Reflectometer Sensing of RF Waves in Front of the HHFW Antenna on NSTX

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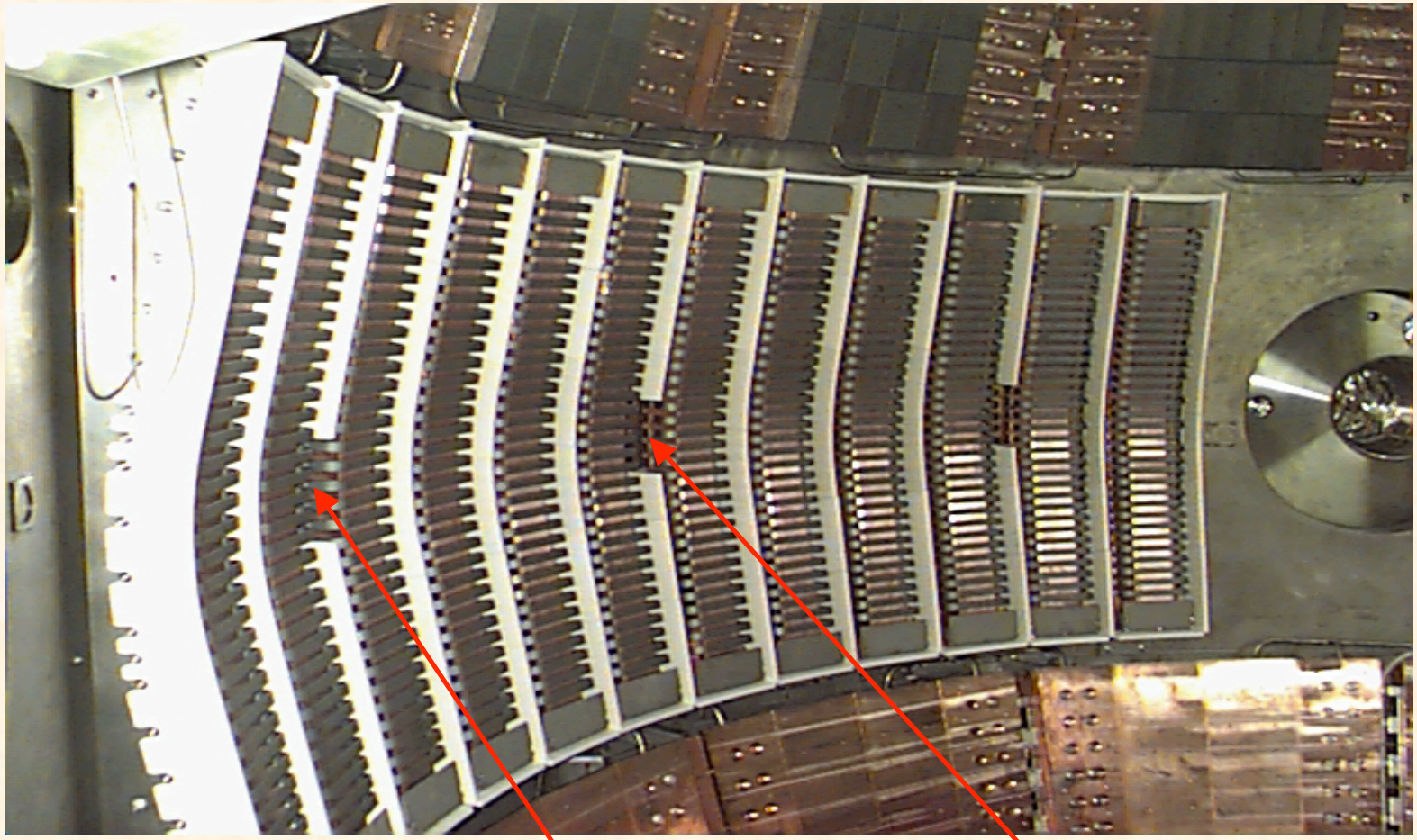
Description of the HHFW Reflectometer on NSTX

