Beating Waves Experiment II (BWX II)

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Outline

* Define problem
* Show experimental setup
* Discuss upgrades

Big Picture

- Efficient ES wave heating
- Applications
  - Plasma thrusters
    - Efficiency is CRUCIAL

Electrostatic Wave Heating

- When $f_{es} = f_{ion}$ energy transfer occurs
  - Landau dampening
- $f_{ion} < f_{es}$ ion gains energy
- $f_{ion} > f_{es}$ ion loses energy
- Take advantage of velocity distribution

Beating Waves

- Beat 2 ES waves

  $f_{es1} - f_{es2} = n(f_{ion})$

- More efficient at high energies (?)
  - Ben Jorns' Thesis
  - Not (yet) experimentally verified

Jorns, Benjamin "Plasma Heating with Beating Electrostatic Waves"

Part II: Experimental Setup

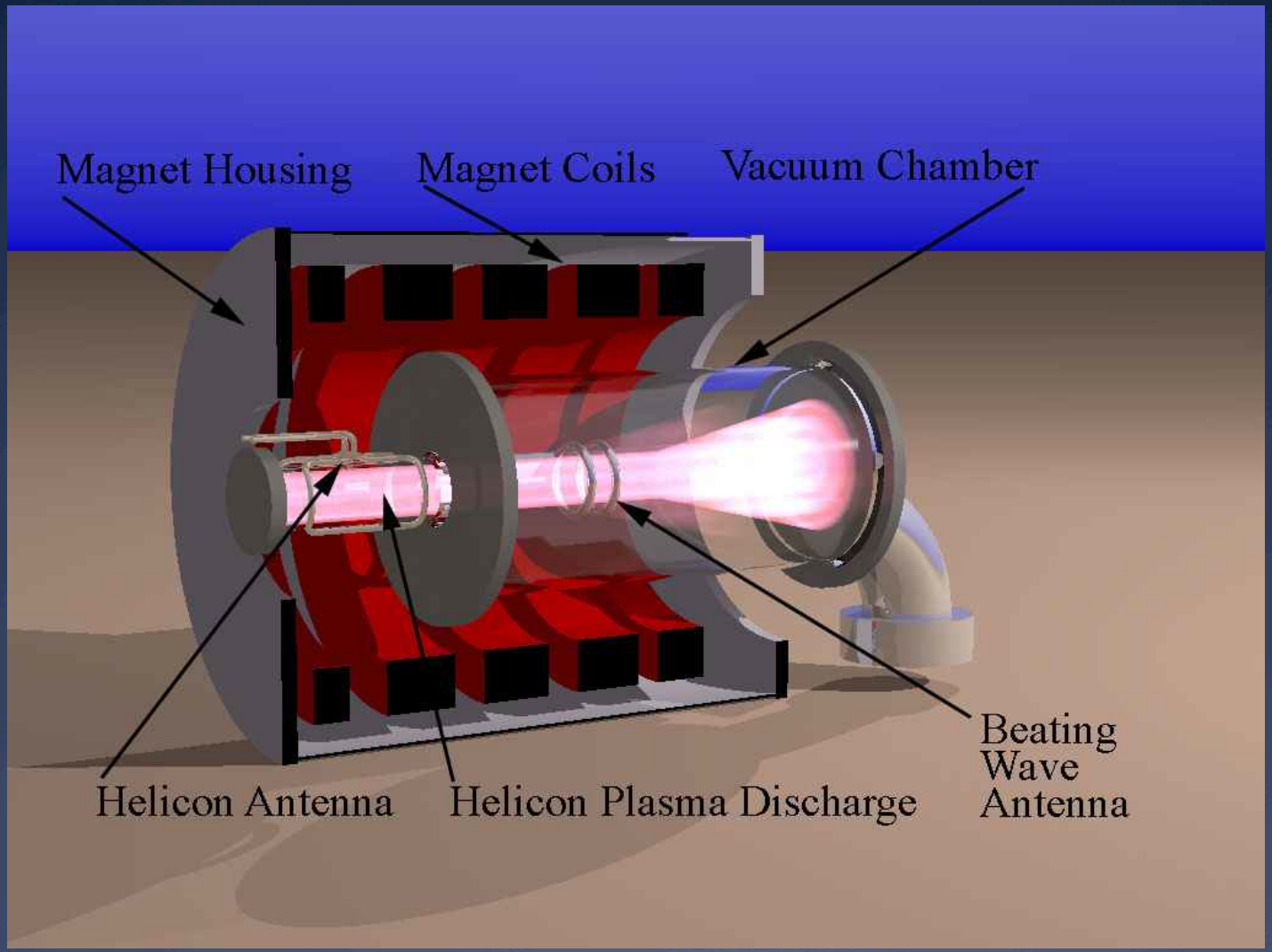


