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A Gyrotron-Powered Pellet Accelerator for ITER* IT

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As fusion energy research enters the ITER era, active control of the core fueling rate and thermonuclear power generation is needed [1]. Gas-puff fueling, the workhorse of contemporary research, must be reserved for edge plasma fueling and accommodating the heat flux in the divertor chamber. A DT-ice pellet fueling system can meet ITER's fueling needs. A 5x5 mm right cylinder pellet has a particle inventory 10% of ITER plasma inventory.

This contribution discusses a new pellet accelerator configuration to fuel ITER-class plasmas with deeper ablation penetration. Contemporary tokamak experiments [2] have established that DT-ice pellets should enter the plasma along a trajectory normal to the high-field-side separatrix to benefit from toroidal drifts. Furthermore, both theory and experiment [3] indicate that the high-speed portion of the trajectory should be straight to avoid breakup created by centrifugal force, implying that the pellet accelerator be located on the high-field-side (HFS) equatorial plane. A device the size of ITER offers new possibilities for locating the accelerator which are not available to present machines.

Consider the ITER design, protrayed in Fig. 1, and note that the thickness of the blanket (0.5 m), vacuum vessel (0.3 m), and thermal shield (0.2 m) combine to have a length of almost 1.0 m available for an accelerator on the HFS of the separatrix, thereby eliminating trajectories which penetrate the main magnet systems. This contribution describes a new pellet accelerator concept which fulfills these requirements. The key innovations are three-fold: dual use of the pellet guide tubes as an electromagnetic waveguide for millimeter

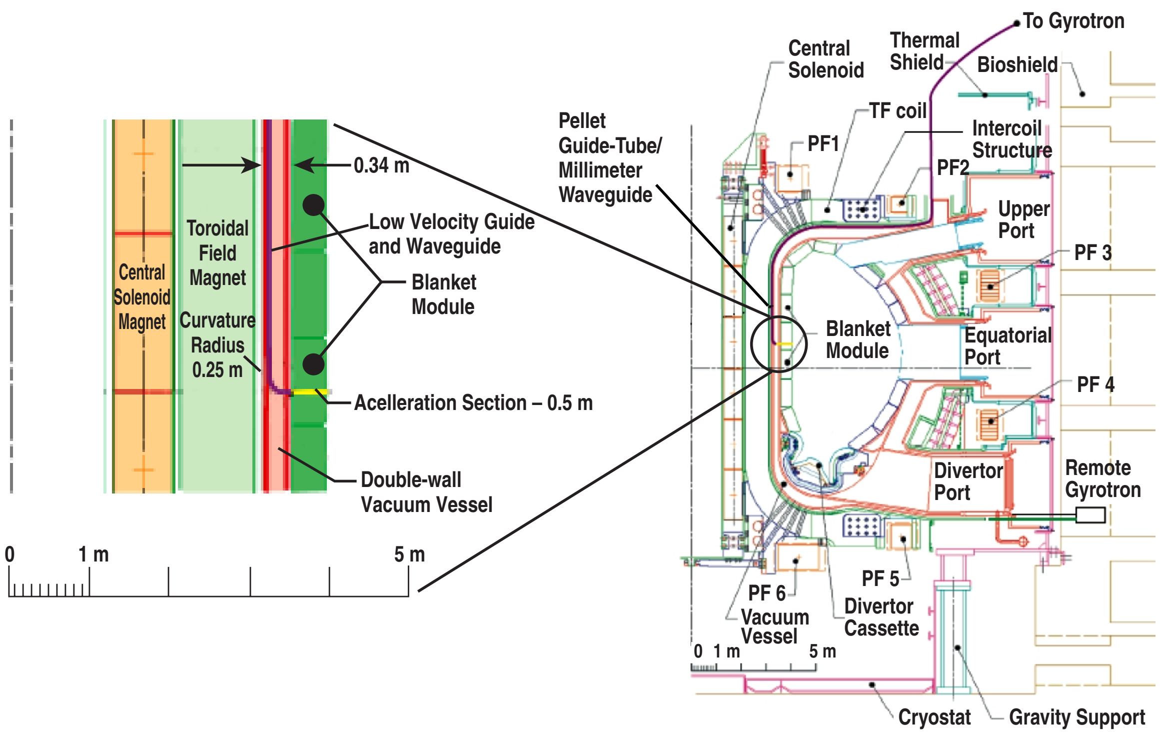

Fig. 1. Poloidal plan view of ITER design; detail of acceleration region.