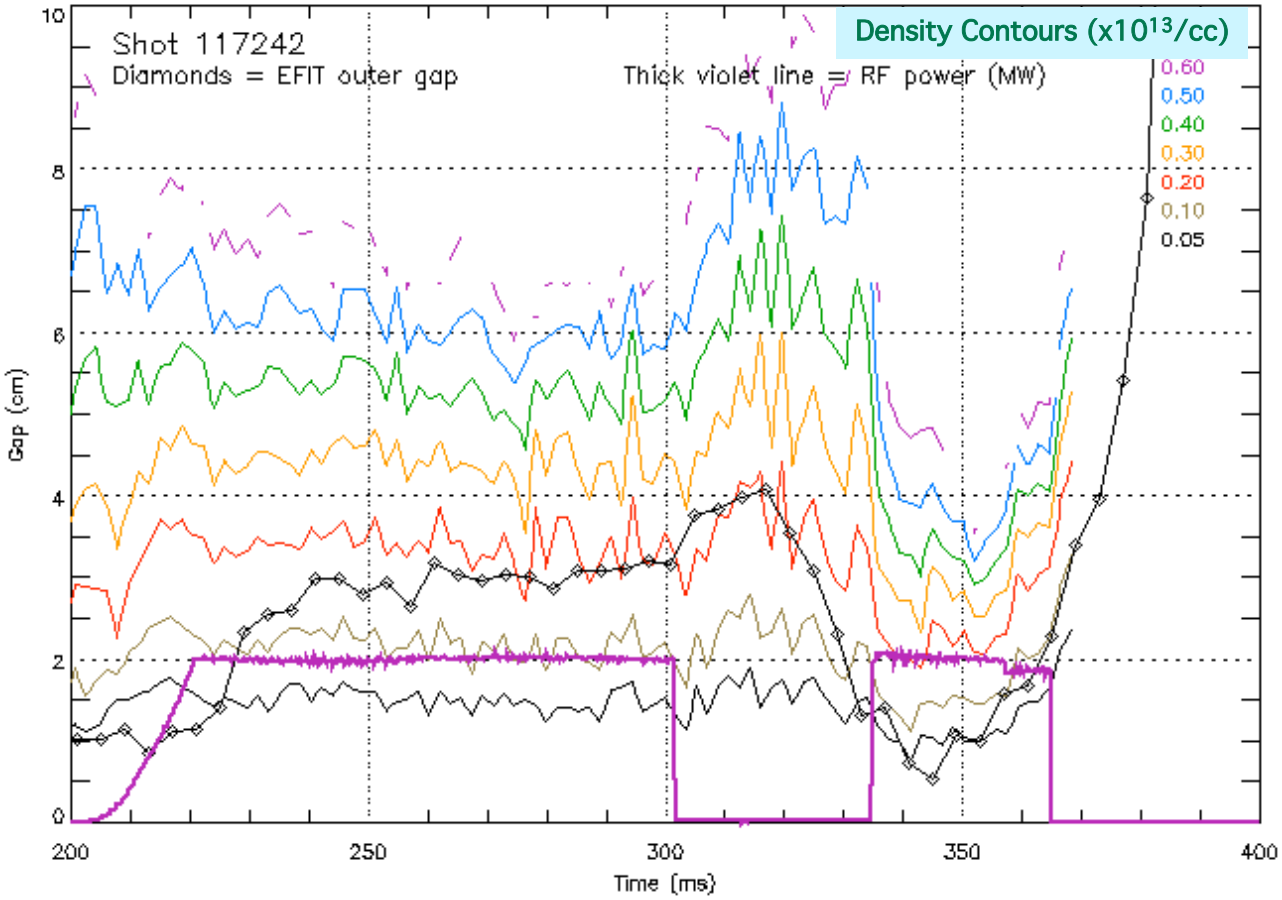
- Access to the plasma is located on the horizontal midplane, between two straps of the HHFW array.
- The X-mode reflectometer scans the frequency range from 6 to 27 GHz, probing the density profile of the scrape-off layer between the HHFW antenna, and the outermost flux surface.
- The probed density range starts below $1x10^{11}$/cc and extends up to nearly $8x10^{12}$/cc.
- Up to 1000 edge-density profiles (automatically generated for each shot) are used to monitor the evolution of the edge-density profile in front of the antenna.
- The I/O demodulator has an IF output frequency range of dc-500 MHz -- so RF wave-related sidebands were already available at the reflectometer outputs

Reflectometer Access is Located Between the 2nd and 3rd Straps of the HHFW antenna



