~~Modeling and~~ Measurements of Micro-instability Dispersion Relations

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PRINCETON E×B WORKSHOP 2018

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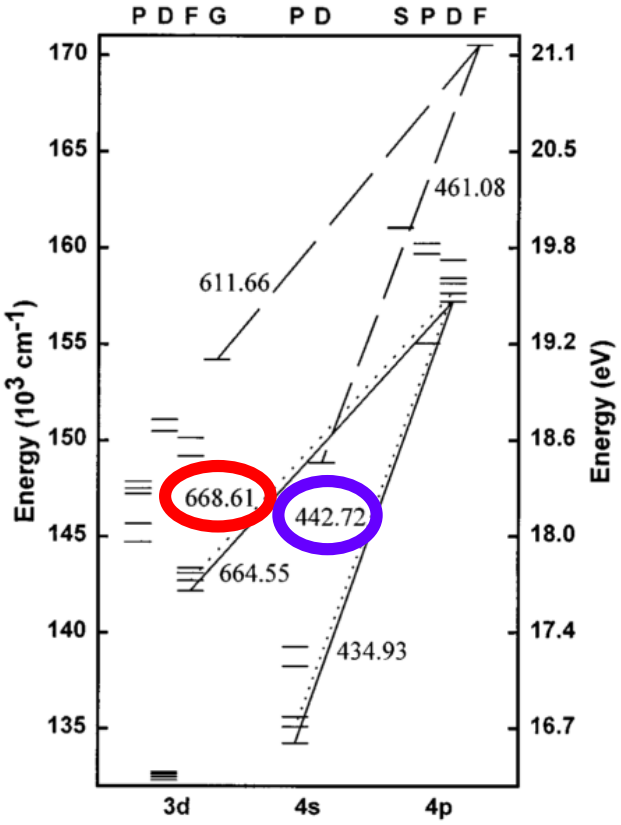
Outline

- Laser-Induced Fluorescence (LIF) Diagnostic
- Active Wave Injection (AWI) Methodology

