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Hydrogen Plasma Dynamics in Magnetic Fields

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Low-pressure, high density hydrogen plasma sources in the presence of a magnetic field are of importance to a number of areas such as material processing, studying fusion-relevant plasma-surface interactions, developing neutral beam injection systems, and plasma propulsion.

The MAGPIE (MAGnetised Plasma Interaction Experiment) plasma facility at the Australian National University supports a diversity of research interests such as plasma-surface interactions with fusion materials, material processing, basic plasma physics and instrumentation development. MAGPIE provides a controlled magnetically focused plasma environment, capable of creating key experimental configurations and plasma conditions to investigate the coupled issues of plasma performance, erosion and redeposition offering impurity control. The linear plasma device utilizes a helicon plasma discharge to achieve high densities in a linear electrode-less discharge with short pulse (< 10 ms), long pulse (seconds) and continuous operation. The high-density (~10^{19} m^{-3}) plasma production region is separated from the region where plasma-surface interactions are studied to allow tailoring of the core plasma properties without unwanted impurities from the process chamber.

This contribution combines a number of studies related to hydrogen plasma dynamics at high densities in a magnetic field including gas heating, plasma chemistry, negative ion dynamics and neutral depletion that have been performed on MAGPIE. The plasma is diagnosed using probe-based laser photodetachment, Langmuir probes, laser induced fluorescence, mass spectroscopy and optical emission spectroscopy. The experimental results are compared and validated with both a zero-dimensional global model and a 2D axisymmetric model.

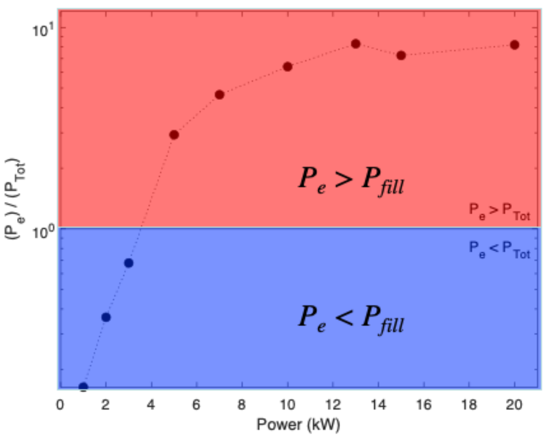

Figure 1. Atomic hydrogen density and electron density as a function of applied RF power.

Figure 1 shows the ratio of the plasma pressure ($p_e = n_e k_b T_e$) to initial fill pressure (10 mTorr) as a function of applied RF power. It can be seen that as the RF power is increased, there is a transiton from a regime where the plasma pressure is less than the fill pressure (red shaded region). At RF powers above 3 kW the discharge transitions from the inductive mode to the helicon mode and the plasma pressure now dominates the gas fill pressure.

Using two-photon absorption laser-induced fluorescence diagnostic, we have found significant depletion of atomic hydrogen in the centre of the chamber when the plasma transitions into helicon mode. Figure 2 shows that as the applied RF power is increased the atomic hydrogen density initially increases from 3.5 x 10^{18} m^{-3} at 1 kW to 4.5 x 10^{18} m^{-3} at 3 kW. Then once the helicon mode is achieved the atomic hydrogen density decreases to a value of 7 x 10^{17} m^{-3}. The electron density (red) increases slowly from 1kW to 3 kW and then more rapidly up to 15 kW. The measurements are supported by a 2D axisymmetric fluid model. We demonstrate that depletion coincides with the plasma pressure dominating the initial fill pressure and it decreases nearly linearly with increasing plasma pressure.

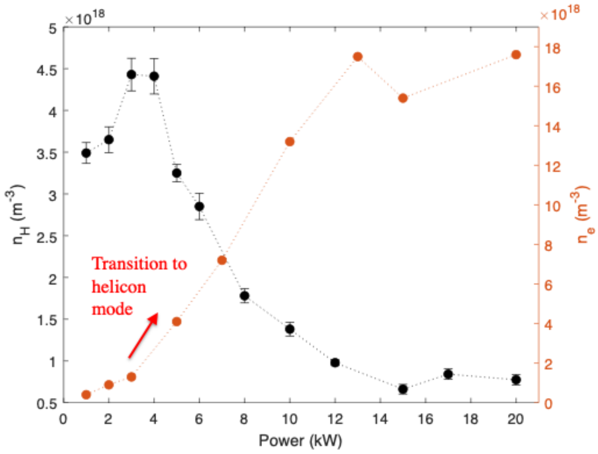

Figure 2. Atomic hydrogen density and electron density as a function of applied RF power.

References

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