Lower Hybrid Antenna Coupling and Power Handling Experiments on MST †

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Abstract

A system for launching slow lower hybrid waves into MST at 800 MHz and $n_{||}$=7.5 has been implemented. The antenna is an enclosed interdigital line using 1/4 wave-length resonators with an opening in the cavity through which the wave is coupled to the plasma. Results of low power (10 W) experiments indicate that antenna loading is density dependent, and that a directional traveling wave is launched. Results of higher power experiments will be presented. Diagnostics include antenna impedance measurements and probes to measure wave fields within the plasma. The power handling capabilities of the present antenna design will be investigated. The results of antenna loading and RF probe measurements will be compared with the results of numerical modeling.

Introduction and Status

- LHCD Antenna has been installed in MST
- Up to 20 kW RF power applied at 800 MHz
- Plasma loading of inboard and outboard antenna ports is asymmetric
- Scalar reflection coefficient at inboard port decreases with applied power
- RF Probes and diagnostics still under development
- Computer modeling of antenna proceeding

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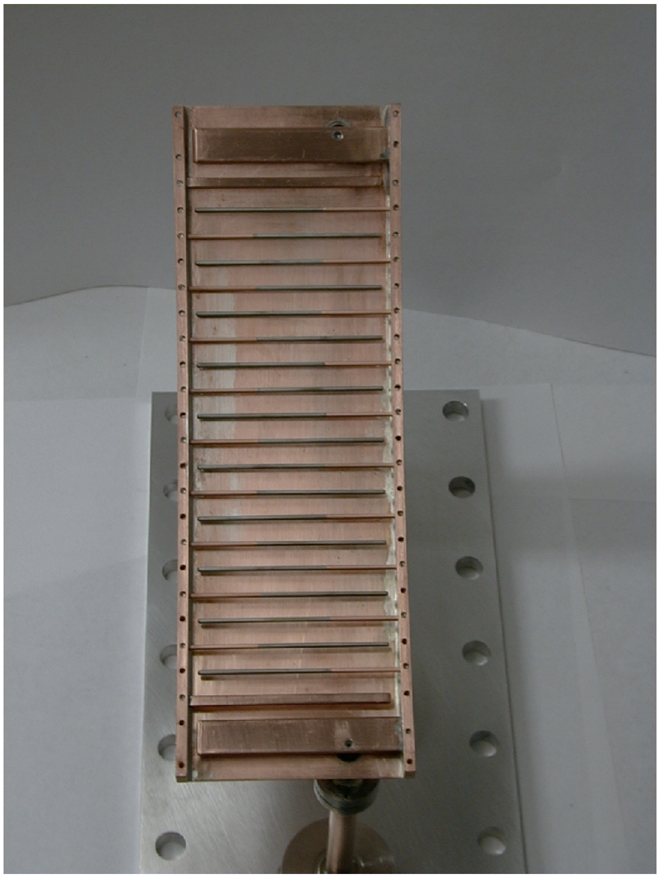
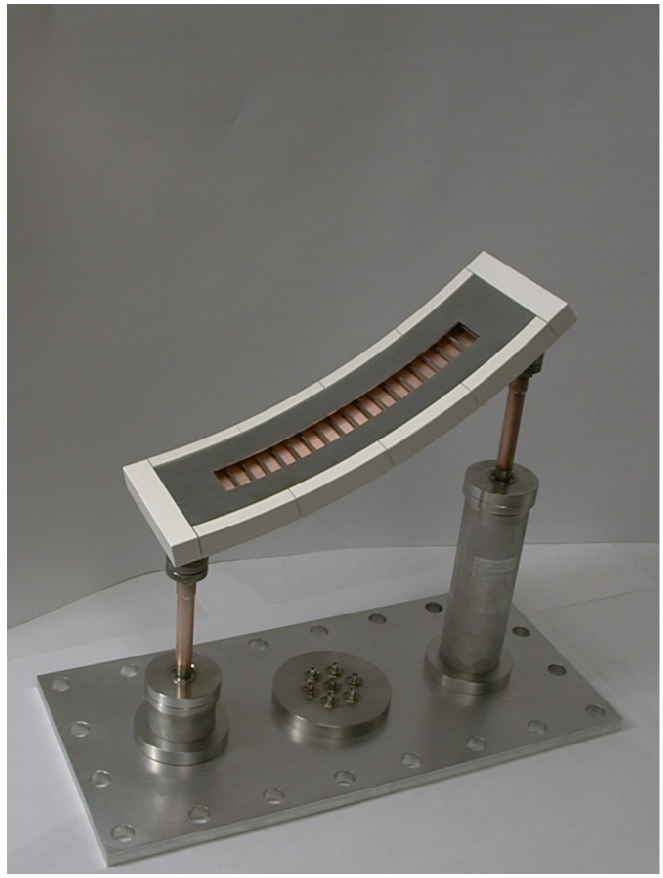
LHCD Antenna Construction



Interdigital Line Detail



Full Assembly

The antenna consists of an interdigital slow wave structure, enclosed in a cavity, with an aperture for electrostatic coupling to the plasma. Phase between rods is $\pi/2$. One port is powered and the other terminated. Wave launch direction is reversed by interchanging driven and terminated ports.

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LHCD Antenna installed in MST

• Plasma facing surface and rods are Molybdenum, edge limiter is Boron Nitride

• Antenna still intact after 1 year in vessel
(photo taken at installation 10/99)

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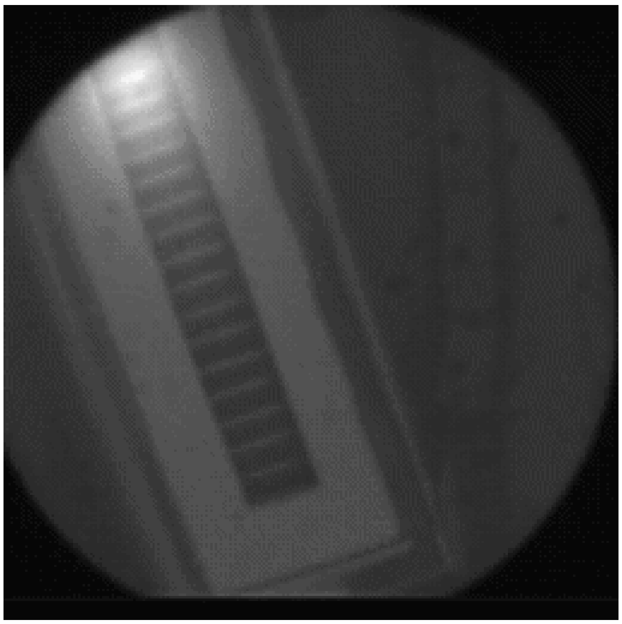
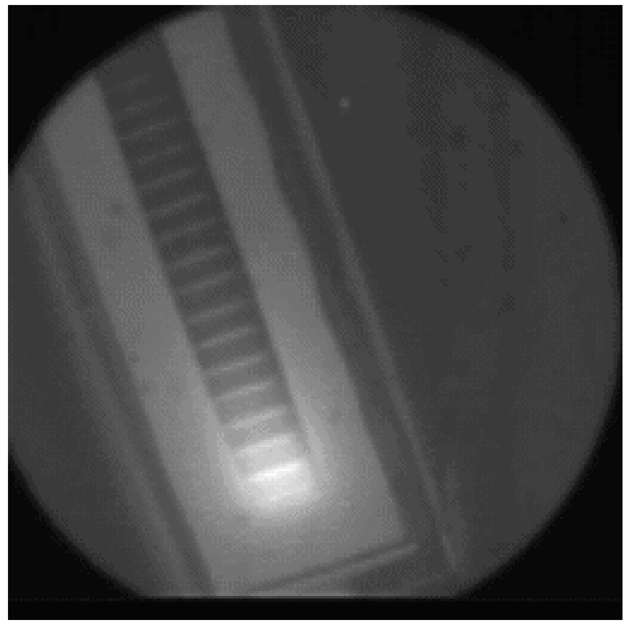
Video Images

