Experimental studies of RF sheath rectification in magnetized plasmas using fast and slow ICRF antennas


Motivation

- Plasma-material interaction (PMI) in discharges with ICRF heating are modified (as was observed on JET, Alcator C-Mod, Tore Supra, ASDEX Upgrade).
- Increased wall material sputtering in ICRF-heated discharges can be explained by RF sheath rectification.
- Contributions of fast wave fields and slow wave fields can not be separated in a tokamak and both have to be studied on a simple dedicated device.
- Understanding of physics of RF sheath rectification for both slow and fast waves separately would give an opportunity to improve ICRF antennas for tokamaks.

What is “RF sheath rectification”?

Electric fields radiated by antenna result in an increased sheath potential (bigger than $V_{\text{sheath}}$) reaching at least several tens of Volts. Bigger fluxes of ions are attracted to the limiting structures.

Current methods to reduce impurity source

- Modification of limiting structures
- 3-strap antennas for more homogeneous distribution of the currents
- Low-Z (e.g. boron) coating of limiters

Antenna and diagnostics

- Planar Langmuir probes ($S = 1 \text{ cm}^2$)
- Cylindrical Langmuir probe ($L = 10 \text{ mm}, d = 2 \text{ mm}$)
- $B_\parallel$ probe

Measurements with Langmuir and $B$ probes

- New antenna which produce fast wave only
- New flange – axial symmetry – 2-D model
- Additional small coil
- New diagnostics: array of Langmuir probes on the back flange, spectrometer and reflectometer

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Device upgrade

- New antenna which produce fast wave only
- New flange – axial symmetry – 2-D model
- Additional small coil
- New diagnostics: array of Langmuir probes on the back flange, spectrometer and reflectometer

Outlook

- An attempt of using RF compensated Langmuir probes was made, similar probes with better design have to be made and tested.
- Compensated probes testing on a similar device ALINE.
- Installing of a Langmuir probe array and measuring a 2-D profile of temperature and density.
- Investigation of a possibility to measure plasma rotation velocity.
- Separate studying of fast wave and slow wave fields using two antennas.

IShTAR: Ion cyclotron Sheath Test ARrangement

- Vacuum chamber with magnetic field coils
- Helicon plasma source
- Isobar gas valve
- Helicon antenna (RF power 1 kW, frequency 5 MHz)
- Main vacuum chamber
- Main big magnetic coils
- Probe manipulator
- Spectrometer
- Small coils

Base pressure $10^{-4}$ mbar
Gas: Argon, Helium
Big coils 8 kA, 0.275 T for 10s and 12 kA, 0.4 T pulsed for 1s (power supply limit)
Small coils 1 kA, 0.1 T for 10s (power supply limit) and 10 kA, 1.0 T (coil limit)