HHFW Heating and Current Drive Studies of NSTX H-Mode Plasmas*

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One goal of 30 MHz high-harmonic fast wave (HHFW) research in NSTX is to provide fully non-inductive plasma current (I_p) ramp-up [1]. The initial approach to achieving this goal has been to heat relatively low I_p (~ 300 kA) inductive plasmas with current drive antenna phasing in order to generate an HHFW H-mode with significant bootstrap and rf-driven current. Recent experiments used only 1.4 MW of RF power (P_{rf}) to achieve a non-inductive current fraction ~ 0.65. This result was achieved by the feedback between the generation of an internal transport barrier, a high core electron temperature, $T_e(0)$ = 3 keV, and a high rf current drive efficiency ~ 0.1 MA/MW. Improved antenna conditioning has resulted in the generation of HHFW H-mode plasmas when $P_{rf} \geq 2.5$ MW at I_p = 650 kA. These plasmas have an ELM-free-like phase with a substantial increase in the total and electron stored energy and a sustained $T_e(0)$ = 5-6 keV. Another goal of NSTX HHFW research is to heat an H-mode initiated by 90 keV neutral beam injection (NBI). There is a competition between direct electron heating, via Landau damping and transit-time magnetic pumping, and wave-field acceleration of fast-ions in HHFW+NBI H-mode plasmas [2, 3]. Improved HHFW coupling to NBI-heated H-modes has resulted in a broad increase in $T_e(R)$ when HHFW heating is applied. Analysis of a closely-matched pair of NBI and HHFW+NBI H-mode plasmas revealed that about half of the antenna power is deposited inside the last closed flux surface (LCFS). Of the power damped inside the LCFS about two-thirds is absorbed directly by electrons and one-third by fast-ions. At long toroidal launch wavelengths, HHFW+NBI H-mode plasmas often have a significant RF power flow outside the LCFS to the divertor and, in addition, edge localized modes (ELMs) can affect the RF power deposition in the core and edge [4]. Recent 3D full wave modeling of NSTX HHFW-heated plasmas, with the model extended to the vessel wall, predicts a coaxial standing mode between the LCFS and the wall that can have large amplitudes at longer launch wavelengths, and the excitation of a "whispering gallery" type mode near the plasma edge [5]. Both these modes could cause significant RF power loss.

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