

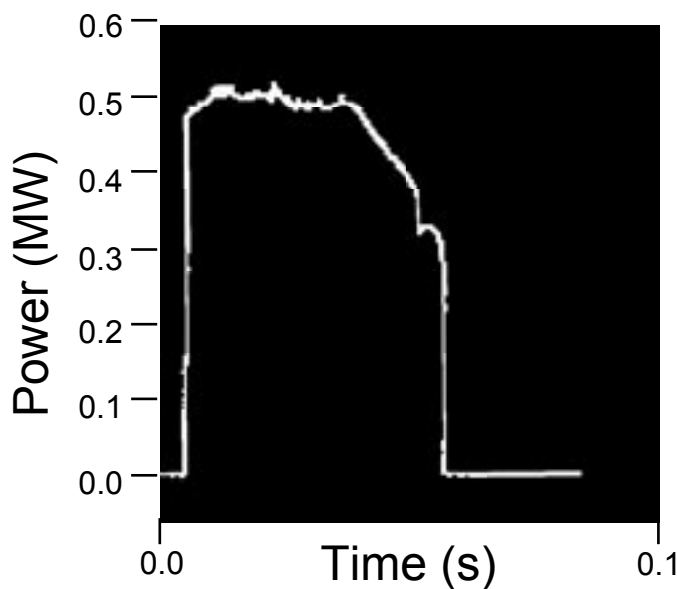
## **High Harmonic Fast Wave Heating in Pegasus - P.H. Probert, G.D. Garstka, T. Thorson, R.J. Fonck,**

The University of Wisconsin An antenna and RF power system has been developed to provide up to 1 MW of RF heating to the Pegasus plasma using high harmonic fast wave (HHFW) heating in the frequency range of about 20 times the ion cyclotron frequency (15 MHz). The antenna consists of a pair of straps driven at 180 degrees of phase, with a parallel wavenumber of 10 per meter. A unique feature of our antenna is that it is rotatable, allowing alignment with the local magnetic field. We have designed the antenna and chosen the phasing to pursue heating and to minimize impurity generation. It has a 50 percent transparency stainless steel faraday shield, closed stainless sidewalls, and closed septum between the straps. The straps are hard-wired in anti-parallel for 180 degree phasing. The power system consists of the 1 MW (upgradeable to 2 MW) system originally developed for use in Alfvén heating and current drive experiments on the Phaedrus-T tokamak. This system has been upgraded with new output cables and improved instrumentation. We have completed low power loading tests into Pegasus plasma, finding 2 ohms loading (2 straps in parallel, 180 degree phasing). Currently, high power tests have begun. The goal is to use the RF to increase the plasma beta. Further, we will explore the use of RF to modify the plasma resistivity and thus the current profiles and to aid in plasma startup.

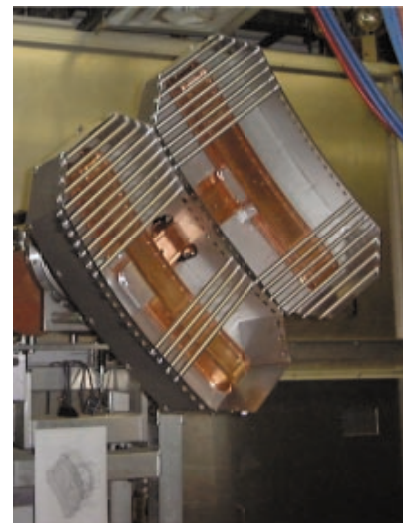


# HHFW Heating to Provide New Tool for PEGASUS

- HHFW system installed and development of heating capability underway
  - $P_{RF} = 1\text{-}2\text{ MW}$  ultimately available
    - *First antenna and power supplies provide  $\sim 0.7\text{ MW}$*
    - *Sufficient to access high  $\beta_t$  regime*
  - Initial loading tests give an impedance of about 1 Ohm
  - Coupled  $P_{RF} \approx 100\text{ kW}$  to date



