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Experimental Investigation of ICRF waves-SOL plasma interactions with RF and Langmuir probes.

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Motivation

- ICRF heated plasmas are seen as one of the cornerstones for steady fusion processes. With two antennas providing up to 20MW of power envisioned for ITER **[1]**, improving the general ICRH performance capabilities is a must-do in the fusion road map.
- In order to maximize ICRF capabilities, antennas must be placed as close as possible to the plasma, so good coupling and power deposition regardless of plasma parameters fluctuations is achieved.
- However, it is experimentally observed that the interaction between the antennas and the SOL plasma gives rise to unwanted phenomena, namely:
  - ➔ Higher impurity production.
  - ➔ Plasma parameters modification.

The problem of coupling

- ICRF waves need to transit a low density evanescent region in the SOL of fusion reactors before they can be used for heating the plasma core.
- The SOL is very intermittent in space and time, with density and temperature fluctuations that can become very significant. Moreover, in H-mode plasmas, Edge Localized modes can substantially vary these conditions.
- The issue of propagating ICRF waves under turbulent plasma scenarios has been a relevant scientific problem since as early as 1982 **[3]** where a Fokker-Planck description for the scattering of wave trajectories was first developed**.**
- Turbulent structures such as plasma blobs present a challenge for ICRF power coupling and several theoretical models are under development **[4,5].**
- However, a consistent experimental study is still necessary to benchmark these new models.

Expectations

- Characterization of the underlying physical mechanisms involved in plasma-wall- ICRF wave field interactions.
- Decoupling the impact of the fast and slow waves in the local and global plasma parameters.
- Study of the influence of passive antenna structures in the spectrum of launched wave vectors.

[1] P. U. Lamalle et al. *Status of the ITER IC Hi&CD System.*
[2] V. Bobkov et al. *ICRH Operation with improved antennas in Asdex Upgrade with Tungsten wall.*
[3] Masayuki Ono, *Effect of low frequency density fluctuations on ion cyclotron waves.*
[4] J. R. Myra and D. A. D'Ippolito, *Scattering of radio frequency waves by blob-filaments.*
[5] J.R. Myra, *Fast wave evanescence in filamentary boundary plasmas.*
[6] R. Ochoukov et al. *A new B-dot probe-based diagnostic for amplitude, polarization, and wavenumber measurements of ICRF fields on ASDEX Upgrade* (Accepted for publication, RSI, 2015)

