Direct Detection of TG Modes in Helicon Discharges

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Summary

• Coupling of helicon waves to TG* modes is required to satisfy the boundary conditions.
• TG modes have large damping rates that give the observed antenna loading.
• Detecting them is hard unless $B_0$ is small, because they tend to localize near the edge.
• They are larger in the RF $J_z$ than in $B_z$.
• An RF current probe was developed for $J_z$.
• With this, the presence of TG modes has been confirmed.

*Trivelpiece-Gould
Faraday shield
$J_z / B_z$ is larger for the TG mode

$\mu_0 J = \nabla \times B = \beta B$, \quad $J_z = (\beta / \mu_0) B_z$

$\beta_{TG, H} = \frac{k}{2\delta} \left( 1 \pm \sqrt{1 - \frac{4k^2\delta^2}{k_s^2}} \right)$

$\delta = \omega / \omega_c$, $k_s = \omega_p / c$ \quad $\beta_{TG} > \beta_{Helicon}$
$\beta_{TG}$ has to be small but $\gg \beta_H$
...and $n$ to the $10^{11}$ cm$^{-3}$ range

![Graph showing the relationship between $n$, $k$, and $\beta$. The graph includes a legend for different values of $B$ and $n$.](image)
The TG "wings" are seen clearly in Jz
An RF current probe

The return winding is needed to eliminate B-dot from J-dot
Magnetic probe

Physical & electrical setup

\[ V = NA \frac{\partial \cdot \hat{B}}{\partial t} \cdot \hat{n} \]

100 mils diam coil
32 mils hypodermic tubing
92 mils ceramic
3D printed coil
center tap grounded 1:1 transformer
bandpass filter

Testing

\[ V = \frac{\partial \cdot \hat{B}}{\partial t} \cdot \hat{n} \]

Helmholtz coil
pickup coil

Hg

\[ V = \frac{\partial \cdot \hat{B}}{\partial t} \cdot \hat{n} \]
Test: rotate the J-dot probe 90 degrees
Jz and Bz
Varying $n$
Varying $B_0$

(a) $30\text{G}$

(b) $40\text{G}$

(c) $50\text{G}$

$J_z$ (arb. units)

$n \times 10^{11}$

- $4.2$
- $4.8$
- no TG

$r$ (cm)
Conclusion

• A new J-dot probe was developed and carefully calibrated at RF frequencies.
• A stable operating range was found where the J-dot probe showed its advantage over a B-dot probe.
• Amplitude "wings" near the edge, characteristic of the TG mode, were seen with only the J-dot probe.
• This feature is not expected from simple helicon theory without the TG modes.