Initial characterization of Argon plasmas in the "MAGnetized Plasma Interaction Experiment" (MAGPIE)

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Abstract:

RF magnetic fluctuation probes and symmetric double Langmuir probes have been utilized to characterize Argon helicon plasma in a converging magnetic field. We observe that when enough RF power is supplied an Ar II blue core mode is formed suggestive of the presence of fast electrons (~30 eV) ([1], [2]). Results indicate a linear increase in the plasma density in the direction of increasing magnetic field. During high power operation (2.1 kW) the plasma density reaches a peak near the maximum gradient of the converging magnetic field, the helicon's phase velocity matches the electron thermal velocity and its wavelength becomes half the antenna size. Radial wavefield measurements during the blue core suggest the presence of an m = +1 second radial mode.

1 Introduction:

The "MAGnetized Plasma Interaction Experiment" (MAGPIE) is a new linear plasma device that has been constructed at the Australian National University to study basic plasma interactions [3] and is the first stage of the Materials Diagnostic Facility at the Australian National University. MAGPIE employs a helicon plasma source to ionize the operating gas; these types of sources are of the electrode-less type and are known for their high ionization efficiency compared to other RF based plasma sources.

In this work we characterize Argon helicon plasma produced in MAGPIE by using RF magnetic probes [4], [5] to observe helicon wave activity and symmetric double Langmuir probes [6] to measure plasma temperature and density for various operating conditions.

2 Experimental setup:

The device, which is shown in Figure 1, consists of two parts: a "source" and a "target" region. The RF power is delivered to the plasma through a 20 cm left handed half turn helical antenna and can be operated in the frequency range of 7-28 MHz in pulsed or continuous mode. Maximum magnetic field strengths of 0.09 and 0.19 T are available at the "source" and target "regions" respectively. A more detailed description of MAGPIE can be found in [3].

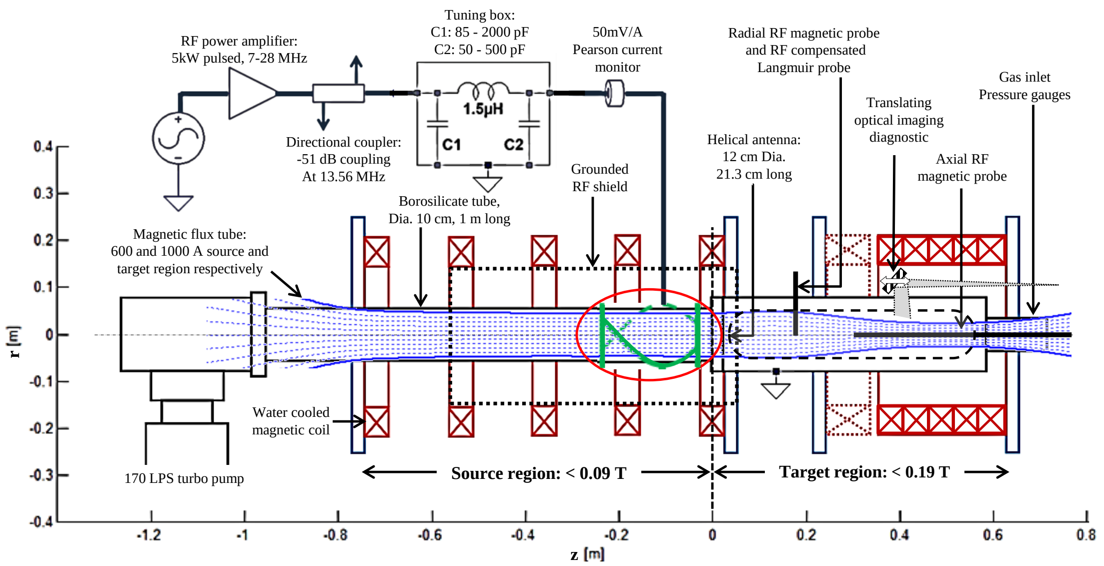


Figure 1, Schematic of MAGPIE.

3 Diagnostics:

The diagnostics employed in this work, an RF magnetic probe and a symmetric double Langmuir probe, are inserted axially through the end plate of the "target" region. The setup allows measurements to be taken from -7 to 49 cm with respect to the "zero" position as depicted in figure 1. The RF magnetic probe is used to measure the propagation, attenuation and structure of the helicon wave fields and the double Langmuir probe is used to measure plasma densities and electron temperatures in the target region of MAGPIE.