During initial high power operation, some localized antenna-plasma interaction was observed:



Inboard Port



Outboard Port

- After several shots the light emission decreased to zero, suggesting gas desorption

- Presently no light emission is seen for input power as high as 20 kW

- A CCD Spectrometer viewing the antenna directly shows no indication of Cu or Mo impurity lines

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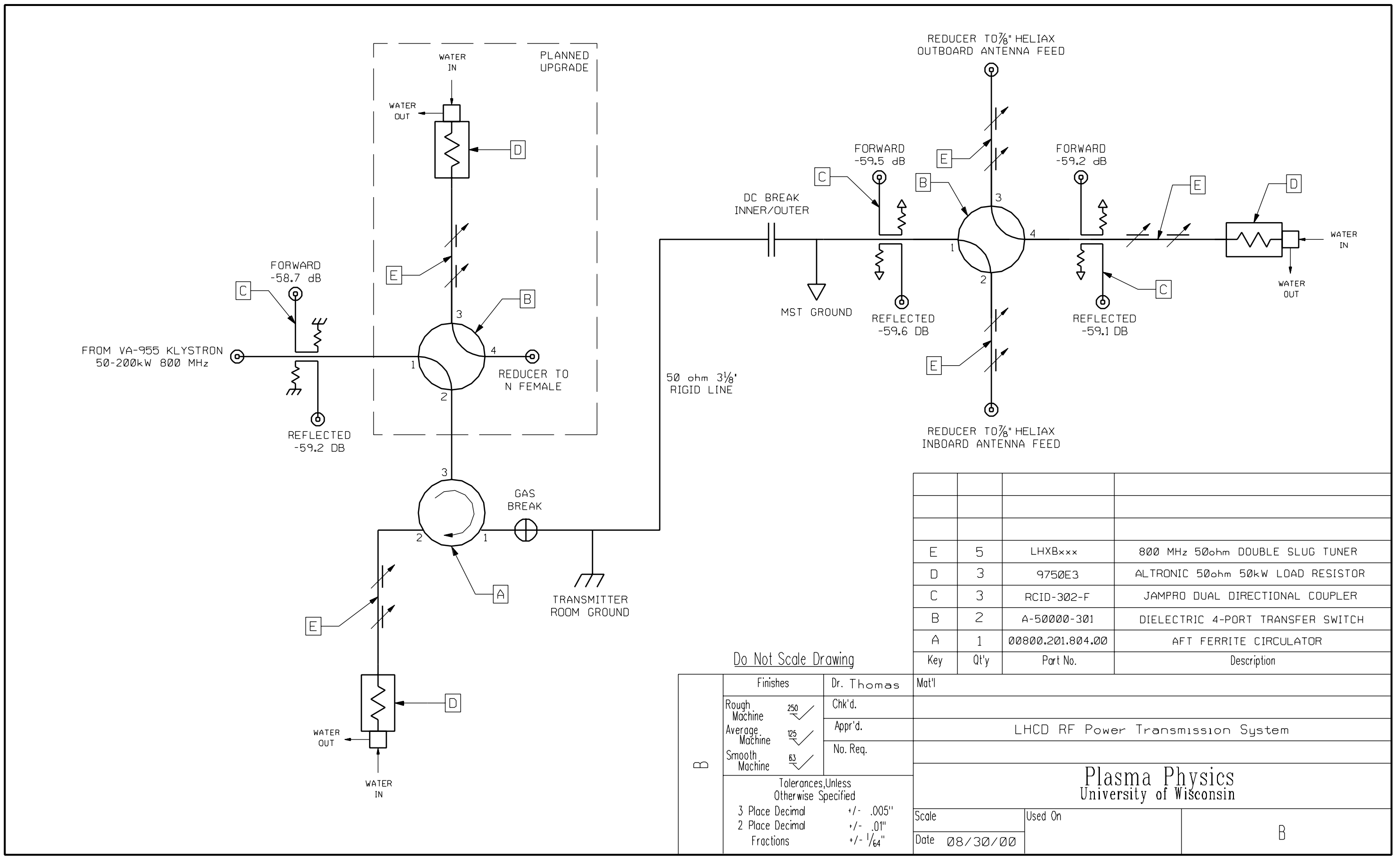
Instrumentation

RF transmission system schematic:



- Directional couplers with diode detectors used to monitor RF power in antenna feed and termination

- $|S_{11}|$ and $|S_{12}|$ calculated

- Improved electronics under development for vector measurements of antenna impedance

