Plasma operation and electric field measurements in IShTAR

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The overall goal of the IShTAR (Ion cyclotron Sheath Test ARrangement) project is to study antenna near-fields in the presence of a plasma and magnetic field to assess theoretical predictions on radio frequency (RF) sheaths and to guide theoretical modelling [1, 2, 3]. For Ion Cyclotron Radio Frequency (ICRF) antenna applications it is favourable to operate at tokamak edge-like conditions for density and temperature. A helicon antenna at a frequency of 11.76 MHz and with power up to 3kW, is used to create argon or helium plasmas in IShTAR.

IShTAR plasmas operations

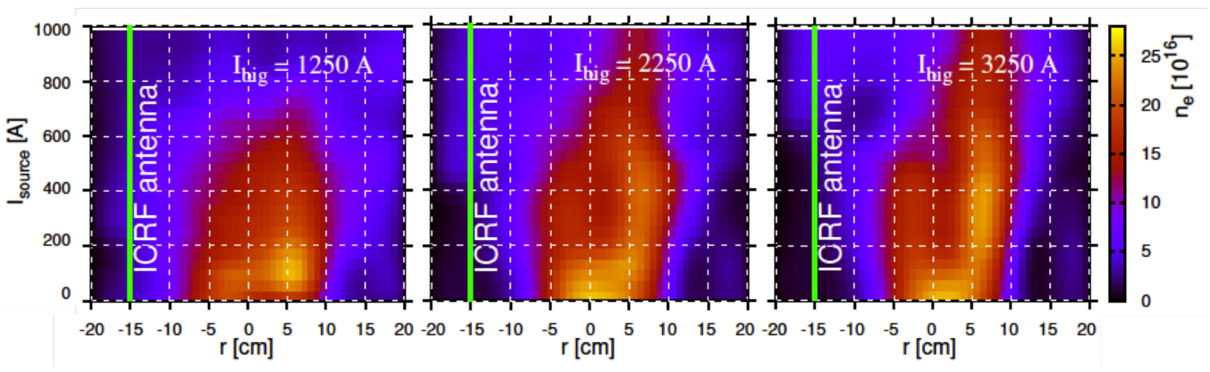

Figure 1: Radial plasma density profiles for various currents in the coils surrounding the main chamber (I_{big}) and plasma source (I_{source}). The radial position of the ICRF antenna is specified by a vertical green line.

Technicalities and capabilities of the IShTAR device have been described in [1, 3]. Plasmas have now been characterised in a systematic way in order to obtain reproducible density profiles. An extensive exploration of the discharge parameters (such as the neutral gas pressure, the gas type, the helicon antenna power and the magnetic field topology) has been performed [4]. A selection of resulting radial density profiles is presented in figure 1. They have been obtained by

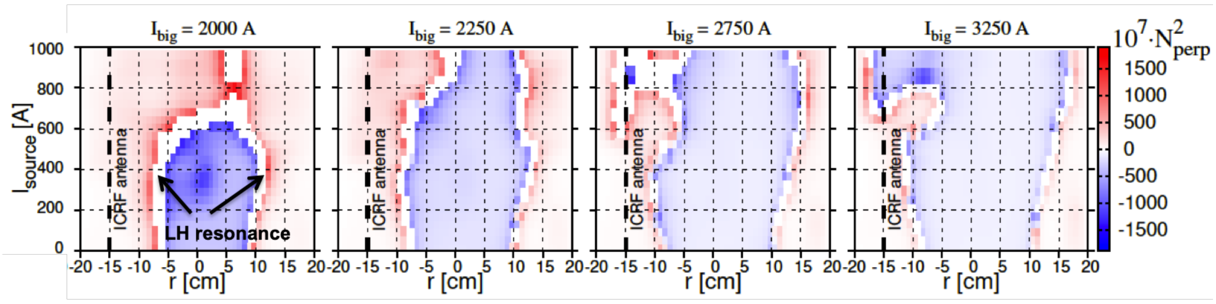

Figure 2: Perpendicular component of the refraction coefficients for the slow wave in a magnetised Ar plasma for $k_{\|} = 10\ m^{-1}$, a frequency of 6 MHz and typical IShTAR density profiles as presented in fig. 1.

an array of Langmuir probes and crossed checked with measurements from an interferometer. A number of techniques have been developed to adapt the traditional single Langmuir probe for measurements in RF discharges [4, 5]. The profiles have been documented in a database, which can be directly used for future operations. It has been found that a high edge plasma density in front of the ICRF antenna can be obtained if the magnetic topology is optimised by adapting the currents in the coils surrounding the main chamber and plasma source, denoted as I_{big} and I_{source} respectively. The basic observation is that for high magnetic fields in the main chamber, corresponding to high values of I_{big}, also high fields in the plasma source are required, as can be seen in the three plots in figure 1. The resulting magnetic topology then expands the plasma profile and increases the edge plasma density.

For the RF sheath studies the behaviour of the slow wave is of particular interest. The slow wave perpendicular component of the refraction coefficient in a magnetised argon plasma for an antenna spectrum with $k_{\|} = 10\ m^{-1}$ is shown in figure 2. Results are based on radial plasma density profiles as presented in fig. 1. Each column corresponds to a fixed value of I_{big}. The wave frequency is 6 MHz, routinely used in IShTAR. The sharp transition of $N_{\perp}^2$ for slow waves from the red to the blue region corresponds to the position of the Lower Hybrid (LH) resonance. These results suggest that the optimum condition to shift the resonance layer in the direct vicinity of the ICRF antenna launcher would be $I_{big} > 3000$ A and $I_{source} > 500$A.

