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Characterization of Hydrogen Plasma in an ECR based Large Volume Plasma Chamber

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Abstract

In the presented work, Hydrogen plasma characterization was studied inside a large volume cylindrical chamber (dia: 1.0 m; height: 1.0 m). The motivation of the experiments was to evaluate efficacy of production of uniform, large-area H^- beam for fusion applications. The plasma was produced inside an indigenously developed ECR based compact size plasma source (CEPS) (dia: 0.09 m, length: 0.11 m) equipped with NdFeB permanent ring magnets and allowed to flow into the large chamber, it is attached to. Since, the experimental chamber has the provision of mounting and igniting multiple CEPSs at its top dome in one go, separate experiments were conducted with: (i) a single CEPS at the center of the top dome, (ii) seven CEPS with identical polarity on all the magnets at the top dome and (iii) six CEPS with opposite polarity on adjacent magnets at the top dome in order to obtain uniform high density plasma over the cross-section-primary requirement to obtain a large area uniform ion beam. The detailed study and characterization on each individual configuration pointed out that the best scheme to work with will be with igniting only single CEPS at center of top dome of chamber. Via this configuration, one can obtain uniform high density plasma with low electron temperature thus conducive for H- generation.

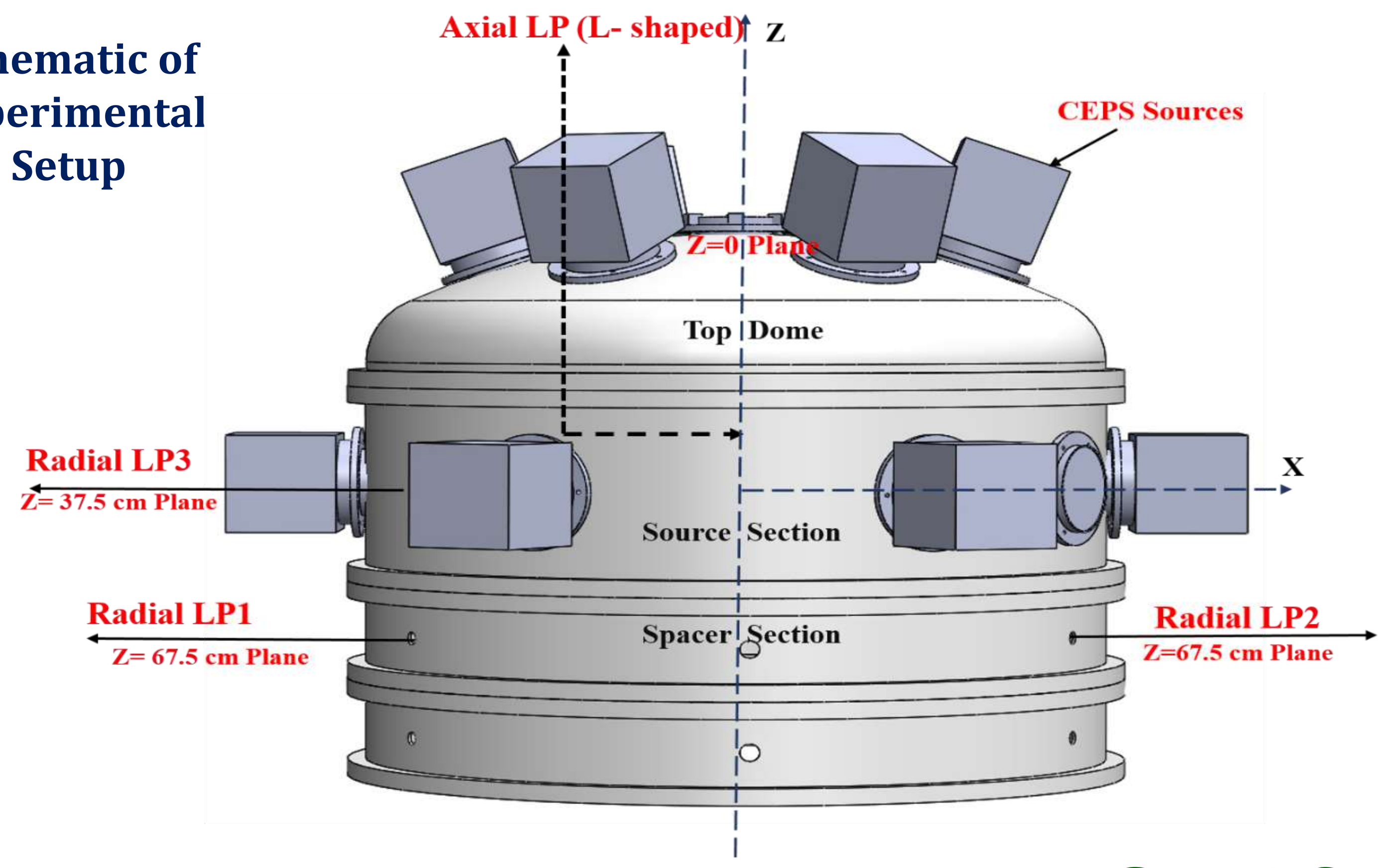
1 Area of Study

Hydrogen plasmas being multi-species discharges viz.; H, H_2, H^+, H_2^+, H_3^+, H^- etc. offer a wide variety of applications. Some notable applications are ion beam (H^+, H^-) production for fusion plasma heating [1] and plasma processing of semiconductors [2-3]. Though the major contribution of hydrogen plasma is towards the former one where a high current negative hydrogen beam is required over a large area for the ignition of fusion plasma. To achieve this, uniform and high density plasma with low electron temperature must be attained with the minimum input power. The current work focuses on the above-mentioned target by experimenting with different number of sources and magnetic configurations.

2 Experimental Set up

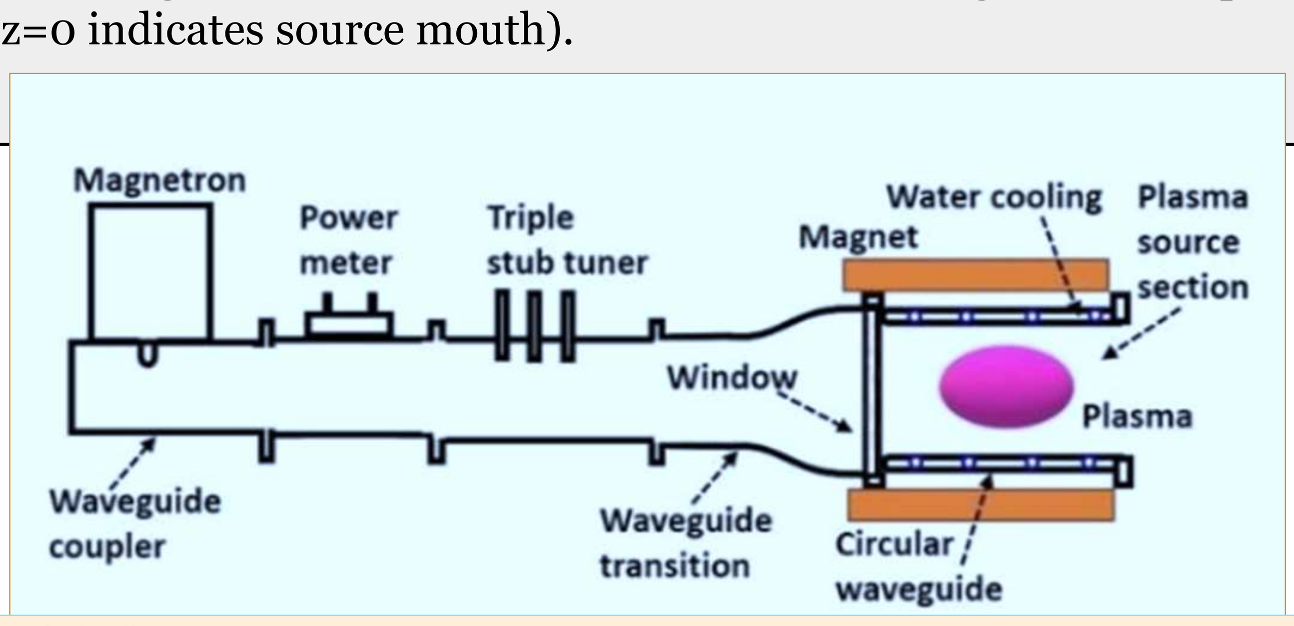
Cylindrical chamber with **diameter ~ 1 m** & **Height~1 m**,
Makes uses of ***Single/Multiple CEPS Sources at Top Dome*** and side wall
Diagnostics: ***Langmuir Probes*** (LP), Placed radially at 2 different ports with @ ***Z ~ 37.5 cm & 60 cm***.