The reflectometer typically operates in swept frequency mode for density profile

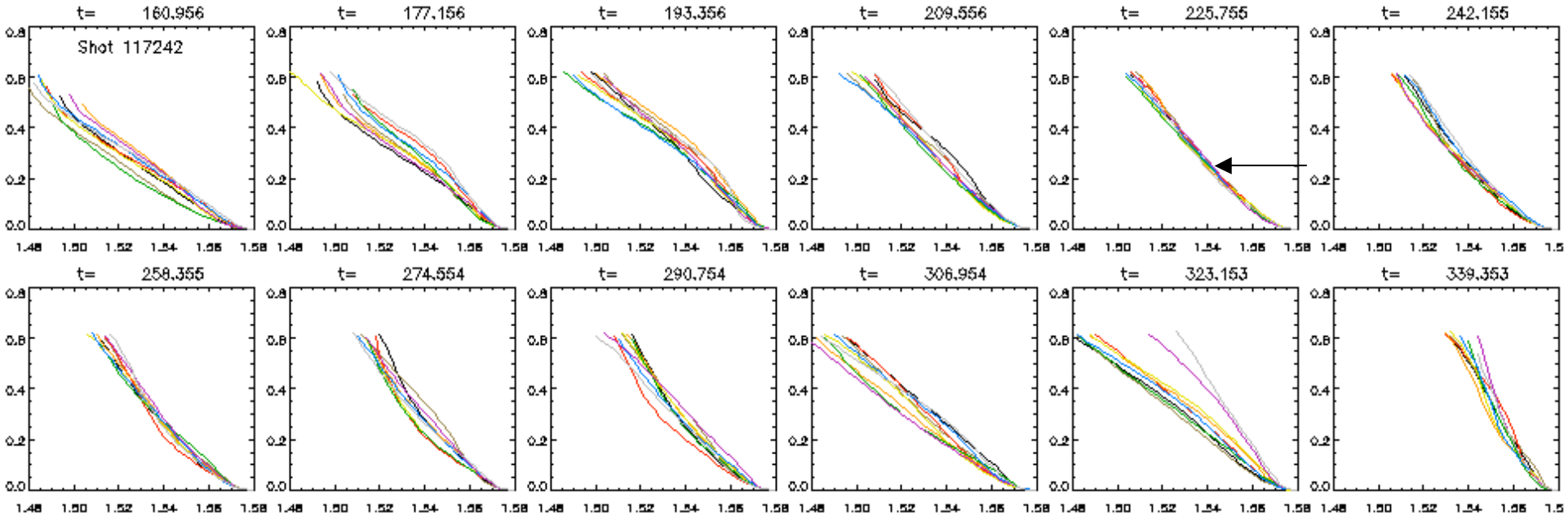
- Contour plot of edge-density profile in front of the HHFW antenna (for 120 degree phasing)
- For this gap spacing, the edge profile measurement also extends 3-5 cm inside the outermost flux surface
- Also displays the time dependence of the outer gap spacing (see black diamonds)
- Note the gradual ramp-up of the RF power starting at 200 msec, and the power reduction at 300 msec



Note: Steep density profiles at t=340 msec is not an RF effect, it is due to plasma hitting the antenna

Phase-Averaged Density Profiles Measured in Front of the HHFW Antenna

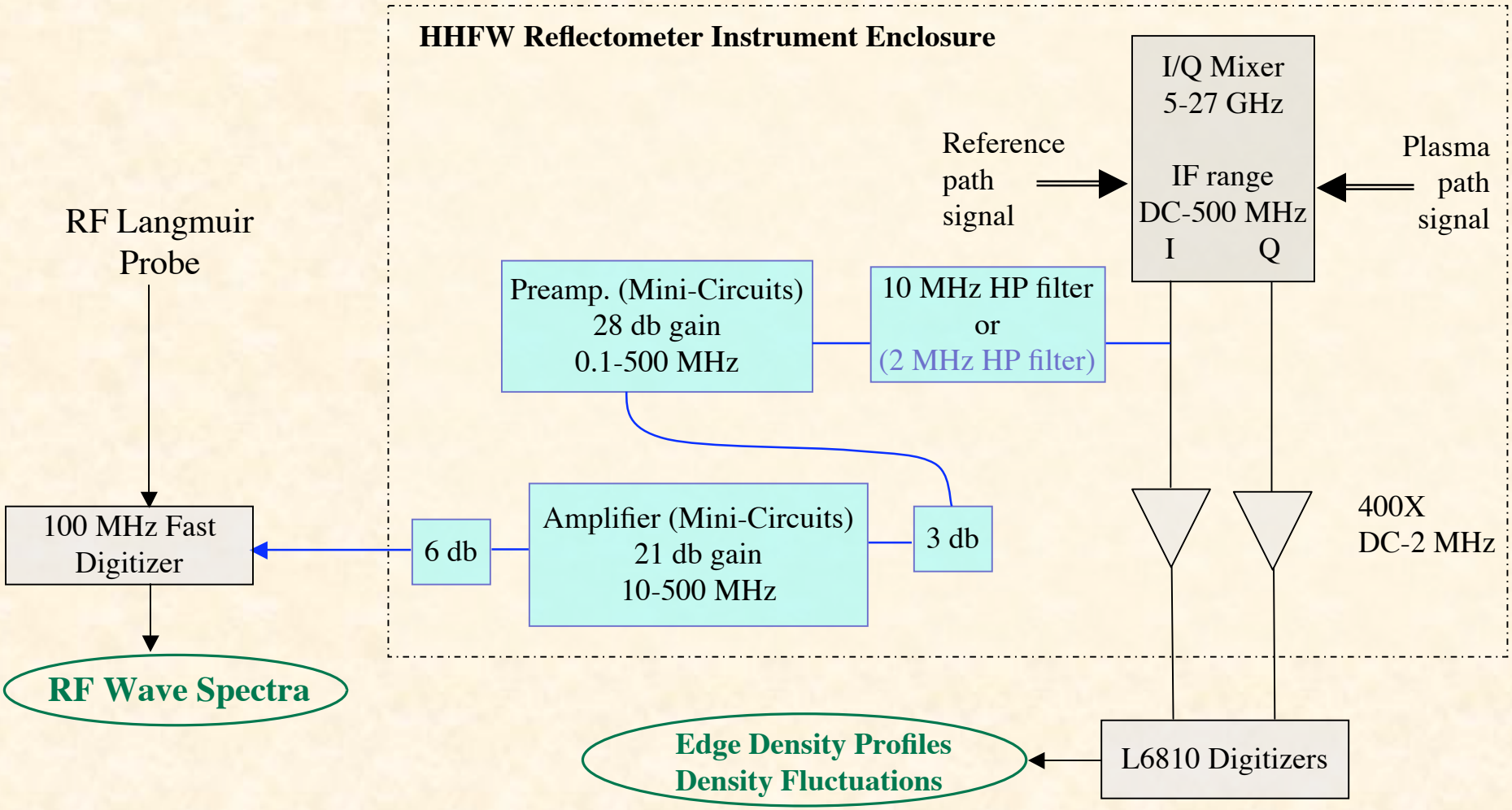
- At 17.5 GHz, the reflectometer probes the plasma edge region at a cutoff density of about 2.5×10^{12}/cc, typically about 3-4 cm in front of the HHFW antenna, depending on the outer gap spacing