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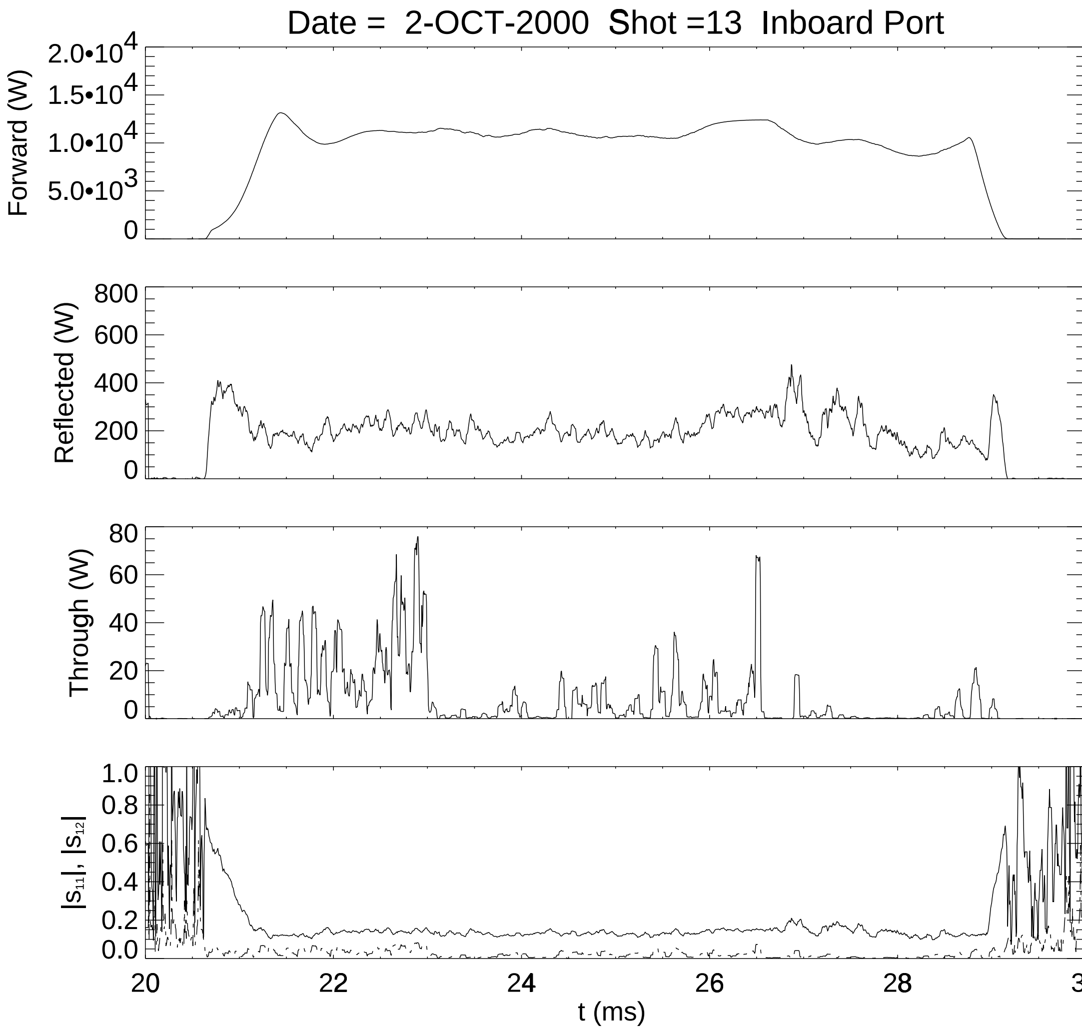
Typical Inboard Port Data

Ip = 425 kA   ne = 6x10^{12} cm^{-3} Prf = 10 kW



• **Input reflection coefficient decreases smoothly as input power rises and impedance match improves**

• **Less than 0.5% of input power exits the outboard port to the load (see next slide)**

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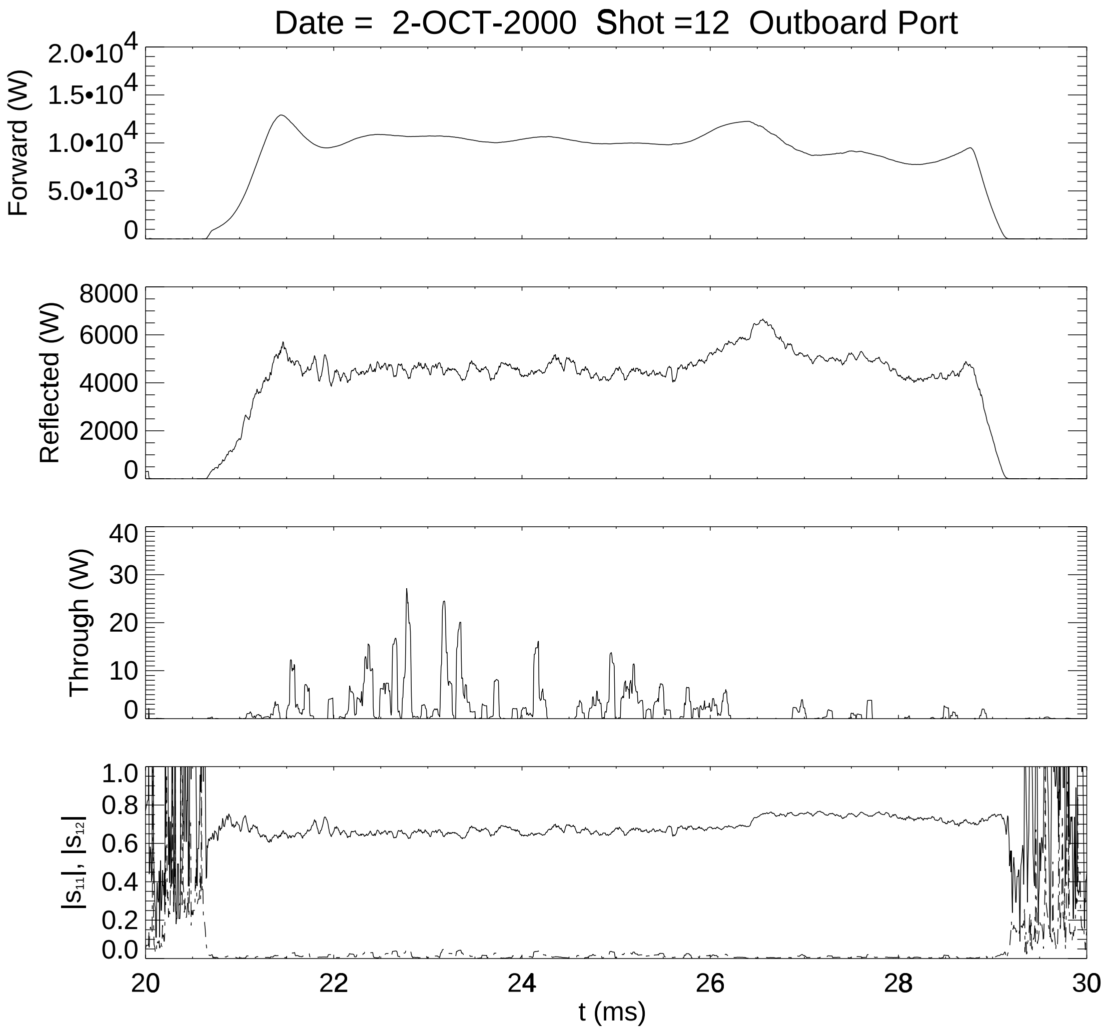
Ip = 425 kA   ne = 6x10^{12} cm^{-3} Prf = 10 kW