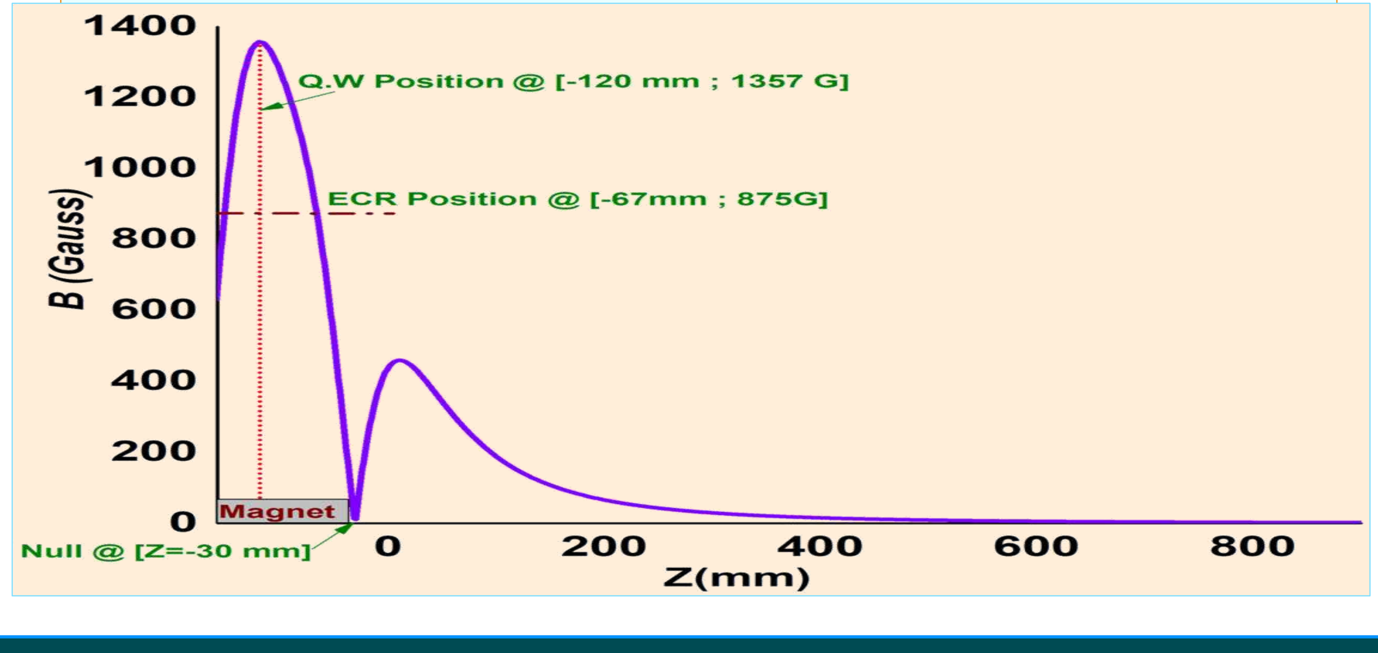
Schematic of Experimental Setup



3 Plasma Production Device : *CEPS*

- CEPS or Compact ECR Plasma Source, patent product of Plasma Physics Lab, IIT Delhi is a portable plasma source which can be mounted on any small/large system for plasma production [4-6].
- The heart of the source lies in the set of suitably placed axially poled permanent ring magnets. These magnets are capable of producing a magnetic field gradient (1300 G – 50 G) thus providing the necessary magnetic field (~ 875 G) for absorption of the incoming microwaves at 2.45 GHz which leads to plasma heating; further the field extends as a diverging field into the expansion chamber. Also the high magnetic field side at one end act as a half mirror and helps in combating losses of high energy electrons
- Following is the schematic of CEPS and its magnetic field profile (z=0 indicates source mouth).

