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Electron dynamics in a current-free helicon double layer

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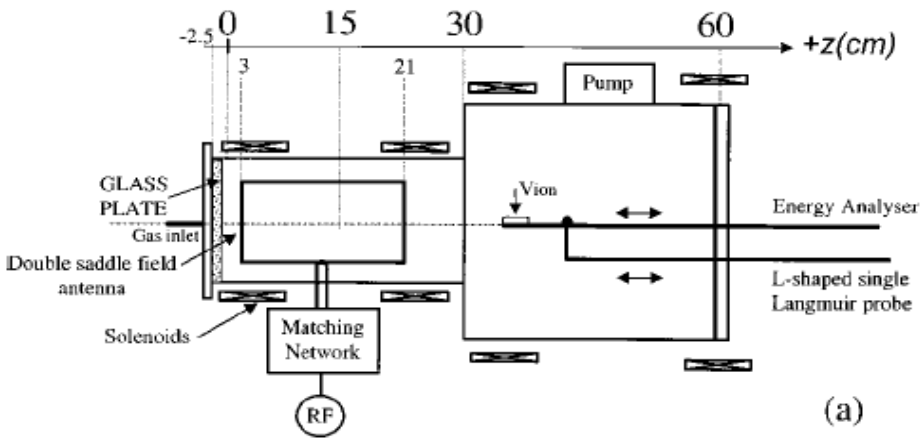
Recent Experiments on Current-Free DL in an Expanding Plasma



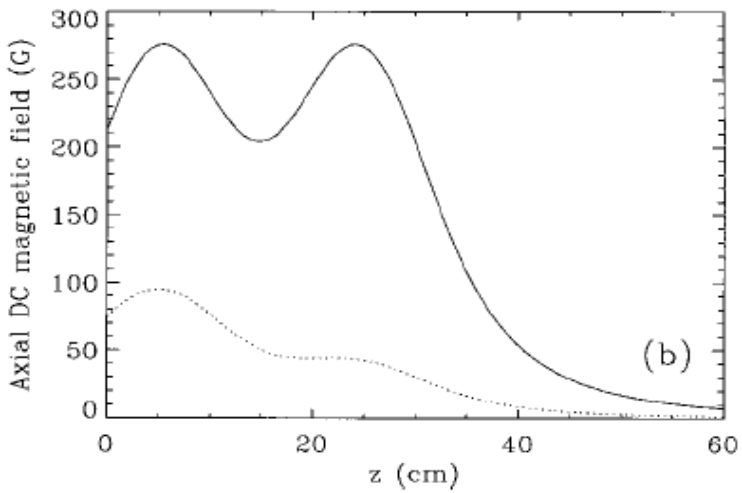
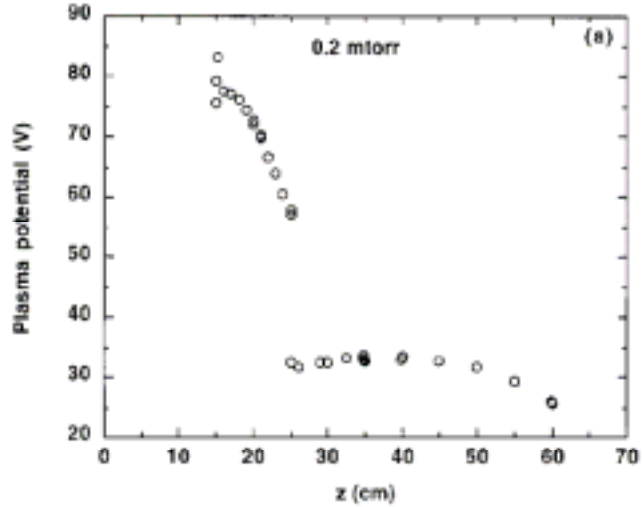


FIG. 1. (a) Schematic of "Chi-Kung," a horizontal helicon system, showing major components and (b) B_z component of the dc magnetic field along axis for the high (solid line)- and low (dotted line)- field cases.



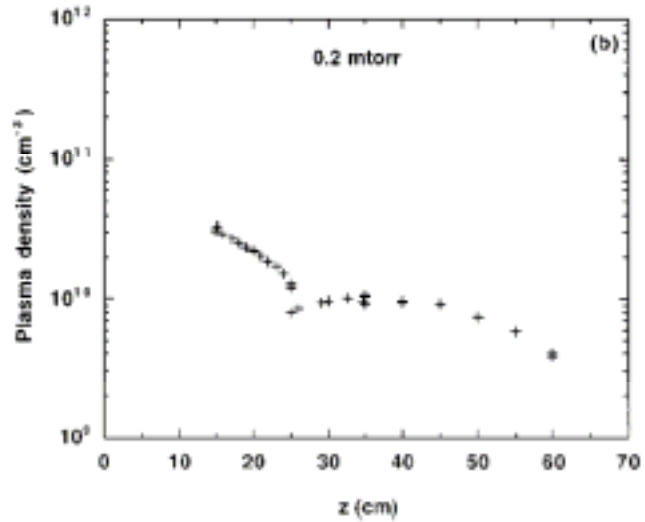


FIG. 3. (a) Plasma potential and (b) plasma density measured with t energy analyzer along the z-axis for 0.2-mTorr pressure, 250 W rf power a high field [Fig. 1(b)] conditions, respectively.