• **Input reflection coefficient remains high at all input power levels, impedance match is poor in the presence of plasma**

• **Outward equilibrium shift may contribute to asymmetry in plasma loading of antenna cavity; inboard BN limiter does not fully shadow outboard end of antenna aperture**

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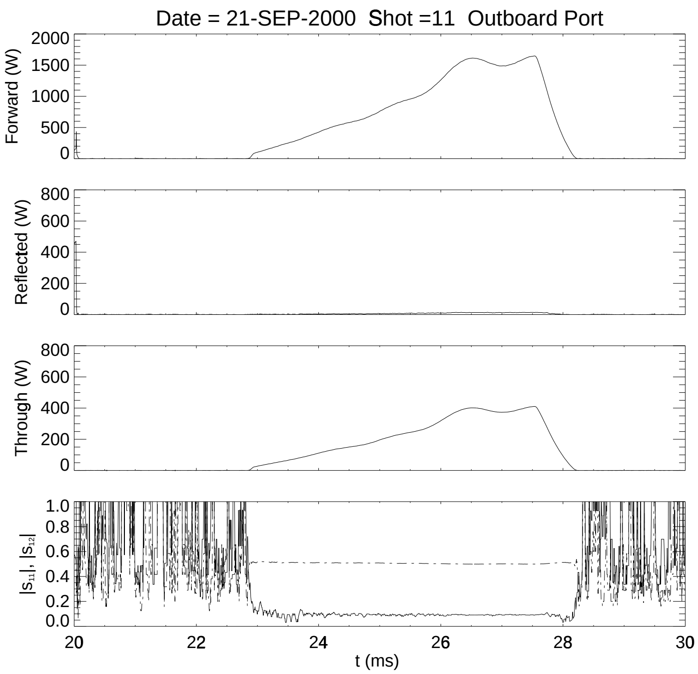
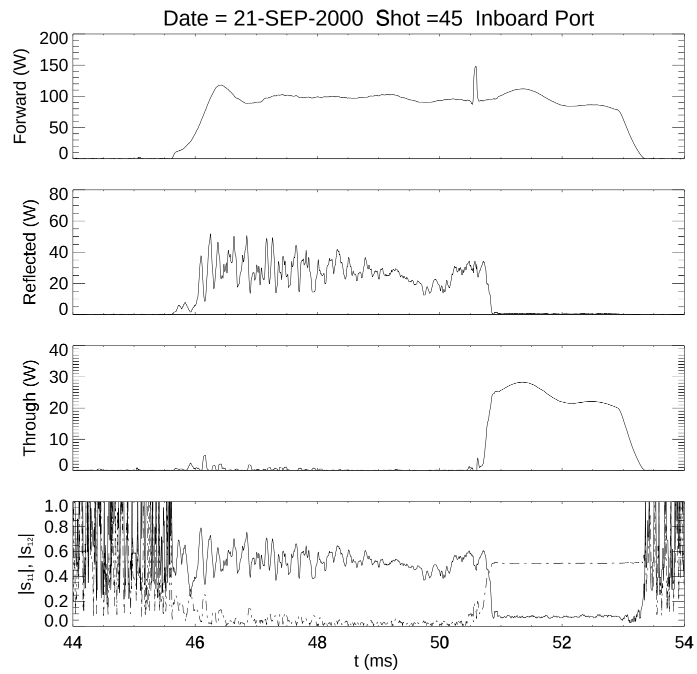
Vacuum vs. Plasma Loading





Vacuum

Plasma Termination at 50.7 ms

- **Both ports are well matched in vacuum**

- **Vacuum impedance match is restored within ~0.5 ms of plasma termination at low power**

- **A distributed limiter is being designed to protect the antenna cavity from internal plasma loading and will consist of an array of narrow Boron Nitride strips across the antenna aperture**

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Computer Modeling

- The Interdigital Line (IDL) coupled to MST plasmas is being modeled at ORNL using RANT3D and GLOSI

- 90 degree phasing between elements gives desired spectrum

- Electric and magnetic fields are found to be appropriate for launching the lower hybrid wave

- Power absorption is consistent with a damping length of ~40cm, approximately twice the length of the present antenna

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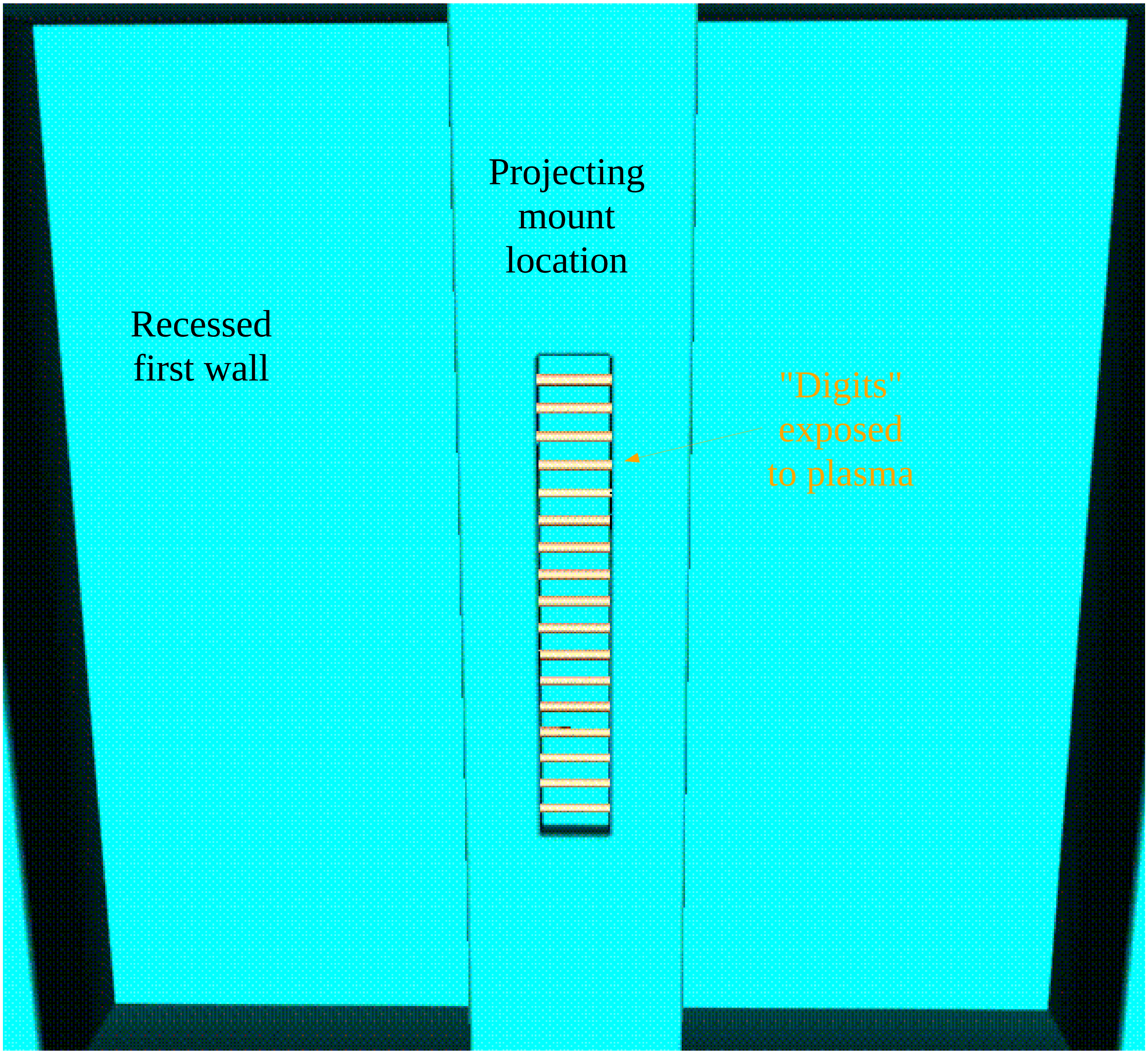
Simulation Geometry

