The effects of the scattering by edge plasma density fluctuations on lower hybrid wave propagation

N. Bertelli[1], S. G. Baek[2], P. T. Bonoli[2], B. Harvey[3], R. R. Parker[2], Yu. Petrov[3], C. K. Phillips[1], E. Valeo[1], G. Wallace[2], J. R. Wilson[1], J. C. Wright[2]

[1]*Princeton Plasma Physics Laboratory, Princeton, NJ 08543 USA*
[2]*MIT Plasma Science and Fusion Center, Cambridge, MA 02139, USA*
[3]*CompX, Del Mar, CA 92014, USA*

Because lower hybrid current drive (LHCD) is one of the most efficient tools to drive current non-inductively in tokamak plasma, it can play an important role for current profile control and instability suppression for the advanced tokamak regime in devices such as C-Mod and ITER. Though the propagation of LH waves in tokamaks has been intensively studied in the past few decades, there are still some unresolved issues. In addition to the well-known spectral gap problem [1], the most recent one is related to the “density limit” in the efficiency of LHCD [2]. The underlying cause of this “density limit” could be the strong interactions between the LH waves and the scrape off layer (SOL) and, in fact, several publications go in this direction. However, it is still an open question exactly which physics mechanism or the combination of different physics mechanisms is responsible. Many explanations have been proposed, such as parametric instabilities [3], collisions [2,4], full wave effects [5] and scattering induced by the plasma density fluctuations [6]. In this work, the role of edge plasma density fluctuations on the scattering and collisional damping of the LH waves is evaluated by implementing a more complete model for the scattering into the ray-tracing code GENRAY. Unlike the recent work on the scattering effects [6] based on the Andrews and Perkins model [7] and other work based on a statistical description of the electron density fluctuations [8], the effect of the scattering here is based on the model of Bonoli et al. [9] which introduces an electromagnetic wave kinetic equation solved by a Monte Carlo technique. The effects of the scattering can both help the LH wave penetration into the plasma core due to the $k_{//}$ upshift through the poloidal field (because of the rotation of $k_{\perp}$ which provides a finite poloidal mode number) and inhibit it for high edge density due to enhanced collisions because rays spending more time in the SOL. Because the earlier studies [9] were done in circular, limited discharges with low ray statistics, it is important to re-evaluate the scattering effects for Alcator C-Mod, utilizing modern computational capabilities to include a larger number of rays for the wave propagation and damping as well as a detailed numerical fit to the plasma equilibrium that fully accounts for LH wave interactions in the region between the launcher and the last closed flux surface. The wave kinetic equation describing the effects of the scattering by the plasma density fluctuations has been implemented in the GENRAY code and a detailed comparison of results from this scattering model with the experimental observations of LHCD at high density on the Alcator C-Mod tokamak and with the results from other studies will be presented. Applications of this model to evaluate scattering effects on lower hybrid current drive efficiency in ITER, and extensions to consider potential scattering effects on the EC heating and current drive scenarios in ITER will also be discussed.

REFERENCES

[1] Bonoli P. T. and R. C. Englade, *Phys. Fluids* **9** (1986) 2937.
[2] Wallace G. et al., *Phys. Plasmas* **17** (2010) 082508.
[3] Cesario R. et al., *Plasma Phys. Control. Fusion* **53** (2011) 085011.
[4] Barbato E., *Nucl. Fusion* **51** (2011) 103032.
[5] Meneghini O. et al., http://meetings.aps.org/link/BAPS.2011.DPP.JO4.11 ; O. Meneghini, Ph.D dissertation, MIT 2011.
[6] Pericoli Ridolfini V. et al., *Nucl. Fusion* **51** (2011) 113023.
[7] Andrews P. L. and Perkins F. W., *Phys. Fluids* **26** (1983) 2537.
[8] Peysson Y. et al., *Plasma Phys. Control. Fusion* **53** (2011) 124028.
[9] Bonoli P. T. and Ott E., *Phys. Rev. Lett.,* **46** (1981) 424; Bonoli P. T. and Ott E., *Phys. Fluids,* **25** (1982) 359.