C. Charles and R. W. Boswell, *Appl. Phys. Lett.* **82**, 1356 (2003).

Ion Acceleration by Current-Free DLs

Downstream IEDF in Chi-Kung

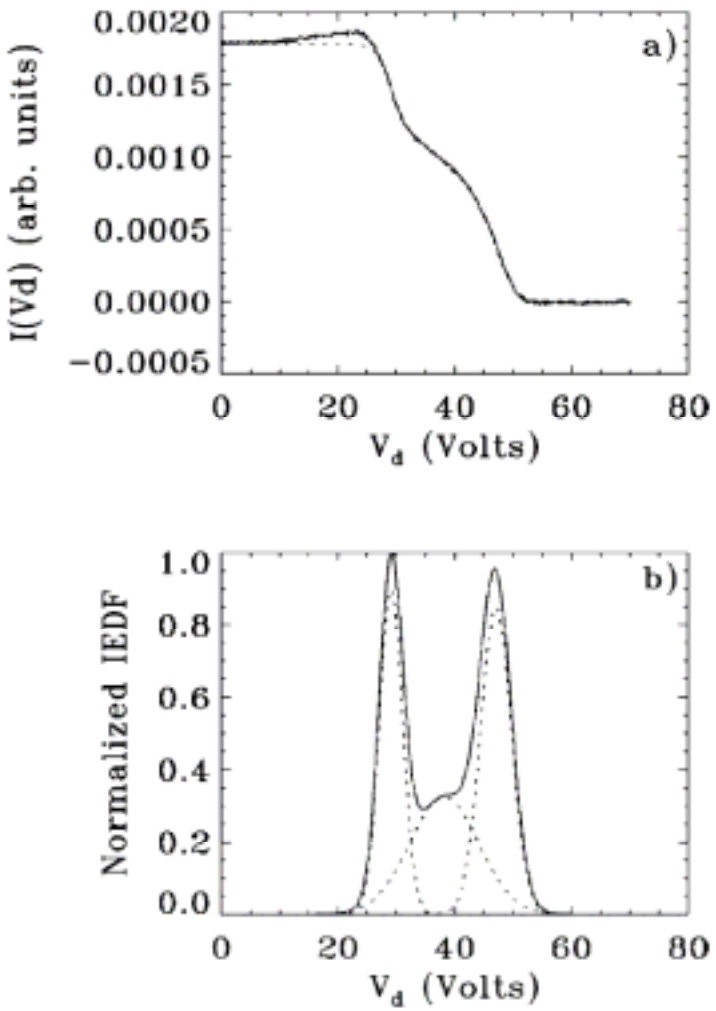
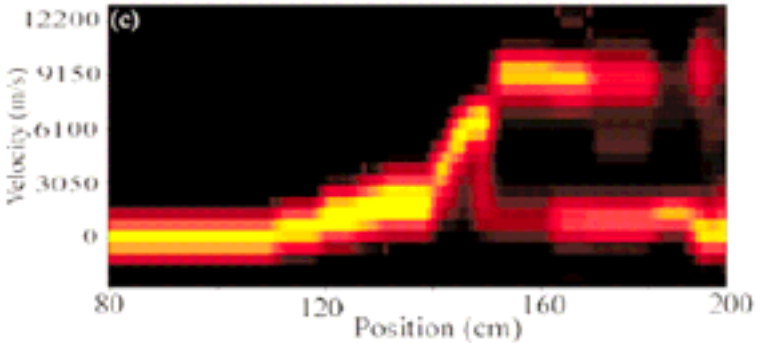


FIG. 7. (a) Typical $I(V_d)$ characteristic (solid line) with data fit (dotted line) and (b) normalized IEDFs with three Gaussian deconvolutions. This reference data set corresponds to the solid line in Figs. 4(a), 5(a), and 10(a).

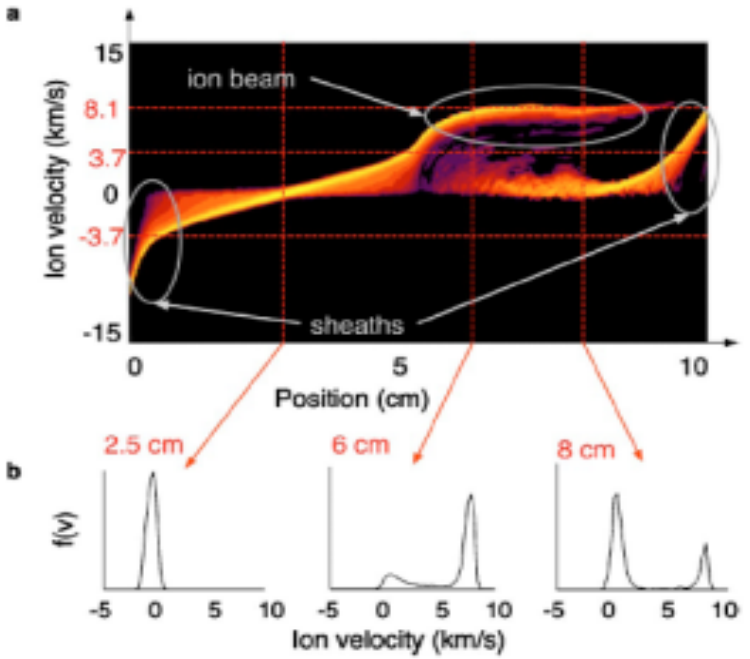
C. Charles and R. W. Boswell, *Phys. Plasmas* **11**, 1706 (2004).

Spatial Profile of IVDF measured by LIF in HELIX



X. Sun et al., *Phys. Rev. Lett.* **95**, 025004 (2005).

Spatial Profile of IVDF observed in PIC simulation



A. Meige et al., *Phys. Plasmas* **12**, 052317 (2005).

EEDF in PIC simulation of Current-Free DL

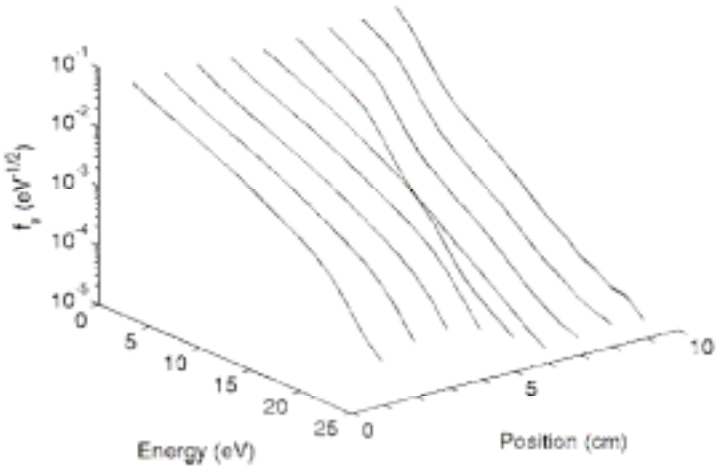


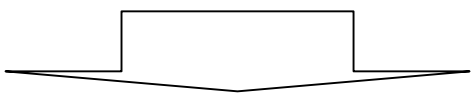
FIG. 1. x-velocity component of the EVDF f_x represented in log scale, as a function of the electron energy and at different positions in a double-layer plasma. The distributions are Maxwellian for the low-energy group of electrons and present a depleted tail at higher energy.