Photo courtesy of EPPDyL

Laser Induced Florescence (LIF)

- Measures T_{ion}
- Operation:
  - Send in laser light
  - Emitted photon is Doppler shifted
  - Analyze frequency intensity
  - Infer ion temperature

Langmuir Probes

- Measures T_e and electron density
- Operation:
  - Applies voltage to plasma
  - Measure/plot V against I
  - Extract T_e, electron density

Part III: Upgrades

* Recall: testing high energy levels

LIF Upgrade

- Parallel and perpendicular temperatures
  - Motivation:
    - Gauge anisotropic temperature
- But Zeeman Splitting
  - Broadens spectral lines
  - Jumbles temperatures data
  - Fix with circularly polarized light

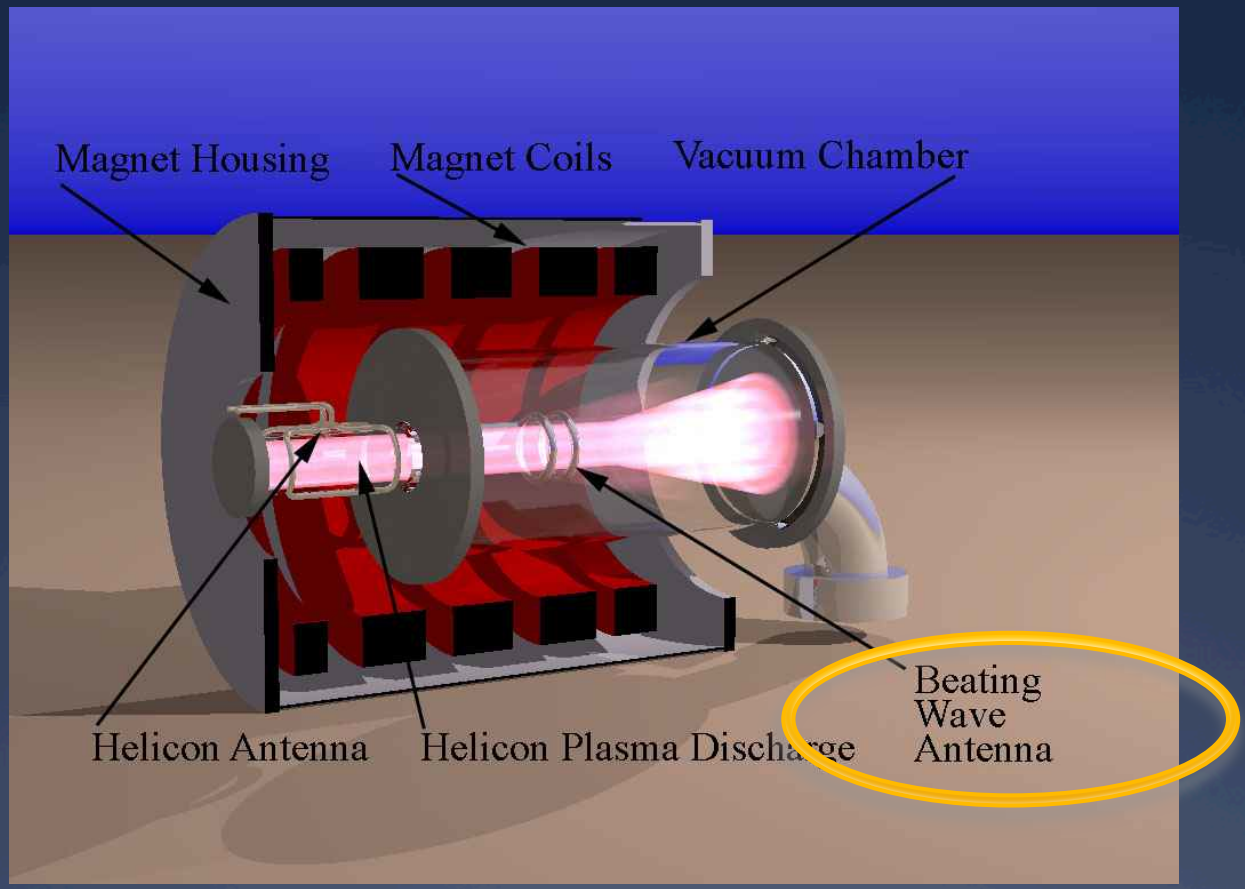
Jorns, Benjamin "Plasma Heating with Beating Electrostatic Waves"