Reflectometer Probing of RF Waves on NSTX

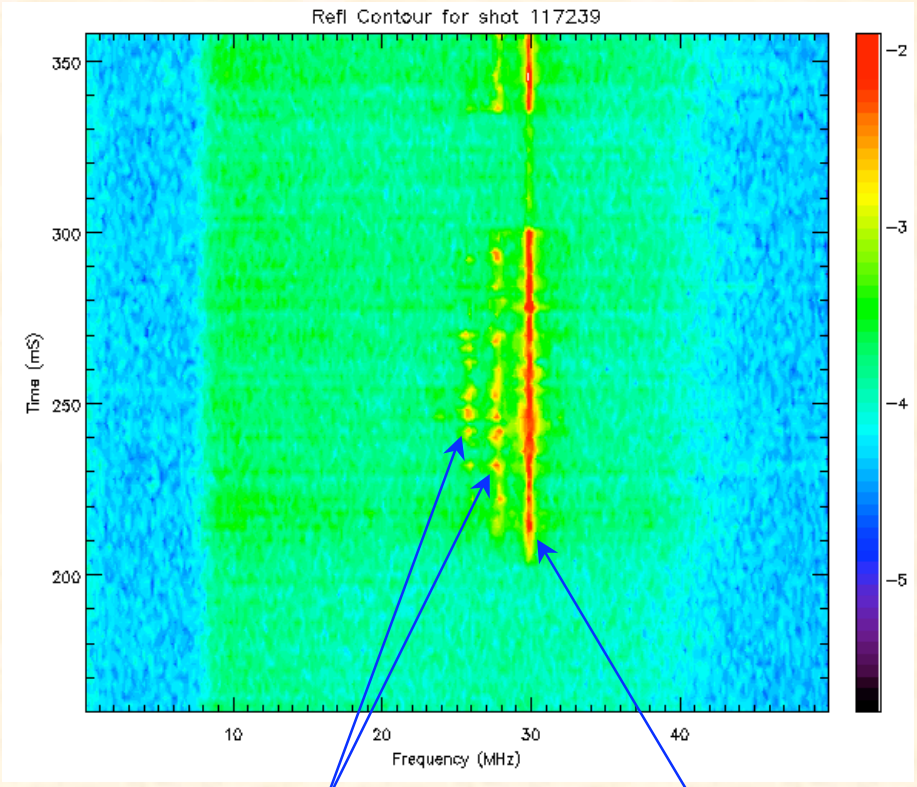
- The HHFW reflectometer has been modified to monitor RF waves in the scrape-off layer in front of the 30 MHz antenna array on NSTX
- The reflectometer can detect the 30 MHz heating wave in the surface of the plasma, as well as electrostatic parametric decay waves
  - The reflectometer signal exhibits 30 MHz sidebands, due to the modulation of the cutoff layer by the electrostatic component of the 30 MHz RF wave
  - The electrostatic parametric decay waves are readily detected at frequencies below the heating frequency, near 28, 26, 24, … MHz (depending on B-field), with corresponding frequency-matched pairs at harmonics of the edge ion cyclotron frequency, near 2, 4, 6, … MHz,
- Detected spectra are similar to those obtained with a floating Langmuir probe that is also located within the HHFW antenna