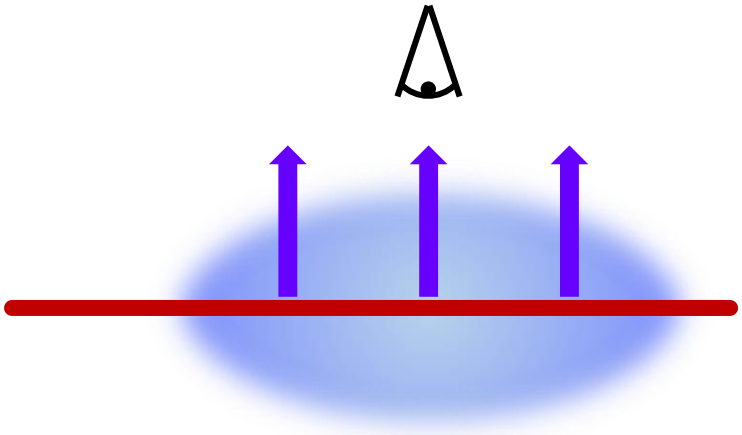
Atomic Spectra

Ar II



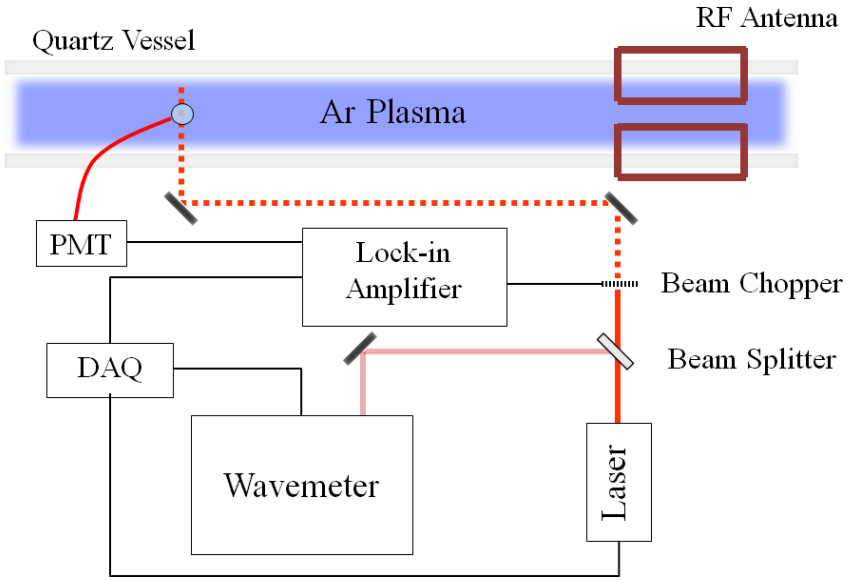
Severn et al. Rev. Sci. Instrum. 1997

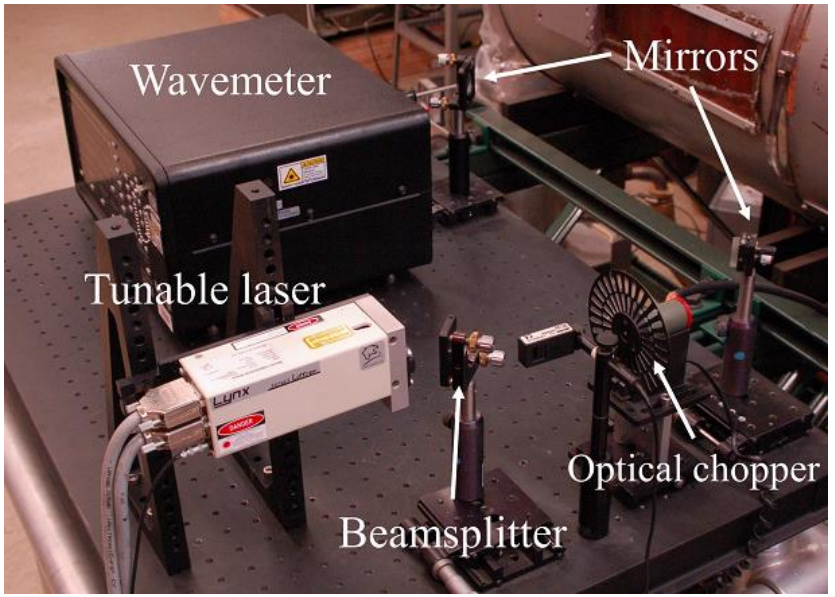
- Excite transition with laser, observe de-excitation fluorescence