RF forward power results from  
~ 50 ms test into dummy load





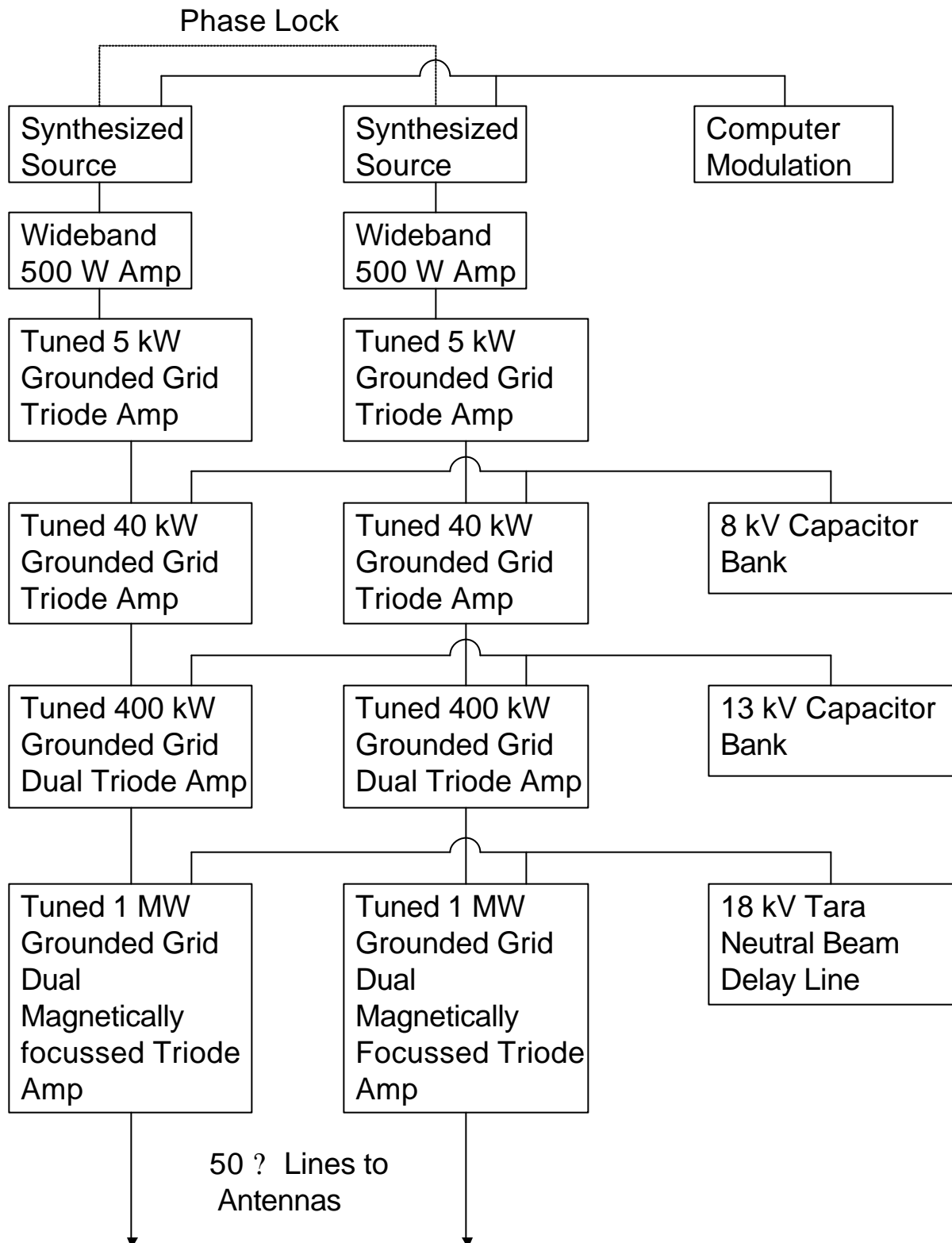
# HHFW Heating Will Aid Pursuit of PEGASUS Goals

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- **HHFW applications:**

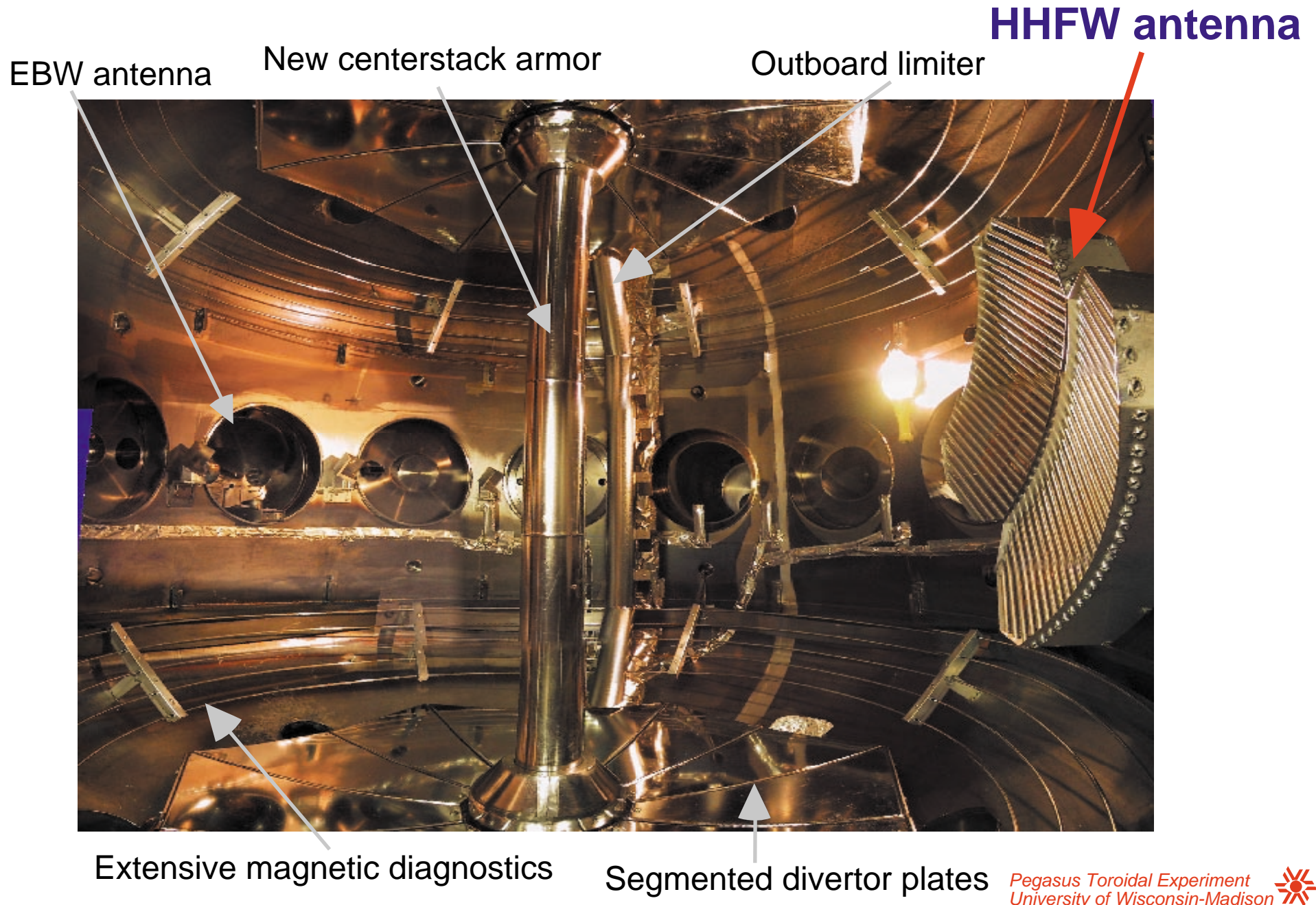
- MHD control
  - *electron heating; reduce resistivity earlier*
- Startup assist via preheating and/or current profile “freezing”
  - *Startup plasma phase: 40% single pass absorption*
  - *High  $\beta$  plasma phase: 100% single pass absorption*
- CD possible with present power supply and new antenna

