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High-Power Hydrogen Plasmas in the Magnetised Plasma Interaction Experiment (MAGPIE)

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The MAGPIE (Magnetised Plasma Interaction Experiment) plasma facility at the Australian National University supports a diversity of research interests such as advanced fusion materials, material processing, basic plasma physics and instrumentation development [1]. The linear plasma device employs a combination of a high-power radio-frequency plasma source, a target chamber and a set of diagnostics for plasma and material analysis. A schematic of the MAGPIE reactor is shown in figure 1. The MAGPIE reactor consists of a 1 m long, 9.8 cm inner-diameter borosilicate source region connected to a 68 cm long stainless steel target chamber that has a number of ports for probe and optical diagnostic access. The plasma is created in the source region by supplying RF power up to 20 kW to an 18 cm long Nagoya III helicon antenna. A magnetically focused plasma is created in the target region of MAGPIE by two sets of water-cooled solenoids. This produces a peak density downstream of the source production region, close to the maximum magnetic field. High plasma densities of 10^{19} m^{-3} have been obtained in hydrogen.

Linear plasma devices such as MAGPIE can provide fusion-relevant plasma conditions to study plasma-facing materials in fusion reactors. Under high particle flux plasma conditions, we study the degree to which both surface morphology and sub-surface defects caused by the plasma-material interaction influence the diffusion, trapping and precipitation of hydrogen and helium species into gas bubbles [2]. These can lead to significant nano-structuring of the surface, which may be beneficial or detrimental for certain applications.

In addition to the material program, we investigate basic plasma physics such as negative ion dynamics in the high-power (20kW) linear plasma device. Low-pressure negative ion sources are of importance to the development of high-energy (> 1 MeV) neutral beam injection systems for fusion devices as well as for many material processing applications. Due to their high-power coupling efficiency and high plasma densities, helicon devices may be able to reduce power requirements and potentially remove the need for caesium. It has been previously observed that the application of a small magnetic field can lead to a significant increase in the plasma density and negative ion production [3].

In this work, we present temporally and spatially resolved results in a pulsed high-power helicon plasma (MAGPIE) operated with a magnetic mirror configuration and demonstrate that exceptionally high negative hydrogen ion densities greater than 10^{18} m^{-3} can be obtained. The negative ion fraction is measured by probe-based laser photodetachment, electron density and temperature are determined by a Langmuir probe, laser induced fluorescence is used to quantify the atomic hydrogen density and optical emission spectroscopy is used to determine the gas temperature. The experimental results are compared with both a zero-dimensional global model and a 2D axisymmetric extension of the global model.

References

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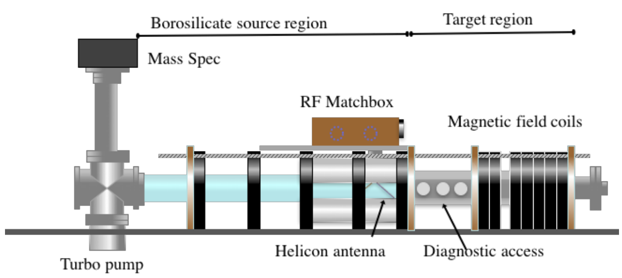

Figure 1. Schematic of the MAGPIE plasma device.