Seminar

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Institute for Plasma Research

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Title: Experimental Study of Millimeter-Scale Solid Hydrogen Pellet Formation, Launching, and System Validation for Integration with Tokamak

Speaker: Dr. Amit Bhojani
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Date: 18th March 2026 (Wednesday)

Time: 10:00 AM

Venue: Seminar Hall, IPR

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Abstract

Core fueling is essential for achieving high-density plasmas in magnetically confined fusion devices [1]. Among the established techniques, pellet injection has proven to be one of the most effective one. Beyond its primary role, pellet injection is also widely employed for disruption mitigation and edge-localized mode (ELM) pacing studies across many fusion experiments. IPR is actively engaged in developing pellet injectors for demonstrating fueling and other relevant studies in tokamak environments. As a part of this initiative, a single-barrel injector capable of delivering solid hydrogen pellets of varying sizes has been successfully developed [2].

This study presents upgrade results of the injector by incorporating a new barrel and a modified launching mechanism to achieve parameters relevant to tokamak experiments in IPR. Through iterative optimization of barrel designs, a new freezing cell and barrel assembly were developed and integrated into the injector cryostat. In one of the accomplishment, the pellet speed reduction (limitations in conventional gas gun device) has been successfully achieved by the introduction of zero-length gun barrel concept, which is limited by the conventional gas gun [3]. It will facilitate to carryout pellet injection from high field side of the tokamak in the future.

The injector incorporates a cryostat operating at 4–8 K, equipped with a freezing cell and a gas-feed system for managing the fuel (H_2) and the propellant (He). A three-stage differential pumping arrangement (DF1 to DF3) is implemented to restrict helium ingress into the tokamak. In the experiment, cylindrical H_2 pellets with a diameter of 0.8 ± 0.2 mm and length to diameter ratio (L/D) of 1.0 ± 0.2 were successfully produced. These pellets are pneumatically launched using a burst of high-pressure helium gas. Pellets achieved velocities of 200–250 m/s, and their trajectories were recorded in real time by a high-speed camera. Applying the gas balance equation, a code in Octave software was developed to simulate the vacuum level at each stage of the differential pumping system. Experimental results shows that during pellet launching, DF3 (chamber before he pellet enters the tokamak) maintains a vacuum of the order of 10^{-5} mbar, with highly effective helium evacuation, and is compatible with tokamak vacuum requirements. Comprehensive transient pressure measurements and residual gas analyzer (RGA)

data for H_2 and He show an excellent agreement with the simulation results. These results confirm the injector's suitability for integration with tokamak experiments.

References:

1. S. L. Milora et al., Nucl. Fusion 35, 657 (1995)
2. J. Mishra et al., Cryogenics, 152, 104227 (2025)
3. J. Mishra et al., Fusion. Sci and Tech., 78(3), 211, (2022)