Newly installed 3-strap antennas at the AUG Tokamak

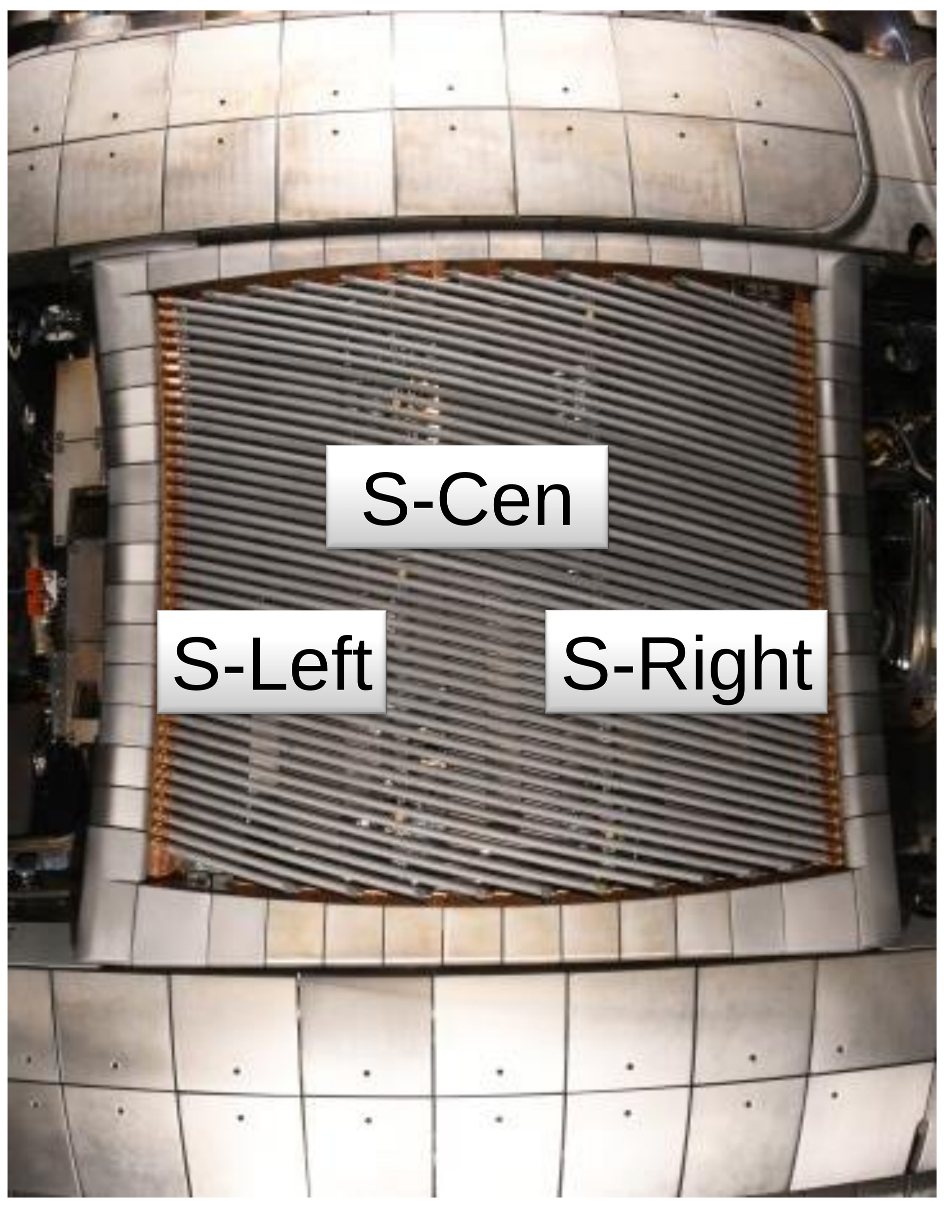

Figure 1: Newly installed three-strap antenna in sector 4 of the Asdex Upgrade Tokamak.

- The three strap antennas' design, recently installed at the Asdex Upgrade Tokamak, follows the principle of minimizing the overall $E_{\parallel}$ in front of the antenna. The $E_{\parallel}$ field component enhaces the RF sheaths, which ultimately can lead to a pronounced sputtering yield.
- By minimizing the peak amplitude of $E_{\parallel}$ averaged along the magnetic open field lines in front of the antenna, the impurity released is expect to decrease, where **[2]**:

$$\langle E_{\parallel}{}^{\mathbf{0}} \rangle = \frac{\mathbf{1}}{\boldsymbol{L_f}} \int E_{\parallel}{}^{\mathbf{0}}\, \boldsymbol{dl}$$

With:
  - $E_{\parallel}{}^{\mathbf{0}}$ *Local peak amplitude.*
  - $\boldsymbol{Lf}$ *Length of the open magnetic field line.*

- Commissioning of the new antennas has recently started and results will be presented in the future.

