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Overview of ion sources for alternative fusion concepts

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Many common nuclear fusion concepts actively being investigated rely on particle injection from ion sources. While many of these sources have been developed in publicly funded laboratories, we have seen a rapidly growing interest from the private sector in recent years, with the number of private fusion companies more than doubling in the last 6 years alone. With this growing interest, a multitude of novel concepts have emerged to increase fusion rates, whether for neutron production or net energy generation. Several of these concepts rely on injecting ions into their systems.

Each company maintains their own requirements for ion beams. Their systems include differing ionization schemes, acceleration techniques, and pumping requirements. This work focuses on four different concepts. The first two, similar to more frequently discussed systems like ITER, implement neutral beam injection (NBI) to add energy to a plasma. In the magnetic mirror geometry of the Wisconsin HTS axisymmetric mirror, NBI thermally heats the plasma directly. In the field-reversed configuration plasmas generated by Helion, where rotated, pulsed magnetic field generates a high energy plasmoid, energy input from NBI is meant in part to nullify instabilities arising in the plasma.

Alternatively, beams are being used to fuse directly. The beam-target fusion of SHINE Technologies bombards a small tritium target with a high energy deuterium beam as a neutron generator. Finally, the inertial electrostatic confinement concept known as the Orbitron being developed at Avalanche Energy injects an ion beam into an azimuthally symmetric electrostatic well, where ions in stable orbits can collide at over 100 keV energies. This work presents an overview of these fusion concepts and discusses the ion beam generation architectures in each.

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