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Positive Ion Source Technology Demonstration for DIII-D Neutral Beam Heating

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Radio-frequency (RF) inductively coupled plasma (ICP) positive ion sources are under development for the DIII-D neutral beam injection (NBI) system. The project targets 25% higher extracted ion current compared to existing arc-discharge ion sources, while increasing operational reliability.
This research program focuses on understanding physical mechanisms behind ion production and optimizing engineering of the RF ICP ion sources. The approach integrates three experimental devices (described below) at different scales with advanced modeling. Hybrid kinetic-fluid plasma simulations validate performance across spatial scales to project achievable ion currents, while finite element electromagnetic modeling informs prototype designs.
LUPIN, a reduced-scale cylindrical setup (20 cm diameter), demonstrates novel multi-strap RF antenna concepts and validates hybrid kinetic-fluid plasma simulations under NBI-relevant power densities. LUPIN operates with up to 20 kW RF power at 2 MHz and features an internal, inertially cooled Faraday screen with comprehensive plasma diagnostics. The SupRISE device investigates power coupling to plasma as a function of RF frequency and chamber dimensions. SupRISE features a full-scale racetrack-shaped quartz vessel with 50 kW RF power available at 4-8 MHz. AMAROK will be a full-scale, full-power pre-prototype that demonstrates homogeneous plasma density across a 48×12 cm ion extraction area, translating to 85 A positive ion beam. The system provides 200 kW installed RF power (2-4 MHz) and gas flow rates of 15 Torr-L/s at 1-10 Pa, replicating the DIII-D NBI conditions.
Recent accomplishments include successful experimental scans on LUPIN to validate comprehensive ion flux modeling, which reveals enhanced dissociation and ionization above 10 kW operation. SupRISE achieved its first plasma with successful power sweeps up to 1 kW at various frequencies. AMAROK facility preparations near completion, and hardware installation is imminent.

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