Electron Cyclotron Emission Radiometer

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Abstract

- The goal of this project was to build a wide band receiver that would be capable of detecting rapid non-Maxwellian bursts in plasma temperature.
  - The receiver measures electron cyclotron emission (ECE) from magnetized plasmas.
  - These rises in electron temperature can be related to instabilities in the plasma.
- The receiver built in this project was tested on the Maryland Centrifugal Experiment (MCX).

Theory

- Optically thick plasmas in thermal equilibrium emit black body radiation according to the following formula:

$$\rho(f,T) = \frac{8\pi f^2}{c^3} kT$$

- Hot electrons are produced when the plasma becomes unstable during interchange and other MHD instabilities.
- Electrons orbit around the magnetic field lines and radiate at the electron cyclotron frequency given by

$$\omega_c = \frac{eB}{m_e}$$

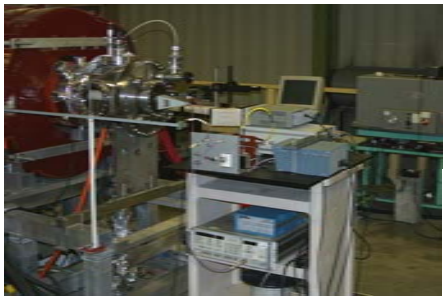
ECE Receivers

Basic Parameters of ECE Receivers

	Ka Band	Ku Band	X Band
Frequency	30-35GHz	12-18GHz	8-12GHz
Sensitivity	Linear gain of 20-70dB	24mV/dB (logarithmic)	24mV/dB (logarithmic)
Dynamic Range	~30dB	100dB	100dB
Noise Level	-50dBm	-90dB	-90dB

Schematic of Receiver

KA and KU/X Band Receivers

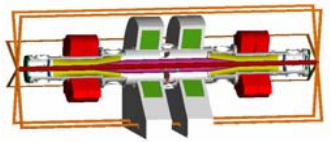


Maryland Centrifugal Experiment (MCX)

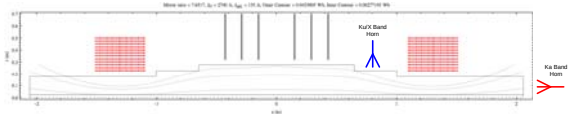
- MCX is a confinement experiment which produces a hydrogen plasma that rotates at supersonic velocities.
- Basic Parameters

MCX Parameters	
Mirror Ratio	7.6
Magnetic Field (midplain)	.2 Tesla
Voltage	10kV
Fill Pressure	5.3 mTorr
Other Diagnostics	Diamagnetic Loop (DML)

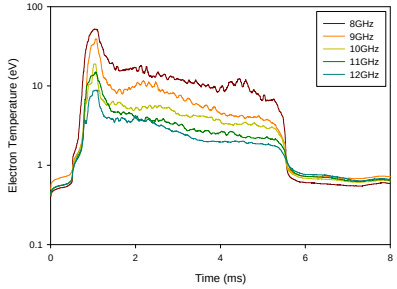
- Cutaway of MCX



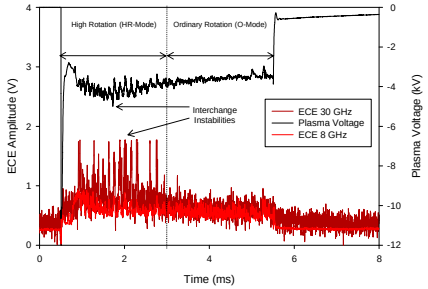
- Magnetic Field Plot



Experimental Results

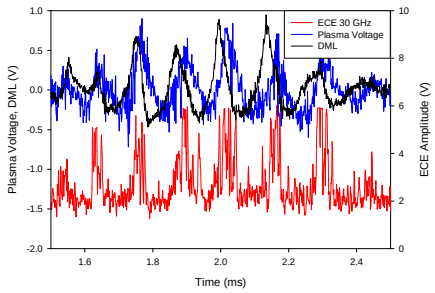


- Electron Temperature vs X Band LO Frequency

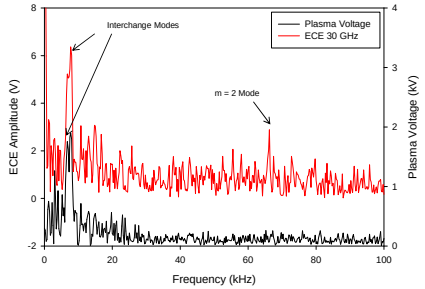


- Comparison of MCX Voltage with ECE Radiation at 8 and 30 GHz

(a)



(b)



- Time (a) and Frequency (b) Plot of Interchanges

Conclusion

- The receivers measured a mean electron temperature that is consistent with MCX theory and optical interferometer measurements.
- Interchange instabilities in the plasma were shown to generate electron temperature ~4x higher than the mean value.
- The m = 2 plasma mode was detected.
- The ECE receivers were able to detect changes in the electron temperature that correlate well with plasma voltage and DML data.

Discussion

- Conjectures
  - Receivers are possibly detecting harmonics of the fundamental electron cyclotron frequency
- Improvements to Receiver
  - Construct a multichannel receiver to simultaneously measure ECE radiation at different frequencies and positions
  - Analyze multichannel data using auto and cross correlation techniques
  - Use a wide band oscilloscope to directly digitize the intermediate frequency signals in quadrature mode
- Future Work
  - It is feasible to apply diagnostic to extremely energetic plasmas such as magnetic reconnection and plasma focus experiments
- Acknowledgments

  - MCX Group
    - William Young, Carlos Romero Talamás, Catalin Teodorescu