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Uniform cold hydrogen plasma production over a large cross-sectional area using plasma expansion

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Hydrogen plasma which can contain several species in molecular (H_2), atomic (H) and ionic (H^+, H_2^+, H_3^+, H^-) states, offer different applications in accelerators[1], lithography[2], neutral beam injection (NBI) for thermonuclear fusion reactor[3], etc. It is well understood that a certain application requires particular approach to the optimization of the plasma parameters. Some of them also demand large area production of uniform plasma, like the NBI requires extraction of H- beam over a grid area of 2 m^2 [3]. Accordingly the plasma source need to produce large area hydrogen plasmas, optimized for H- generation. The present work focuses on similar approach, however utilizing an electron cyclotron resonance (ECR) instead of the conventional rf ICP for plasma generation [3], in order to make the H- source more energy efficient.

The plasma is produced inside a 2.45 GHz compact electron cyclotron resonance (ECR) plasma source (dia: 9.0 cm, length: 11.5 cm) at low pressures (1 – 3 mTorr) and low input power (~ 500 W) and was allowed to expand into a large volume plasma chamber (dia and length ≈ 100 cm) which had the source mounted coaxially on its top dome [4]. Langmuir probe measurements showed a striking differences between the upstream and downstream plasma properties. Dense (n_e ~ 10^{11} cm^{-3}) and hot plasma (T_e ≈ 50 eV) was observed at source mouth (z = 0), which rapidly cooled down to ~ 6 eV over the distance of 5 cm during expansion (Fig 1 a). However at this point a separate small population of warm electrons (T_e ~ 50 eV) was identified to coexist along with the cold bulk electrons. Further expansion towards the far downstream resulted in additional reduction in T_e to ~ 1 eV and fairly uniform plasma almost over the entire cross sectional area, without significant fall in n_e (Fig 1 b and c). It is envisaged that the presence of diverging magnetic field (produced by the permanent ring magnets of the ECR source) and the small population of warm electrons played significant role in sustaining such uniformity at the far downstream. Low T_e and uniformity provides a good platform for large area H- generation (surface/volume process) since the probability of stripping loss of H- by high energy electron collision is greatly reduced.

References

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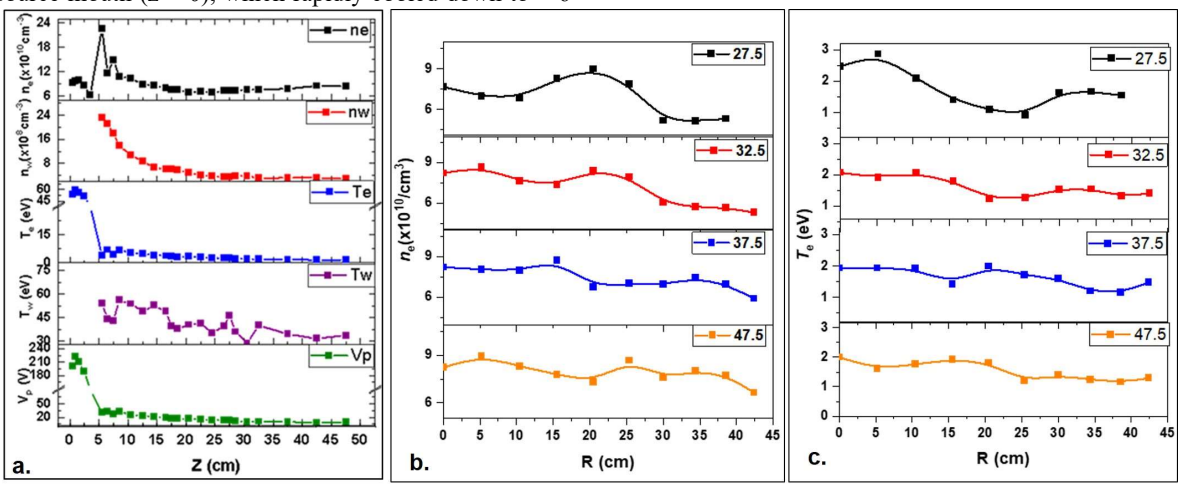

Figure 1: a. Axial variation of plasma parameters. b. and c. Radial variation of plasma density and electron temperature at different z plane (in cm) inside the expansion chamber