# Pegasus RF System





# 2-Strap Antenna Installed

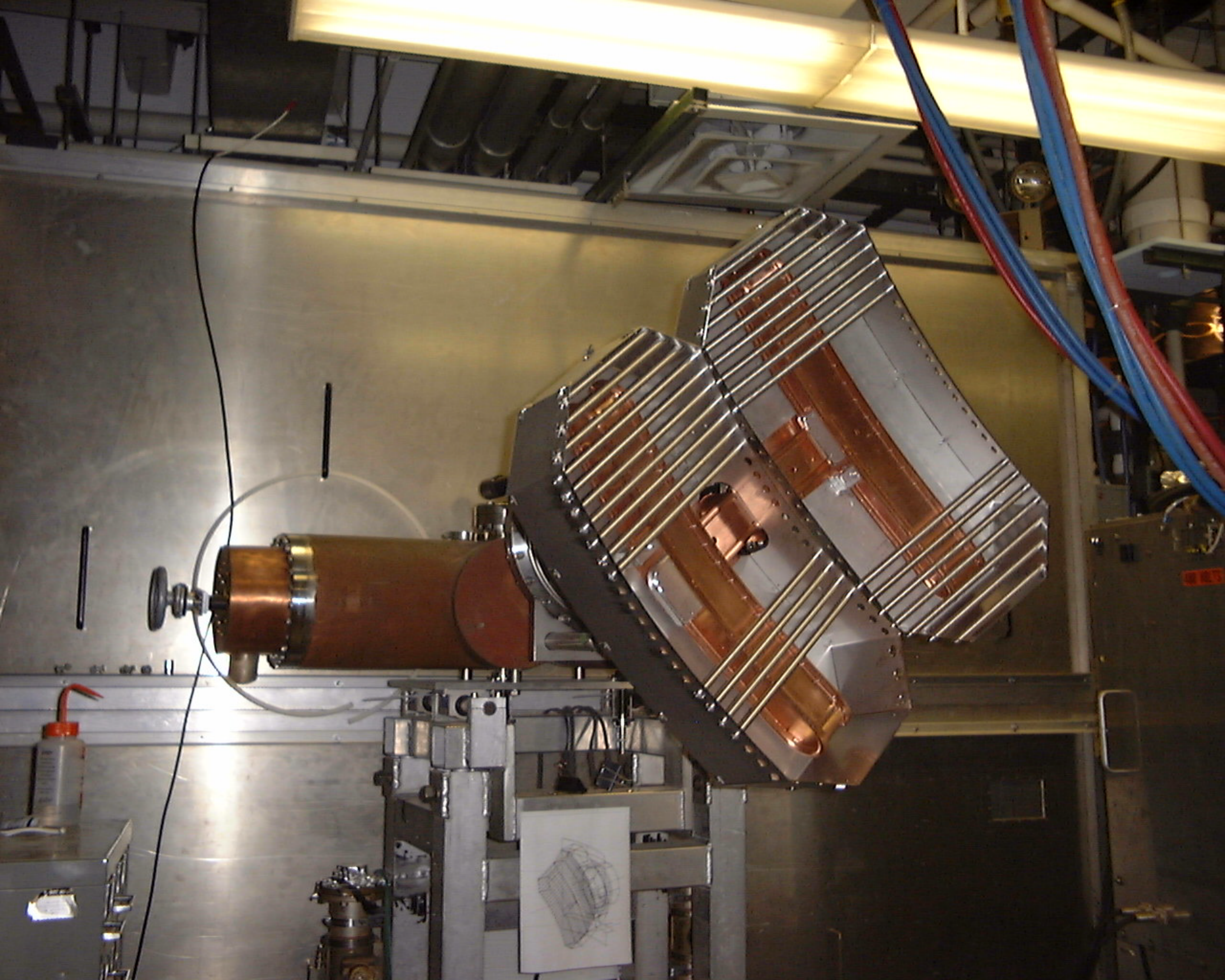


Antenna is a 2 strap design, fed in antiparallel for 180 degree phasing. The straps are curved and mounted to fit a .85 m radius sphere.

$k_{\text{parallel}} = 10.5 \text{ m}^{-1}$ ,  $n_{\text{parallel}} = 30$ ,  $f = 15 \text{ MHz}$ .

A stainless faraday shield with 50% transparency is used. The antenna sides are solid stainless, and there are solid stainless septa between the straps.



