Basic plasma science experiments in support of divertor and scrape-off layer studies

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1. Project aim

- Use the York linear plasma device as a route to improved understanding of plasma phenomena in the scrape-off layer and divertor plasmas in tokamaks

Current focus:

- Measurement of fluctuations in plasma parameters due to turbulent instabilities

2. Divertor plasmas

The scrape-off layer and divertor plasmas (Fig. 1) act as the ‘exhaust’ system for the fusion plasma. Divertor plasma properties can vary [1]:

- Ion density: 10^{18} – 10^{21} m^{-3}
- Electron temperature: 0.1 – above 50 eV
- Partially ionised
- Fluctuations on timescales of the order of microseconds (due to instabilities)

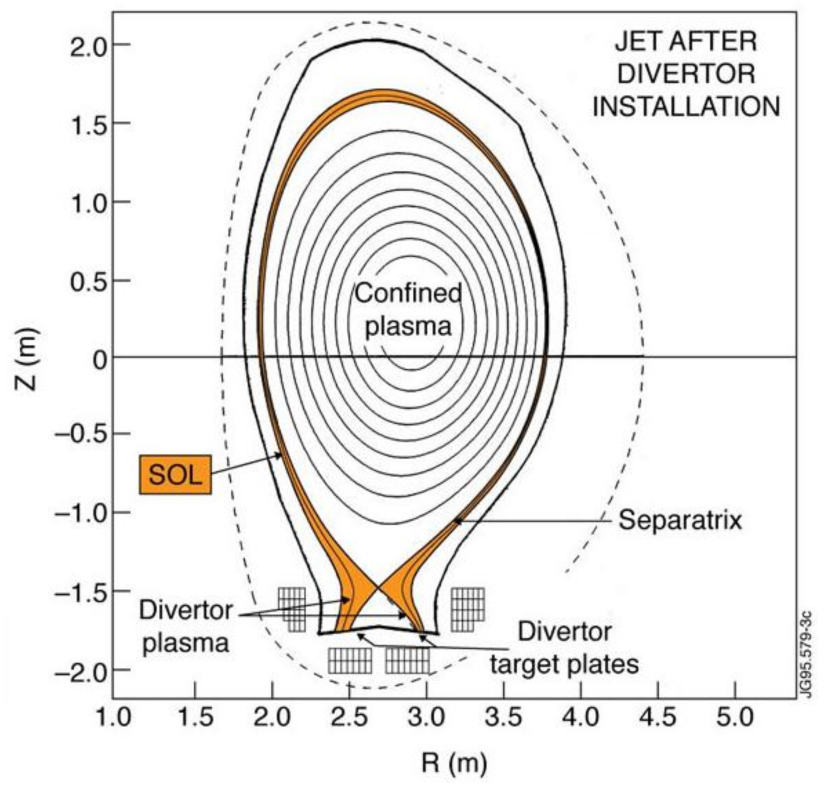

Figure 1: JET plasma configuration, showing divertor and scrape-off layer (SOL). *(http://www.efda.org/fusion/focus-on/limiters-and-divertors/)*

3. York linear plasma device

The linear device at the York Plasma Institute is capable of producing a steady plasma column in a vacuum vessel 1.5m long. A schematic diagram of the equipment is shown in Fig. 2. The hydrogen plasma source is a modified duoplasmatron, Demirkhanov-type source, and the plasma is confined to a column a few centimetres in diameter (Fig. 3a) by an axial magnetic field (max. ~0.07T) [2].

The maximum plasma parameters are as follows [2]:

- Ion density: ~10^{18} m^{-3}
- Electron temperature: ~15 eV

These parameters are similar to those found in divertor and scrape-off layer plasmas. The linear geometry of the device means that plasma phenomena in these regimes are simpler to study, relative to the toroidal geometry in tokamaks.