Depletion from Maxwellian EEDF at the energy corresponding to the local plasma potential or the DL potential drop

A. Meige and R. W. Boswell, *Phys. Plasmas* **13**, 092104 (2006).

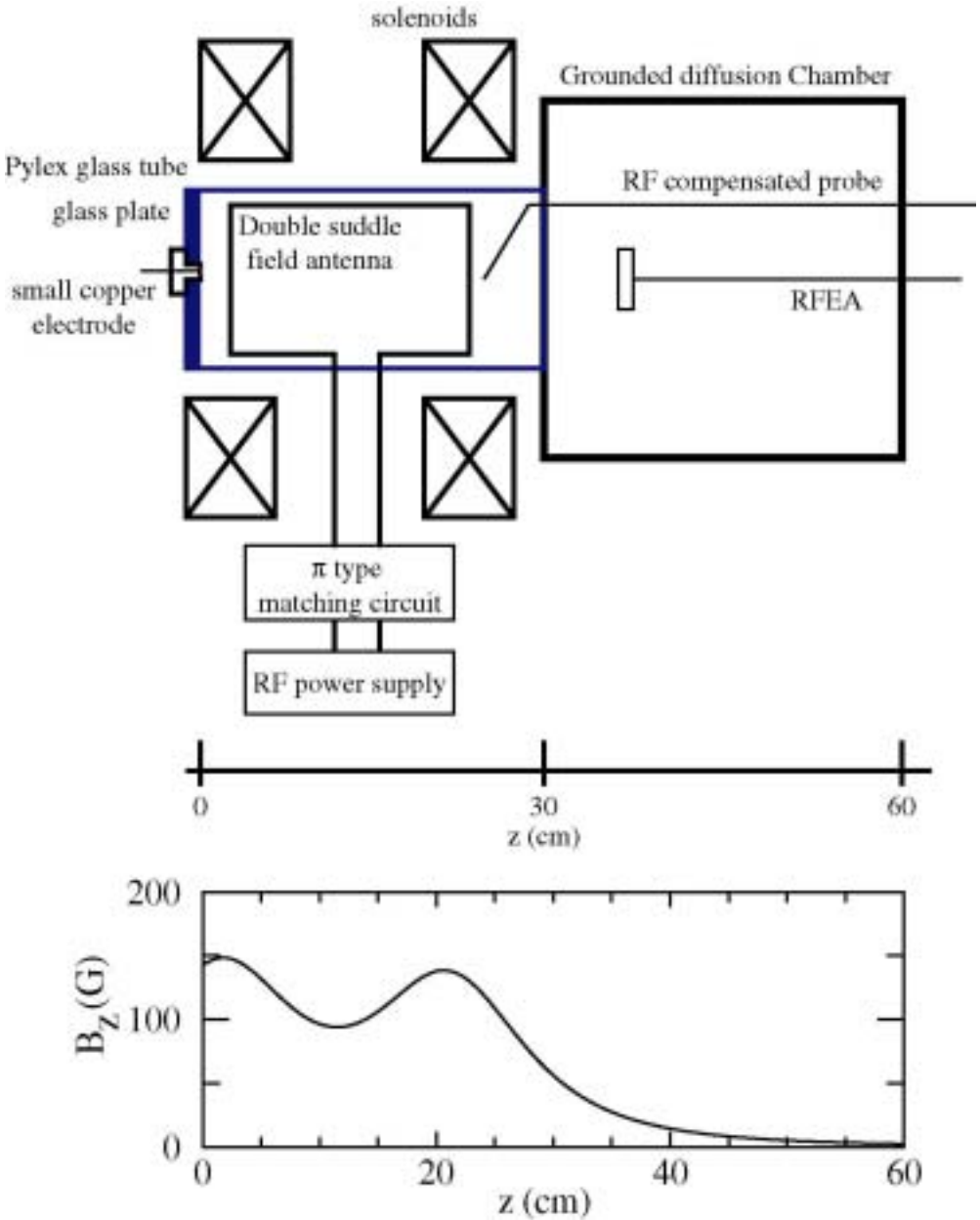
Purpose

Experimental data on electron dynamics has been absent in the previous experiments.



In this work, we report the experimental data on the electron dynamics in a current-free helicon DL.

Experimental Setup (Chi-Kung @ ANU)



Plasma Production

Helicon wave (ICP) discharge
in diverging magnetic field

Plasma Diagnoses

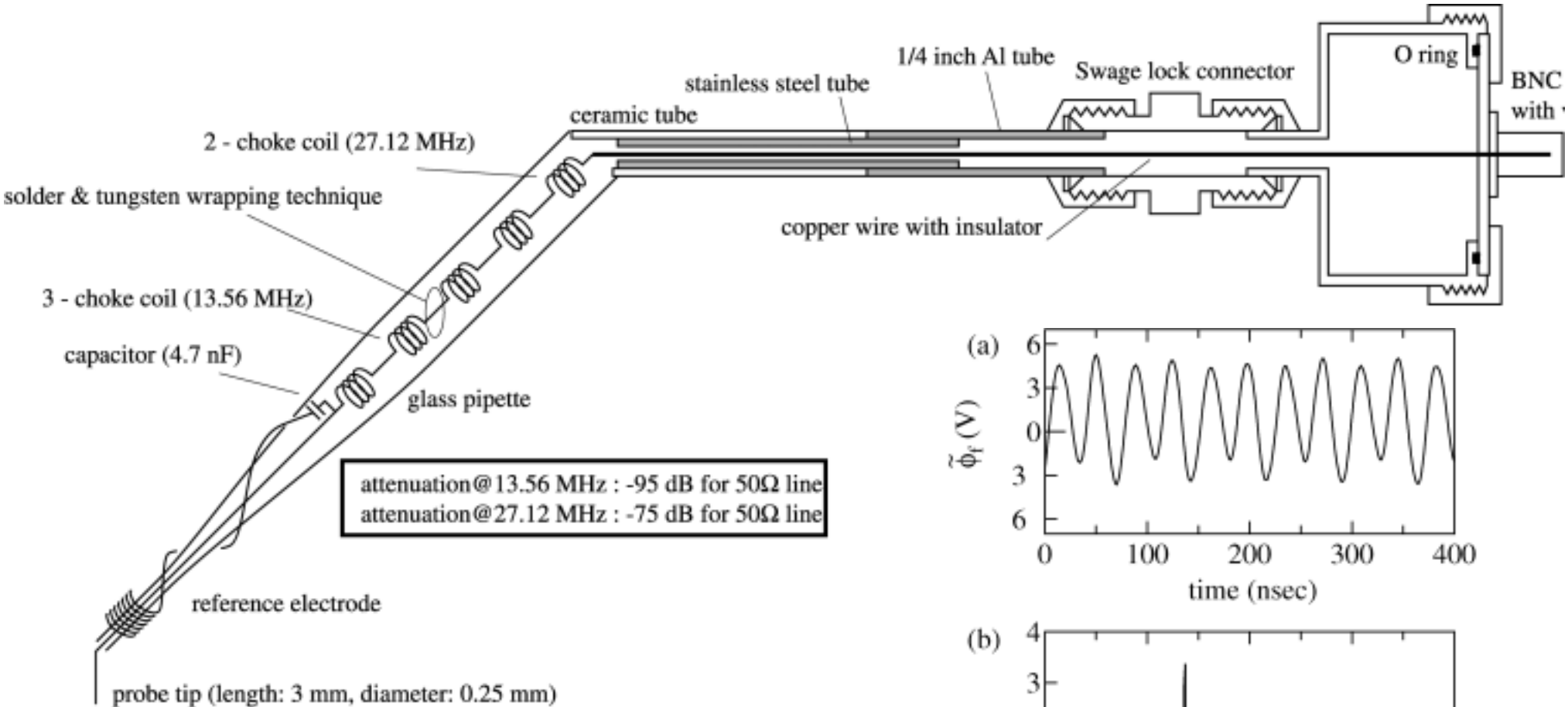
Ion

Retarding field energy analyzer (RFEA)