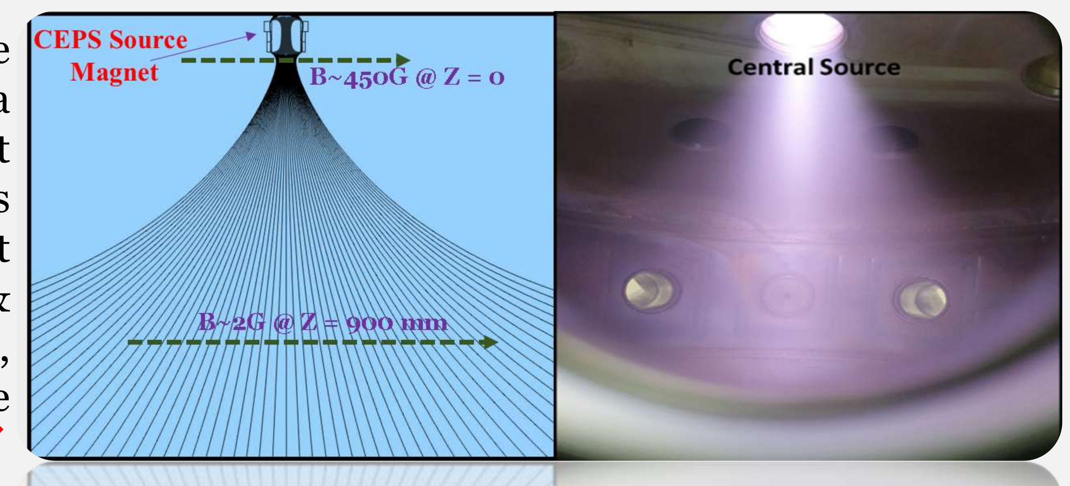




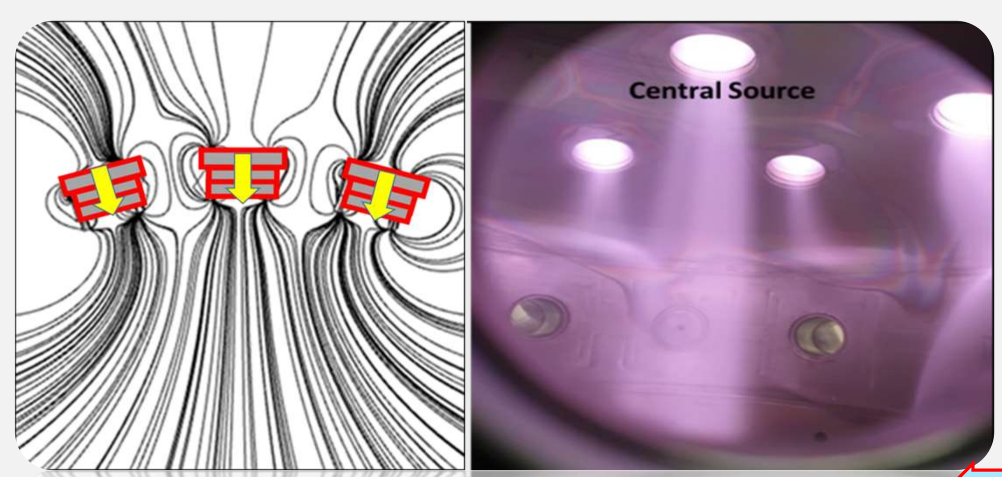
4 Different Schemes Utilised

i) Single *CEPS* at top dome

When only single CEPS at central port of top dome was ignited at 400W & 2 mTorr, flaring of plasma inside the chamber was observed as depicted in right side of the image. The left hand figure depicts simulated magnetic field lines inside the chamber. It is observed that both the magnetic field lines & plasma are showcasing similar behaviour. Thereby, inferring that Hydrogen plasma strictly follows the magnetic field of lines.



