excited by PDIs may possibly still have beneficial properties. In particular, the excitation of ion waves such as lower hybrid waves is possible and characteristic frequencies escaping the plasma could present diagnostic opportunities.

References

[1] J. Preinhaelter, et al., J. Plasma Physics 10, 1-12 (1973)

[2] V. Shevchenko, et al., Fusion Science and Technology, 52:2, 202-215 (2007)

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Session Classification: Parametric instabilities