Preliminary RANT3D model of Inter-Digital Line for MST 800 MHz, truncated side-walls, fixed $\pi/2$ incremental phasing current amplitudes linearly adjusted to balance power between input, output, and launched into the plasma



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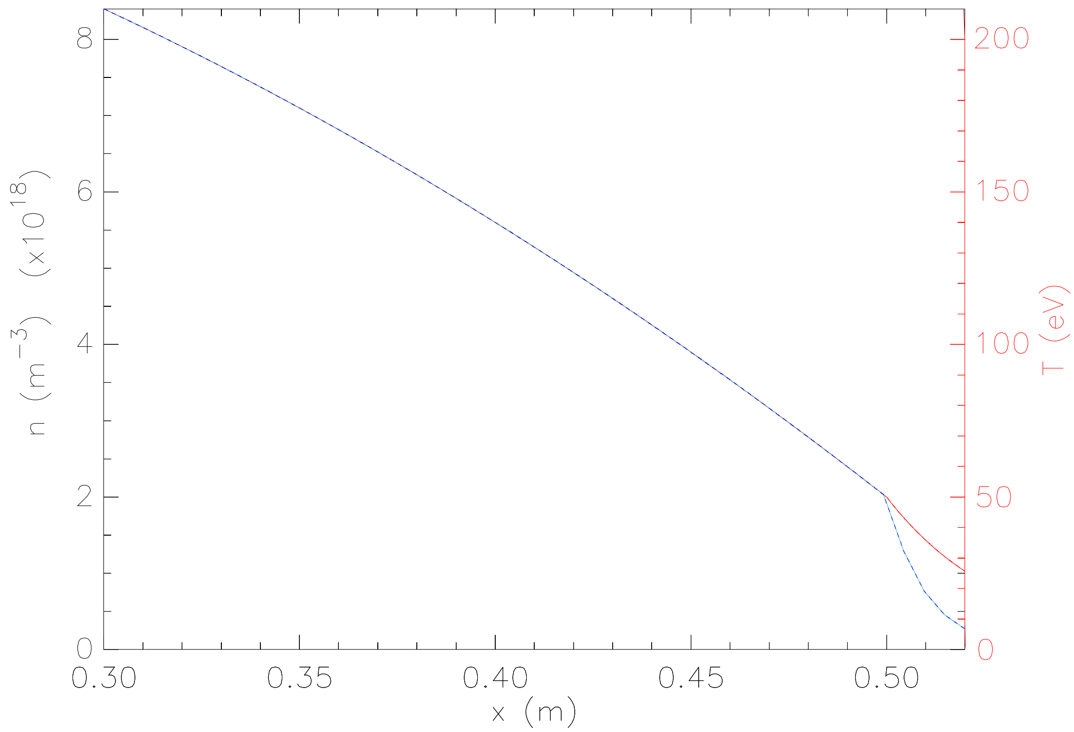
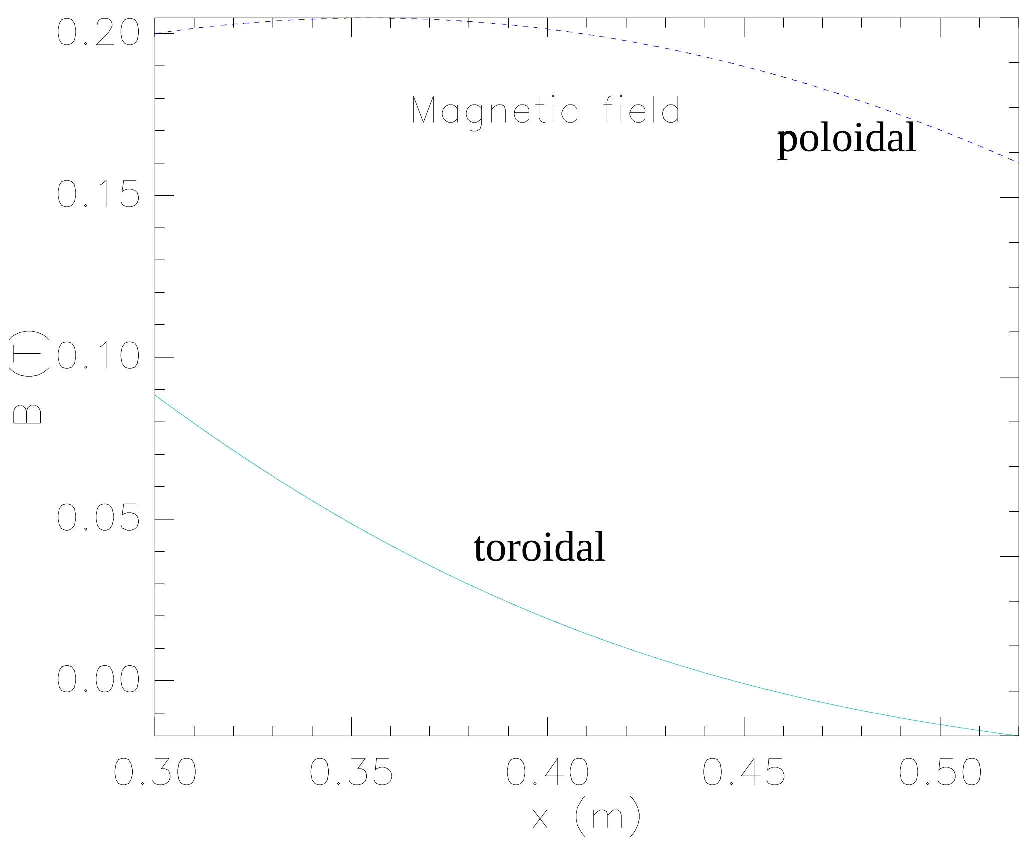
Parameters for Warm Plasma Slab Model





