Experimental Test in a Tokamak of Fusion with Spin-Polarized D and ^{3}He

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An experiment to test polarization retention of highly polarized D and ^{3}He fusion fuels prior to their fusion reactions in a Tokamak is in preparation. The fusion reaction rate with 100% vector polarized reactants is expected from simple theory to increase by a factor of 1.5. With presently available polarizations, fusion reaction enhancements of ~15% are achievable and of significant interest, while several avenues for obtaining higher polarizations are open. The potential for survival of initial fusion fuel polarizations at ~10^8 K plasma core temperature (~5 keV) throughout the time interval preceding fusion burn was addressed in a seminal paper in 1982[1]. While the positive conclusion from those calculations suggests that reaction enhancements are indeed feasible, this crucial factor has never been tested in a high temperature plasma core because of difficulties in preparation and injection of sufficiently polarized fusion fuels into a reactor.

Our solution to these problems employs a new source of highly polarized D in the form of solid HD which has been developed and used in our laboratories[2,3]. Solid HD is compatible with fusion physics in view of its simplicity of elemental composition and very long (many days) relaxation times at 4K temperature, allowing efficient polarization-preserving cold-transfer operations[4]. Containment and polarization of the HD within polymer capsules similar to those used in inertial confinement fusion (ICF) is an innovation which simplifies the cold-transfer of polarized fuel from the dilution refrigerator polarization-production apparatus to other liquid helium temperature cryostats, for storage, transport and placement into the barrel of a cryogenic pellet gun for firing at high velocity into the reactor.

The other polarized fuel partner, ^{3}He, has been prepared as a polarized gas[5] for applications including high-energy polarized targets and magnetic resonance imaging (MRI) scans. It will be introduced into the reactor by loading at high pressure into a thick-walled ICF- type polymer shell for injection into the plasma core with a room temperature injection gun. Based on current experience[2, 3, 5], polarizations of both D and ^{3}He of ~55% are projected, producing a fusion yield increase of about 15%.

A collaboration is being developed for implementing this experiment at the DIII-D Tokamak experiment at San Diego, operated by General Atomics for the U.S. Department of Energy. Calculations indicate a 10% fusion yield increase in the 14.6 MeV protons from the D-^{3}He reaction will provide a statistically significant test of

polarization retention in the plasma. Injection of the polarized fuels into a ^{4}He plasma improves the discrimination of the effects of polarized fuels. Details of the HD fuel preparation, of the polarization processes, and of the injection into the plasma will be presented. If the expected fusion reaction yield increase indicative of polarization retention is detected, a route to significantly improved second generation D-^{3}He fusion would be established, as well as confidence to undertake the more difficult polarization of tritium, which would offer important cost savings and improved prospects of ignition in the ITER program.

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