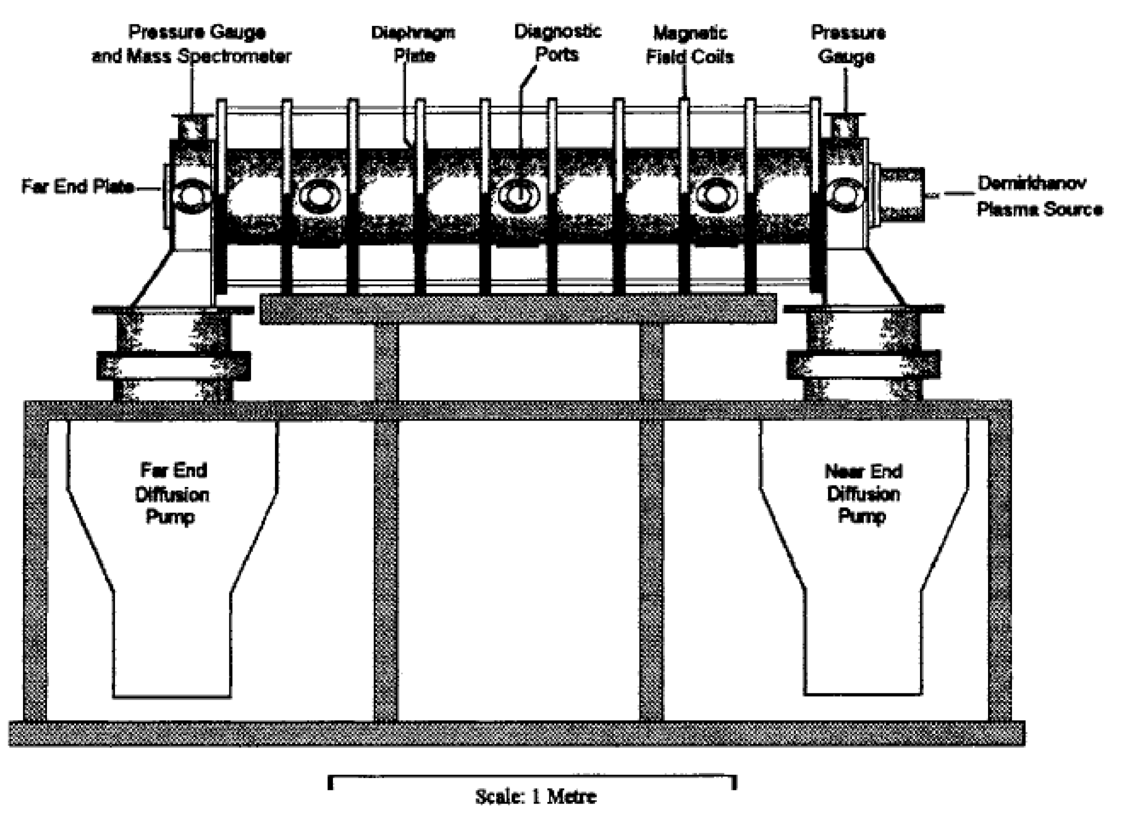

Figure 2: Schematic diagram of the linear device [2].

4. Langmuir probes

- Small (~1mm diameter) wire tip inserted into the plasma (see Fig. 3b)
- Apply and vary a bias voltage, V, to the probe tip to draw a current, I, from the plasma
- IV characteristic used to calculate floating and plasma potentials, ion and electron densities and electron temperature
- Single probe limited to a time resolution of ~0.1ms due to the time taken to sweep the bias voltage – insufficient for measuring plasma fluctuations