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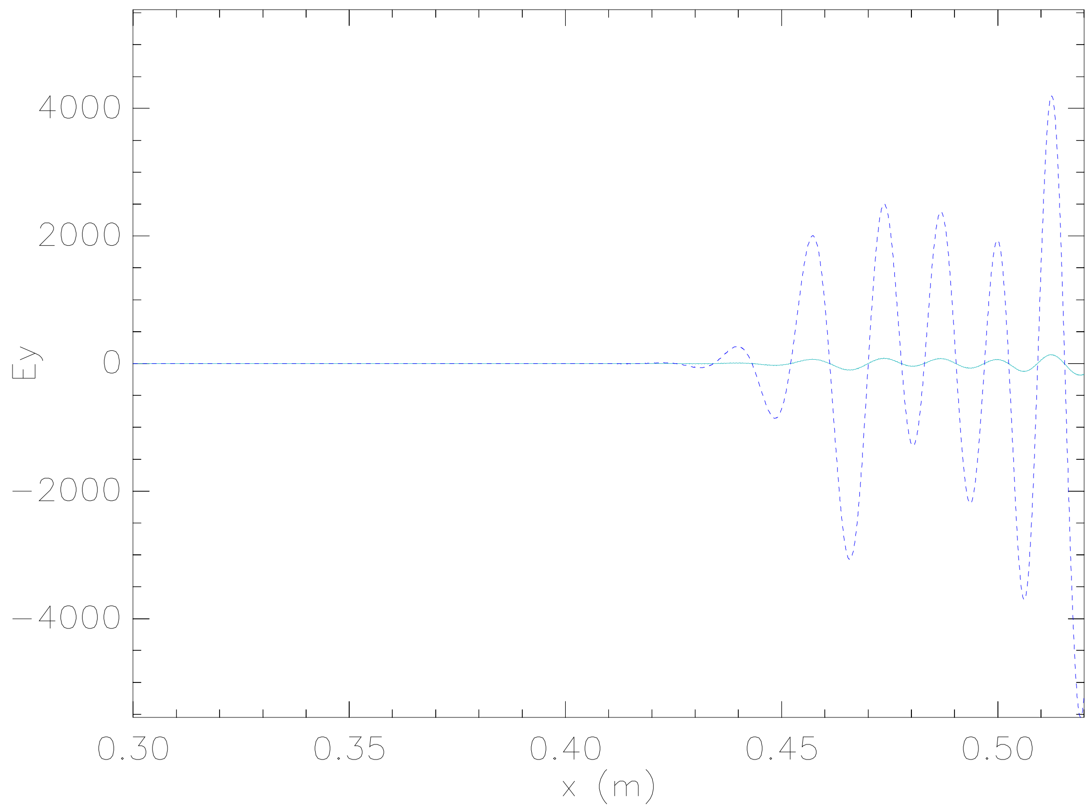
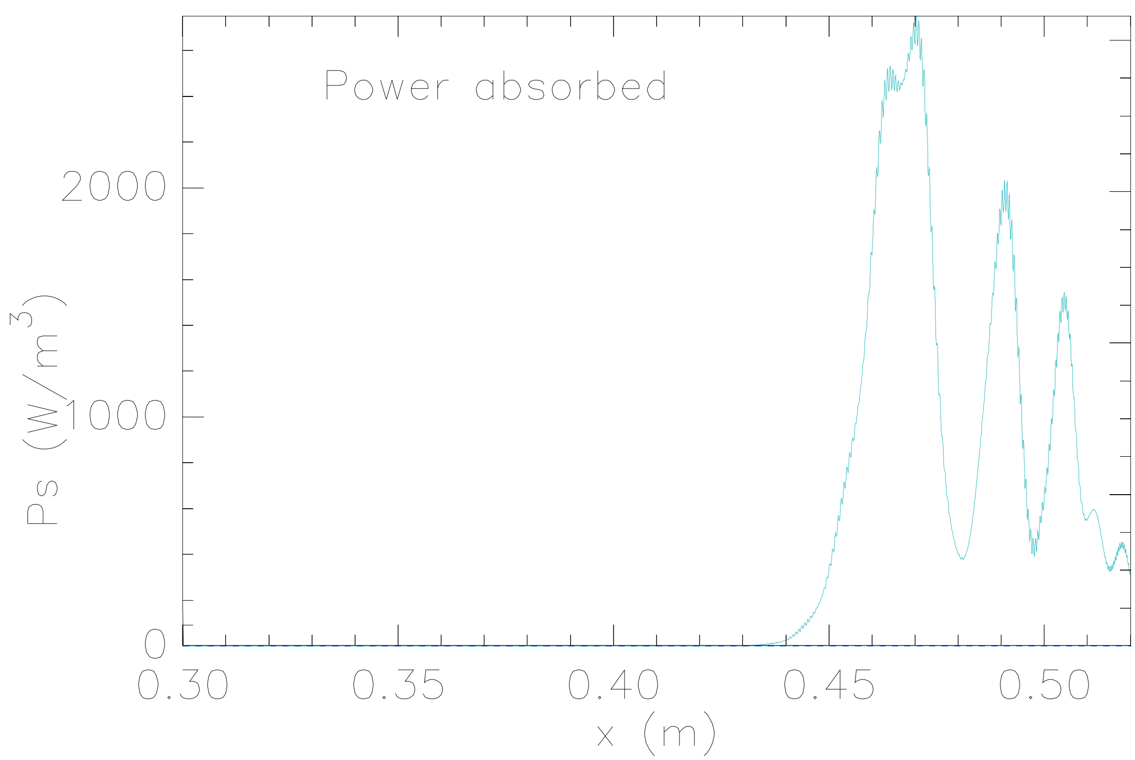
E Field and Absorbed Power vs. Minor Radius