RF Wave Monitoring Circuit
HHFW Reflectometer

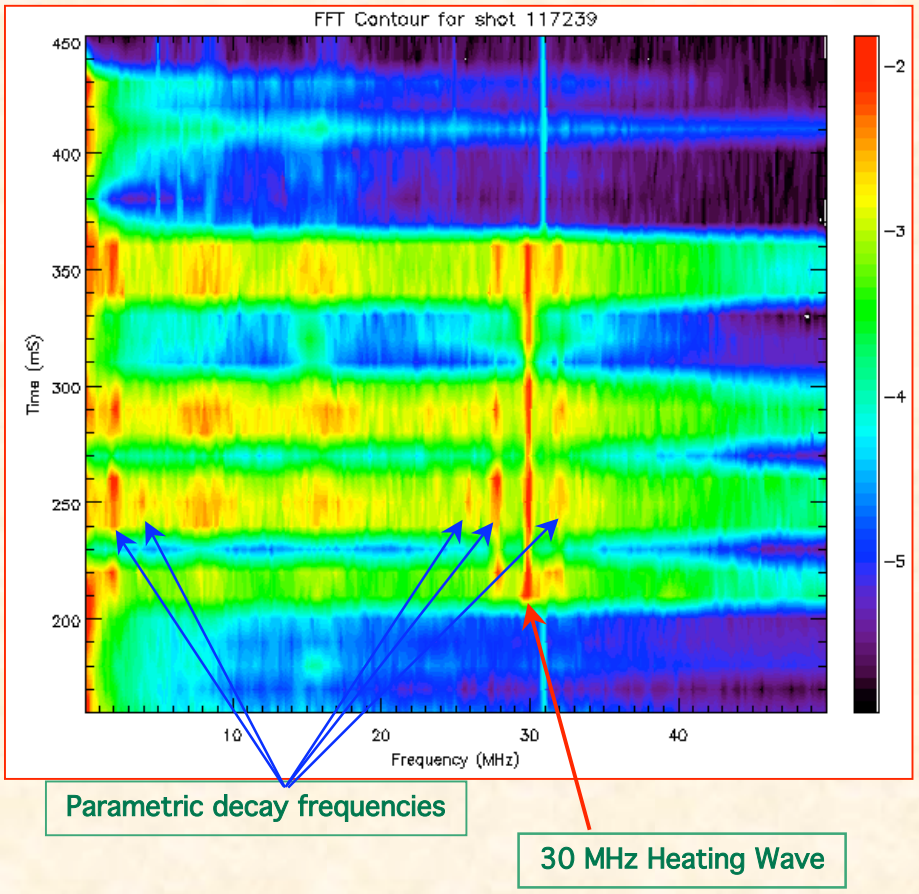


Comparison of Reflectometer RF Spectra with Langmuir Probe Spectra

Reflectometer RF Spectra



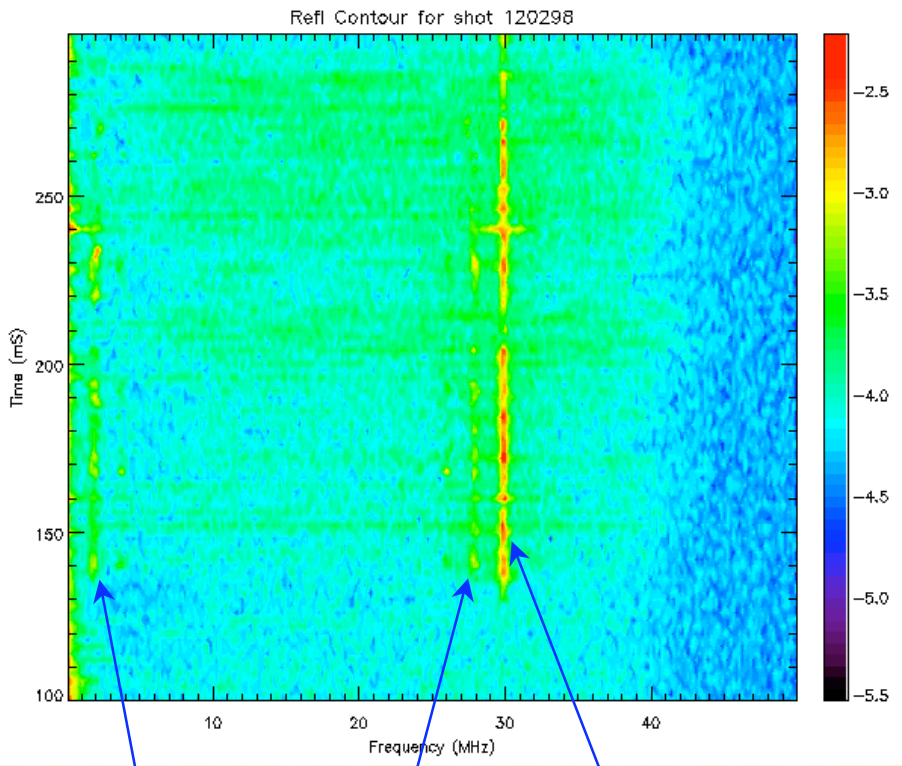
RF Langmuir Probe Spectra



Recent Spectra Obtained using 2 MHz High-Pass Filter, revealing PDI waves at 2 & 4 MHz