Turbulence at the SOL

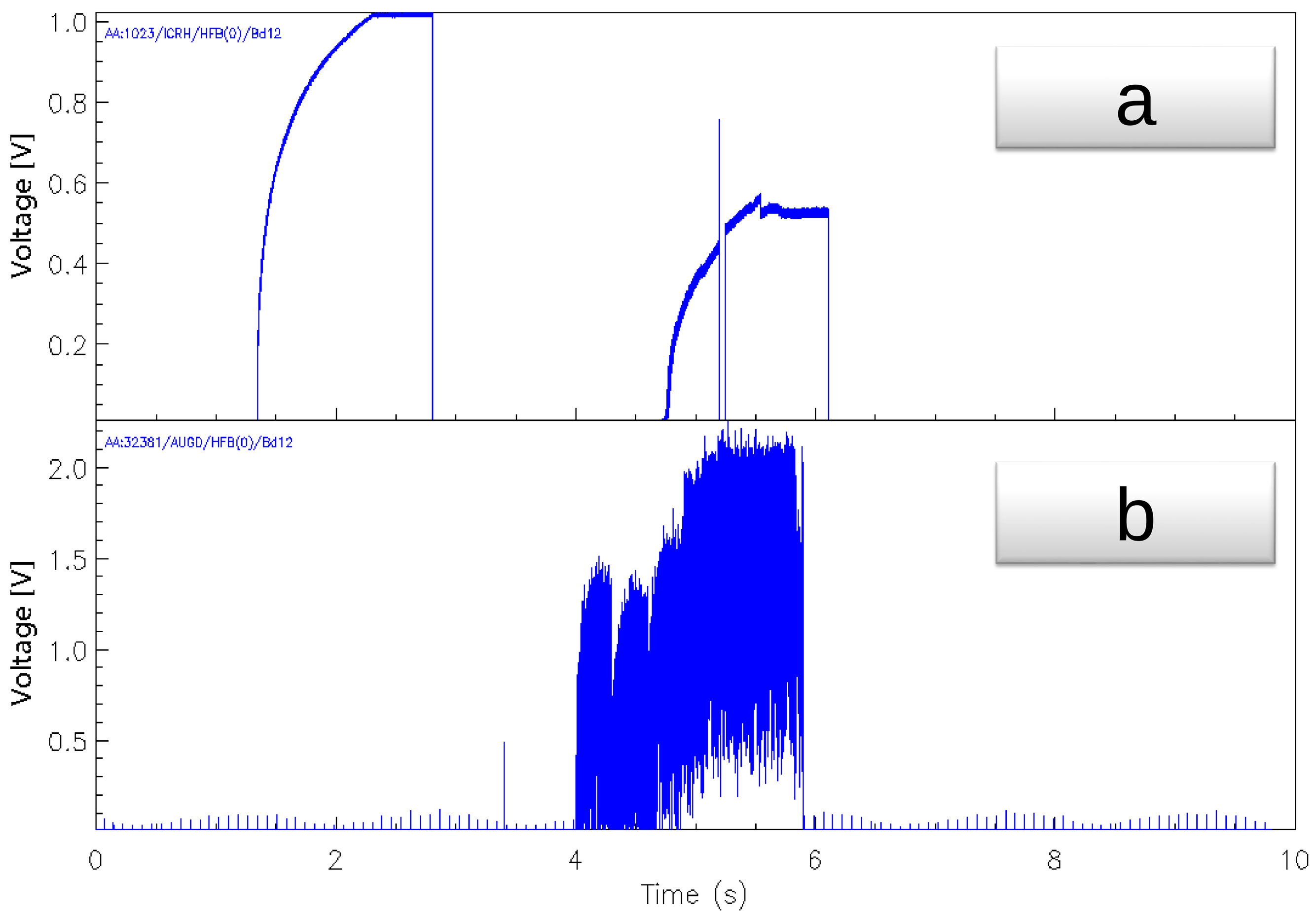

Figure 2: Unconverted ICRF magnetic field amplitude measured by B-dot probe for a) Shot in vacuum and b) Shot with plasma.

- As it can be experimentally seen, fluctuations in the SOL density as well as turbulent phenomena such as Edge Localized Modes, can severely affect ICRF-Plasma coupling.
- For this reason, a consistent quantification of plasma parameters in the SOL and wave properties is mandatory in order to unveil the underlying physical phenomena behind plasma-ICRF waves and materials interactions.

Experimental Approach

Both plasma parameters at the SOL and wave properties will be measured using sets of different probes.

➔ A set of five Langmuir Probes in Sector 8 will help to quantify local plasma parameters. These probes will also be used to study turbulence.

➔ RF probes will measure the toroidal distribution of the Amplitude for the launched ICRH waves. In addition, a set of ten field-aligned RF probes will be used to study the parallel wave number spectrum of the launched waves **[6].**

➔ This setup is expect to be further complemented with an array of probes mounted on the midplane manipulator, in which an emissive probe, a ball-pen probe, an additional Langmuir probe and a Mach probe will be installed.

