Recent results on coupling fast waves to high performance plasmas in DIII-D*

R.I. Pinsker[1], T.C. Luce[1], P.A. Politzer[1], D. Milanesio[2], R. Maggiora[2], J.C. Hosea[3], J.R. Wilson[3], A. Nagy[3], P.M. Ryan[4], G.R. Hanson[4], R.H. Goulding[4], L. Zeng[5], M. Porkolab[6]

[1]*General Atomics, P.O. Box 85608, San Diego, CA 92186-5608 USA*
[2]*Politecnico di Torino, Dipartimento di Elettronica, Torino, Italy*
[3]*Princeton Plasma Physics Laboratory, Princeton, NJ USA*
[4]*Oak Ridge National Laboratory, Oak Ridge, TN USA*
[5]*University of California, Los Angeles, CA USA*
[6]*Massachusetts Institute of Technology, Cambridge, MA USA*

Fast Waves (FWs) at 60 and 90 MHz are used in DIII-D for central electron heating and current drive. Coupling of FWs to high-performance discharges is limited by low antenna loading in these regimes. To extend the application of high-power FWs to such regimes, methods of increasing the antenna loading in these regimes are needed. Such methods must be compatible with good confinement and with the application of the other DIII-D heating and current drive systems. Improvements to the FW system in DIII-D have enabled a systematic study of loading enhancement techniques, including reduction of the antenna/plasma distance, gas puffing into the far scrape-off layer (SOL) to modify the electron density profile to increase the loading[1], and study of other parameters that affect the balance between fueling of the far SOL by ELMs and pumping by the cryopumps. New and existing reflectometers and other edge diagnostics are used to improve modeling of the antenna loading with the TOPICA code [2]. Quantitative understanding of the physics that determines the loading resistance and its dependence on edge density profiles is demonstrated. The dependence of the resistive loading on the plasma/antenna gap has been the subject of detailed study, as this is of great significance for ITER as well as for DIII-D. New poloidal limiter tiles with higher thermal capabilities allowed operation of high performance plasmas at antenna/plasma gaps ~2 cm smaller than with the previous limiter tiles; this reduction of wave evanescence enabled significantly higher power FW operation at a given antenna voltage. Gas puffing was successful in increasing the minimum loading between ELMs by as much as a factor of 6. However, the high core density that resulted from strong gas puffing was not compatible with core ECH at second harmonic. Hence, in experiments where the EC and FW core heating efficiency was compared, gas puffing was not used. Instead, reduction of the pumping rate without puffing improved the minimum loading between ELMs to a level sufficient for MW-level coupling on two of the three FW antenna systems. The result of the FW/EC comparison was that the core FW heating efficiency appeared to be nearly 100% in this regime, consistent with the high first-pass direct electron absorption of ~75% that is predicted by the ray-tracing code GENRAY in this high electron beta regime. Ray-tracing shows a very significant upshift of $n_{||}$ for 90 MHz FWs on the first pass as a result of the poloidal field effects in this whistler-like wave propagation regime; this is the dominant reason for the FW direct electron absorption to be stronger than the predictions of a slab model.

[1] R.I. Pinsker, et al., Proc. 37th EPS, Dublin, 2010, paper O4.124
[2] V. Lancellotti, et al., Nucl. Fusion **46** (2006) S476.

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