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# LANGMUIR PROBE MEASUREMENTS IN POWERFUL RF-SOURCES FOR NEGATIVE HYDROGEN IONS

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Powerful RF sources for negative hydrogen ions are one of the key components of the neutral beam injection system for the international fusion experiment ITER which is presently under construction in Cadarache, France. Hydrogen plasmas with a high dissociation and ionization degree are generated by inductively coupling in a ceramic cylinder (24 cm diameter; 14 cm length) at a filling pressure of 0.3 Pa using a RF frequency of 1 MHz at a power level of 80 kW. In the IPP RF prototype source the plasma expands into a rectangular expansion chamber of 24 cm depth facing the first grid, the plasma grid, of the three grid extraction system. Negative hydrogen ions are produced at the plasma grid by the surface effect, i.e. the effective conversion of atoms and positive ions at surfaces with a low work function. For lowering the work function cesium is seeded to the hydrogen discharges forming a thin layer of cesium at the surfaces, most important at the plasma grid for direct extraction of generated negative ions. A magnetic filter field is used to reduce the electron temperature and density from typically 10 eV and $10^{18}$ m$^{-3}$ in the driver to 1 eV and $10^{17}$ m$^{-3}$ close to the grid to minimize the destruction of negative ions by electron stripping and to reduce the co-extracted electron current. The latter can be reduced further by applying a bias voltage of typically 15 V between the plasma grid and the source chamber. Extracted current densities of negative hydrogen ions of 30 mA/cm$^2$ at an electron to ion current ratio below one are achieved in these sources meeting the ITER requirements [1,2]. As shown by measurements [3] the negative hydrogen ions form the majority of the negative charge close to the grid resulting in an ion-ion plasma which is a special feature for these kind of sources.

Present investigations concentrate on the optimization of the filter field, i.e. its strength and position, and on the cesium conditioning since both determine strongly the plasma homogeneity above the grid and the source performance.

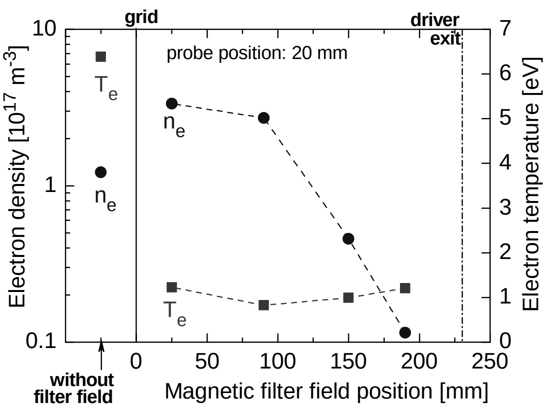


Fig. 1: Dependence of the plasma parameters measured close to the extraction system on the axial position of the magnetic filter field (plasma grid position: z = 0) and without magnetic field.

A movable and RF compensated Langmuir probe system is available to measure profiles of plasma parameters such as electron density and temperature as well as plasma and floating potential in the driver and close to the grid [4]. In addition, fixed probes are installed at 2 cm distance to the grid to routinely measure plasma parameters.

In order to study the

influence of the axial position z of the magnetic filter field on the plasma parameters and the extracted currents, a flexible magnetic frame has been installed outside the source replacing the standard field which is created by permanent magnets in the source at z = 30 mm. The maximum field strength in the centre of the x,y-plane is 7 mT. Figure 1 shows the plasma parameters measured with the fixed probe (x,y-plane centre) for different positions of the magnetic frame and without magnetic filter in hydrogen discharges without cesium seeding. The electron cooling effect of the magnetic filter is clearly to be seen; a reduction from 6.5 eV to 1 eV is observed almost independent on the filter field position; the electron density however changes drastically. A reduction by more than one order of magnitude is obtained by mounting the field close to the driver exit (z = 190 mm), reducing the co-extracted electron current. Although the latter is highly desirable the positive ion flux will be reduced resulting in a lower compensation of the negative space charge which is build up by the negative hydrogen ions created at the grid. Thus, less negative ions can leave the surface and are available for extraction. In addition, plasma generation in the driver is more difficult, i.e. unstable, at low pressure. In conclusion, the filter field should be positioned close to the plasma grid which is also favorable for bending the negative ions into the direction of extraction.

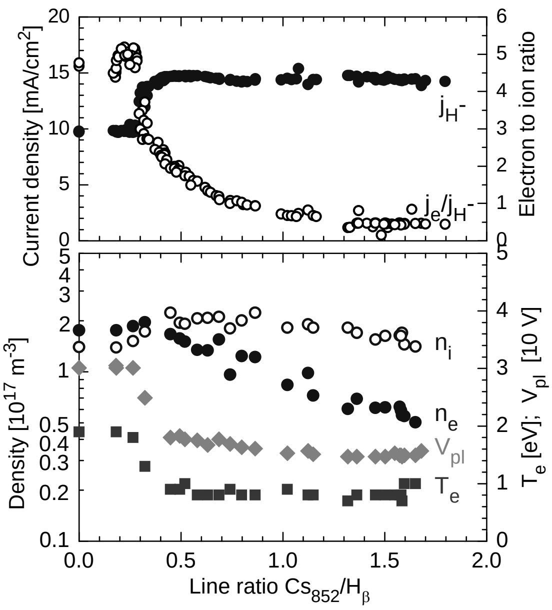


Fig. 2: Extracted current densities and plasma parameters as a function of the cesium amount.

Figure 2 shows the change of extracted currents and plasma parameters close to the grid with the filter field at z = 90 mm with cesium seeding of the discharge. The amount of cesium is indicated by the line ratio of the cesium emission line at 852 nm to the Balmer line $H_\beta$ both measured with a survey spectrometer using a line of sight parallel to the grid. With increasing cesium amount, i.e. increasing amount of negative hydrogen ions produced by the surface effect, the electron density decreases resulting in a decrease of the extracted electron to ion ratio whereas the positive ion density determined from the ion saturation current of the probe remains constant. A sharp decrease of the electron temperature and plasma potential is observed indicating a transition from pure hydrogen plasmas to plasmas with remarkable cesium amount and amount of negative hydrogen ions. It will be shown that the current-voltage characteristic changes also which makes data analysis difficult, even impossible. The paper discusses also the dependence of the probe characteristics and plasma parameters on the position of the probe in the x,y-plane but also in axial (z) direction as well as the changes with the filter field orientation.

## Reference

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