Seminar

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Institute for Plasma Research

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Title: Development of pulsed supersonic beam system for tokamak edge diagnostics and other applications

Speaker: Mr. Milaan Patel
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Abstract

Supersonic molecular beam injection (SMBI) system is an important section of the edge diagnostics of tokamak where helium atoms are injected into the edge and spectroscopic data with CR modeling is used to estimate the temperature and density[1]. Other than plasma diagnostics, SMBI is also used for fueling[2], ELM mitigation[3], transport studies[4] and to reduce the heat flux on diverter plates[5] etc. in tokamak. There is also a significant interest on using SMBI for basic and applied research like, laser cluster interaction[6], low energy cluster surface interaction and basic spectroscopy of atomic and molecular reactions[7]. For the edge diagnostics application, it requires good spatial and temporal resolutions and hence the SMBI has to be operated in pulse mode (1-5ms) with high beam density and low divergence.

In an SMBI system, supersonic molecular beam of neutral gas atom is formed by first generating the supersonic jet and then extracting the supersonic core from the jet boundaries using a skimmer. The extraction is a challenging task which requires precise control of jet parameters and skimmer location. Pulsed operation introduces additional complexities due to dynamic background and the transient behavior of the jet itself. This transient behavior is not yet quantified under actual operating conditions due to measurement limitations. Hence, existing SMBI systems are designed with ideal theoretical approach and steady state assumptions. In this work appropriate diagnostics are conceptualized and implemented to measure the flow parameters and quantified the transient behavior to effectively develop a pulsed SMBI system to implement for the edge diagnostics of tokamak as well as for other basic studies and applications.

The effect of increasing background pressure on jet boundary is studied by measuring the shock location experimentally. Axial flow velocity of the pulsed supersonic jet is measured using a novel probe exploiting time-of-flight technique. Measurements reveal the effects of dynamic background and background penetration[8]. The axial density of the jet is estimated using Pitot probe technique in which flow rate correction is applied to account for internal boundary layer formation. A novel supersonic nozzle profile is conceptualized to generate high axial density for far field flow which is validated using DSMC simulations. The performance is also demonstrated experimentally using a nozzle manufactured by additive manufacturing followed by internal surface smoothening using modified acetone vapor smoothening technique[9]. Transient effects are measured by Rayleigh scattering technique using the atomic clusters as tracers. With careful alignment and calibrations, the sensitivity of this set up increased

by an order of magnitude so that complete spatial and temporal profiles of the jet can be visualized. Measurements reveal cluster growth followed by saturation trends in the jet core, growth at the barrel shock boundaries and disintegration at the normal shock boundaries[10].

With complete characterization of the jet, an experimental system is designed to generate supersonic molecular beam. Conditions for generating the molecular beam is identified using Knudson curve estimated from the experimentally measured jet parameters. A novel shielded ionization discharge (SID) probe is developed to validate the operating region and optimize the skimmer position to have high beam density and low divergence. Finally, the range of density and divergence of the molecular beam that can be generated with the developed SMBI system is briefly discussed.

References

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