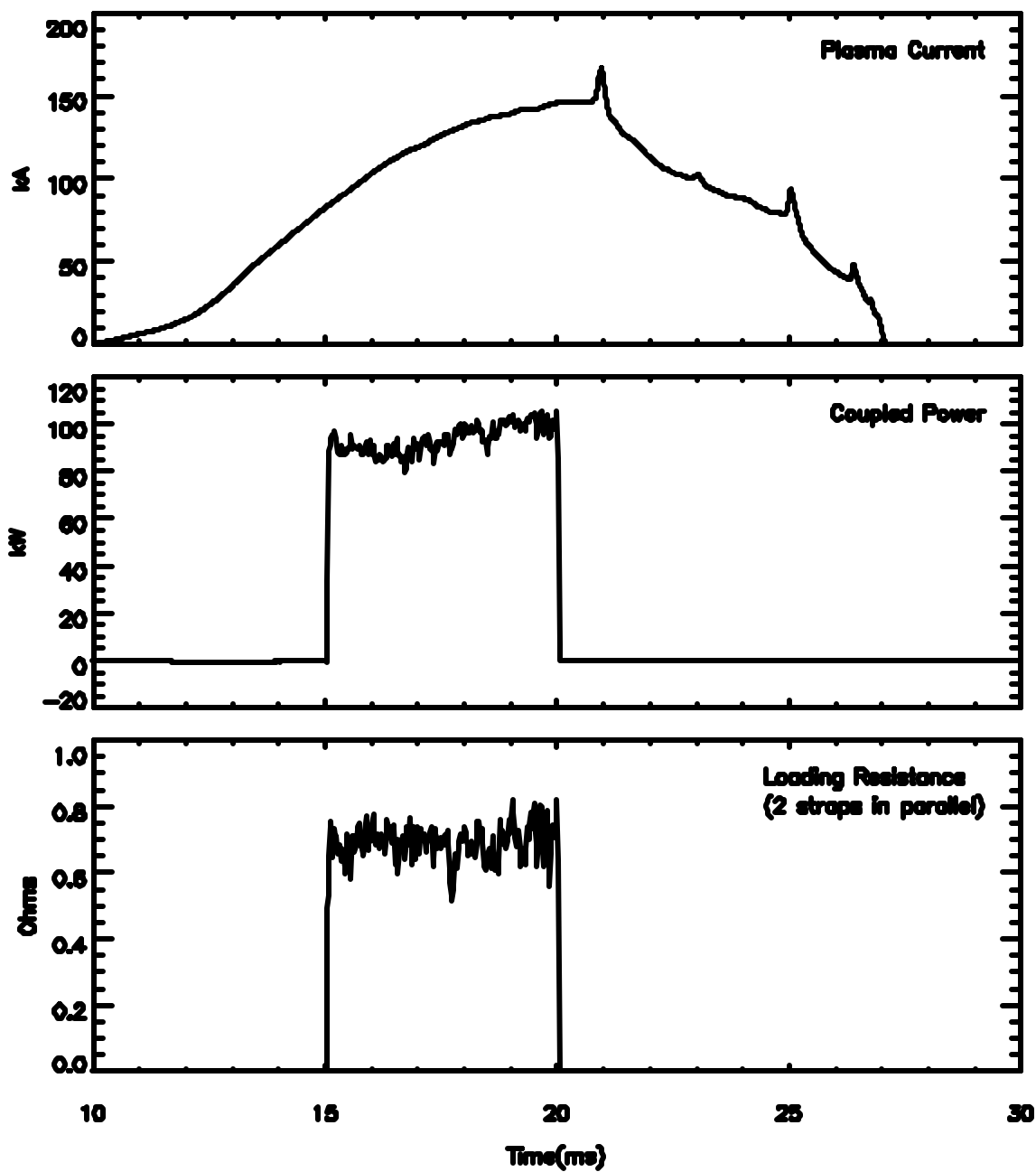




Excellent loading of 1.2 ohms per strap was obtained, largely insensitive to plasma conditions, as predicted by the slab model. 100 kW coupled power has been obtained so far. Matchbox arcs have limited the power. Coupling is good during current ramp-up.



# Shot 13215





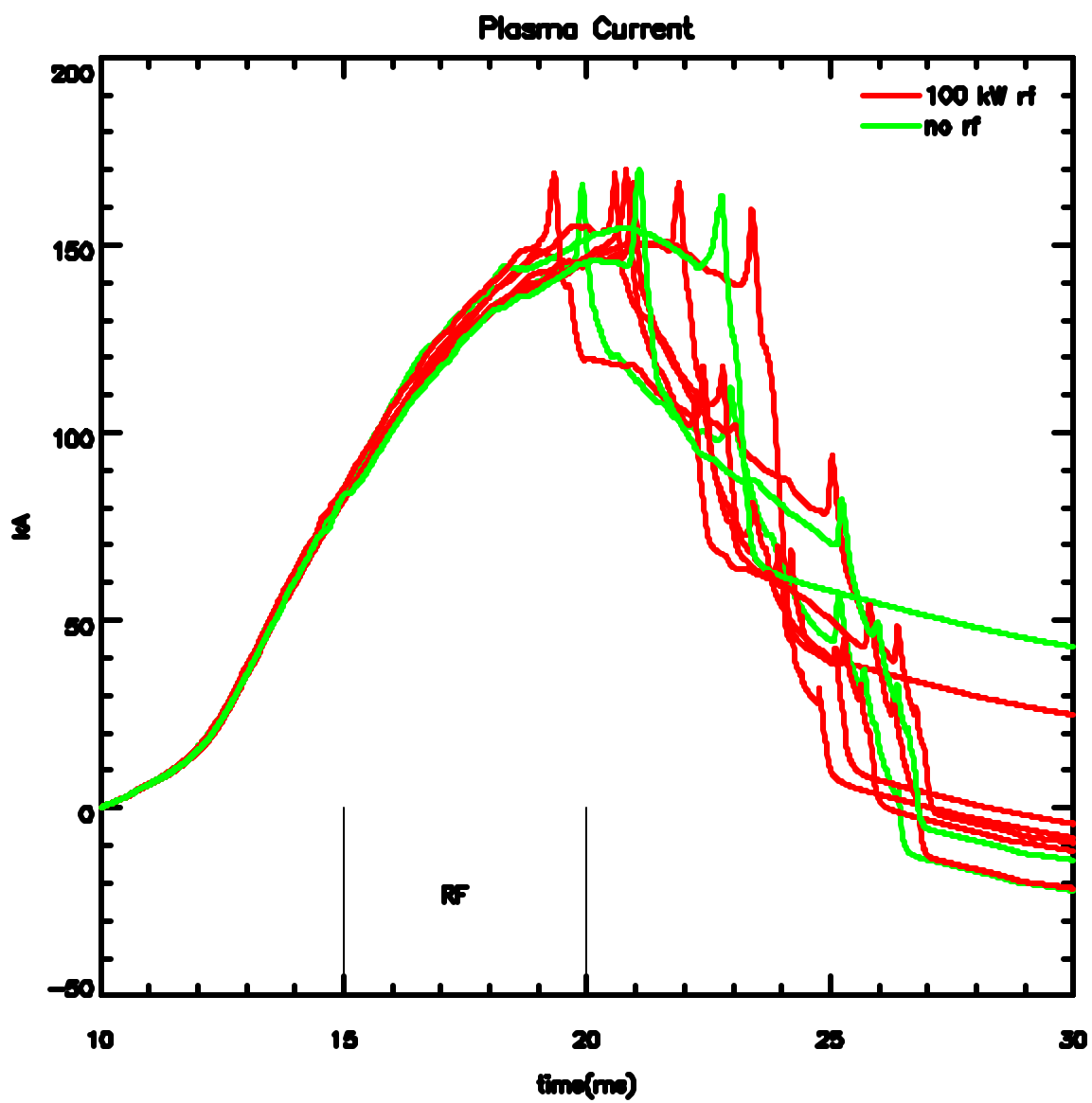
# No Strong Effect on Plasma During First Loading Tests

