Investigation of the plasma parameters in the expansion region of a negative hydrogen ion source for fusion

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Measurements were performed by two Langmuir probes moving in parallel from the plasma source exit (driver) up to the plasma grid (PG). Results show that depending on the position and strength of the magnetic field, the plasma flowing out of the driver is inhomogeneous and remain so along the expansion region. The presence of the magnetic filter field (FF) is clearly responsible of the properties of the plasma: no inhomogeneity is seen when the FF is removed. A relation between the temperatures and densities can be derived from the mean energy flux conservation.

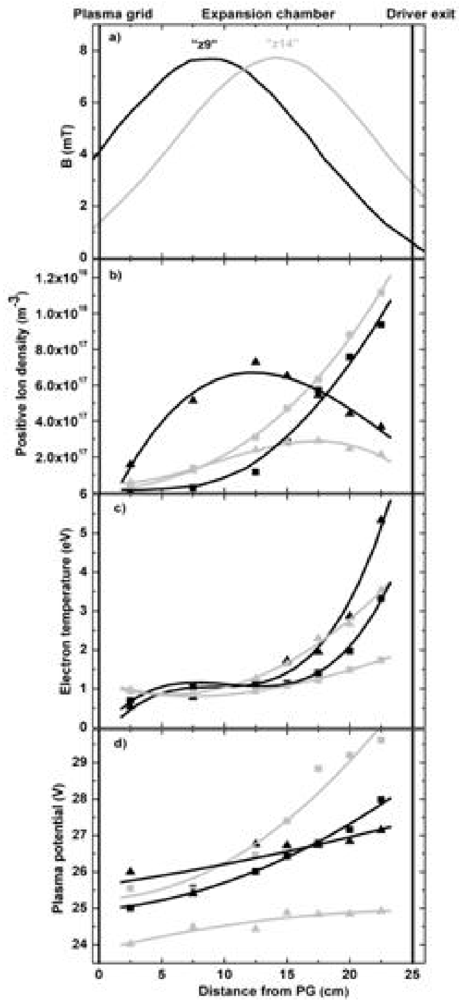
IPP Garching is participating in the development of the ion source for neutral beam heating and the diagnostic neutral beam at ITER [1, 2, 3]. The source was previously described in great detail [1]. Briefly, the source is operated at a low hydrogen or deuterium pressures (0.3 Pa) and high RF power (up to 100 kW). Caesium is evaporated in order to reduce the workfunction of the inner surfaces and to increase the conversion of neutrals and positive ions into hydrogen negative ions. Most of the negative ions generated on the plasma grid can be extracted. The extraction of negative ions inevitably leads to the co-extraction of electrons. The magnetic filter field reduces the electron temperature and density and hence diminish the amount of co-extracted electrons. Moreover, the reduction in the electron temperature diminishes the destruction of negative ions by electron impact. The magnetic field is generated by permanent magnets and located between the driver and the accelerator. It has a maximum strength of 8 mT.

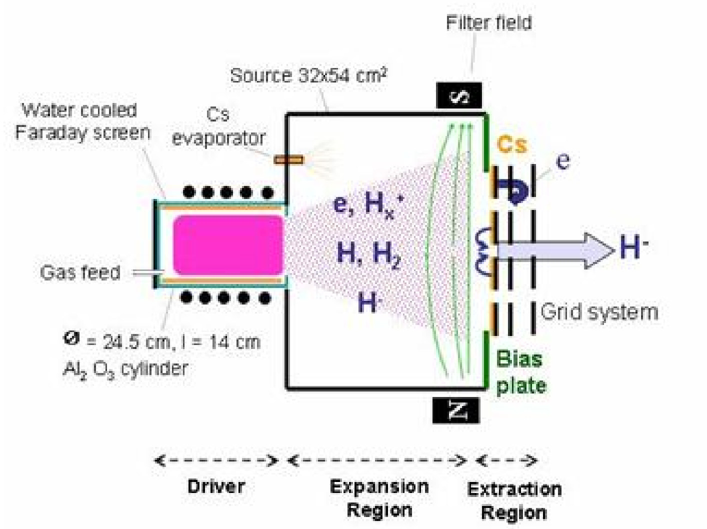
The figure 1a, b c, and d present two magnetic configurations, the positive ion densities, electron temperature, and plasma potential for the two RF compensated probes obtained when no Cs was evaporated at a pressure of 0.6 Pa H_2 and 40 kW of injected RF power. The black and grey lines are related to the corresponding FF configurations [4] while the straight and dashed lines represent the top and the bottom probes respectively. On figure 1b, one can see that the plasma flowing out of the driver is already inhomogeneous (the magnetic field penetrates into the driver), the densities measured at the top and bottom probes also have a different behavior. The presence of the maximum in the bottom probes for both configurations could be due to either a shift of the plasma in the bottom direction, or the presence of an exit angle at the driver exit, induced by the FF. One can see on figure 1c that the electron temperature in the bottom part is systematically higher than in the top part, at the driver exit. A decay is then observed. The potential profiles also show a strong difference along the expansion region. The differences in the observed plasma parameters are magnified at the driver exit location, when the FF is moved towards the driver. Moreover, the top and bottom plasma parameters are homogeneous when the FF is removed, while the reversal of the FF direction gives a reversal of the measured top/bottom plasma parameters. This proves that the FF is the only parameter responsible of the observed behaviours.

Interestingly, for both FF configurations, the higher temperature (bottom) is associated with a lower density (see bottom on figure 1b). Conversely, the lower temperature on figure 1c (top) is associated to a higher density. Using the mean energy flux conservation [5], one can derive that [6], at each z position

$$n_{e,t}(z)T_{e,t}^{3/2}(z) \simeq n_{e,b}(z)T_{e,b}^{3/2}(z) \tag{1}$$

with n_e and T_e being the electron density and temperature respectively, the subscript t and b referring to top and bottom respectively. This simple relation shows, that despite showing strong plasma parameters differences, the mean energy flux flowing out of the driver is locally conserved at each z position in the expansion region.





a, b, c, and d show the variation of the magnetic field intensity, the positive ion density, electron temperature and plasma potential. The colors are related to the FF position on fig a, while the straight and dashed represent the top and bottom probe respectively. On the right side can be seen a schematic representation of the source

References

[1] E. Speth et al, *Nucl. Fus.* **46** (2007) S220.

[2] L. Schiesko et al, *Nucl. Fus.* **51** (2011) 113021.

[3] L. Schiesko et al, *Plasma Phys. Control. Fusion* **53** (2011) 085029.

[4] P. Franzen, L. Schiesko, M. Fröschle, D. Wünderlich, U. Fantz and NNBI Team, *Plasma Phys. Control. Fusion*, **53** (2011) 115006.

[5] T. E. Stringer, *Plasma Phys. Control. Fusion* **33** (1991) 1175.

[6] L. Schiesko et al, *Plasma Phys. Control. Fusion*, submitted.