Electron

RF compensated probe
& pulsed Langmuir probe technique

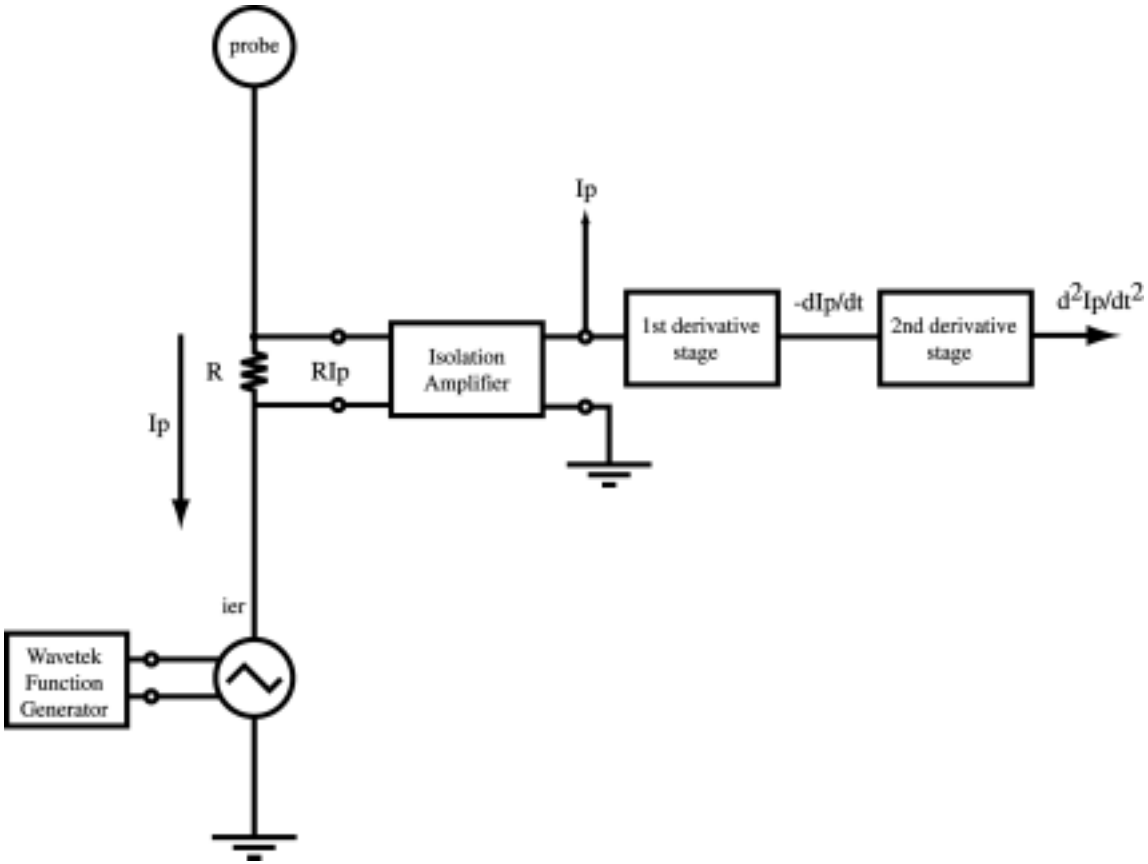
EEDF diagnosis (1): RF compensated probe



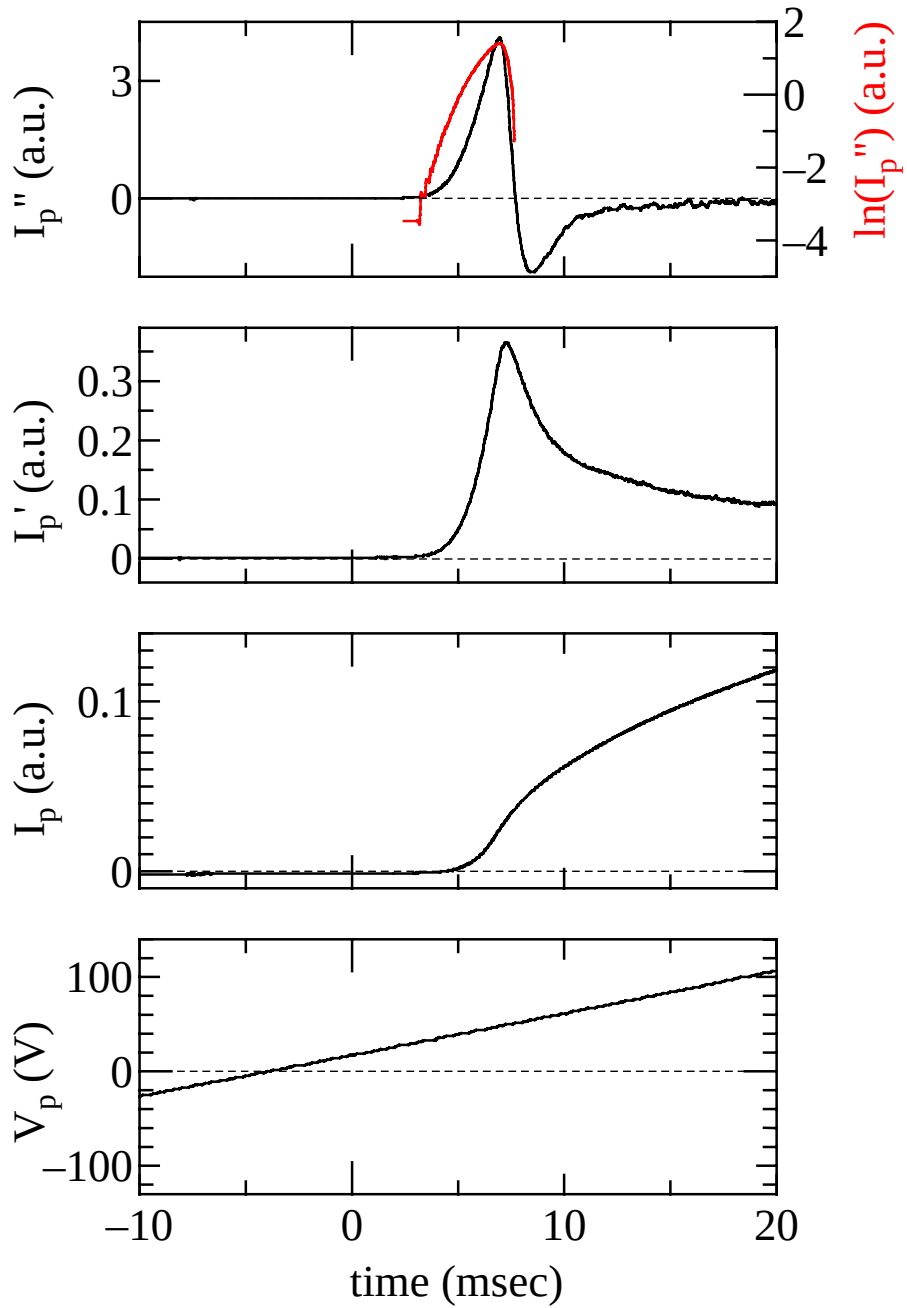
Potential oscillation in rf-driven plasma

