A High-Velocity Microwave-Powered Pellet Launcher for ITER*

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A novel pellet acceleration concept using microwave power from MW gyrotron sources has been developed that could pave the way for high-speed >3 km/s inner-wall pellet injection on ITER-class tokamaks.[1,2] In the proposed concept, a high gas pressure is created by evaporative explosion of a composite "pusher" medium attached behind the deuterium-tritium (DT) fuel pellet, which consists of small micron–sized conducting particles embedded in a D_2 ice slug, thus facilitating volumetric absorption of microwave energy by dissipation of eddy currents flowing within the particles only. Microwave power is delivered to the pellet-pusher module along a waveguide, which also functions as the pellet guide tube. Using a perturbation theory, a formula was derived for the attenuation (damping) distance of TE_{mn} and TM_{mn} modes propagating in the pusher medium for both rectangular and cylindrical waveguide walls. The damping distance elongates exactly in proportion to the length of the expanding pusher gas, such that wave absorption remains constant in time (self-matched heating). A third order differential equation in time is obtained for the acceleration length L, and all the other gas dynamic variables follow from this. A scaling law is derived which predicts that a pellet of mass M_p reaches a velocity $v_p \cong (P_{wave} L / M_p)^{1/3}$, where P_{wave} is the (constant-in-time) wave power absorbed. Also presented is the derivation of an analytical formula[3] for the penetration depth of DT pellets in a step-linear temperature profile, which represents the edge pedestal profile expected in ITER. Penetration distance increases much more strongly with velocity than the conventionally accepted 1/3 power law scaling. A factor of ten increase in pellet velocity would thus lead to significantly deeper fuel deposition profiles than would result from the currently envisioned 300 m/s pellets injected from the inner wall of ITER.

[1]P.B. Parks and F.W. Perkins, US Patent Application 11/256,662, "Microwave-powered pellet accelerator," filed on October 21, 2005.

[2]P.B. Parks and F.W. Perkins, "A gyrotron-powered pellet accelerator for tokamak refueling," submitted to Nucl. Fusion (2005) and General Atomics Report GA-A25270 (2005).

[3]F.W. Perkins, "A theoretically based pellet penetration formula for pedestal temperature profile in burning plasmas," to be submitted to Nucl. Fusion Lett. (2006).

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