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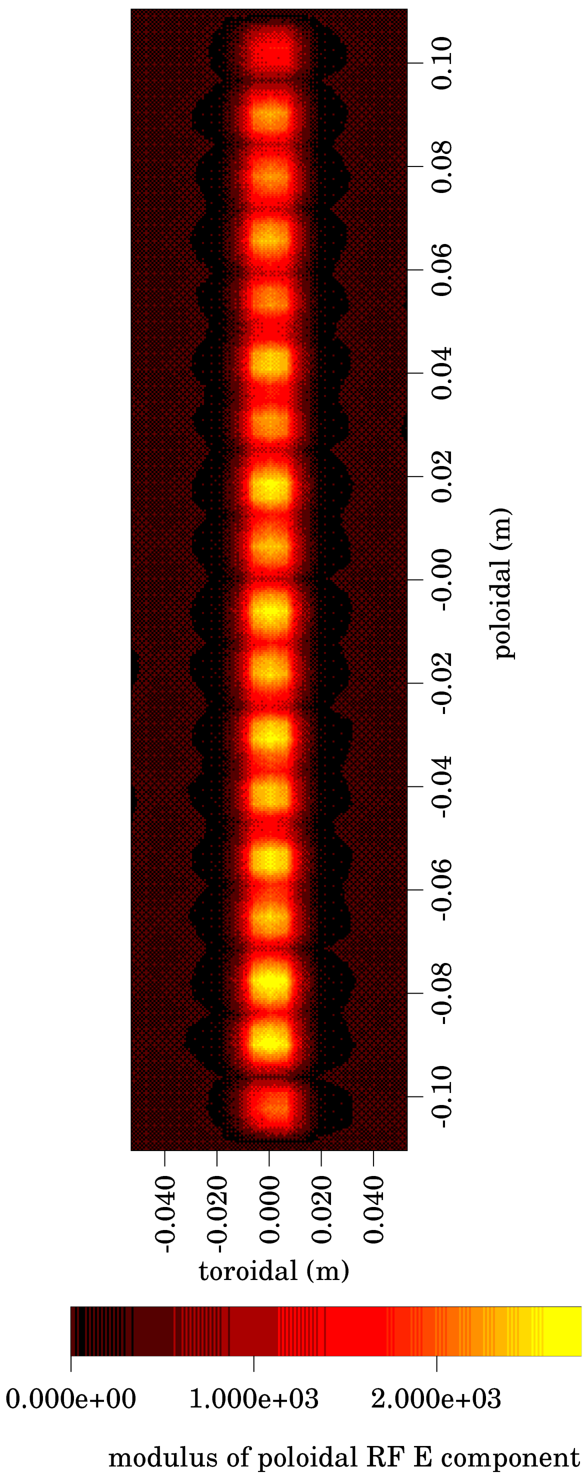
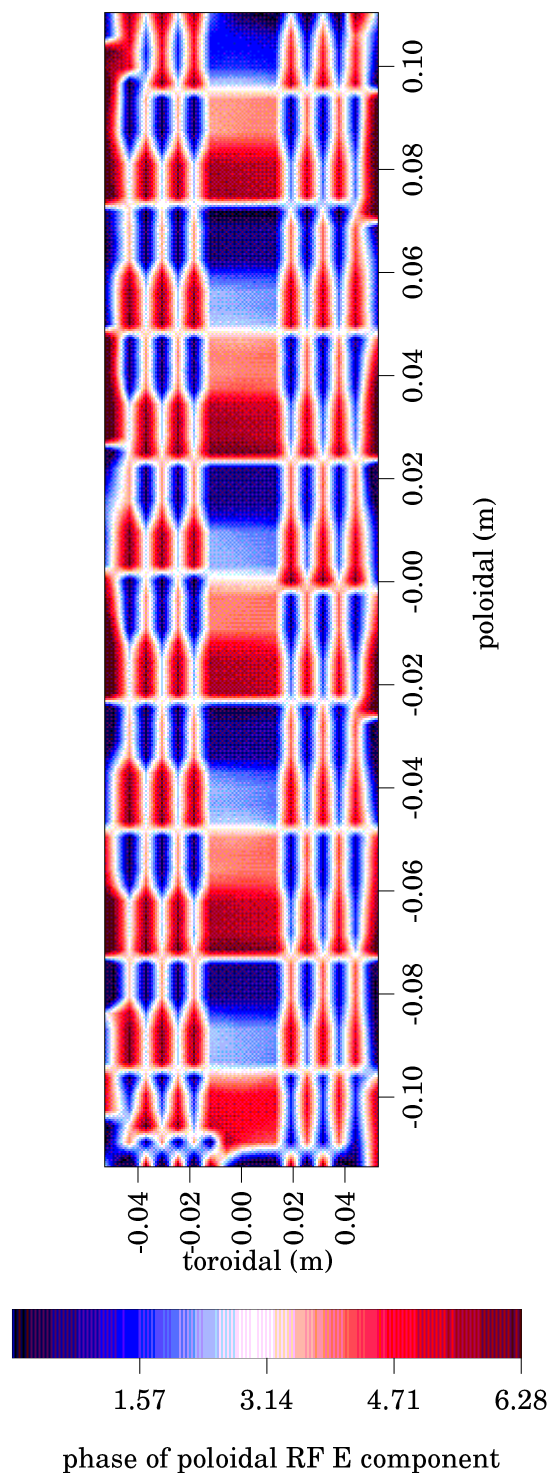
Electric Field

Poloidal electric field and phase are correct for lower hybrid
~37% power to plasma, ~63% of power to the dump