I. D. Sudit and F. F. Chen, Plasma Sources Sci. Technol. **3**, 162 (1994).

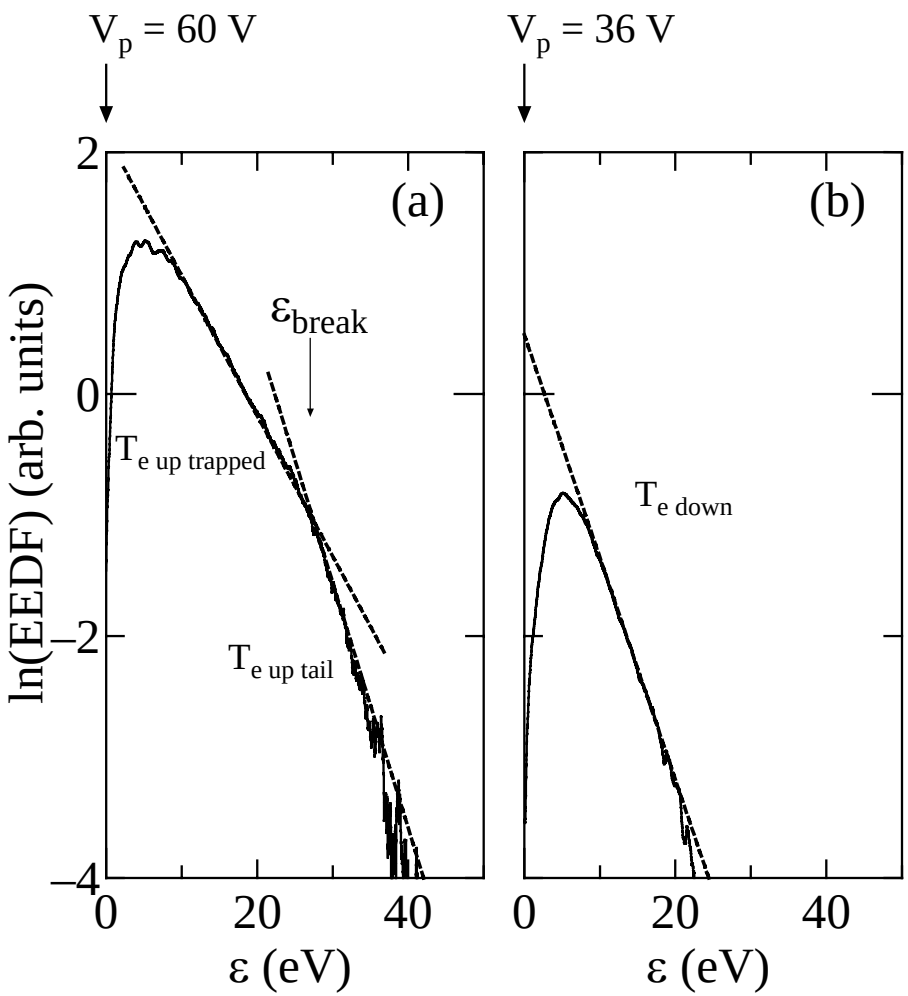
EEDF diagnosis (2): Measurement circuit



When ramp signal is applied on probe,
d^2I/dt^2 is proportional to d^2I/dV^2, i.e., EEDF.



Upstream and Downstream EEDF



Upstream EEDF

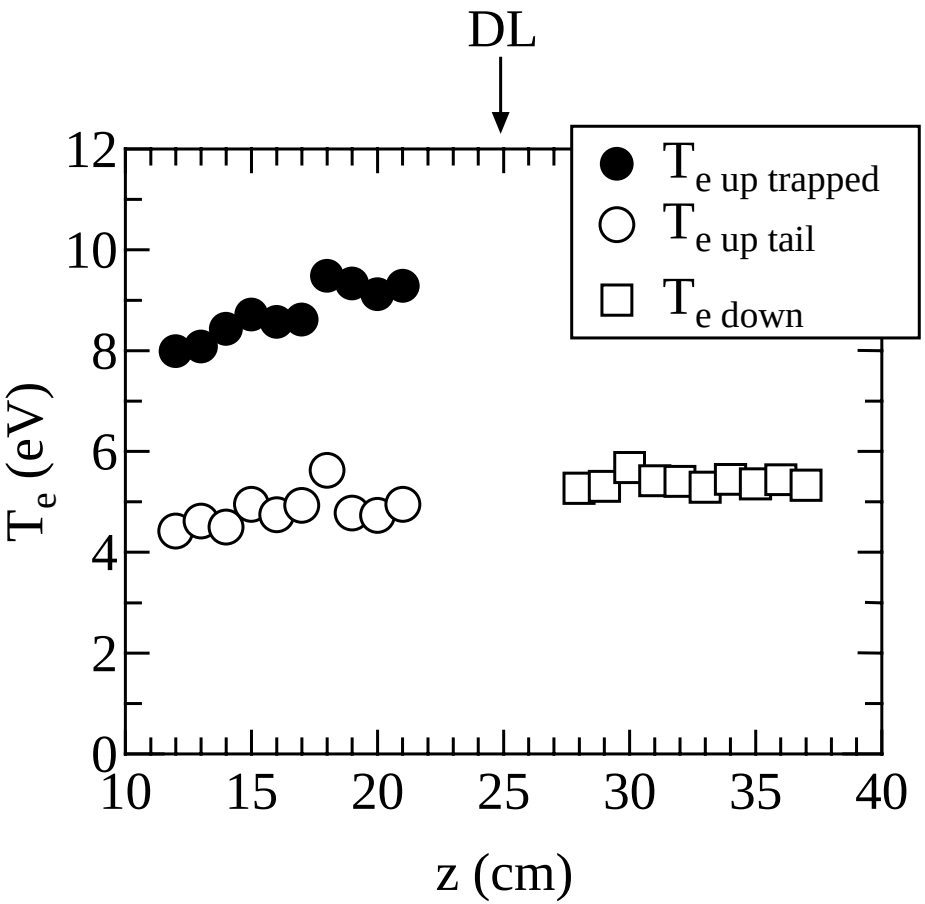
- can be characterized by two temperature ($T_{e\ up\ trapped}$, $T_{e\ up\ tail}$)
- shows a depletion from Maxwellian around the energy corresponding to DL potential drop