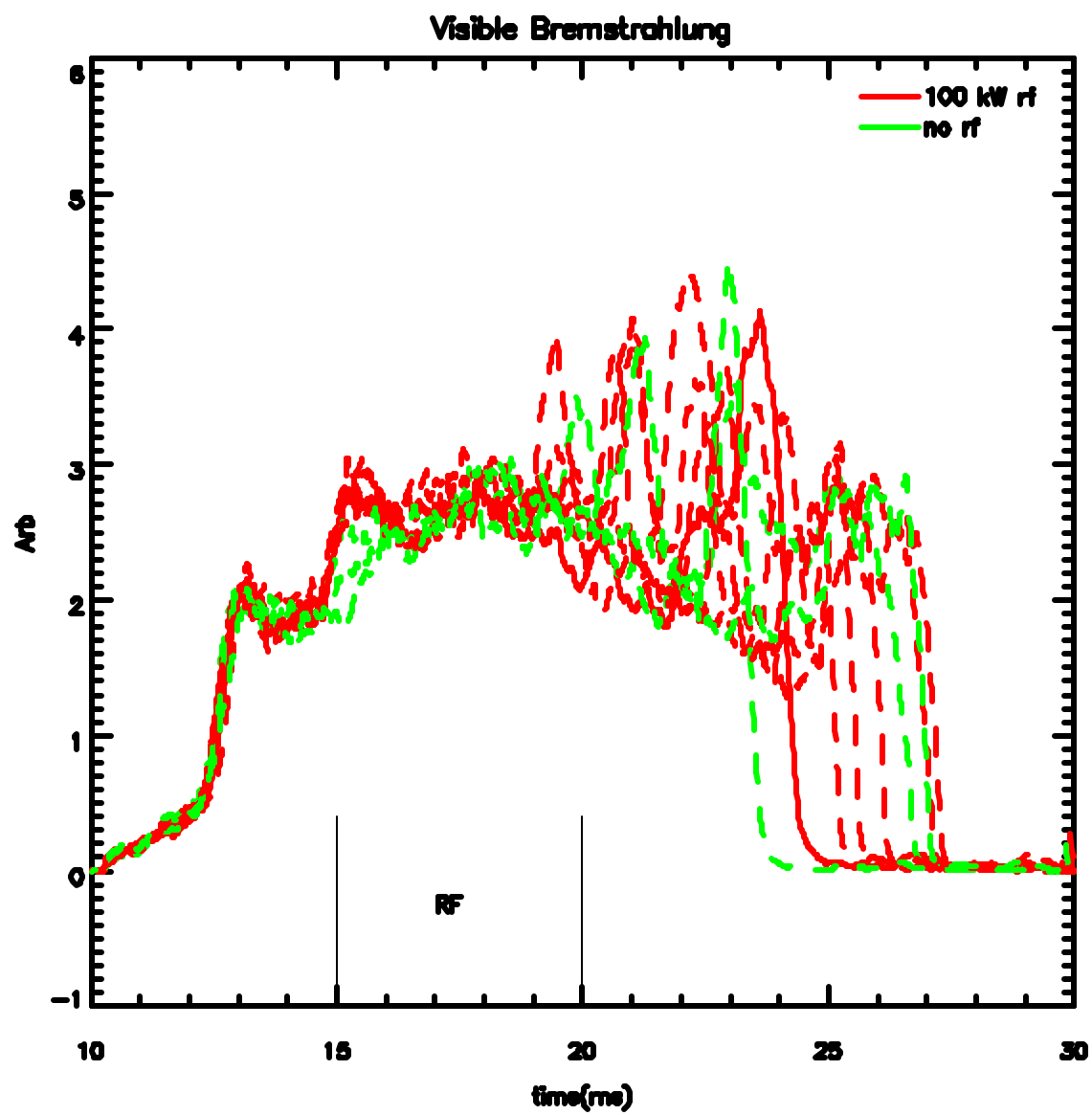
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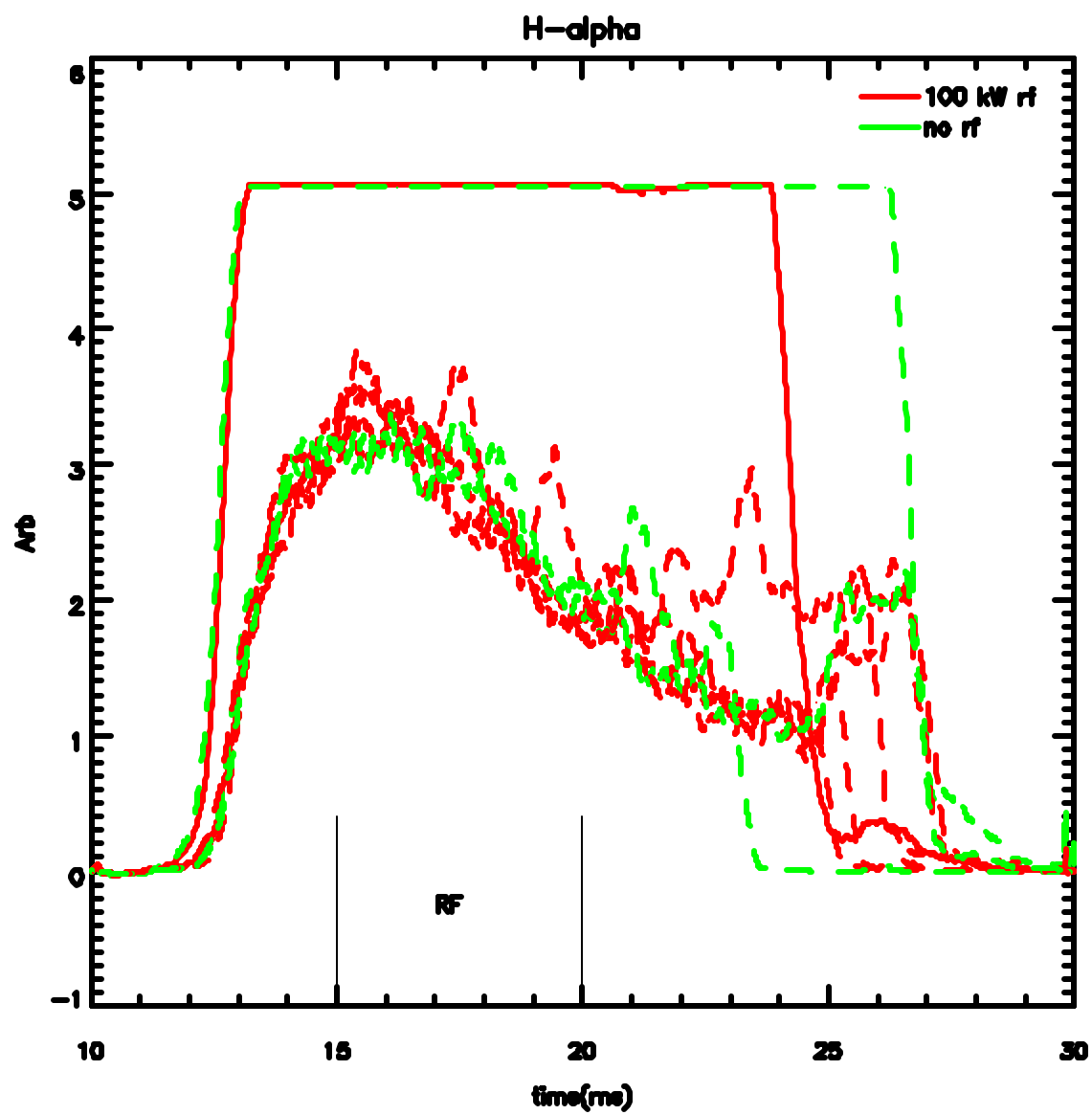
- **Plasma-antenna gap not controlled**
  - Can attain good loading, but expect efficient heating requires tailoring of gap distance
- **Plasma waveforms from plasma show no significant changes during low-power RF**
  - Plasma current, visible bremsstrahlung,  $H_{\alpha}$
  - $P_{RF} \sim 100$  KW
  - Test shots emphasizing RF system control and loading tests
- **Near-term: turn attention to conditions needed for heating**
  - Density control and reproducibility: between-shot gettering
  - Efforts to control plasma-antenna gap
  - Increase injected power to several 100 KW

