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DOUBLE LAYER BEAM FORMATION IN THE NJORD DEVICE AND ITS DEPENDENCE ON MAGNETIC FIELD CONFIGURATION.

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Introduction

A double-layer is a nonlinear potential structure within plasma, and it can potentially accelerate plasma charges into beams. Current-free double layers (CFDLs) forming self-consistently in expanding magnetised plasma is of relevance to space plasma phenomena such as the aurora and coronal funnels on the sun, and has been actively investigated in laboratory since they were reported by Charles recently [1]. A signature of a CFDL is an ion beam which can be detected by means of a retarding field energy analyzer (RFEA).

How the CFDL forms, whether it is due to an insulated plasma source which anchor the DL to the walls, or whether it can be detached from the plasma source, is a question which has recently been addressed by some authors. Recently, evidence has been provided [2] that the double layer in an expanding magnetised plasma can exist at least some hundreds of Debye lengths in front of the insulating plasma source tube and can consequently be considered to be ”self supporting” insomuch as it is not directly attached to the insulating walls of the source.

Another question, which has been investigated theoretically, is what role the geometry [3] and magnetic field [4] may play in the formation of the CFDL and the ion beam. In this work, the magnetic field geometry has been altered from an expanding magnetic field to a bottle shaped field by means of a third coil placed downstream of the double layer. The influence of the field variation on the ion beam has been studied by acquiring the ion energy density profiles with the probe facing both upstream and downstream direction, and by measuring the density and potential fluctuations as the field geometry is altered.

Experimental setup.

The Njord device has been constructed for space plasma related experiments, with special focus on instabilities in plasma flows. It consists of a 14 cm diameter, inductively coupled, 13.56 MHz plasma source in conjunction with a 60 cm diameter and 1.2 m long cylindrical vacuum chamber. The source is adopted from the one used in the ”Chi-Kung” device at

Australian National University, and has a double-saddle rf-antenna fed with 13.56 MHz CW from a Henry Radio 8K Ultra rf amplifier The rf power output used for plasma breakdown in this experiment was held in the range 150-300W. Some more detail may be found in [2]. The experimental setup is shown in Fig. 1 a). A weak magnetic field of maximum 15 mT is applied in the source region by means of two coils outside the saddle-type helicon antenna placed around the pyrex tube source chamber. In addition, a third coil is placed 58 cm downstream from the end plate of the source, which defines the origo along the axis of the source. The field produced by the latter coil can be varied from 0 to 15 mT, so that an inflection point is produced between the 2nd and 3rd coil already at fields of less than 5 mT at the 3rd coil, as indicated in Figures 1b) and 1c).