Downstream EEDF

- shows almost Maxwellian with temperature $T_{e\ down}$
- shows $T_{e\ down} = T_{e\ up\ tail}$

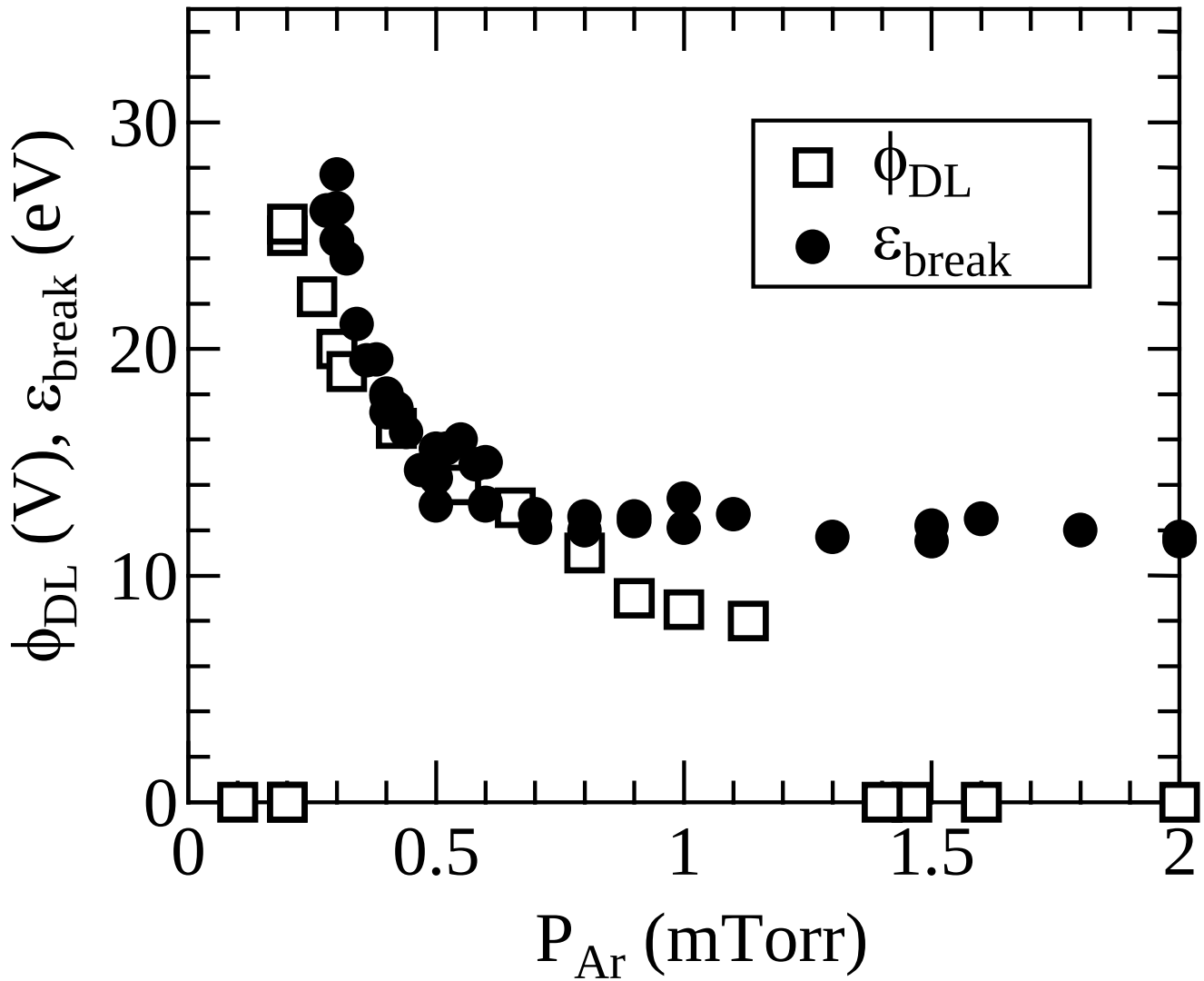
Electron energy distribution function in (a)the upstream (z = 17 cm) and (b)the downstream (z = 36 cm) for P_{Ar} = 0.3 mTorr.