Plasma current, visible  
Bremsstrahlung, and H-alpha show  
no significant changes during 100  
kW of RF.



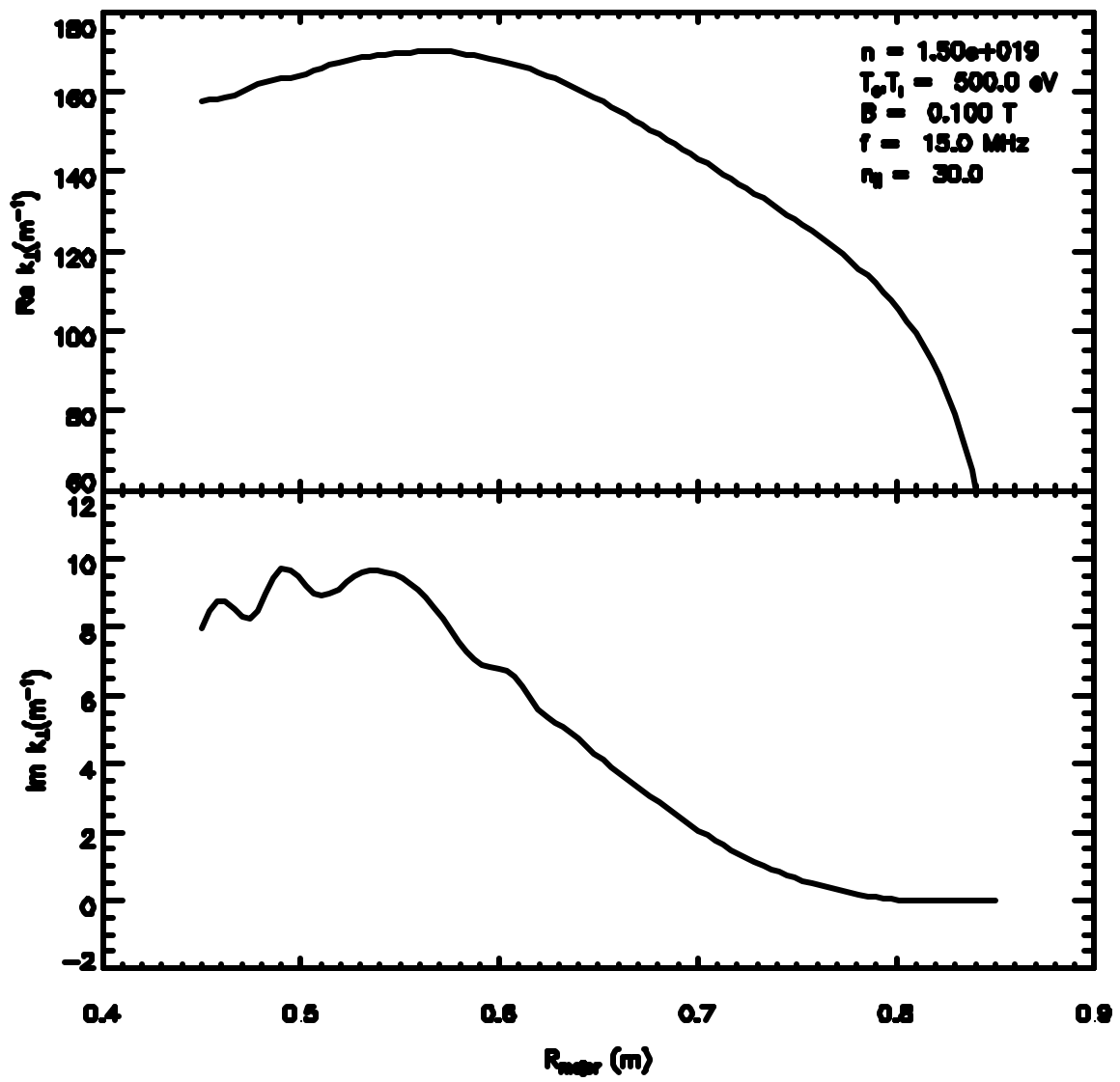




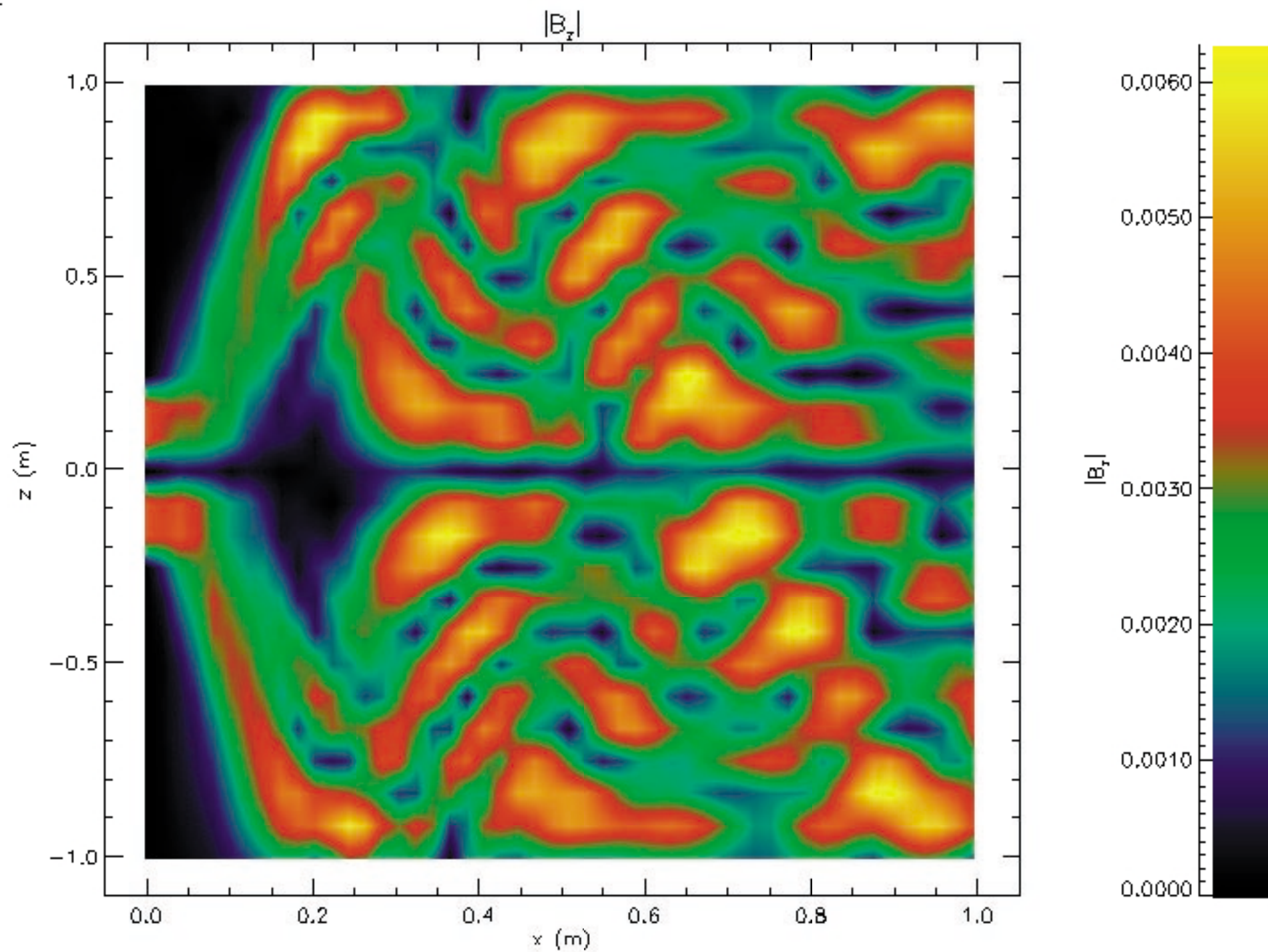




Slab model shows good absorption of RF for Pegasus parameters, little ion absorption.

