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AN EFFICIENT, RADIATION-HARDENABLE, 800-keV NEUTRAL BEAM INJECTION SYSTEM

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Tokamak reactors will operate essentially steady-state, and will require some means of sustaining the circulating current that provides plasma confinement. In principle, this current can be driven by RF waves or by neutral beams injected tangentially into the plasma. We have recently studied the feasibility of developing a suitable 800 keV negative-ion-based neutral injection system; the proposed application is for current drive and heating of the FED-A Tokamak. Recent advances and new concepts in negative ion generation, transport, acceleration, and neutralization make it appear likely that an efficient, radiation-hardened neutral beam injection system could be developed in time for this proposed application. These new developments include the operation of steady-state H⁻ ion sources at over 5 A per meter of source length, the concept of using strong-focussing electrostatic structures for low-gradient DC acceleration of high-current sheet beams of negative ions and the transport of these beams around corners, and the development of powerful oxygen-iodine chemical lasers which will make possible the efficient conversion of the negative ions to neutrals using a photodetachment scheme in which the ion beam passes through the laser cavity.

A beamline capable of delivering 25 MW of 800 keV neutral deuterium atoms to the plasma uses two banks of three negative ion sources each; each source is 1.1 m high, and produces 5.5 A of D⁻ ions (this is approximately 50% higher in current per unit length than has been achieved with existing LBL ion sources). These sheet beams are accelerated to 200 keV by a conventional electrostatic accelerator. After acceleration to 200 keV, the beams are transported through a pumping and matching section by an electrode system that uses electrostatic strong focussing provided by alternating transverse electric fields (this is the TFF, or Transverse Field Focussing concept). The beams are accelerated to the final energy of 800 keV by the main TFF accelerator, which uses the same concept. TFF transport sections are also used to transport the 800 keV sheet beam, about 1.5 cm wide at this point, through multiple 90-degree bends in a channel through the neutron shielding. These bends prevent line-of-sight streaming of neutrons and greatly attenuate the neutron flux. Preliminary calculations indicate that the flux of 14 MeV neutrons through the beam duct will be attenuated by about a factor of 10⁵, and that the flux of lower-energy streaming neutrons will be attenuated by a similar factor.

After the sheet beams exit from the neutron shield, they merge and pass through a series of laser cavities where 1.3 micron radiation from an array of shielded oxygen-iodine chemical lasers removes one electron

*On assignment from Neigion, Inc.
from the negative ions and converts approximately 97% of them into neutral atoms. The remaining ions are swept from the beam by an electrostatic deflector.

The beamline vacuum vessel is a double-walled chamber constructed of low-activation 5254 aluminum alloy; the volume between the walls is filled with water for neutron moderation and absorption. Pumping is by cryopumps capable of on-line regeneration, of the type under development at LLNL.7

A single such beamline would be capable of continuous injection of 25 MW of 800 keV neutral deuterium atoms into the plasma. Because of the high efficiency of the laser photo detachment process, and the use of narrow laser cavities with thin sheet beams to minimize losses in the laser, the overall power efficiency of the system is expected to be approximately 70%.8

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