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FTP/P1-19: Local Current Injector System for Nonsolenoidal Startup in a Low Aspect Ratio Tokamak

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The Pegasus experiment is an ultralow aspect ratio spherical tokamak that is developing nonsolenoidal startup and current growth techniques. Helicity injection from localized current sources in the plasma periphery have produced plasma currents up to 0.15 MA with less than 4 kA injected, and the resulting plasmas provide stable target plasmas for further current drive. This localized helicity injection startup technique requires the development of robust, high current density sources (~ 1 kA/cm^2) that can exist in the plasma scrapeoff region during plasma initiation, growth, and possibly sustainment. An integrated assembly of active arc plasma sources and a passive electrode emitter is under development for this application to MA-class spherical tokamak applications. Compact arc plasma current sources are used for initial current injection along vacuum field lines to produce a tokamak-like plasma through null formation and Taylor relaxation. Further current growth is realized through helicity injection from these arc sources or passive electrodes in the plasma edge region. Use of passive metallic electrodes can greatly simplify the design and allow for higher injected currents to optimize the resulting plasma current. The compact, active arc sources provide an extracted current stream that appears to be governed by a double layer sheath at the arc exit region. At voltages greater than eV/kT ~ 10 and high currents, the extracted current scales as V^1/2, presumably due to sheath expansion or the Alfven-Lawson cuurent limit for electrons. Control of the arc plasma density through active gas feed control and detailed design of the arc chamber should provide active control of the effective loop voltage applied to the tokamak plasma. The arc source and electrode structures are isolated from the edge plasma by a local BN limiter and nearby scraper limiter assembly. This mitigates interactions between the injector assembly and the plasma, and resulting impurities in the plasma are negligible. High-current power supplies using IGCT solid-state switches regulate the injector current according to a pre-programmed waveform. This startup approach places minimal demands on machine design, appears scalable to MA levels in large facilities, and offers the possibility of hardware that can be withdrawn before a fusion plasma enters the nuclear burn phase.

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