NSTX

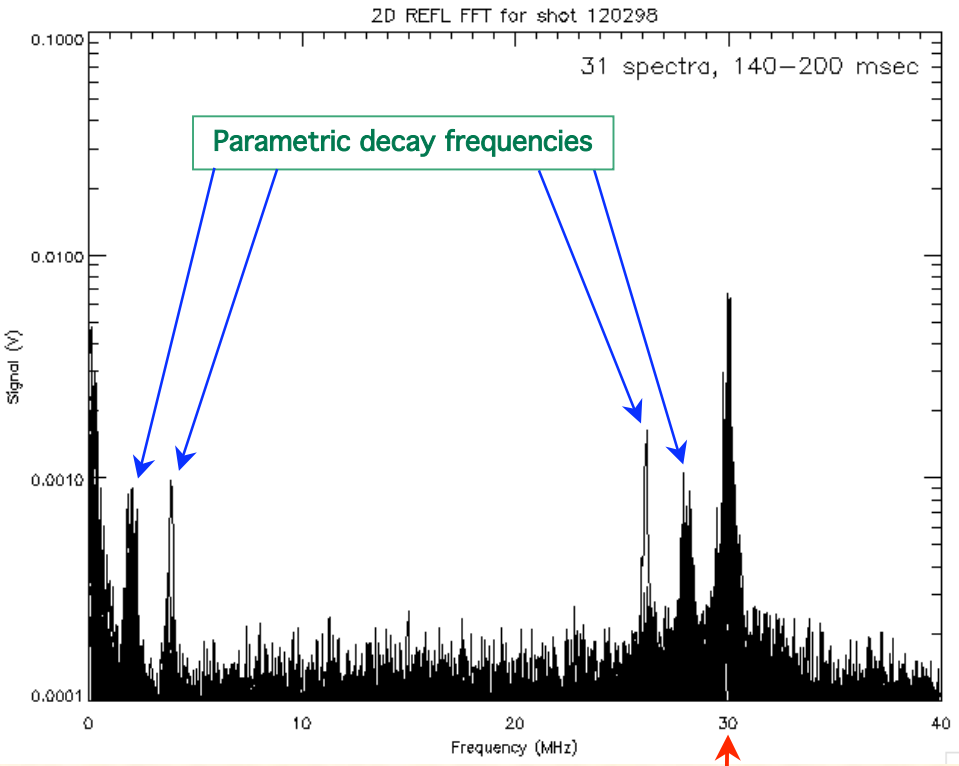
Reflectometer RF Spectra



Parametric decay frequencies

30 MHz Heating Wave

Overplotting 31 Spectra, 140-200 msec



30 MHz Heating Wave

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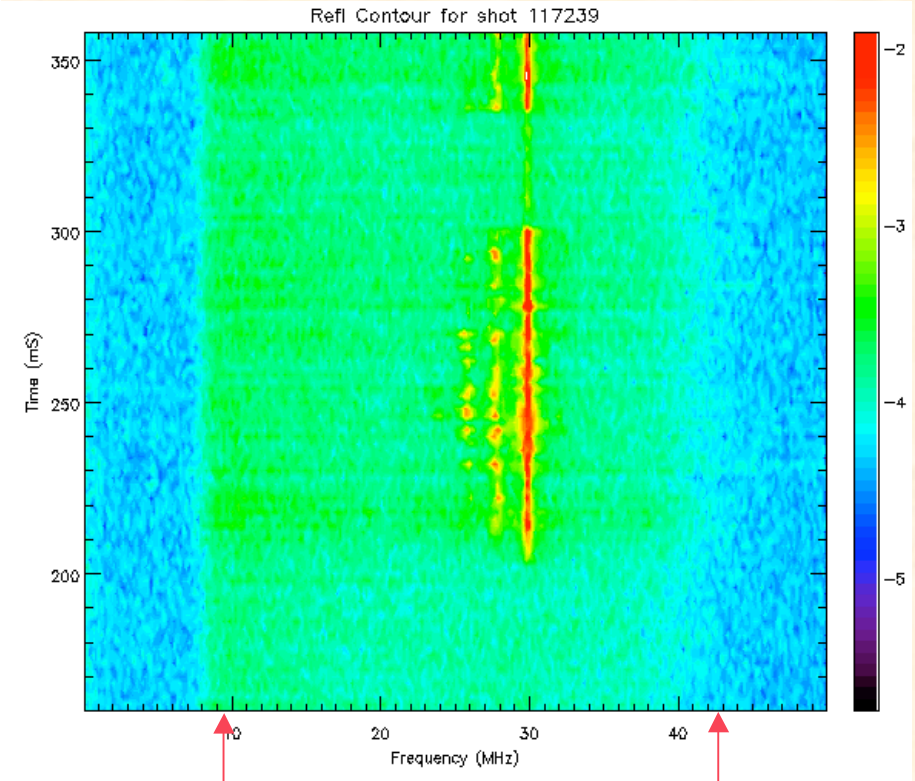
Comparing Reflectometer RF Spectra for Different Antenna Phasing