3.1 RF magnetic probe:

The probe tip consists of 2 sensing coils that sample radial and axial helicon wave magnetic components simultaneously. Each coil is 3.5 mm in diameter, has 6 turns of 0.5 mm copper wire. The probe shaft is made of a grounded 1.7 m long stainless steel shaft, which is inserted into a borosilicate tube 1.7 m in length and 12 mm in outer diameter. Common mode chokes are used to implement electrostatic rejection during the measurement procedure.

3.2 Double Langmuir probe:

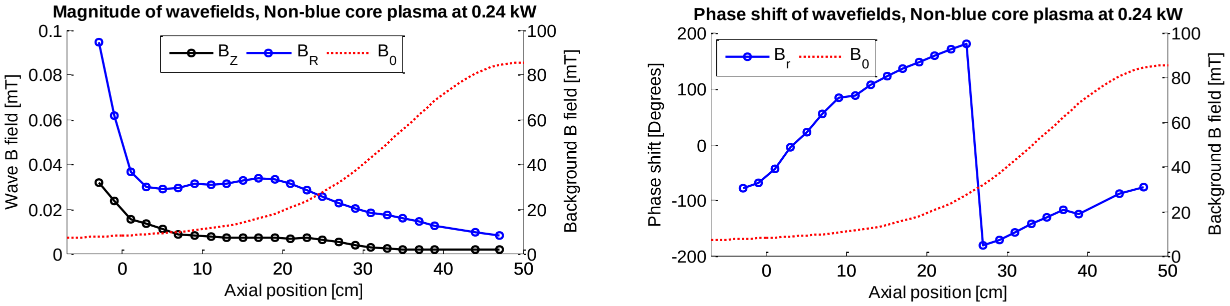
The probe tip consists of two parallel Molybdenum wires (length: 5 mm, radius: 0.1 mm) positioned perpendicular to the magnetic field, separated by a distance of 3 mm and supported by a ceramic former. A 1:2 isolating transformer is employed to drive a time varying potential between the probe tips (-25 to 25 V) while allowing them to electrically float in the plasma, this allows them to have much better RF immunity compared to single tip RF compensated Langmuir probes. Ion saturation current is used to determine the plasma density and the slope of the I(V) characteristic at the floating potential is used to infer the electron temperature [6].

4 Measured helicon wave fields and plasma parameters:

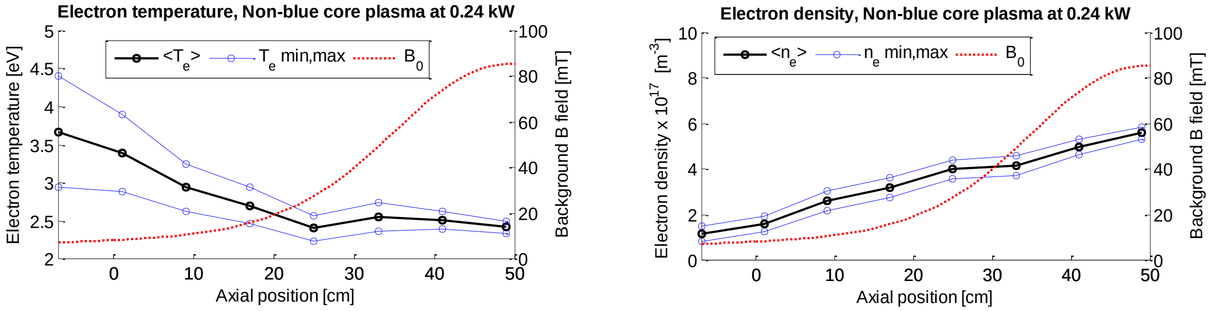
Helicon wavefields and plasma parameters were measured in the target region (-7 to 49 cm) under the following conditions: 0.41 Pa (3.1 mTorr) in Argon, 2.5 mS pulse width at 6 Hz and RF power levels of 0.24 kW and 2.1 kW at 13.56 MHz. The magnetic field employed is shown in figure 2. During 2.1 kW operations we observe the formation of a blue-cored plasma [1], [2] associated with the production of Argon II ions.