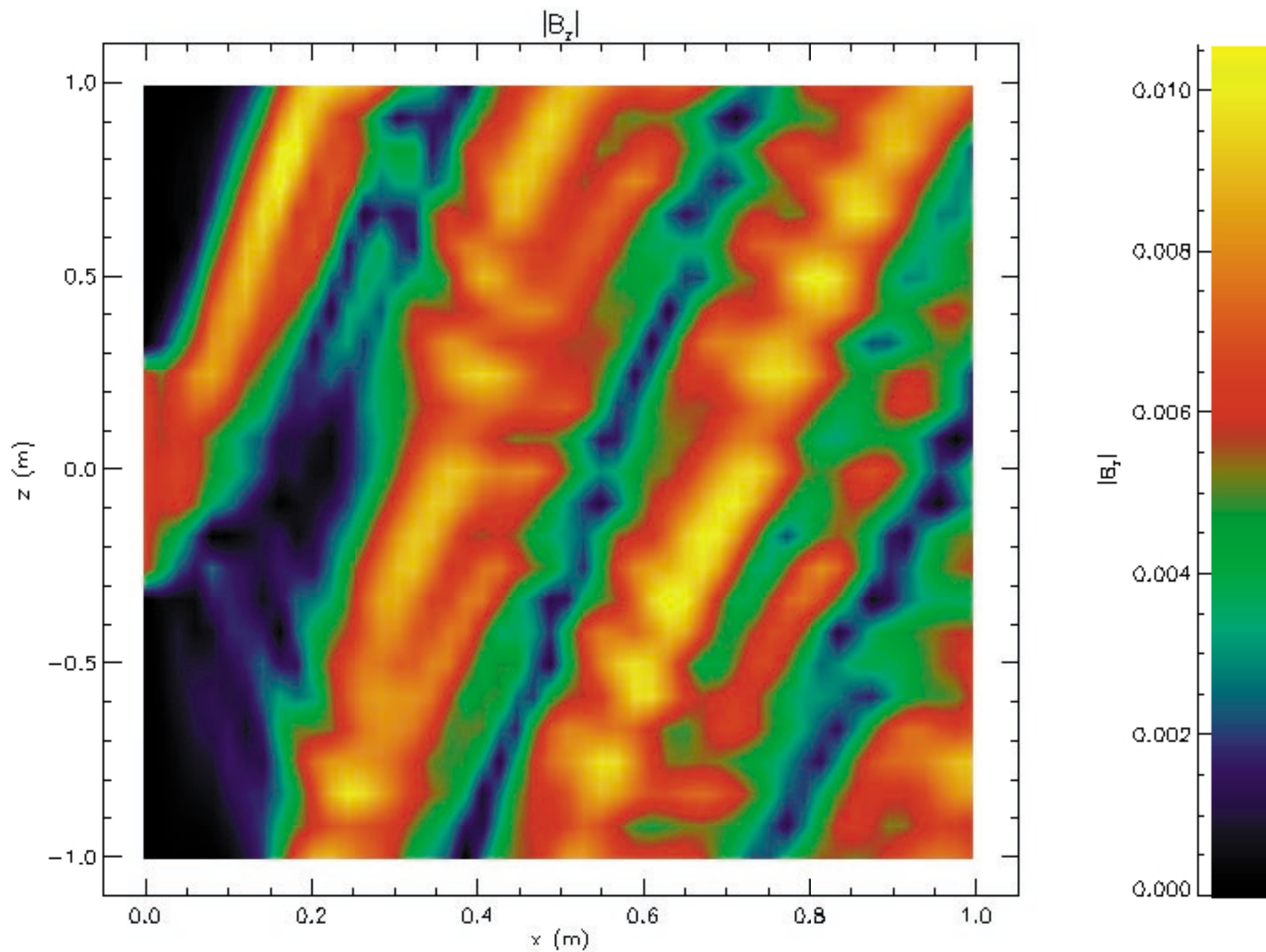


Sample Wave Fields Propagation into Plasma for 180° Phasing





# Sample Wave Fields Propagation into Plasma for 60° Phasing





## • Near-term Goals

- Increased control of plasma conditions
  - *Density control, reproducibility, improved equilibrium field control*
- Suppression of large internal resistive MHD modes
  - *Increased  $I_p$  ramp time*
  - *Attain higher  $T_e(0)$  during formation*
  - *Maintain  $q(0) > 2$  during formation*
- Control onset of suspected external kink modes
  - *Maintain  $I_p$  ramp time*
  - *Maintain high  $q_{95}$  during formation*
  - *Edge control: edge cooling, shear, etc.*
- Access to very high  $\beta_T$  regime
  - *Increase  $I_p$ ,  $N_e$ ,  $T_e$*
  - *Improved access to low- $B_t$  regime*



# Summary: HHFW Efforts Underway

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- **Flexible 2-strap high-power antenna installed**
  - Can be tilted to align with B-field
- **Power supplies and source tested to 0.7 MW**
  - $f = 11 - 19 \text{ MHz} \sim 10 - 20 \times f_{ci}$
- **First tests on machine shows good loading with plasma present**
  - PRF up to 100 KW
- **Next Campaign: move to plasma heating**
  - Increase power
    - Replaced faulty vacuum capacitors in matchbox*
  - Develop conditions for heating
    - Plasma reproducibility and density control*
    - Emphasize gap distance control*
    - Pre-programmed now, feedback proposed*