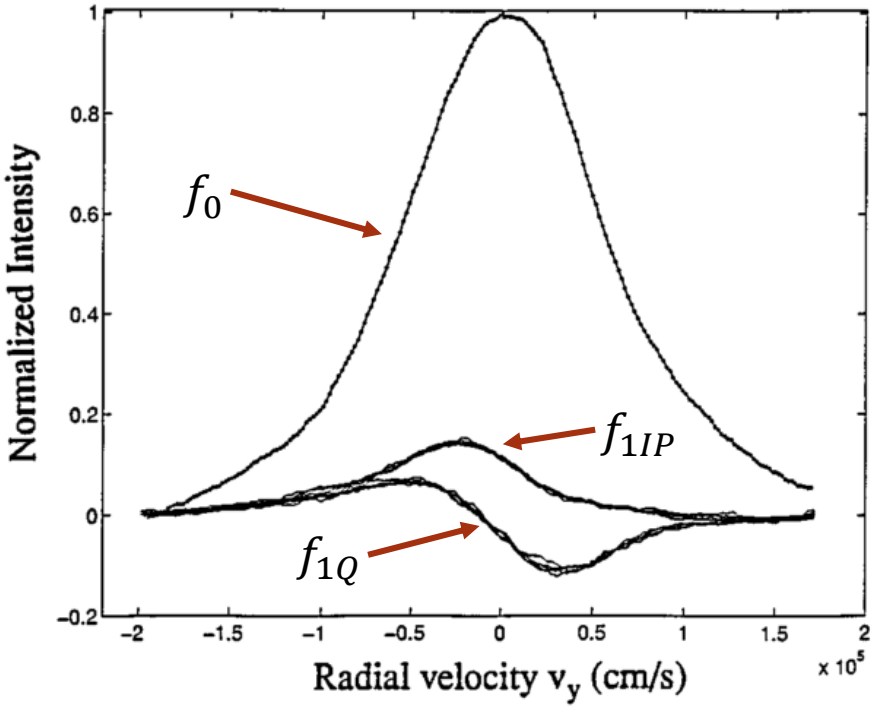
→ Laser-Induced Fluorescence

LIF System

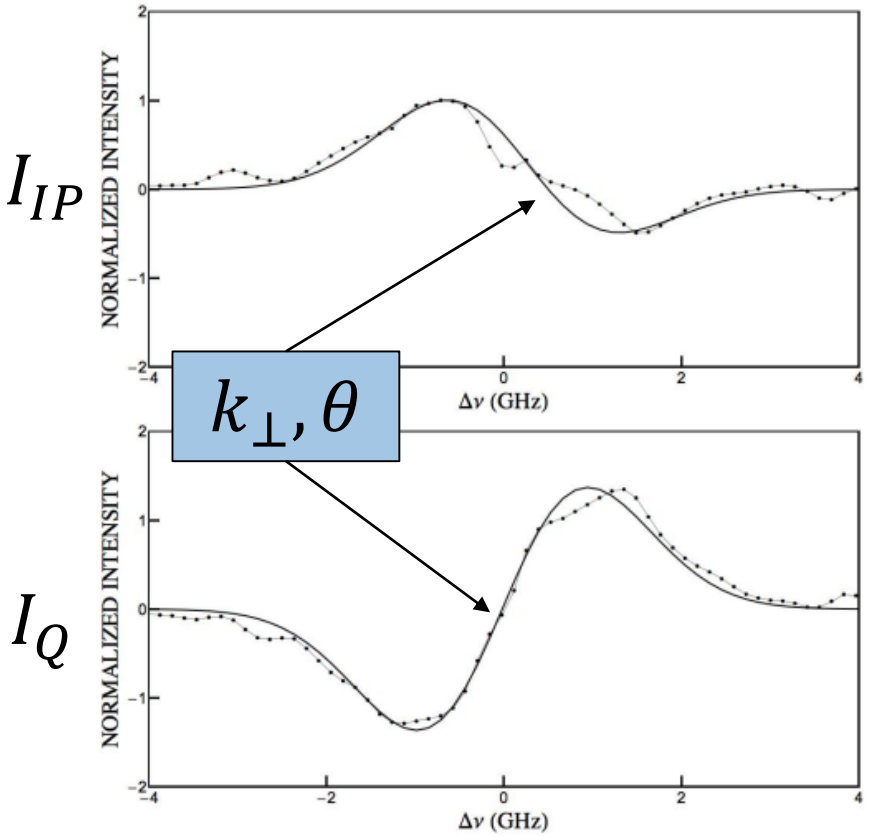

Quartz Vessel
RF Antenna
Ar Plasma
PMT
Lock-in Amplifier
Beam Chopper
Beam Splitter
DAQ
Wavemeter
Laser


