Seminar

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Institute for Plasma Research

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Title: Studies on Extraction of an Ion beam and its Transport from a Multi-Cusp Gridded Ion Source

Speaker: Mr. Bharat Singh Rawat
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Date: 18th March 2024 (Monday)

Time: 10:30 AM

Venue: Seminar Hall, IPR

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Abstract

Multicusp gridded ion sources have applications in space propulsion, surface modification studies, and neutral beam injectors for fusion research. The majority of applications for low power ion sources include mass spectrometers, surface modification studies, ion implantation, and electric thrusters. The main parts of these ion source systems are multicusp plasma chamber, ion extraction system, space charge neutralizer, and beam transport systems. The electrical efficiency of these ion sources depends on the confinement of primary electrons in the plasma chamber with a suitable magnetic multicusp configuration and performance of ion extraction system consisting of a set of thin multi-aperture grids. Additionally, adequate space charge neutralisation of the ion beam needs to be provided to confirm the proper extraction and transport of the ion beam.

In this thesis, a ring cusp ion source has been designed and developed to produce the ion beam of heavy ions (e.g. Ar^{+}) within the energy range of 1-2 keV and the beam currents up to 100 mA. In this ion source, a hot filament is utilised as a cathodes to produce the plasma discharge. The positive ions in the plasma are extracted out and accelerated using an electric field applied between two extraction grids having multiple apertures. The magnetic cusp configuration of the plasma chamber has been optimised to maximise the confinement of primary electrons by using a simulation tools, CST-Studio. The extraction system, also known as ion optics, was designed and developed using OPERA-3D trajectory simulations for minimising the ion beam divergence. Thermo-structural analysis has been carried out to avoid the deformation in the ion extraction grids resulting from the thermal loads from the plasma and beam ions. Experimental investigations have been carried out to study the extraction and transport behaviour of ion beams with and without the space charge neutralisation. The characterisation of the extracted ion beam is carried out by measuring the beam profiles and estimating ion beam divergence and the beam currents at different locations along the beam path using an eleven-channel Faraday Cup Array (FCA) and a nine-channel Fixed Wire Array (FWA). The FCA is designed with multiple electrodes for filtering out the primary electrons and slow-moving charge exchange ions, while suppressing the secondary electrons emitting from the ion collector. Using a mathematical model that considers the ion beam as a superposition of multiple Gaussian beam-lets directed towards a focal point, measured radial profiles of ion current density have been utilised to determine the beam divergence and focal length. The beam attenuation due to charge exchange processes, radial transport of slow-moving charge exchange ions, space potential and fluxes of neutralizing electrons in the ion beam are also investigated to understand the beam transport and neutralization processes in the ion beam.