Langmuir Probe Upgrade

- Issue with single probe:
  - RF interference
  - Draws current from plasma
- Solution: double probe
  - Measures current *across* two tips
  - Does not depend on floating potential

Owens, D.K. "Lecture IV: Langmuir Probes"

Beating Wave Antenna



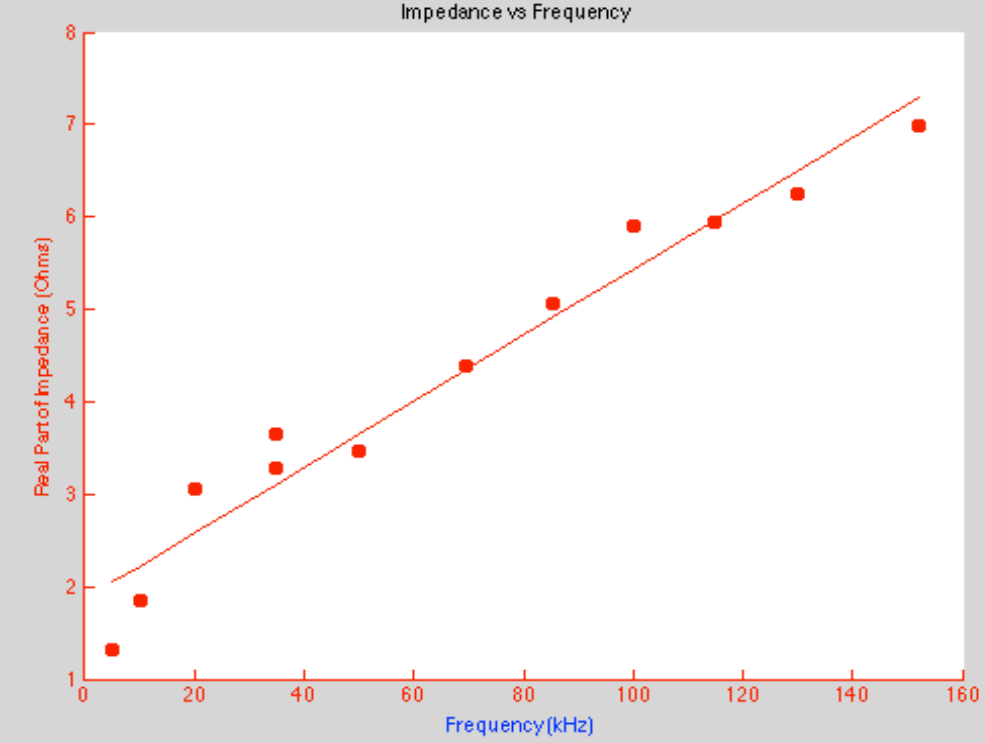