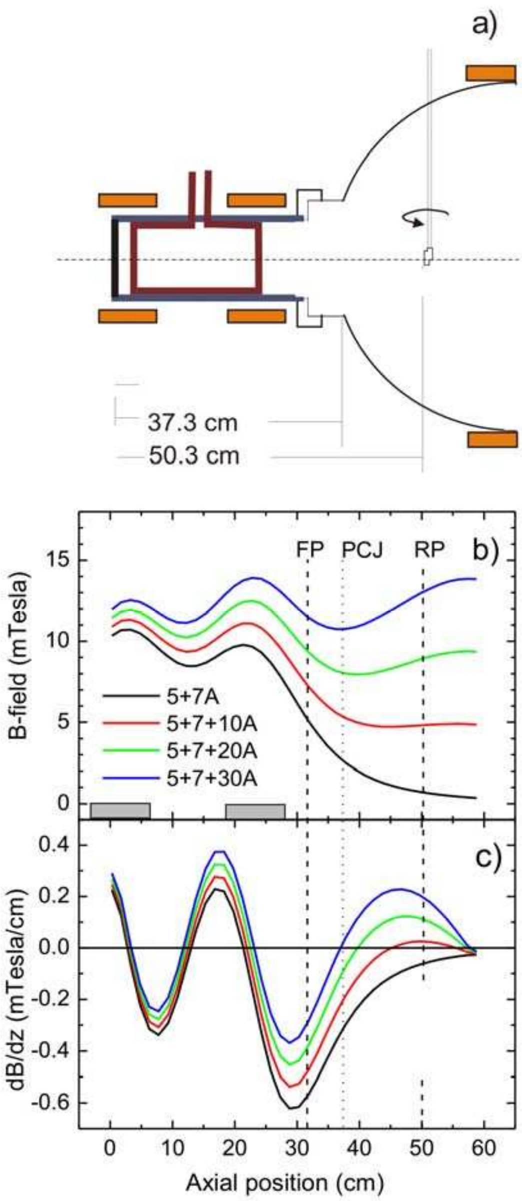

Figure 1. Sketch of the experimental setup a) with calculated magnetic field at the axis b) and its derivative c) for four different magnetic fields.

A retarding field energy analyzer (RFEA) is inserted in the ion diffusion region of low-pressure argon plasma at 0.18 mTorr.. The latter can be rotated 360° around its axis, providing measurements of ions arriving from both upstream and downstream directions. The RFEA had orifice diameter 1 mm, and was constructed with a mesh across the orifice in the grounded front end plate. Its electron repeller grid was biased at -85V, the discriminator grid had variable bias from -100 V to +100 V, the secondary repeller grid was biased at -18 V, and the collector at -10 V.

The distance between each grid was 0.5 mm, resulting in an overall distance between the front end grid and the collector of 2.0 mm. The discriminator was biased in 400 steps per scan. At each step the collector current, measured over a 10kΩ resistor, was digitized into 300 samples which were then averaged into one single value, and written to file for further analysis.

Results and discussion.

The ion energy distribution function (IEDF) obtained by the RFEAs were analyzed with the method described in [5]. An example of two IV-curves with beam is shown in Fig. 2. It is obtained at a B-field configuration of 5A in coil 1, 7 A in coil 2, and 28 A in coil 3 (consistent with a mirror-shaped magnetic field, see Figure 1b). The black trace is obtained with the RFEA facing the source, and the inverted red trace is obtained with the RFEA facing downstream. The leftmost peaks at about 75V and 95 V are interpreted as the bulk ion distribution, apparently having a plasma potential of the same values, respectively. The larger peaks at about 120V and 130V are considered beams with energies of about 45 V and 30 V, respectively. So why is there this large difference in apparent plasma potential when the probe is at opposite rotations? In Fig. 3, the centre positions of the peaks are plotted as a function of current in coil 3. The open and closed symbols represent peaks from the RFEA facing upstream and downstream directions, respectively. The black symbols represent the first peak which is interpreted as the bulk plasma potential. Note that upstream data from 2 to15A is not available. It is apparent from the plot that as the coil current is increasing above 16 A, the difference between up-and downstream plasma potential $V_{p,down}$ increases from equal values at 16 A until up to about 20V at 30

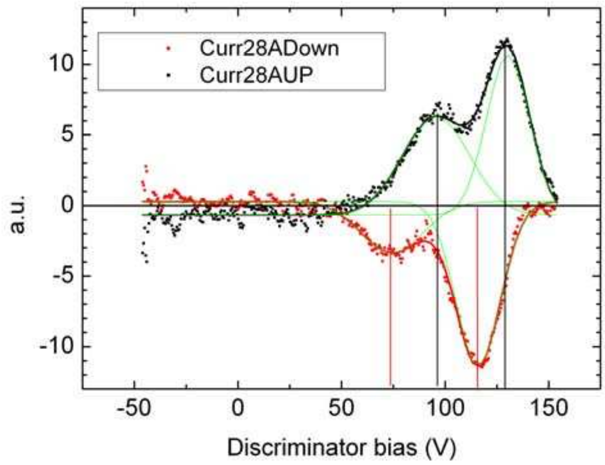

Figure 2. The IEDF of the RFEA facing the upstream plasma (black plot) and facing the downstream plasma (red, inverted plot).Dots corresponds to the derivative of the7 points averaged RFEA current signal. Full lines representntsthe sum of the two fitted Gaussian peaks.