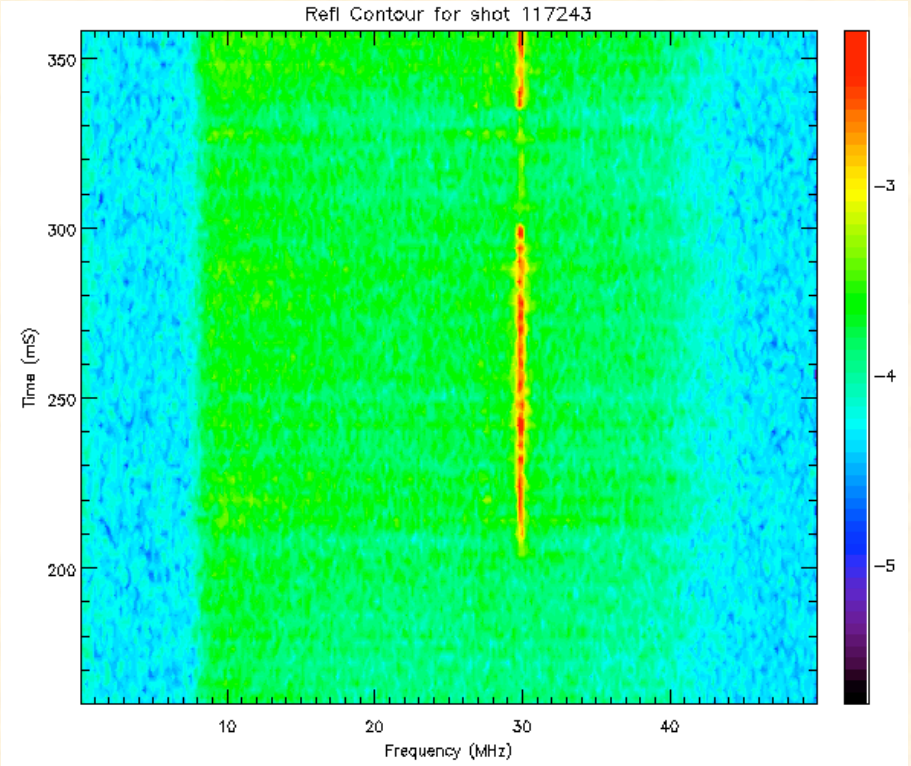
-90 degree phasing (2 MW, 4 cm gap)



High-pass filter roll-off

Anti-aliasing LP filter roll-off

180 degree phase (1.8 MW, 4 cm gap)