Beating Wave Antenna

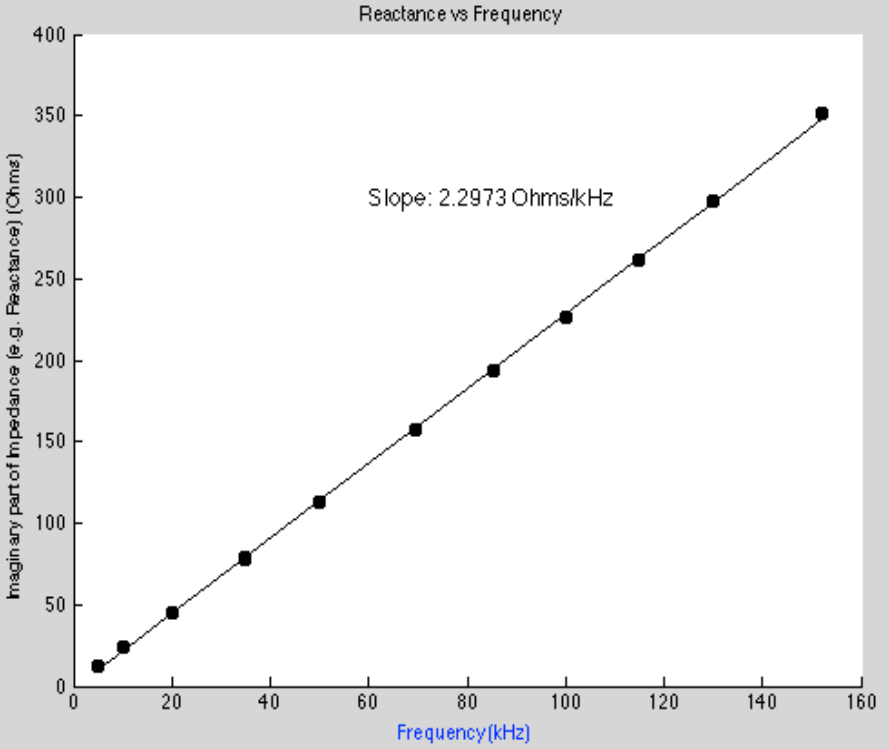
- Maximize efficiency of radiated energy
- Update old design
  - Was for planar waves
    - Test theory
- Use square Helmholtz design

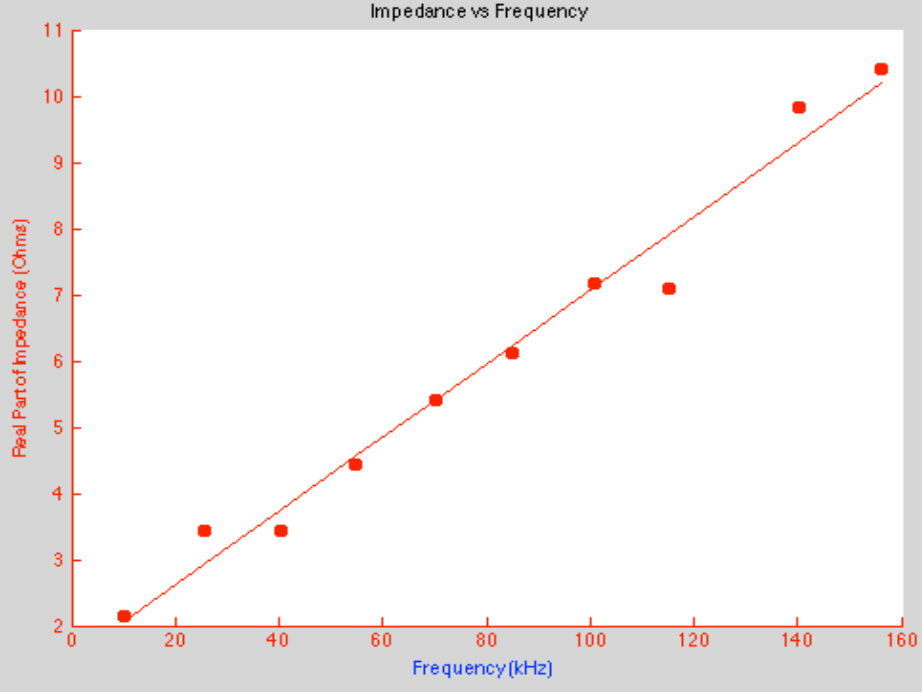
Kline et al "Ion Heating in the HELIX Helicon Plasma Source"

