Seminar

Institute for Plasma Research

Title : Studies of cavity modes on plasma and its influence on ion beam in a microwave ion source

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Abstract :

Microwave based Electron Cyclotron Resonance (ECR) ion sources are very popular among the accelerator community. For last few decades many physicists/engineers are involved in the research and development of such ion sources to meet the growing needs of high current, low emittance stable ion beam even for the material processing industries and nuclear applications. The production of a high current ion beam depends on the plasma density as well as the confinement time of the plasma particles. The high density plasma is generated in an ion source cavity by the appropriate coupling of the MW electric field energy to the gaseous particles through the ECR as well as off-resonance heating methods. Generally, the wavelength of the MW electric field is within the comparable range of the ion source cavity dimension. Therefore, the electric field after entering into the ion source cavity becomes a guided wave and is distributed throughout the cavity following the pattern of a particular type of cavity resonant mode. The enhancement of the plasma density and the improvement of its confinement are also associated with the plasma perturbations and its non-uniformity across the cavity based on mode structure. These phenomena influence the extracted ion beam in terms of beam emittance, beam halo formation and beam oscillations etc. A good quality ion beam (high current and low emittance) is achievable by adopting the proper launching scheme and correspondingly optimizing the MW coupling into the plasma. One of the main influential parameter that can control the efficiency of the MW power coupling to the plasma and hence the beam quality is the cavity resonant modes that are excited by a properly designed ion source geometry and magnetic field configuration. Therefore, the motivation of the current thesis is to develop a microwave ion source to study the cavity mode generated plasma, the power coupling mechanisms and its influence on the qualities of the extracted ion beam.

In the current study three cavity modes are observed which have influenced the plasma parameters significantly. Two power coupling phenomenon are identified, parametric decay (PD) and phase modulation (PM) to explain the over dense plasma and high energy electron generation respectively inside the ion source cavity. The cavity modes generate electrostatic waves through PD that causes to raise the density far beyond the cut-off corresponding to the launched 2.45 GHz MW frequency. Correspondingly, the temperature of the plasma particles are increased due to the heating through the electrostatic and the phase modulated wave. Due to the different energy coupling from each of the cavity mode electric fields, a $E \times B$ drift force is exerted on the plasma and the plasma pulsates at the PM frequency near the plasma boundary regions. These phenomena are transmitted into the ion beam that impacts the beam emittance and its stability significantly. The above mentioned experimental findings are validated using spatio-temporal MW-plasma simulation considering the boundary conditions, similar to the experimental configuration and the operating environment.

It is concluded that MW power coupling is sensitive to the cavity geometry and magnetic field configuration. Cavity geometry and magnetic field play a decisive role in designing an ion source for optimal beam performance. The multiple cavity mode based heating is an efficient power coupling mechanism, which can be considered as an alternative to the power coupling based on the frequency tuning method.