IShTAR: a test-stand for ICRF antenna sheath studies

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The IShTAR (Ion cyclotron Sheath Test ARrangement) test-bed is a linear magnetic device with a length of 1 m and a plasma radius of about 0.2 m. It is equipped with a helicon plasma source and an ICRF (Ion Cyclotron Resonant Frequency) single strap antenna. The main goal is to investigate the interactions between the launched RF wave and a plasma, which is similar in terms of plasma density, temperature and wave propagation to a tokamak edge [1, 2]. The experimental data will be used to validate the models of rectified sheaths created by the electric fields of an ICRF antenna. Sheaths are the source of spurious sputtering and hot spots and limit the ICRF wave performance. The test bed offers, in comparison with a tokamak, better accessibility for the diagnostics, a higher flexibility for the control of the plasma parameters, more dedicated experimental time (IShTAR can have up to 60 discharge of 8 s per hour) and, for modifications (e.g. to the antenna), a much faster turn-over (the machine can be opened, closed and pumped down in a single day).

The ICRF single strap antenna has an optimized geometry for the cylindrical plasma, it is powered at 1kW with a frequency at 5 or 15 MHz, power upgrades are foreseen in the future. B-dot probes are used to measure the ICRF wave profile without and with plasma (while filtering out the helicon wave) to evaluate which radial and longitudinal eigenmodes are generated due to the size of the vacuum vessel, which is small - relative to the wavelength - and how they affect the components of the electric field at the antenna/plasma interface. The modification of the plasma characteristics due to ICRF are inspected with the Langmuir probe, especially the change of the density profile due to additional ionization and the evolution of the plasma potential in the RF sheaths on the field lines connected to the antenna box. In addition, the distribution of the E-fields in the plasma and around the antenna components is a crucial input to all RF sheath models, but they are poorly diagnosed in the big fusion experiments, because of constraints in accessibility to install proper diagnostics and the challenging measurement methods. Therefore the IShTAR project is testing different approaches, a theoretical benchmark can be found in [3], most of them are based on the Stark effect, which causes an E-field dependent splitting and shifting of selected wavelengths in the passive optical spectrum. The difficulty however is to get a good spectral resolution to isolate the effective shift caused by the E-field, since it is disturbed by the static magnetic field [4]. An alternative, but more complicated approach, is to use Doppler-free saturation spectroscopy to eliminate disturbing effects and highlight the E-field influence only. The modeling of the Zeeman and Stark effects on the selected transitions of He I for IShTAR plasma parameters is based on the fully quantum mechanical code – Explicit Zeeman Stark Spectral Simulator (EZSSS) [5].

References:

[1] R. D'Inca et al, AIP Conf. Proc. 1689, 050010 (2015) [2] K. Crombe et al, AIP Conf. Proc. 1689, 030006 (2015) [3] R. D'Inca, A. Kostic et al.: "Characterization of the RF plasma on the IShTAR testbed", 43nd EPS Conference on Plasma Physics, 2016, Leuven, Belgium, ECA Vol. 40A, O5.129. [4] A. Kostic et al.: "Feasibility study of Passive Optical Emission Spectroscopy for the electric field measurements in IShTAR", 22nd RF Topical Conference, C-42, 2017, Aix-en-Provence, France. [5] E. H. Martin: "Electric field measurements of the capacitively coupled magnetized RF sheath utilizing passive optical emission spectroscopy", PhD Thesis (2014), North Carolina State University.

Possible collaborations with LAPD – UCLA.
Contribution for the Joint Session.