Wavemeter
Mirrors
Tunable laser
Optical chopper
Beamsplitter

Data Interpretation

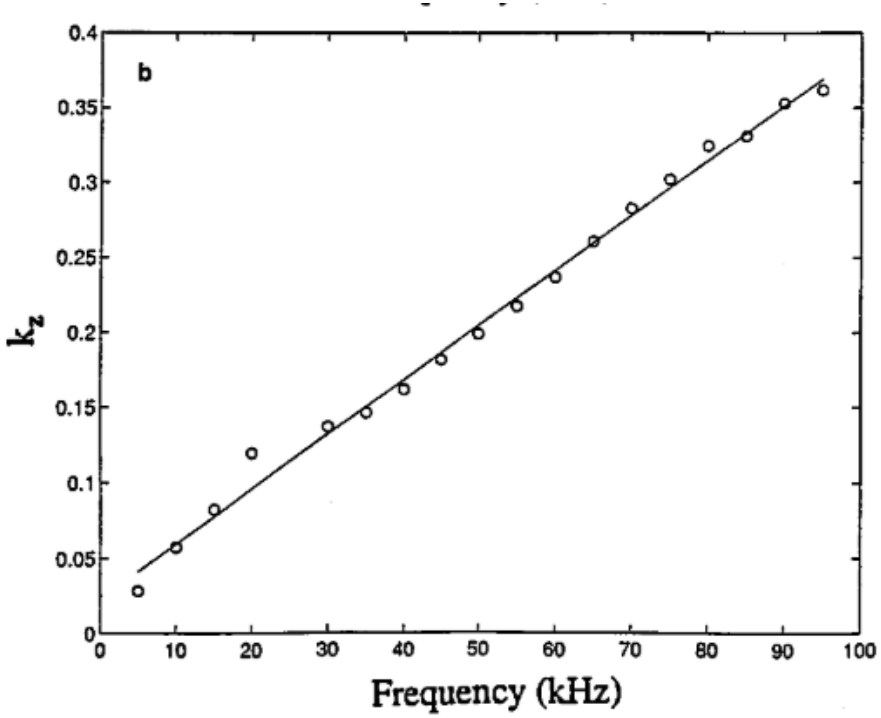


Sarfarty et al. PoP 1996

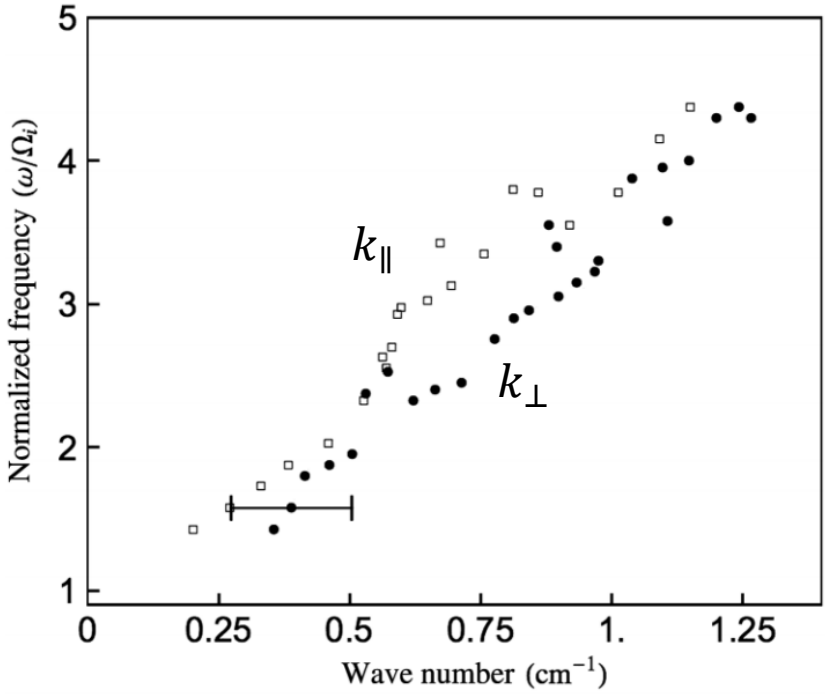


Jorns PhD Thesis 2012

Sample Dispersion Data



Sarfarty et al. PoP 1996



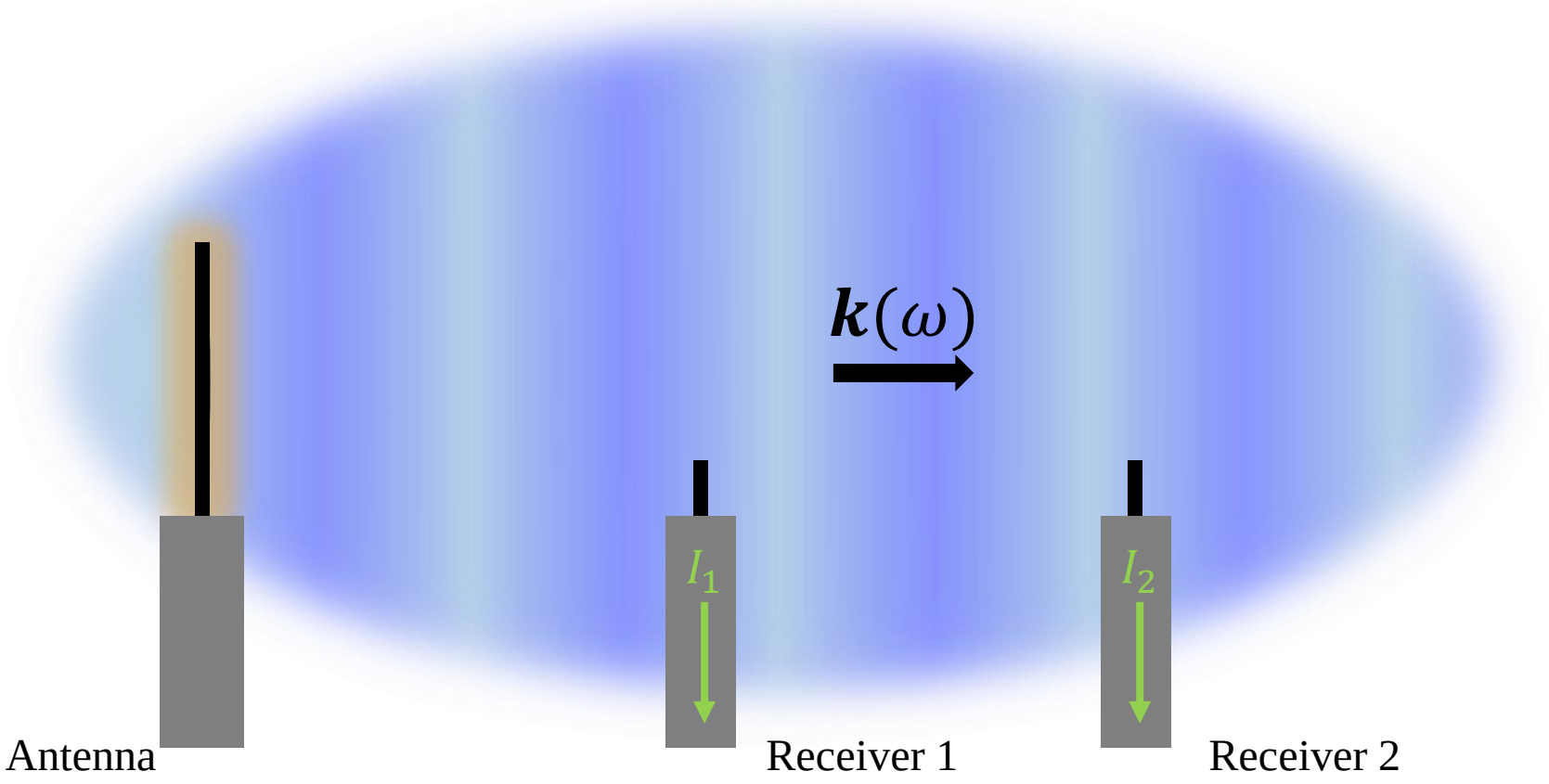
Jorns, Choueiri PRL 2013

Active Wave Injection

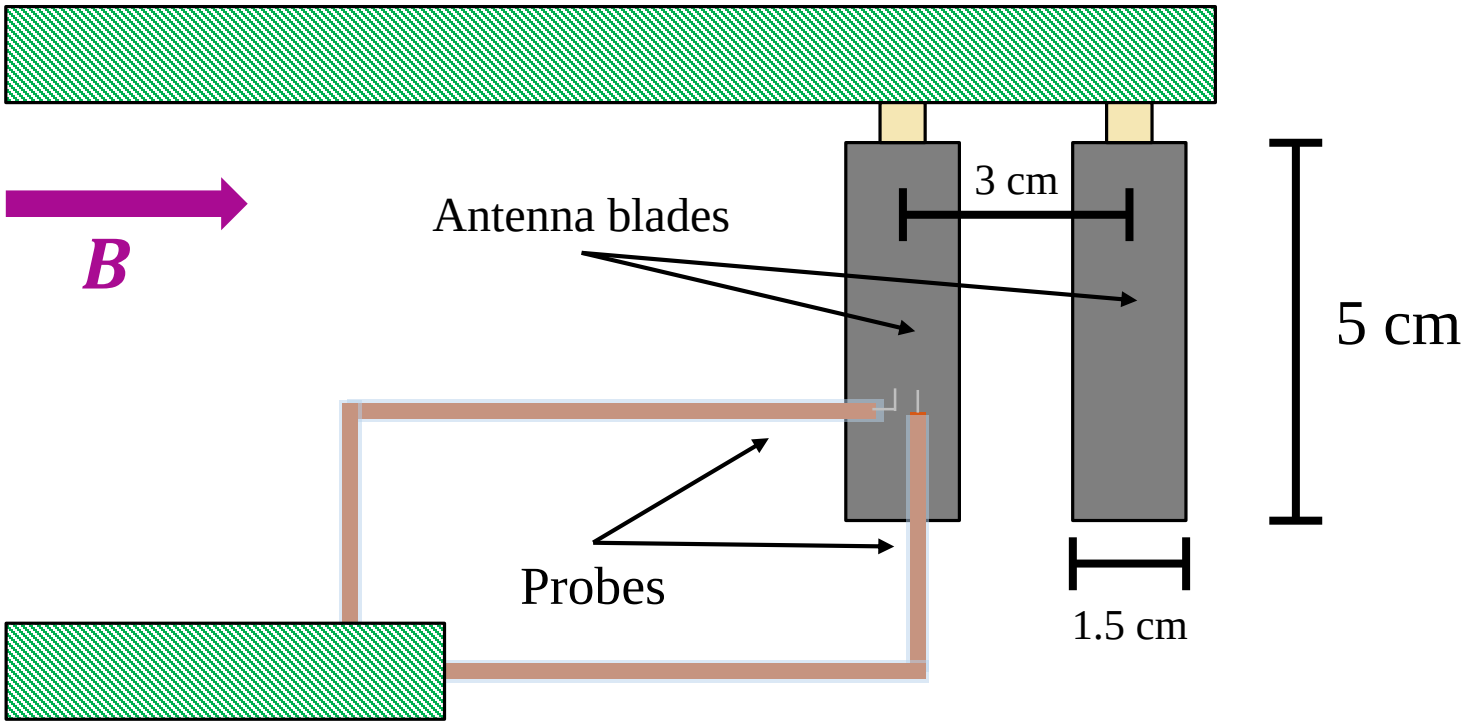
Goal: Measure complex wavenumber $\boldsymbol{k}$ of a plasma wave at various frequencies ω_1, ω_2, ... simultaneously to get the dispersion relation *in one shot*

Approach: Excite waves with an antenna at various frequencies by injecting a harmonically-rich signal into the plasma and conduct Fourier interferometric analysis of ion-saturation-current receiver probes