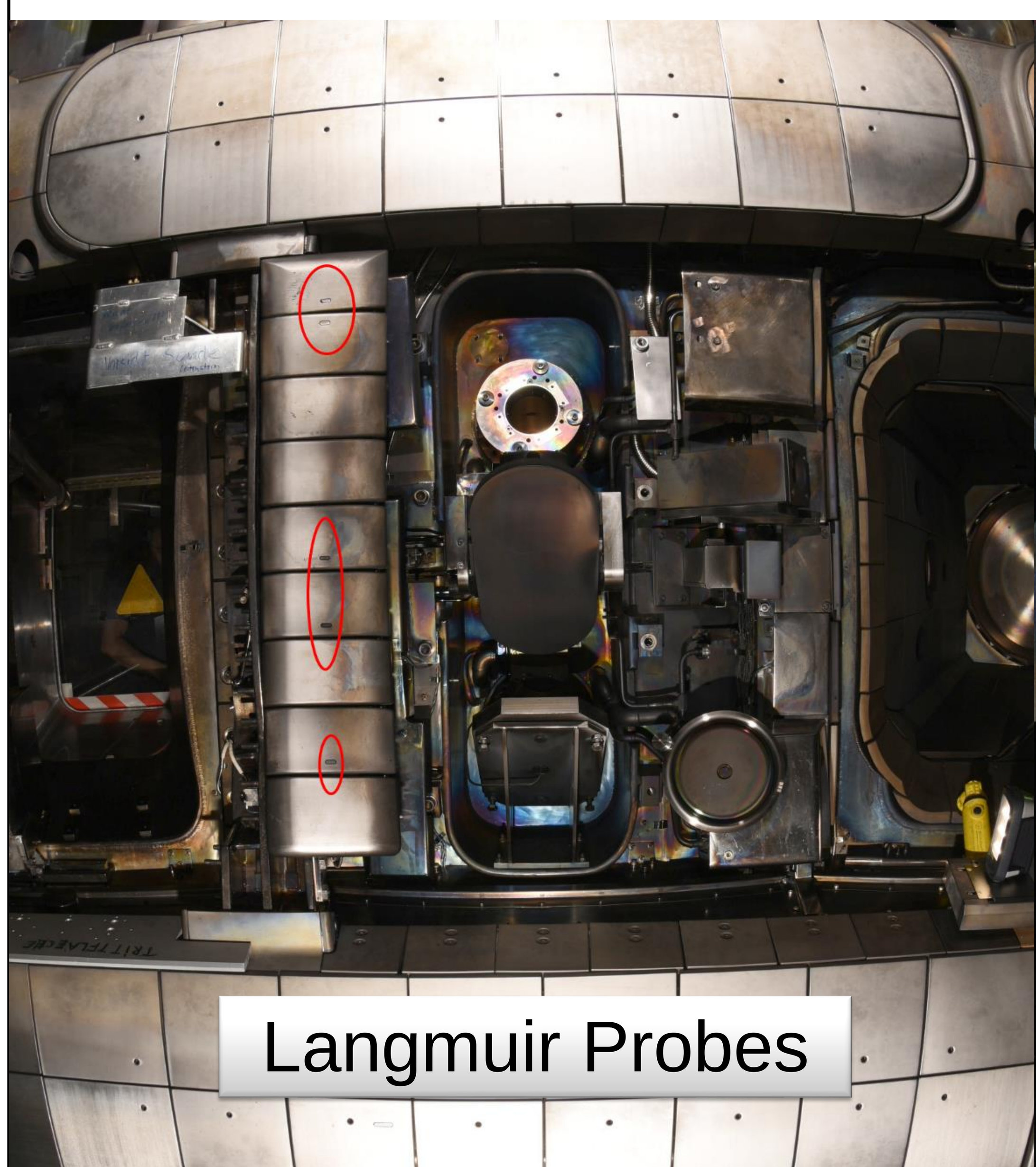

Figure 3: Flush Mounted Midplane Langmuir Probes in Sector 8 of the Asdex Upgrade Tokamak