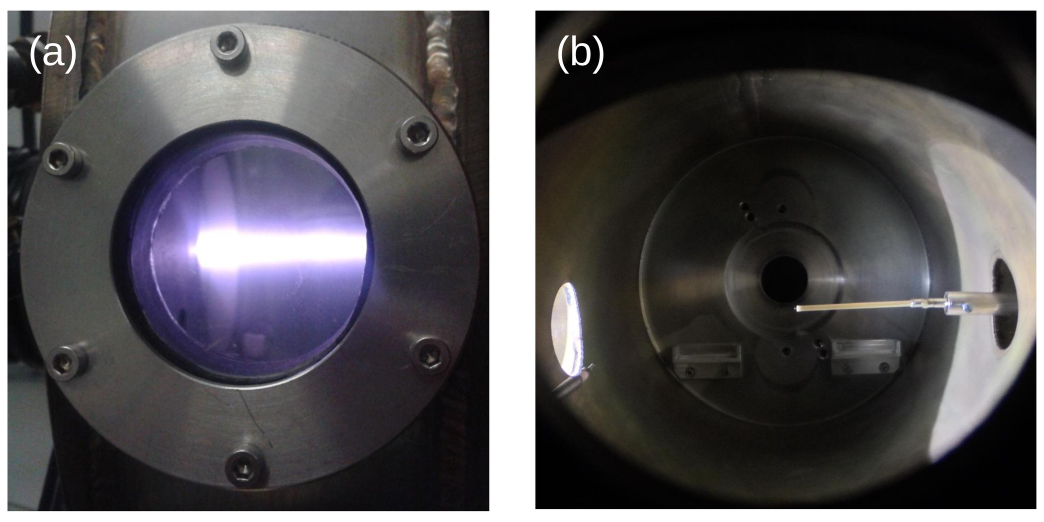

Figure 3: Photographs of (a) the plasma column through a vacuum vessel port (actual size); (b) the Langmuir probe in situ on the device (vessel is 24cm in diameter).

5. Initial results

The results shown here are from rough initial probe measurements. Figure 4 shows an example of an IV characteristic taken from near the middle of the plasma column. The shape is as expected from probe theory.