4.1 Plasma operation at 0.24 kW:

During this mode of operation no blue core is observed, the wavelength of the helicon is about 42 cm (approximately twice the antenna length), its resonant electron energy (93 eV) is much greater than the electron thermal velocity and thus electron-wave interaction is not expected. Furthermore, we observe that the electron temperature decreases while the electron density increases linearly in the direction of increasing magnetic field.



a) Axial helicon wavefield at 0.24 kW

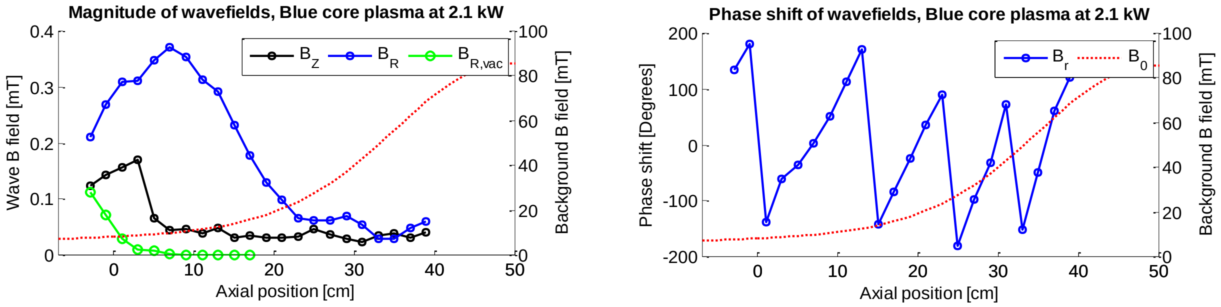


b) Axial electron temperature and density at 0.24 kW

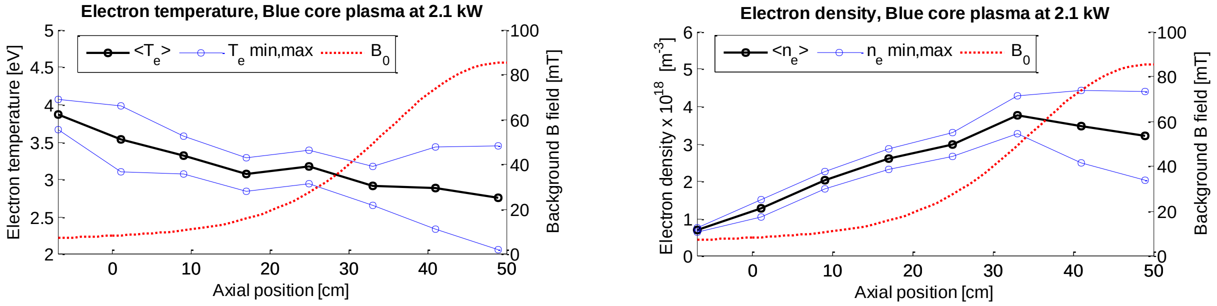
Figure 2, Axial helicon wavefield, electron temperature and plasma density during 0.24 kW operation

4.2 Plasma operation at 2.1 kW:

During this mode of operation a blue core is observed, the wavelength of the helicon is about 22 cm near the antenna and decreases to about 10 cm well into the target region. The wave's resonant electron energy (phase velocity) is in the range of 3 to 10 eV and thus electron-wave interaction is expected. This resonance could be the cause of the observed Ar II blue core. Furthermore, we observe that the electron temperature decreases while the electron density increases linearly in the direction of increasing magnetic field and reaches a maximum of about 4 x 10^{18} m^{-3} at the location where the gradient of the background magnetic field peaks.



a) Axial helicon wavefield at 2.1 kW



b) Axial electron temperature and density at 2.1 kW

Figure 3, Axial helicon wave field, electron temperature and plasma density during 2.1 kW operation

5 Conclusions:

With the use of magnetic and electrostatic probes we have observed the behaviour of helicon waves and plasma parameters in converging magnetic fields for various levels of RF power. We have observed that during the blue core mode the phase velocity of the helicon wave matches that of the electrons, possibly leading to electron-wave interaction. In addition, we observe an increase in electron density with a corresponding decrease in electron temperature in the direction of increasing magnetic field.

6 References:

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