Role of Fast ICRF Waves in Plasma Potential Enhancement in the SOL of Alcator C-Mod

55th APS DPP Annual Meeting
Denver, CO USA Nov 14-18, 2013

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Key Results:

1. Enhanced potentials (FP) are observed in regions inaccessible (blocked) to slow waves launched directly by active antennas.
2. Fast wave (FW) fields observed in blocked regions:
   • FW field strength is modulated by core sawtooth oscillations.
   • FP modulations correlate with FW field modulations.

Implication: surfaces not magnetically mapped to active antennas may become impurity sources.
High Z impurity contamination is universally observed with ICRF antenna operation.

- Molybdenum source at antenna scales with RF power.

Underlying physics is yet unclear and observations differ.

- C-Mod and JET\textsuperscript{1} data indicates local antenna source is present but not dominant.
- In ASDEX-U, RF limiters is the dominant impurity source.\textsuperscript{2}

1. V. Bobkov et al., 20\textsuperscript{th} Int. Conf. on Plasma-Surface Interactions, Aachen (2012).
2. R. Neu et al., 20\textsuperscript{th} Int. Conf. on Plasma-Surface Interactions, Aachen (2012).
Plasma Potential is Strongly Enhanced with ICRF.

Plasma potential >100 V are observed.

- Induce sputtering of Mo by D+ ions.
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Oscillating $E_{||}$ leads to DC potential on open field lines.

- Electron mobility $>>$ ion mobility along B-field.
- Electron current dominates over ion current per RF cycle.
- DC potential forms to preserve ambipolarity condition.

Conventional explanation is ICRF antenna excites some $E_{||}$.

- $E_{||}$ is often associated with slow wave.
Probes are a combination of magnetic and emissive probes.

- Magnetic probes monitor all RF components.
- Emissive probes monitor plasma potential.
- Langmuir probes for plasma density (ne) and electron temperature (Te).

Gas puff imaging provides plasma potential profile in scrape off layer.

Probes may be mapped magnetically but lack direct connection with antenna due to structures.
RF Enhanced Plasma Potential is Dependent on Field Mapping

Plasma potential enhancement is larger when diagnostic has an unblocked mapping to the active antenna.

Enhanced plasma potential is present for case where diagnostic is mapped but is blocked.
• Possible large surface area impurity source.
Observe significant $\Phi_p (>100 \text{ V})$ but limited density range $10^{16} < n_e < 10^{17} \text{ m}^{-3}$.

Lower bound is $\Lambda_0 = 1$.

- Consistent with theoretical predictions (Myra PRL 2008).
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Upper bound is $n_e = n_{\text{LH}}$

Affected region is limited by mapping and $n_e$ profile:
- C-Mod slow wave impurity source typically would be limited to antenna.
- Yet source enhancement observed at additional locations.

![Diagram showing Slow ICRF Wave $k_{\perp}$](image)

![Graph showing Average $\Phi_p$ (V) vs. Local $n_e$ (m$^{-3}$)](image)
Enhanced plasma potential observed on mapped but blocked probe.

Fast wave fields present in blocked regions.
Antenna toroidally closest to probes induces largest changes.

Fast wave fields and plasma potential respond to core $T_e$ fluctuations.
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Suggests unabsorbed fast wave is generating enhanced plasma potential.
Converting Fast Waves Field to Slow Wave Field or $E_\parallel$

Incident fast wave field incident on a surface oblique to the magnetic field.
Converting Fast Wave Field to Slow Wave Field or $E_{||}$

**Conducting Surface Boundary Condition:**

$E_{t'} = E_{t, FW} \ (\Sigma E_t = 0)$
Converting Fast Wave Field to Slow Wave Field or $E_\parallel$

Conducting Surface Boundary Condition:

$E_{t,\text{SW}} = E_{t,\text{FW}} (\Sigma E_t = 0)$
Good Agreement between Calculated and Measured Plasma Potential

Model* that estimates FW-induced $\Phi_P$ via conducting boundary matches data trends:

- Depends on FW dispersion relation.
- $n_{\perp}$ is determined by the surface geometry and is a reasonable estimate.

*D’Ippolito et al., PoP, 2008
Regions inaccessible to directly launched slow waves experience $\Phi_p$ rectification:

$\Phi_p$ enhancement correlates with fast wave field strength:
- Result is well modeled by far field fast wave rectification theory.

Implications: surfaces not magnetically mapped to active antennas may become impurity sources.