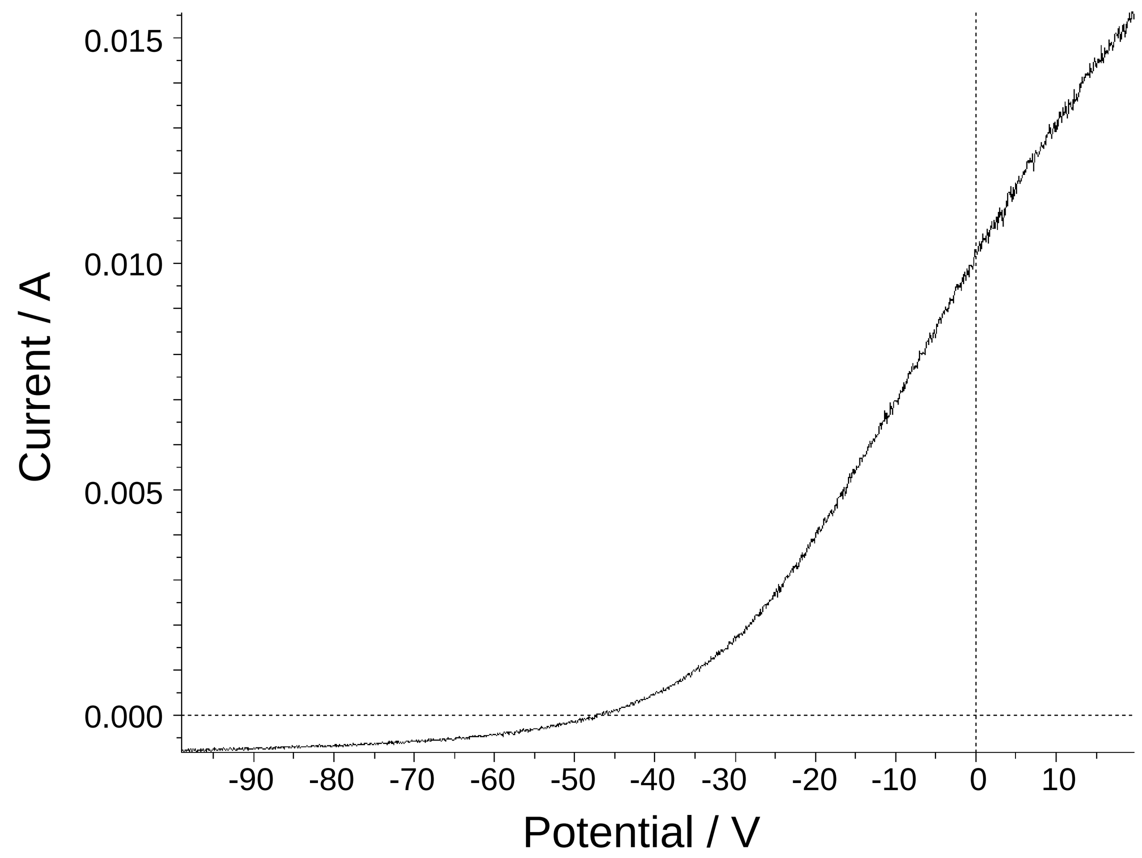

Figure 4: Example Langmuir probe IV curve from the linear plasma device.

IV characteristics were measured for different radial positions (uncalibrated) and the ion density and floating potential calculated for each data set. The results are plotted in Figure 5. The curves are consistent with the presence of a plasma column.

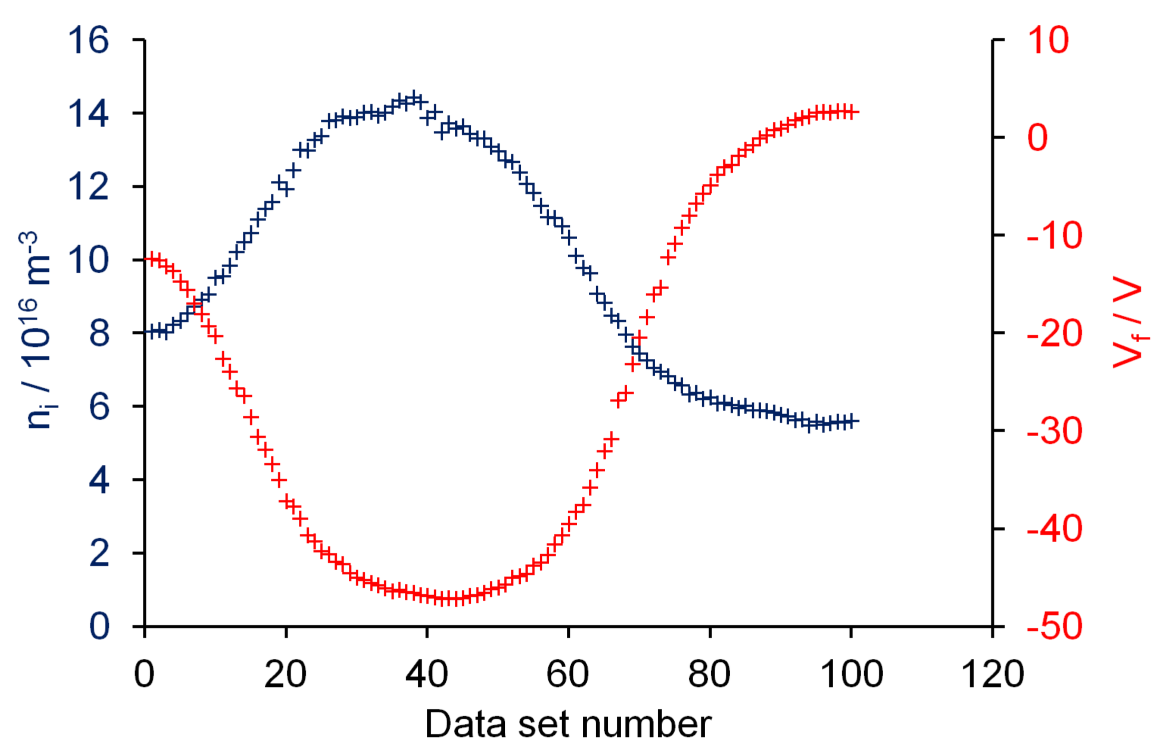

Figure 5: Ion density (left-hand axis) and floating potential (right-hand axis) plotted against the data set number (corresponds to different positions, not evenly distributed radially). Dashed line indicates approximate position of the centre of the plasma column.

Results cont.