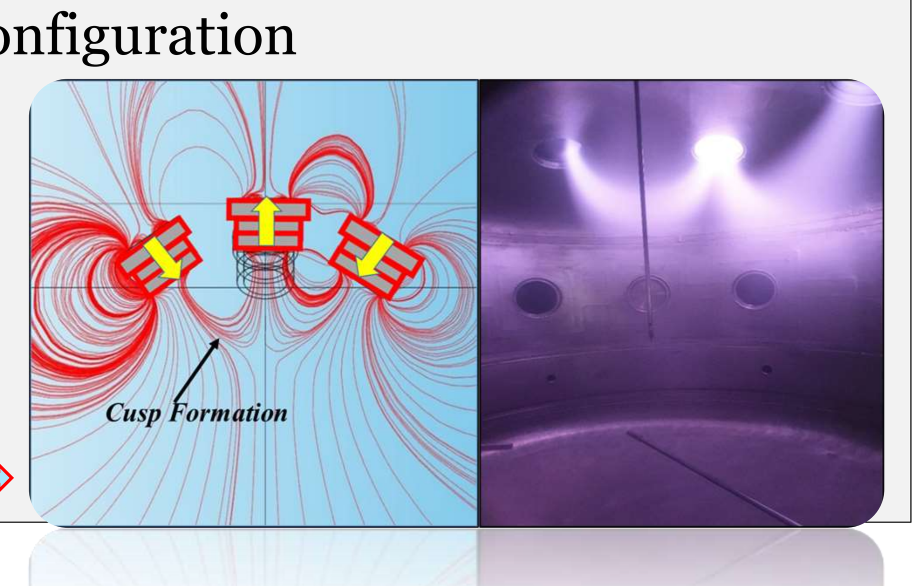
ii) 7 CEPS in *Uni-polar* configuration



In this scheme, seven sources (CEPS) were ignited at the top dome. The sources were positioned in such a way that all magnets were aligned with identical polarity. All the 7 CEPS were fired at 400W of input power each & 2 mTorr of gas pressure. For this scheme, we observed streaks of plasma strictly following magnetic field of lines but not mixing to generate homogenised plasma in any plane of chamber.