Electric field measurements

Furthermore, progress was made for electric (E) field measurements using passive optical emission spectroscopy. An ANDOR monochromator "Shamrock 750", with a focal length of approximately 738 mm and aperture of f/9.7 is used, in combination with an ANDOR intensifier camera from the series "IStar 334T", which provides high resolution and high sensitivity as well

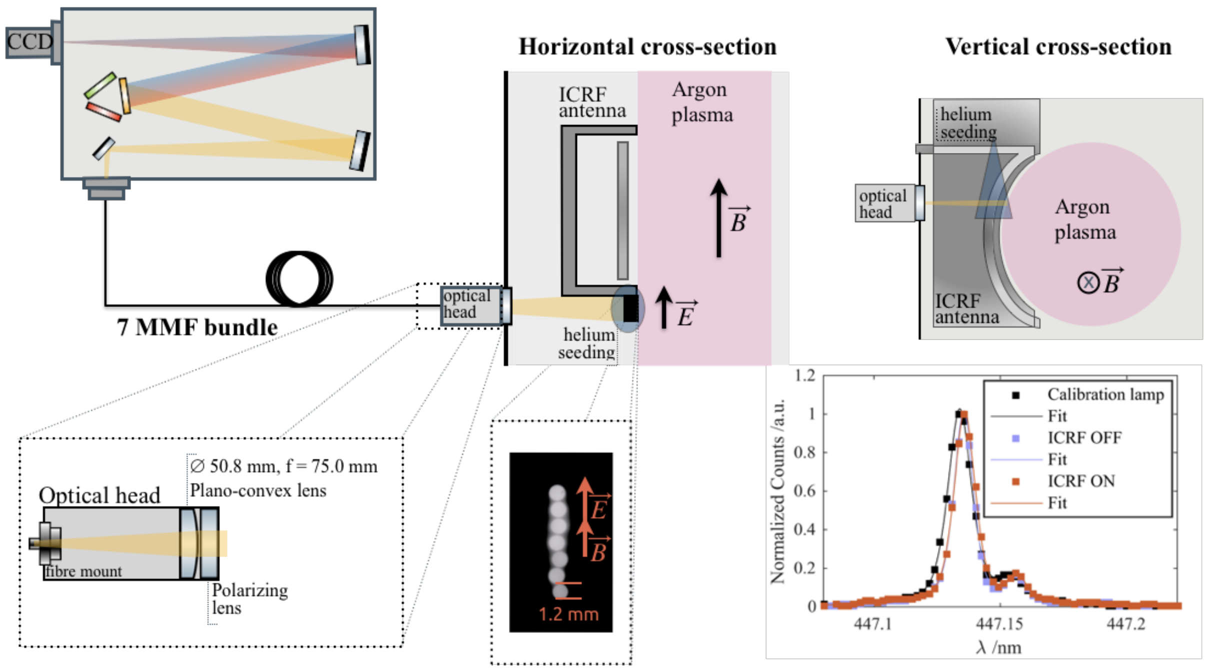

Figure 3: Set-up of the passive optical emission spectroscopy system and measured He I spectral line at 474.1 nm.

as fast acquisition rates. The monochromator, in a Czerny-Turner optical mount, is equipped with three interchangeable gratings: (i) a 600 l/mm grating with blaze angle at 500 nm; (ii) a 2400 l/mm, holographic grating optimised for the range 190-800 nm; and (iii) a grating with line density of 3600 l/mm, also holographic and optimised for 180-500 nm. A new gas injection system has been implemented, which allows for a local gas puff of helium in the vicinity of the ICRF antenna in order to increase the emission intensity of the spectral lines at the location of the sheath. Indeed, with the local injection of helium, argon can be chosen as main operating gas. It was found previously that argon plasmas in IShTAR have densities typically about ten times higher than in pure helium. A schematic of the system is depicted in figure 3. For high E-fields (above 1 kV/cm) Stark effects can be observed on the helium spectra as they are resolved by the IShTAR spectroscopic system. Typically He I at 474.1 nm (4^3D-2^3P) is selected. A line shift up to 0.002 nm was measured at the metal walls of the antenna box, corresponding to an E-field of 2.56 kV/cm. More details on the E-field measurements are presented in various publications [7, 8, 9]. Recently a fibre bundle has been installed to complement the single fibre observation point, with the aim to resolve the E-field evolution inside the sheath. The array focuses 7 fibres onto a 1 cm spot at the edge of the ICRF antenna. The fibres are stacked on top of each other at the entrance slit of the high-resolution spectrometer. The fibre array will give information on the evolution of the electric field in the direct vicinity of the antenna box and inside the sheath [10].

Conclusions

IShTAR is a suitable environment to study RF sheaths and develop diagnostics. Interferometer and probes have been used for an improved characterisation of the operation of IShTAR. A sensitivity to the magnetic topology has been observed. Density profiles can be tailored to bring the lower hybrid resonance layer close to the ICRF launcher. In that way optimal condition for sheath studies are created. Successful electric field measurements by passive optical emission spectroscopy have been obtained close to the antenna box. The signal to noise ratio was improved by installing a local gas-puff for helium at the antenna view-point. The installation of a fibre bundle has been completed, it will allow for sheath resolved E-field profiles [10]. Future plans also include a feasibility study for active Doppler-Free Saturation Spectroscopy in the IShTAR device [11, 12].

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