Active Wave Injection

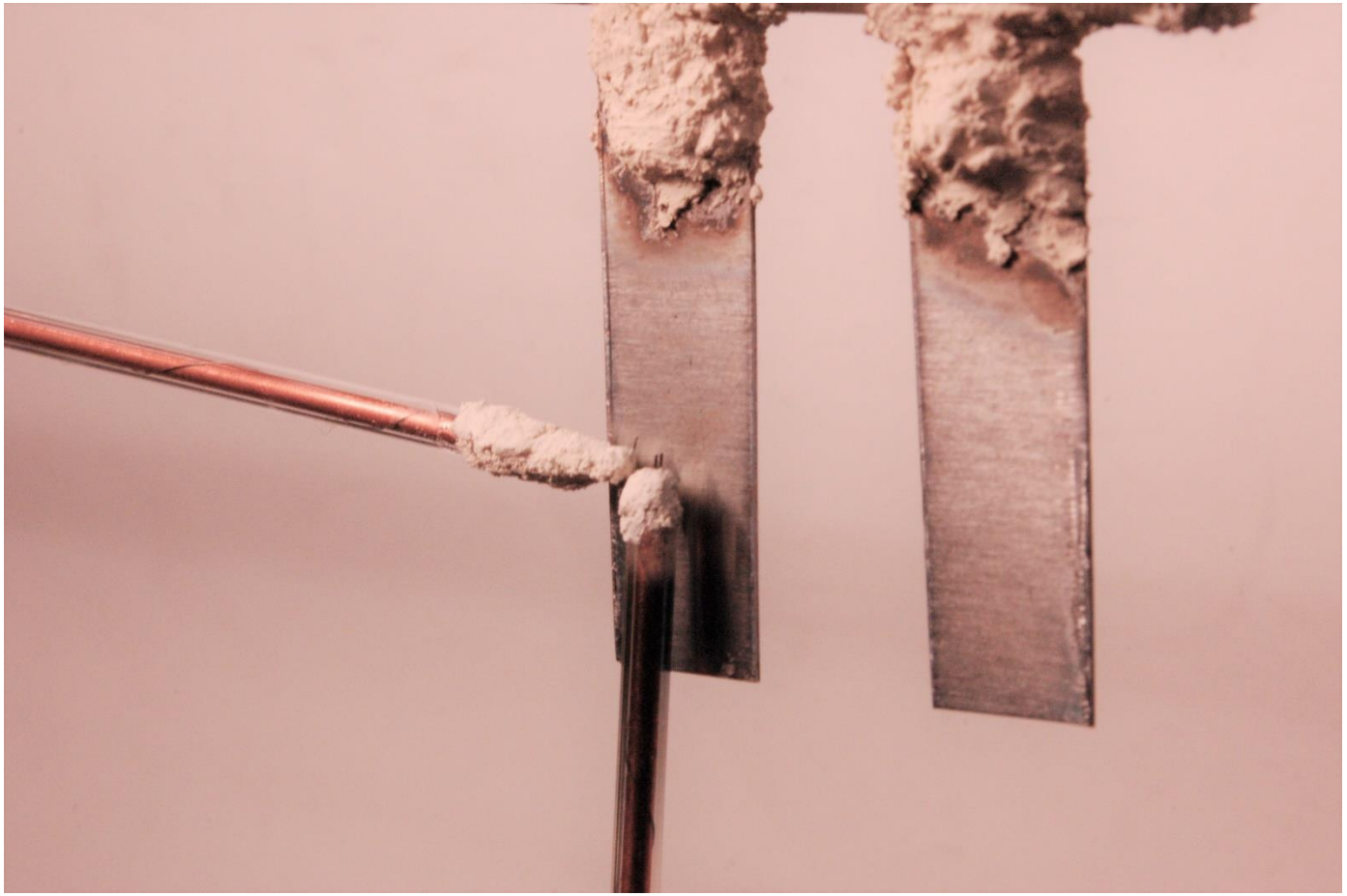


AWI Diagnostic Schematic



Side view

AWI Diagnostic Prototype



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