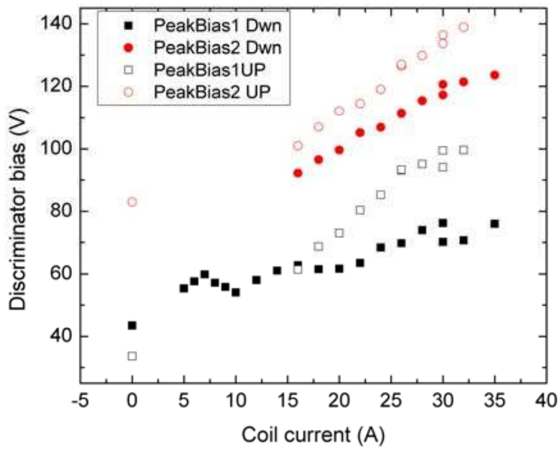

Figure 3. Discriminator bias for Gaussian peak fits of the IEDFs as a function of current in coil 3. Filled and open signal correspond to peaks in the IEDFs of the RFEA facing downstream and upstream directions, respectively. Black and red symbols represent low-energy and beam peaks, respectively.

A. This could be interpreted as flow induced in the plasma from the 16 A point. The upstream $V_{p,up}$ is higher than the downstream, indicating that the flow (as can be expected) is going in the downstream direction, with an inferred energy of $(V_{up} - V_{down})/2$. Thus the apparent flow has an almost linearly increasing directional energy from zero at 16A to about 10V at 30A. On the other hand, it should be noted that as the RFEA is a large grounded object and will thus create a wake, such that a direct estimate of the flow speed can be inaccurate. These measurements will therefore be complemented with measurements by f.ex Mach probes and emissive probe for alternative measurements of flow and plasma potential. We also note that an additional ion beam has a similar discrepancy between up- and downstream potential, which may be interpreted as it being embedded in the background plasma flow. It is not possible to discern a beam in the signal at lower coil currents. Furthermore, this beam seems to occur only from 16 A and upwards, and at the same time as there is indication of flow in the background plasma. Looking at the ion saturation current density, representative of the ion density as function of the coil current (Fig. 4), we see that the density has a maximum at the same magnetic field as the background plasma starts flowing and a beam appears. As the apparent flow increases, the plasma density decreases. This may be understood as a signature of the loss of confinement due to the bulk plasma flow. The density maximum and onset of the flow takes place at a current of about 16A in the 3rd coil. Although it is still not clear from these preliminary results, what causes the apparent flow and the energetic beam for higher fields, we may still conclude that the shape of the magnetic field is playing an important role in the beam and flow formation.

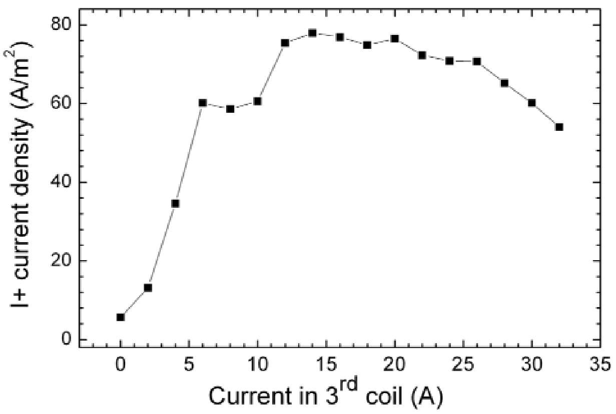

Figure 4. Ion saturation current vs. current in 3rd coil

1. C. Charles, et al., *Current-free double-layer formation in a high-density helicon discharge.* Appl. Phys. Lett., 2003 82 1356.
2. H. S. Byhring, et al., *Simultaneous probe measurements of a detached double layer.* Submitted to Phys.Plasmas, 2008.
3. C. S. Corr, et al., *Ion beam formation in a low-pressure geometrically expanding argon plasma.* Appl. Phys. Lett., 2007 91 241501.
4. A. Fruchtman, *Electric field in a double layer and the imparted momentum.* Phys. Rev. Lett., 2006 96 065002.
5. C. Charles, et al., *Laboratory evidence of a supersonic ion beam generated by a current-free "helicon" double-layer.* Phys. Plasmas, 2004 11 1706.