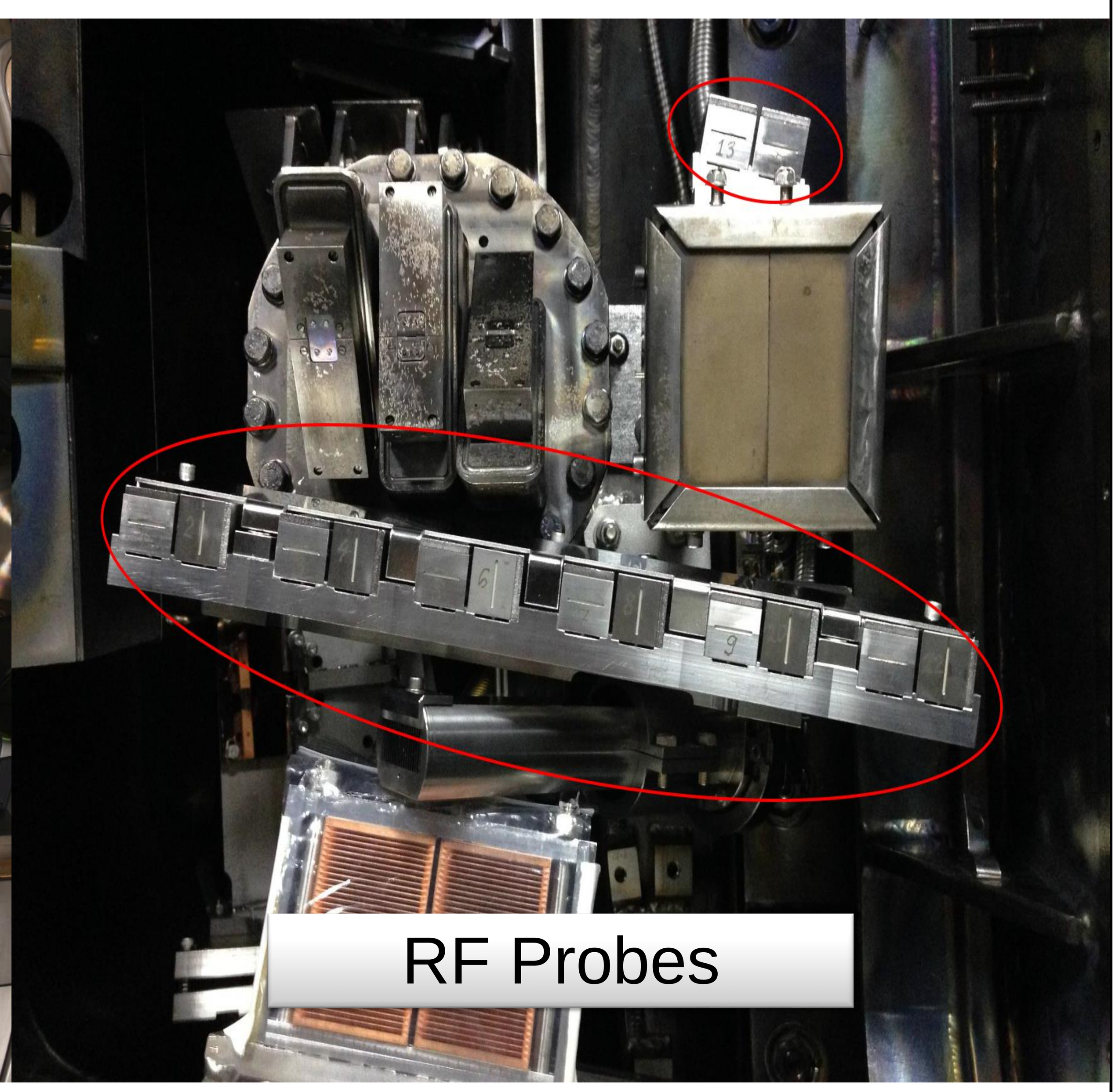

Figure 4: Field-aligned RF Probes in Sector 11 of the Asdex Upgrade Tokamak.

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