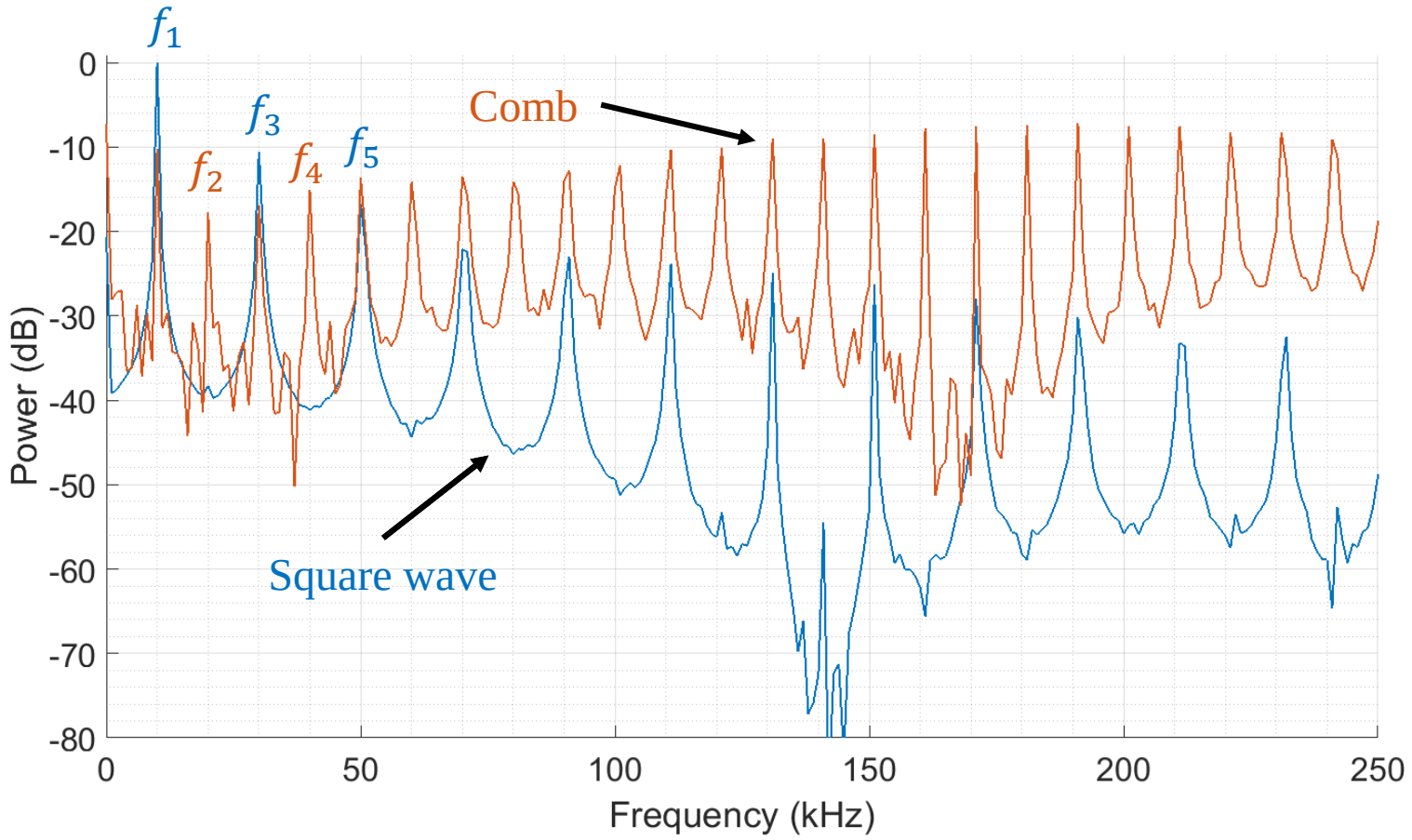
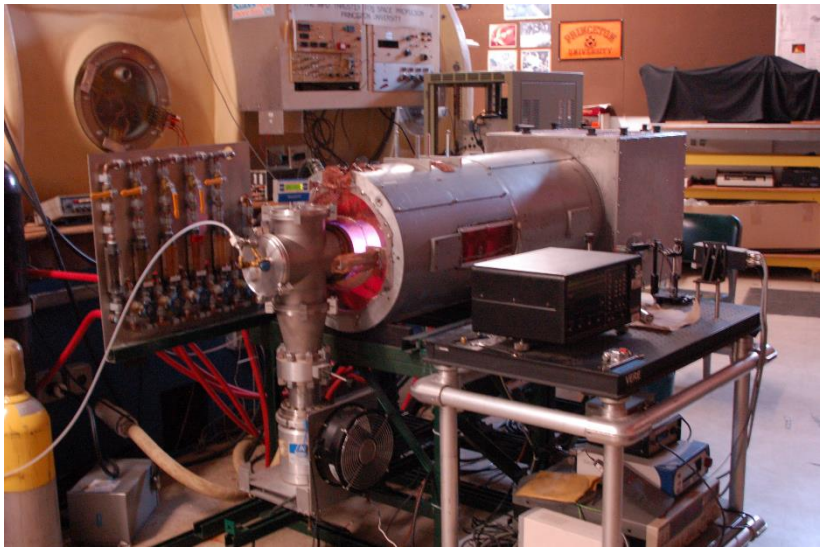
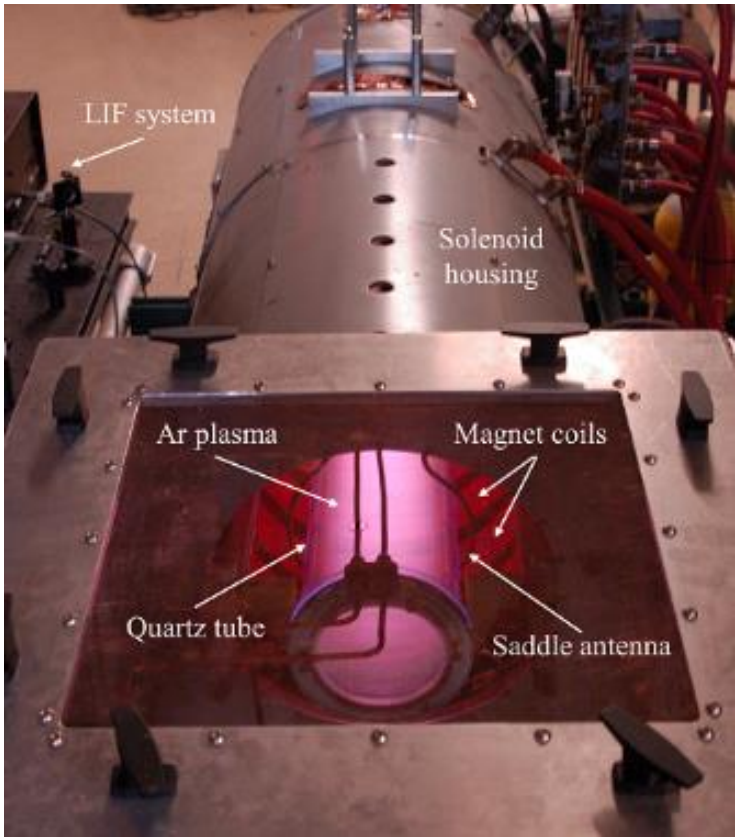
Harmonic Comb Generator