Electron temperature T_e versus Axial Position z



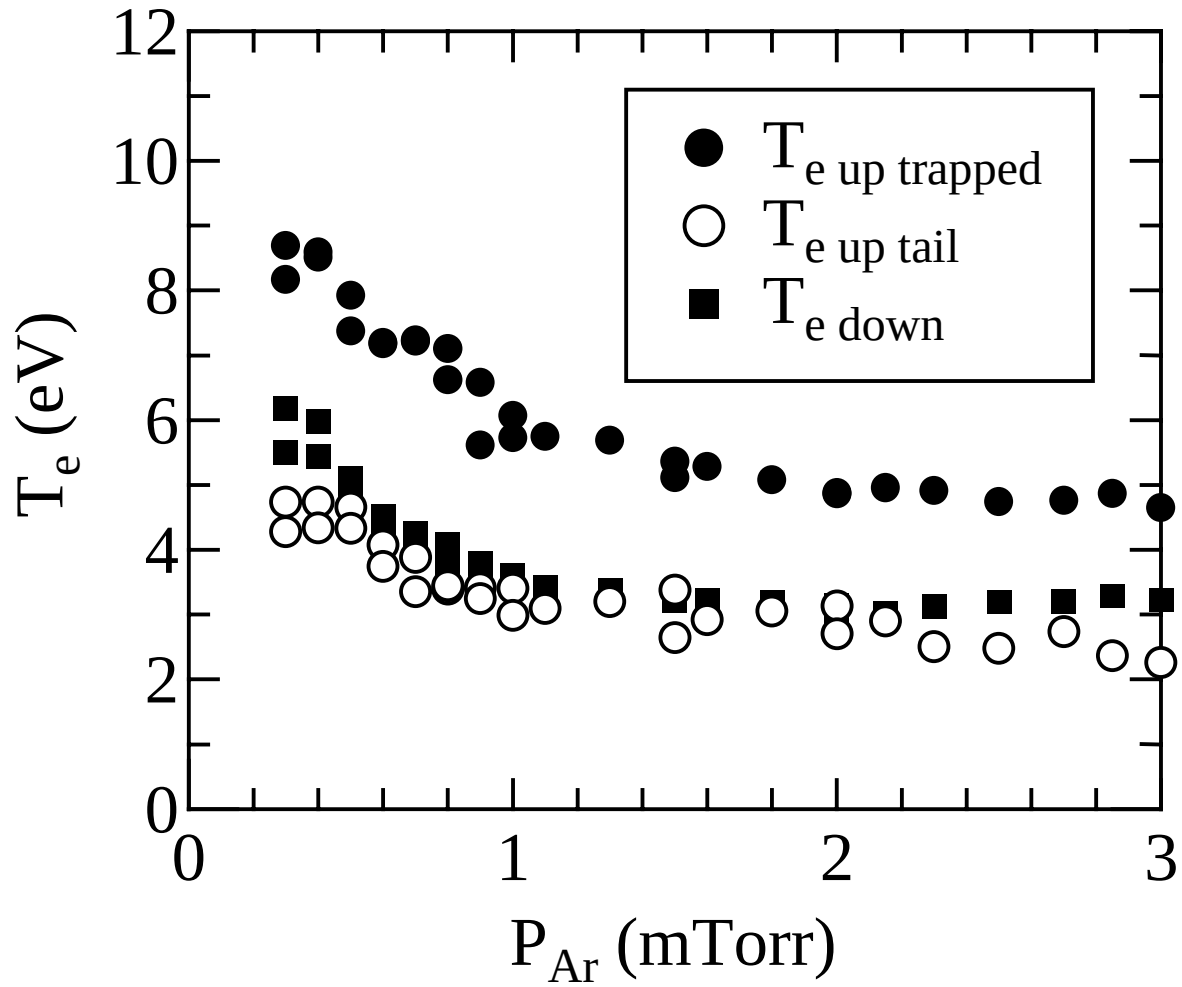
- T_e profile shows the bulk temperature drop around DL region
- $T_{e\ up\ tail} = T_{e\ down}$
- EEDF near DL appears to have a Druyvesteyn form without any part resembling a Maxwellian. This is probably because we are trying to measure the EEDF in a very strong electric field where it is expected that this type of distribution would be detected (W. P. S. Tan, J. Phys. D **6**, 1206 (1973)). Thus, there is no analysis in this area.

Break Energy ε_{break} versus Gas pressure P_{Ar}



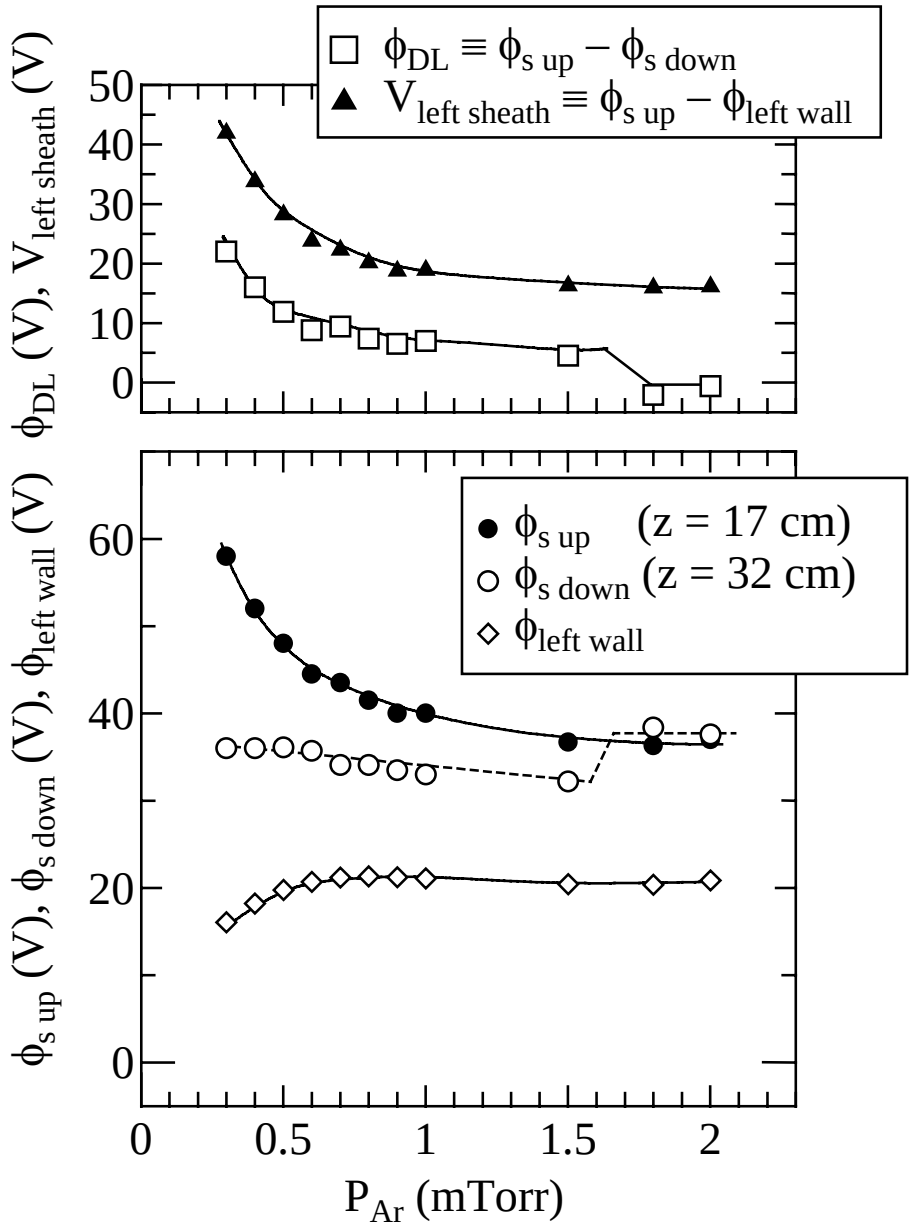
ε_{break} tracks the potential drop of the double layer!!!