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waves, a composite pellet structure which absorbs millimeter waves, and a diamond millimeter-wave window to absorb recoil and enable efficient acceleration pellets using a gun configuration.

The gyrotron powered accelerator [4,5]. The proposed pellet injection scenario proceeds as follows. Initially, pellets are fabricated remotely and injected with sufficiently low velocity – e.g. 10 m/s – to survive propagation along curved guide tubes to a point where the remaining path is straight and along a major radius vector. At this point, millimeter wave power from gyrotrons is introduced into the waveguide/guide-tube. A composite pellet structure, illustrated in Fig. 2, with a diamond millimeter wave window/recoil tamper transmits the gyrotron power into a pusher gas chamber seeded with sufficient microscopic absorbing lithium or graphite microspheres to effect 2-pass absorption using a thin metallic reflector, as shown. The resulting high pusher gas pressure accelerates the pellet and tamper in an efficient gun configuration. A theoretical scaling formula $V \cong (PL/M)^{1/3}$ gives the pellet velocity V in terms of the accelerator length L, gyrotron power P, and pellet mass M (all in SI units).

This concept has three key components: 1) to obtain the concentration of conducting microspheres, we assume the microspheres are large compared to a skin-depth and calculate the currents required to shield out the millimeter wave magnetic field and the resulting eddy current heating. The concentration of microspheres follows from the requirement that their integrated heating be equal to that associated with 2-pass absorption in a medium of uniform conductivity. 2) The diamond portion of the composite pellet is both a millimeter wave window and fixed (or free) recoil tamper. 3) Acceleration by the gas pressure of vaporized D_2 ice uses a 1-D gas-dynamic model in the limit where spatial variation of the pressure vanishes. A third-order differential equation in time is obtained for the acceleration length L, and all other gas-dynamic variables. The pressure is assumed to obey the ideal gas EOS. Numerical/analytical solutions are portrayed in Fig. 3 [4].

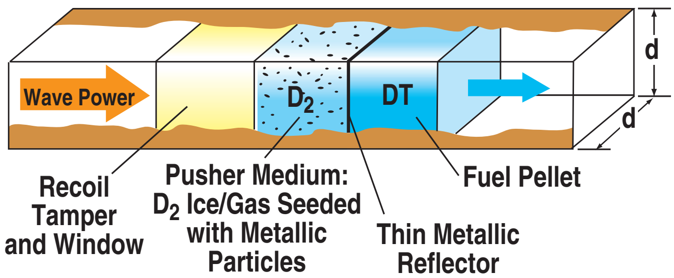

Fig. 2. Composite pellet structure.

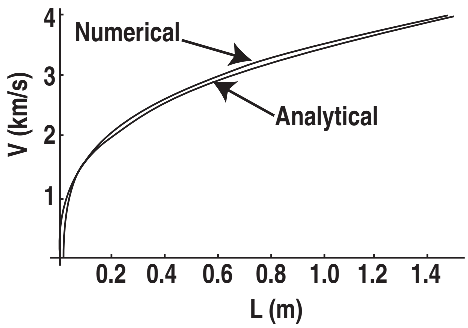

Fig. 3. Acceleration trajectory.

Gyrotron power sources and composite pellet structures can be combined to produce a pellet launcher with parameters of interest to fueling tokamak reactors. Pellet velocities an order of magnitude in excess of those now planned are predicted while the straight guide-tubes avoid pellet fragmentation caused by centrifugal force. A standard ablation formula [6] predicts penetration lengths of ≈0.6 m, in contrast to 0.2 m for the currently-planned injectors.

[1] L.R. Baylor, *et al.,* Phys. Plasmas **12**, 056103 (2005).
[2] P.T. Lang, *et al.,* Nucl. Fusion **42**, 388 (2000).
[3] S.K. Combs, *et al.,* Proc. of 17th Symp. On Fusion Eng., Vol. 2, 1102 (1998).
[4] P.B. Parks and F.W. Perkins, “A Gyrotron-Powered Pellet Accelerator for Tokamak Refueling,” General Atomics Report GA-A25270 (submittesd to Nucl. Fusion, 2005).
[5] P.B. Parks and F.W. Perkins, US patent application No. 11/256.663 “Microwave-Powered Pellet Accelerator,” filed on October 21, 2005.
[6] P.B. Parks and M.N. Rosenbluth, Phys. Plasmas **5**, 1380 (1998).