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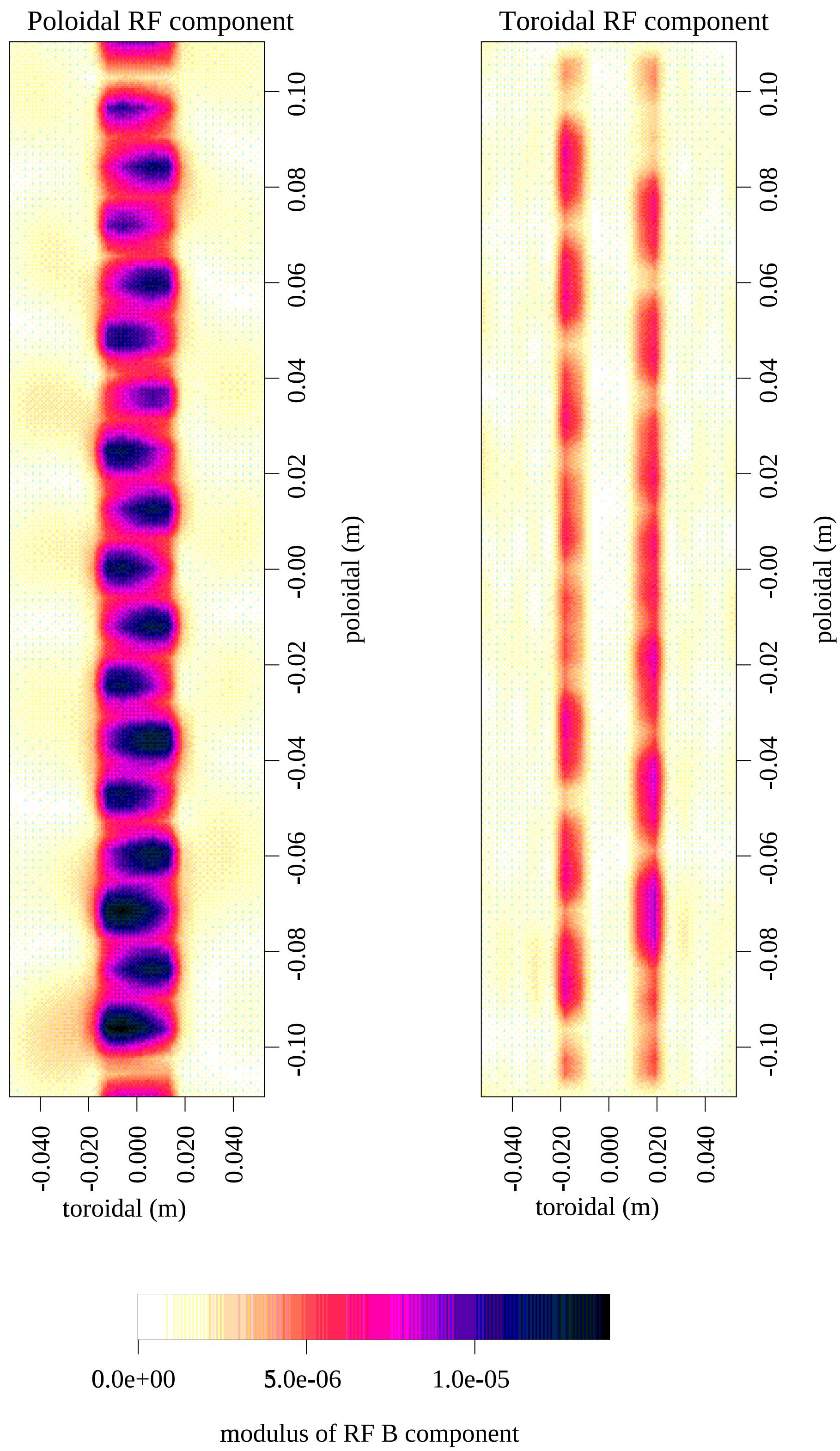
Magnetic Field

Approximately consistent magnetic field components for IDL in MST using RANT3D model



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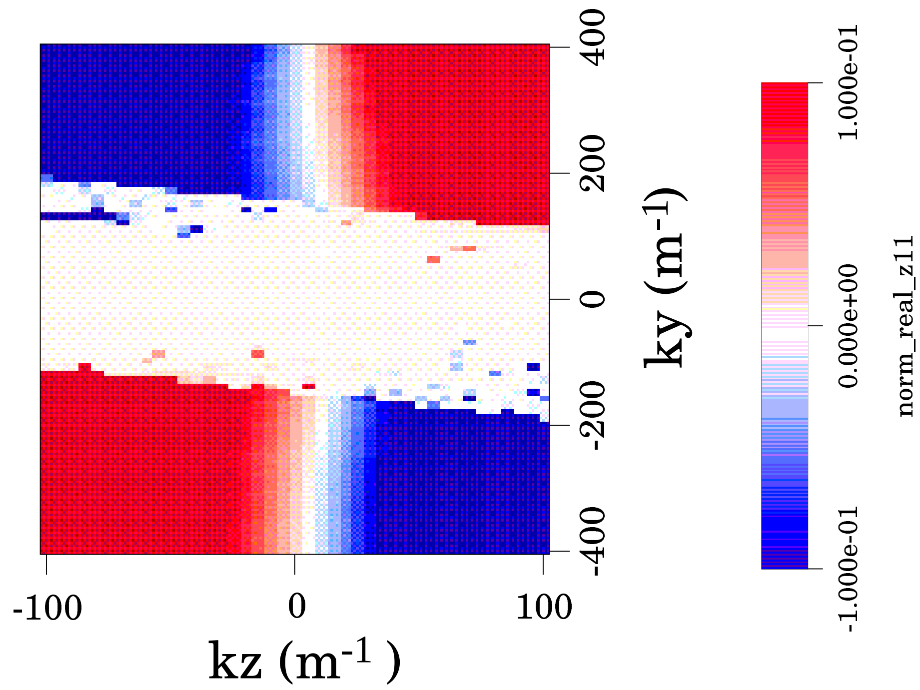
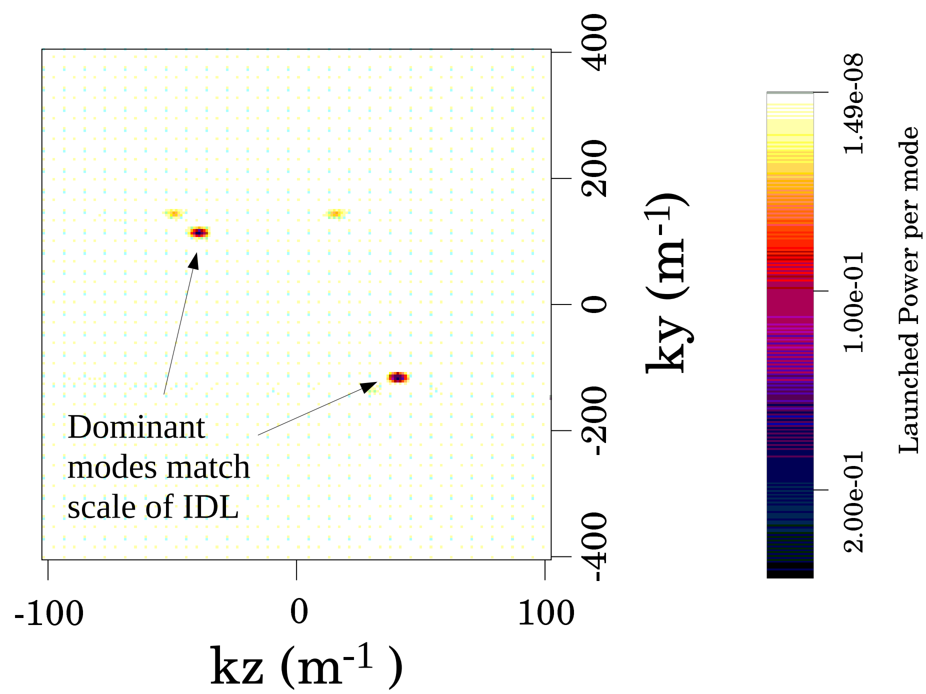
Wave Spectrum

Plasma response to main driving polarization



IDL launches power at desired angle



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Summary

• LHCD System is installed and functional, plasma loading problems are presently being addressed

• A limiter is being designed to control density along front of antenna

• 3D electromagnetic computer modeling of antenna coupled to plasma is ongoing

• Preliminary results are in good agreement with previous circuit simulation and measured fields of bench prototype, and also indicate desired plasma response

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Reprints

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