Antenna Comparison

- Examine complex impedance
  - No vessel, no live tests
- $Re\{Z\}_{square} < Re\{Z\}_{plane}$
  - Less energy into heat
- $Reactance_{square} > Reactance_{plane}$
  - Stronger B fields launched


Impedance vs Frequency
Real Part of Impedance (Ohms)
Frequency (kHz)


Reactance vs Frequency
Slope: 2.2973 Ohms/kHz
Imaginary part of Impedance (e.g. Reactance) (Ohms)
Frequency (kHz)


Impedance vs Frequency
Real Part of Impedance (Ohms)
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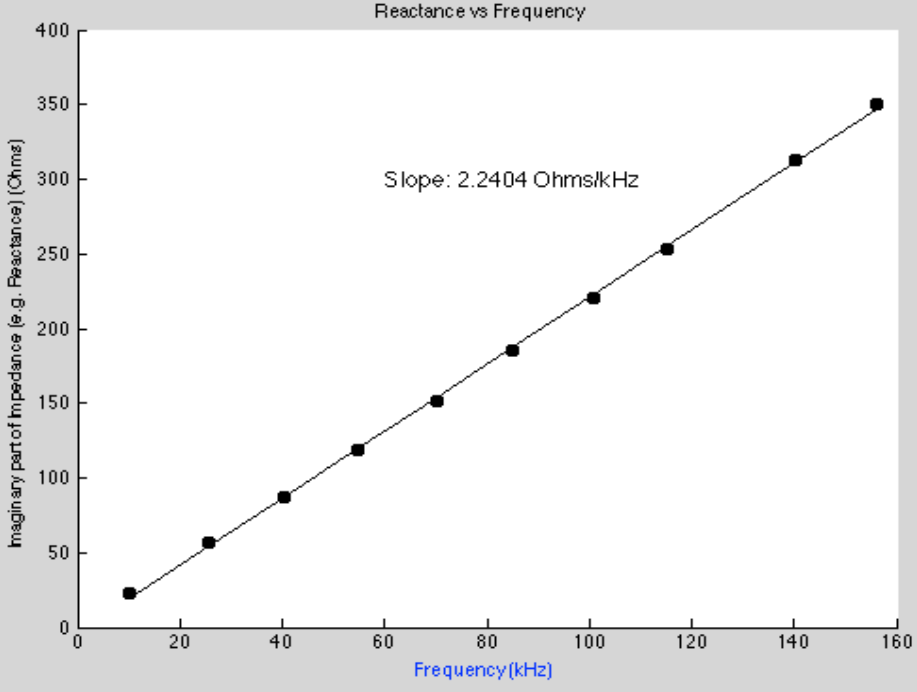
Reactance vs Frequency
Slope: 2.2404 Ohms/kHz
Imaginary part of Impedance (e.g. Reactance) (Ohms)
Frequency (kHz)

Caveats

- Different wave structure launched
- HELIX group had helicon plasma
- Will be tested this year

Works Cited

- Jorns, Benjamin. "Plasma Heating with Beating Electrostatic Waves." Diss. Princeton University, 2012. Print.
- Kline, John L. "Resonant Ion Heating in a Helicon Plasma." Thesis. West Virginia University, 1998. Print.
- Kline, John L., E. E. Scime, P. A. Keiter, M. M. Balkey, and R. F. Boivin. "Ion Heating in the HELIX Helicon Plasma Source." *Physics of Plasmas* 6.12 (1999): n. pag. *Aip.org*. American Institute of Physics, 26 Aug. 1999. Web. 30 Sept. 2013. <http://pop.aip.org/resource/1/phpaen/v6/i12/p4767_s1>.
- Owens, D.K. “Lecture IV: Langmuir Probes”