Laboratory Experiments on the interaction of electromagnetic waves at plasma gradients

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Accomplishments

• Launched 1-10, 100 kW microwave pulses across $B_{0z}$ to interact with plasma at Upper hybrid or plasma frequency resonance locations
• Observation of electron heating at resonance layer
• Detailed measurement of Cherenkov radiation of shear Alfvén waves
• Observation of the generation of lower hybrid waves at resonant location
• Two publications in refereed journals (JGR, RSI)
two publications


How can a lab experiment relate to processes in space?

1) In the lab waves can be launched at either \( w_{LH} \) or \( w_{pe} \). The polarization of the incoming wave can be changed arbitrarily.

2) Waves generated at resonant locations can be studied in detail.

3) Diagnostics: \( \mathbf{E}, \mathbf{B} \) – 3 axis probes, spectroscopy, microprobes, Mach probes, Langmuir probes

* from presentation K. Papadopoulis
Experiments on Mode conversion

Simulated heating by EB waves

Typical parameters

\[ f_{pe} = 9 \text{ GHz} \]
\[ f_{ce} = 1 \text{ GHz} \]

Harmonics at

\[ f = f_{pe} \pm nf_{ce} \]

can be observed and the waves studied
UCLA experiments: Plasma modification and wave generation by cross-field high power rf pulses

Intense X-band microwave pulses (200 kW, near \(f_{pe}\) or \(f_{uh}\)) are delivered into a magnetized plasma column transverse to \(B_0\). Heating energy is found to be deposited in a narrow layer determined by plasma density and background magnetic field.

Generation of low frequency waves from 9.6 GHz microwave bursts
Electron Heating MEASURED WITH A STEP-SWEPT LANGMUIR PROBE

\[ f_e(E) \]

Single Pulse

Multiple pulses
Lower hybrid waves are generated

Electrostatic waves measured with an electric dipole probe

note:

\( f_{ce} = 1.1 \text{ GHz} \)
\( f_{LH} = 26 \text{ MHz} \)

\[
\sin^2 \theta_c = \frac{\omega^2 \left( \omega_{pe}^2 + \omega_{ce}^2 - \omega^2 \right)}{\omega_{pe}^2 \omega_{ce}^2}
\]
Wave frequency $f_{ci} = 122$ kHz
d$z = 3.84$ m

Wave Components
Are they Alfvén waves?

Wave amplitude proportional to input microwave power

Dispersion measured
Density Striation

$\delta n / n = 10-15\%$

$n_{\text{min}}$

$n_{\text{max}}$

$\delta x$

Plasma Parameters

$B_{oz} = 50 \text{ G} \quad f_{ce} = 140 \text{ MHz}$

$n_{\text{max}} = 1.0 \times 10^{12} \text{ cm}^{-3} \quad f_{pe} = 9 \text{ GHz}$

$R_{ce} = 1.2 \text{ mm} \quad \delta x = 10-15 R_{ce}$

Helium $R_{ci} = 1.3 \text{ cm}$
Field aligned Density striations have been created in the past.
Visible light creation of cavity
Experimental Setup

3 axis B field

3 axis E field
1) Using biased disc create density striation (size is variable)
2) Launch microwave burst at 9 GHz
3) Use Efield probes to detect EBW
4) Use Langmuir probes to measure increase in electron temperature
DURIP proposal submitted

Intent : To purchase microwave hardware (arbitrary waveform generator, high power amplifier, mixers...) to enable launching tailored microwave waveforms (swept amplitude/frequency) And measure E,B with a heterodyne system
cathode
plasma column
waveguide
magnet
microwave generated striations
Electric Field Probes

Challenge: They must be Debye scale in size

\[ \lambda_D = \sqrt{\frac{K T_e}{4 \pi n e^2}} \]

In space (auroral ionosphere) \( \lambda_D \) is 1–10 m

In LAPD \( \lambda_D \) is 30 microns
Previous Work on Phase Space Holes
E Field Probe

Bond Pads

Probe Tips
E Field Probe: $-\nabla \Phi$

Constructed at UCLA MEM’s lab
**Fig. 2.** A solitary positive hump with corresponding dipolar parallel electric field measured on the two most distant probe tips. Here and elsewhere, the parameters used for normalization correspond to the background electron populations prior to the beam injection.
1) There are several MEMS microprobes at UCLA \( \delta \vec{r} \approx \lambda_D \)

2) The microprobes measure electric field

3) Without the DURIP hardware it is possible to mix the signal from these probes to an accessible range \( f < 2 \text{ GHz} \)

4) multi (10 tip) probes with tip separation of a fraction of the electron Bernstein wavelength can be constructed without MEMS.

5) correlations with 2 tips one of which is moved with micron step size using techniques we have developed