An oscilloscope was used to explore the fluctuations of the floating potential and its power spectrum in real time. An example power spectrum is shown in Figure 6. The peaks may correspond to plasma instabilities; e.g. the peak at ~30-40 kHz is likely to indicate electron drift waves.

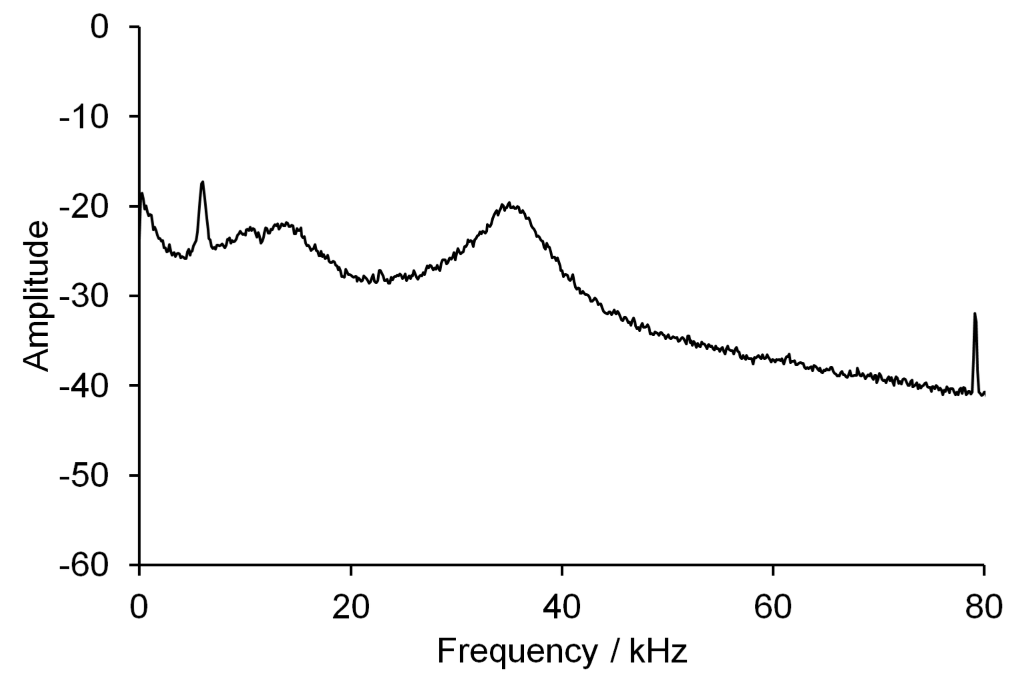

Figure 6: Example power spectrum from monitoring the floating potential of the plasma column.

6. Future work

Short term

- Calibrate probe position relative to plasma column and measure:
  - More accurate radial profiles of plasma parameters
  - Power spectra (with positional data)
  - Time sequences of plasma parameters (limited temporal resolution)

Mid-term

- Develop azimuthal probe configuration

Long term

- Develop probe configuration capable of high temporal resolution (e.g. mirror probe [3], ball pen probe arrays [4])
- Study detachment of plasma column from vessel end plate – applications to divertor plasma detachment to reduce divertor heat flux
- Compare results to BOUT++ simulations [5]

7. Conclusions

- Initial Langmuir probe measurements indicate that the equipment is behaving as expected
- Power spectra suggest the presence of plasma instabilities, including drift waves
- Further work is required to improve the accuracy and reliability of probe data before moving on to study the properties of the plasma column

8. References

[1] C. S. Pitcher & P. C. Stangeby (1997), *Plasma Physics and Controlled Fusion*, *39*, 779–930
[2] M. G. Rusbridge et al. (2000), *Plasma Physics and Controlled Fusion*, *42*(5), 579–602
[3] B. LaBombard & L. Lyons (2007), *The Review of Scientific Instruments*, *78*(7)
[4] J. Adamek et al. (2004), *Czechoslovak Journal of Physics*, *54*, C95–C99
[5] B. D. Dudson et al. (2009), *Computer Physics Communications*, *190*(9), 1467–1480

9. Acknowledgements

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