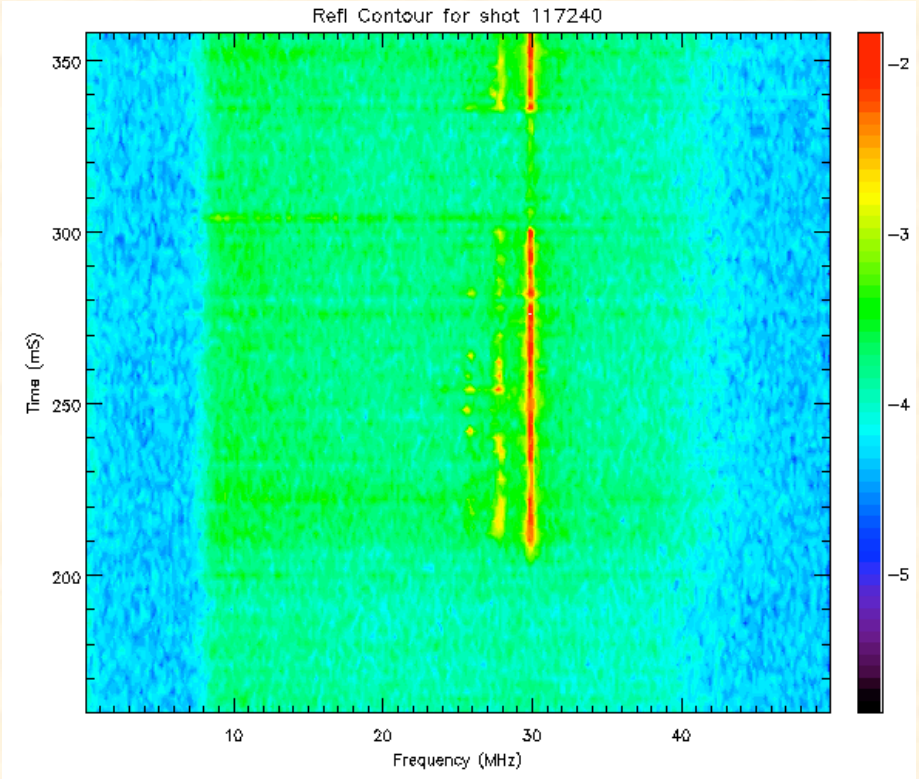
Dependence on Outer Gap Spacing
(plasma density in front of the antenna?)

- For 300 kA plasmas with a fixed probing frequency of 17.5 GHz (cutoff density 2.5×10^{12}/cc)
- Compare data for small vs. large outer gap
  - 3 cm gap, shot 117240
  - 8 cm gap, shot 117250
- Parametric decay spectra are most prominent for the largest (8 cm) gap spacing, which has the lowest density at the antenna

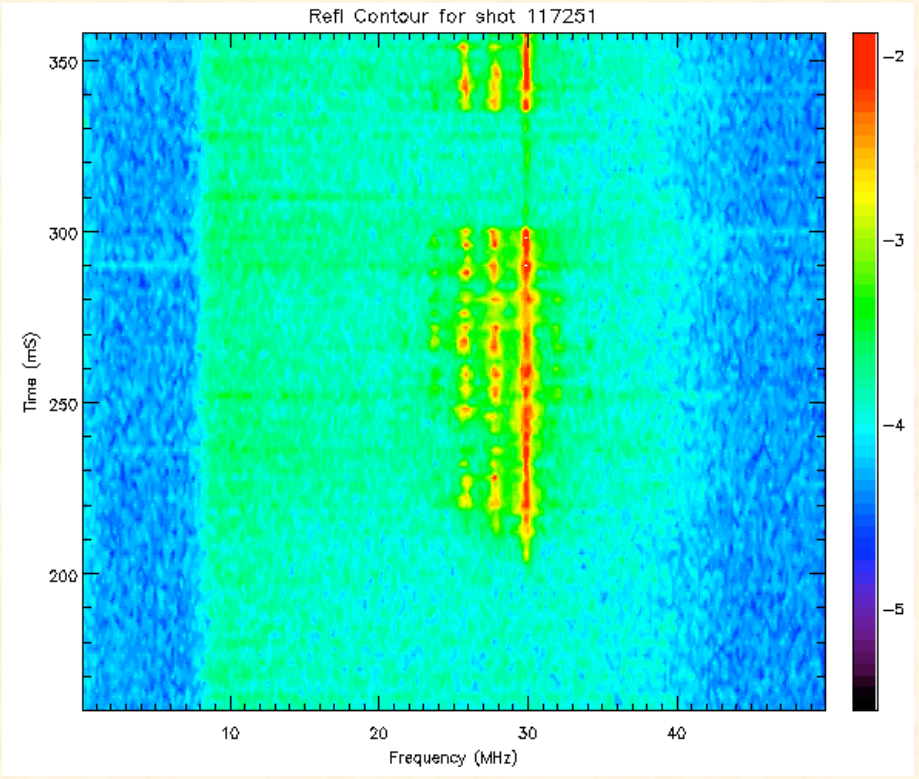
Comparing RF Spectra for Two Gap Spacings
(-90 degree phasing, 2 MW RF power)

Note the intermittency of the parametric features in the reflectometer spectra

3 cm outer gap spacing



8 cm outer gap spacing



Summary: Monitoring RF waves in front of the HHFW antenna using the edge reflectometer

- Have only looked at a fraction of the RF wave data - typically 20 μsec snapshots every 2-10 msec.
- Find evidence of systematic variations of parametric decay spectra with antenna phasing.
- See indications of a power threshold in the 100-400 kW range for co-CD phasing, depending on outer gap.
- Have observed a dependence on outer gap spacing, suggesting a dependence on plasma parameters in the scrape-off region.
- Have not yet seen any indication of systematic changes with probing location within the scrape-off layer.
- Have not yet seen a dependence on plasma current.