Plasma Source



13.56 MHz RF argon discharge
10 solenoid coils produce
526 G background field



Validation Study

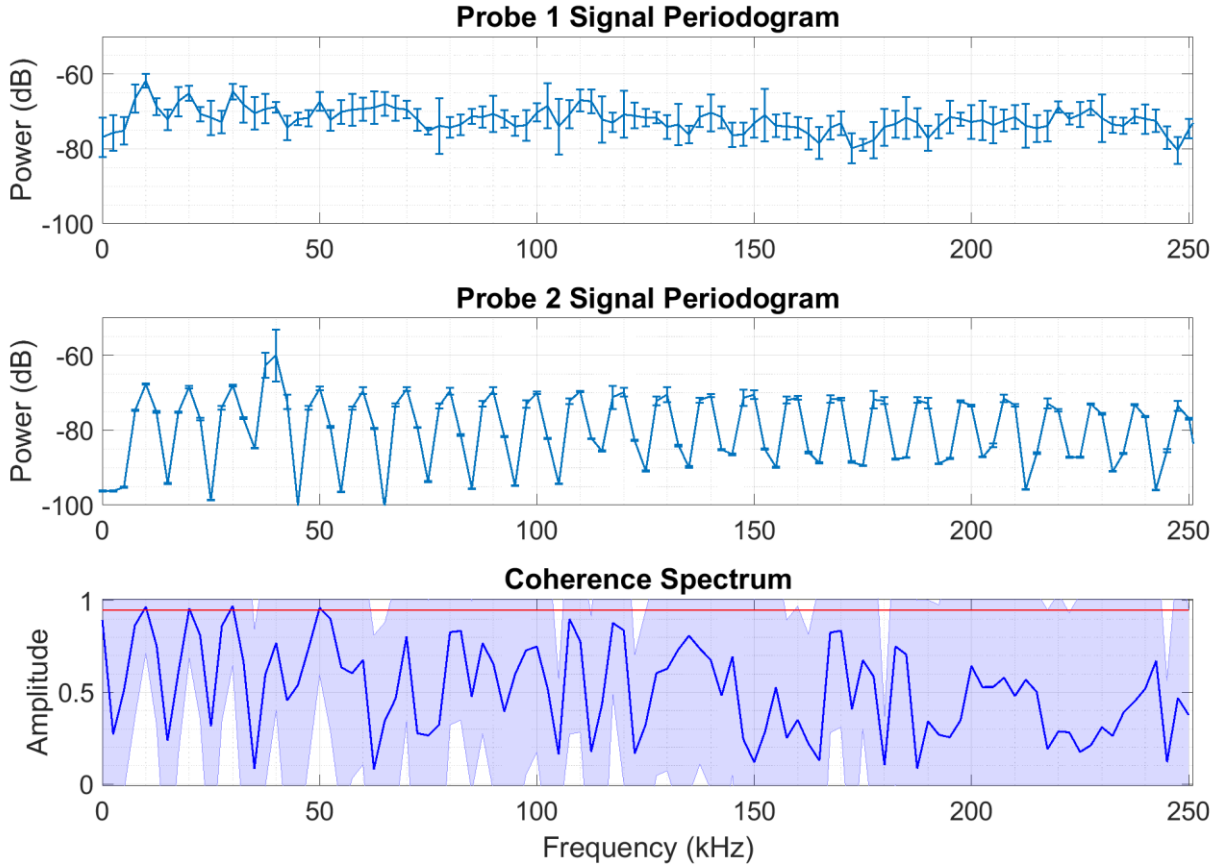
- Electrostatic Dispersion Relation

$$k_\perp^2 + k_\parallel^2 + \sum_s \frac{1}{\lambda_{D,s}^2}\left[1 + \sum_n e^{-b_s}\, I_n(b_s)\, Z\left(\zeta_{n,s}\right)\zeta_{0,s}\right] = 0$$

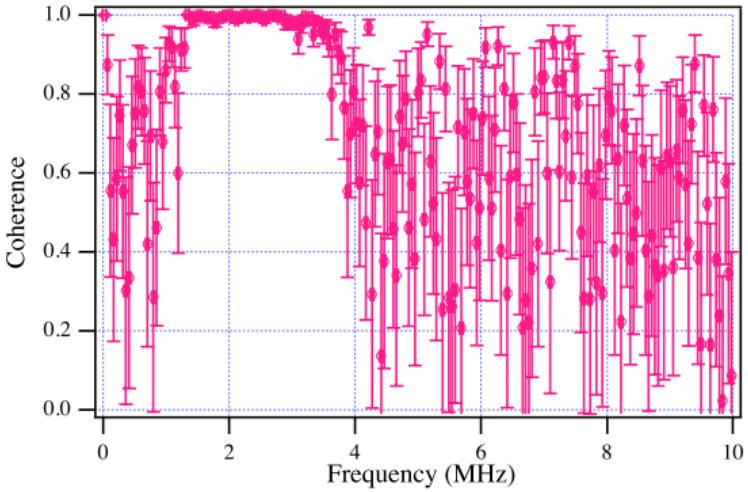
$$\zeta_{n,s} = \frac{\omega - n\omega_{c,s} - k_\parallel v_{d,s}}{\sqrt{2}k_\parallel v_{th,s}},\ b_s = \frac{k_\perp^2 v_{th,s}^2}{\omega_{c,s}^2}$$

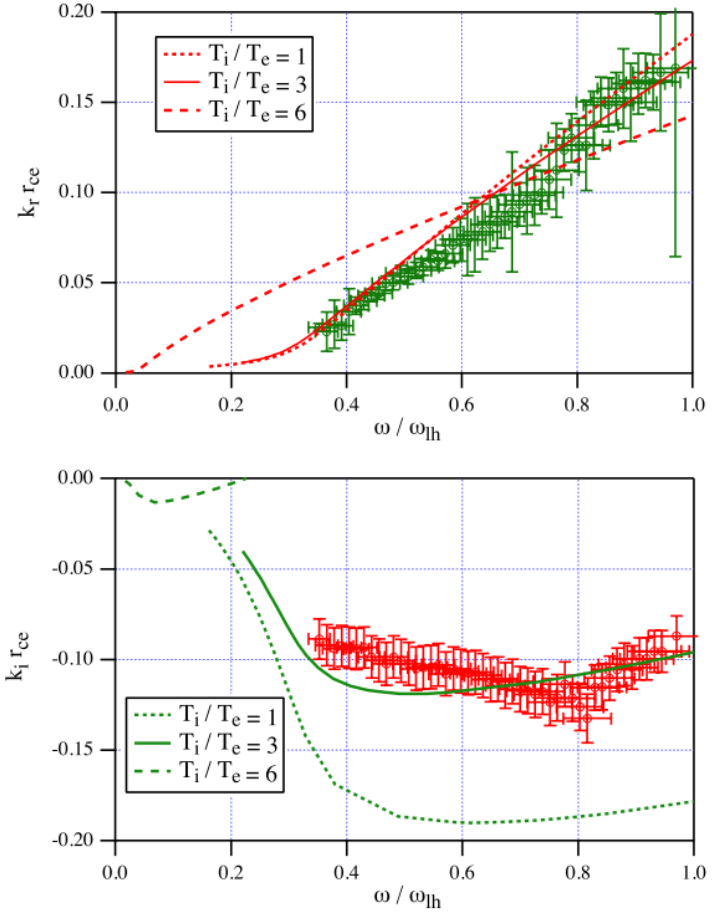
- Focus: Electrostatic Ion Cyclotron Waves

Initial Results – 150 W plasma



Lower-Hybrid Current-Driven Instability





Choueiri *et al.* IEPC-91-100

Thank You