iii) 6 CEPS in *Cusp* configuration

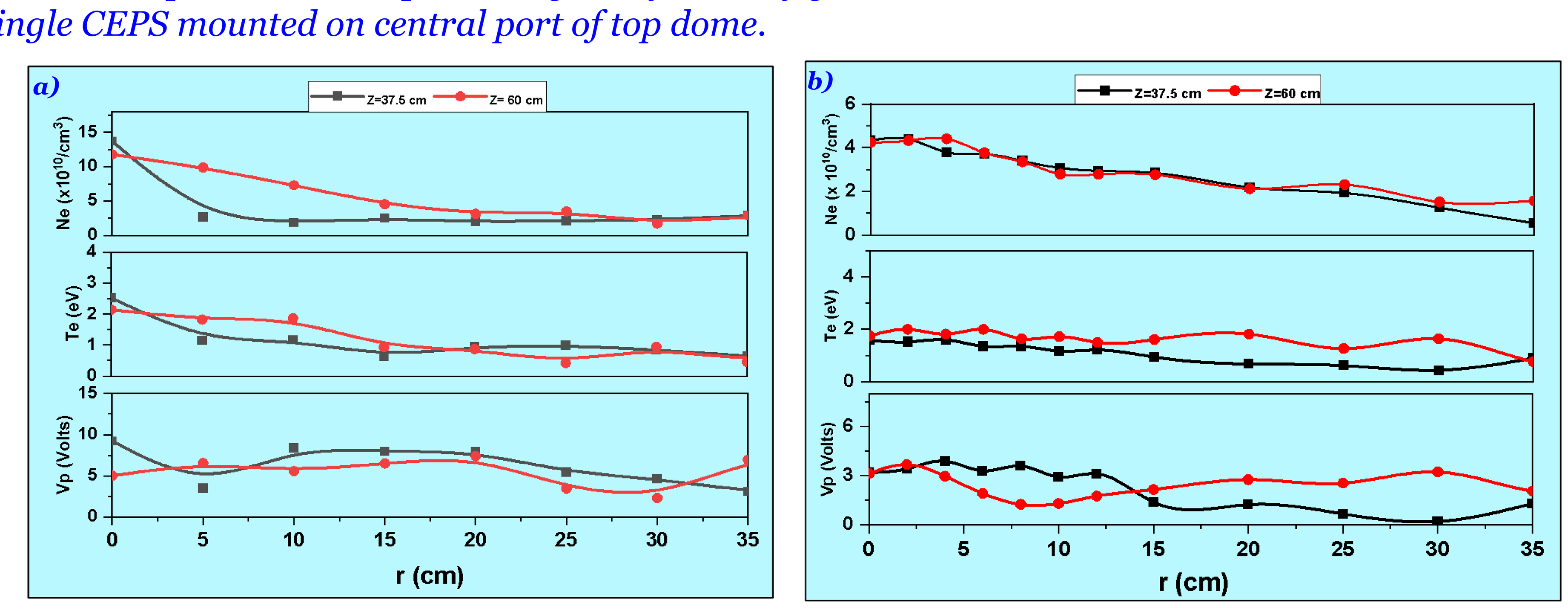
iii) In this scheme the six peripheral CEPS were ignited. No CEPS was mounted at the center. However the orientation of the magnetic polarity of adjacent magnets was kept opposite. With this sort of arrangement, cusp shaped magnetic field structure were formed. Like the earlier case, the plasma was found to be glued to the magnetic lines of forces and oscillated between adjacent source leading to unstable plasma formation and microwave reflected power.



5 Plasma Profiles

Following are the radial profiles (at Z = 37.5 cm & Z= 60 cm) of Plasma density (Ne), Electron temperature (Te) & Plasma potential (Vp) of Hydrogen plasma at pressure of ***2m Torr & 400 W*** of input microwave power obtained with

a) 7 CEPS at top dome in Uni-polar magnetic field configuration &
b) Single CEPS mounted on central port of top dome.



From above graphs, it can be summed up that though the central density is quite high with 7 CEPS sources (~10^{11} cm^{-3}) for both the planes, the uniformity is poor. However with, only single CEPS that utilises a mere power of 400W, we are getting moderately uniform density (4 × 10^{10} cm^{-3}) profile with electron temperature in the range of 1-2 eV. Presence of warm population was also noted (not shown here), with density of the order of 10^8 cm^{-3} and temperature in the range of 60-80 eV.

6. Conclusion :

Conclusively, it can be said that after experiment with different magnetic field schemes and number of sources, Single CEPS mounted on central port of top dome out shadowed all other schemes. The plasma followed the flaring of magnetic field of lines inside the volume of the chamber and hence quite uniform plasma was obtained in the downstream region (~60 cm) of system. In the next leg of the experiments, density variations with power can be studied in detail aiming to get higher density of the order of 10^{11} cm^{-3} in the same downstream region. Also, fabrication & mounting of an axially aligned Langmuir probe has been planned in order to give more insight of plasma parameters near to the source.

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