Electron temperature T_e versus Gas pressure P_{Ar}

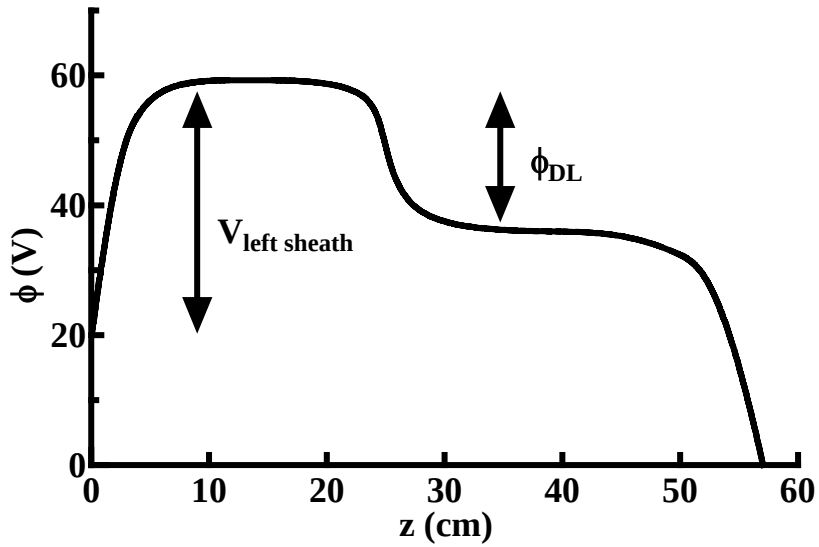


$$T_{e\ up\ trapped} > T_{e\ up\ tail} \quad T_{e\ down}$$

Left-side wall potential

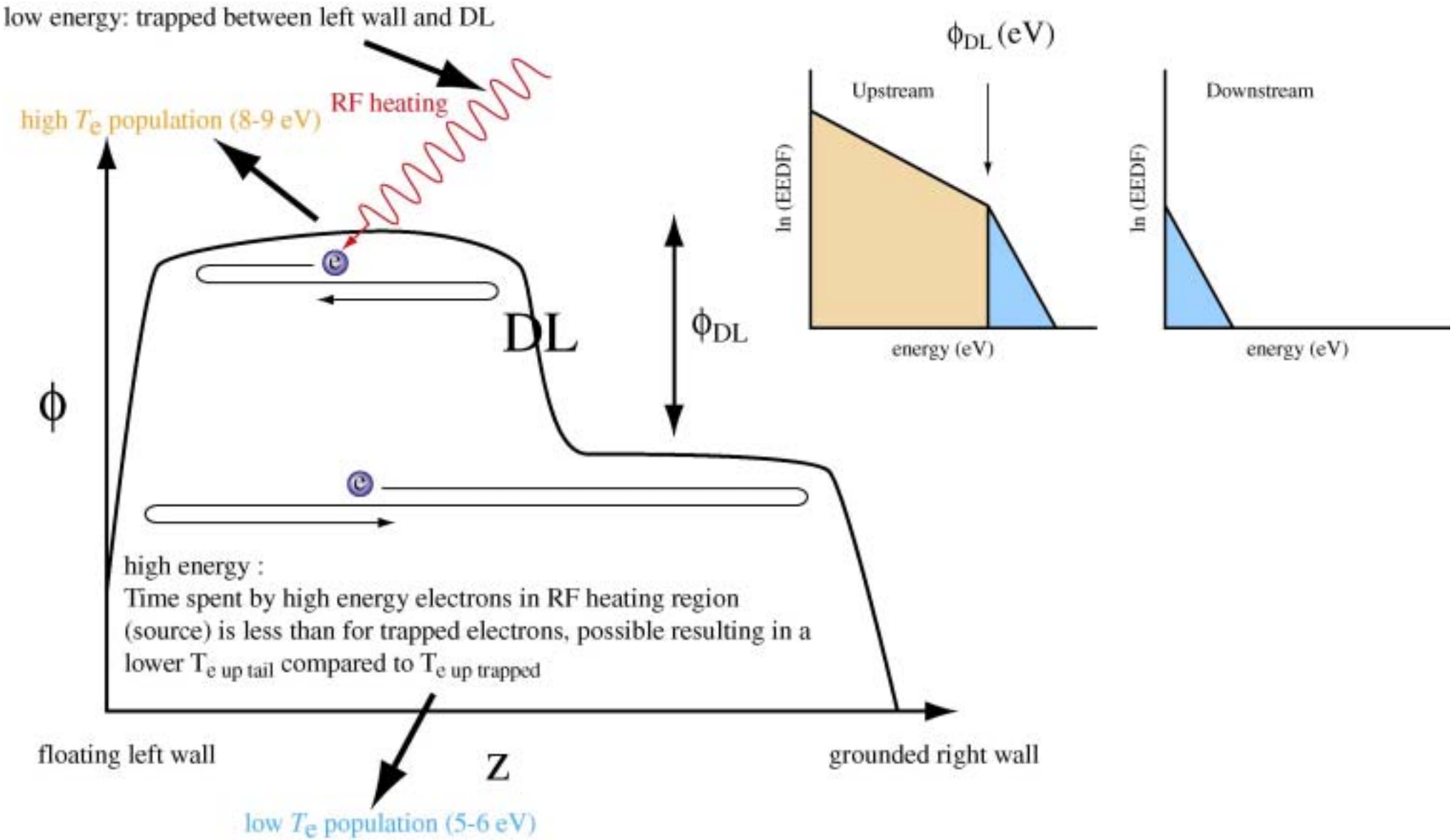


$$V_{left\ sheath} > \phi_{DL}$$



Electrons trapped by the DL can not escape to the floating left wall !

1-D Electron Dynamics in Current-Free DL



Conclusion

We succeeded in getting the first experimental data on the electron dynamics in the current-free helicon double layer.

The upstream EEDF is non maxwellian and shows a tail depletion from a break energy corresponding to the potential drop of the double layer.

The low energy electrons exhibit a high temperature and are trapped in the heating area between the left wall and the double layer.

The high energy electrons exhibit a low temperature and leak to the downstream plasma as shown by the EEDF measured downstream.

These electrons neutralize the ion beam created by acceleration through the DL potential drop. The break energy of the upstream EEDF is found to track the potential drop of the double layer.

Acknowledgements

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