EBW EMISSION FROM THE MST REVERSED FIELD PINCH

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ABSTRACT

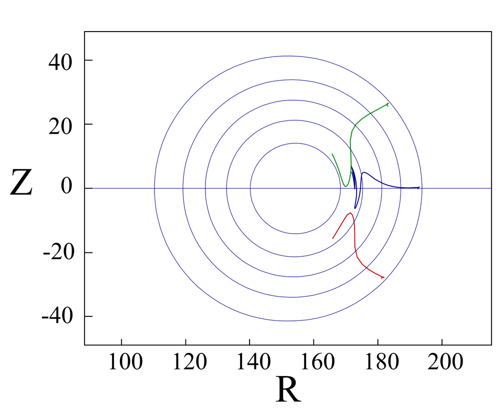
Experiments on the MST have observed blackbody levels of emission in ECRF ($\Omega ce < \Omega < 3\Omega ce$). Since the plasmas are overdense ($\Omega pe \sim 15\Omega ce$), we speculate the emission is due to either OXB or XB mode conversion of electrostatic electron Bernstein wave (EBW) to the electromagnetic waves at the plasma edge. A 16 channel, absolutely calibrated radiometer simultaneously measures the radiation temperature for frequencies between 4 and 8 GHz. Measured radiation temperatures are similar in magnitude to electron temperatures measured by Thomson scattering; the radiation is partially polarized in X-mode; and the signatures of suprathermal electrons are observed during sawteeth and startup. Initial indications are that measured temperature fluctuations are corelated with core MHD activity, suggesting the emission originates from the central part of the plasma. This observation opens up the possibilities for ECE diagnoses of the electron temperature, electron heating and current drive via the EBW and potentially magnetic field diagnostics for RFP as well as spherical tokamak.

MOTIVATION

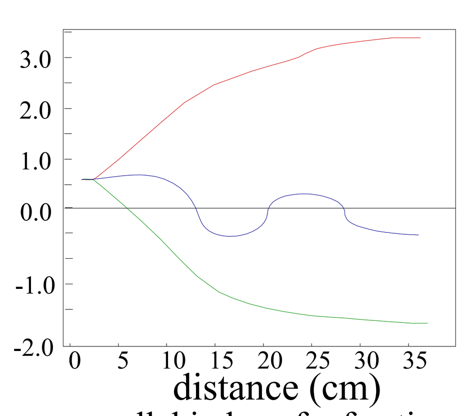
MHD simulation shows the possibilities to sustain Taylor state by controlling the current profile through noninductive current drive. This can reduce the magnetic fluctuation arising from tearing mode responsable for poor confinement in RFP. Two rf experiments, lower hybrid (LH) and electron Bernstein wave (EBW), have been shown to be theoretically feasible and are being initiated to investigate heating and current drive in Madison Symmetric Torus (MST). RFP being overdense conventional electromagnetic O or X-mode in electron cyclotron range of frequency (ECRF) do not propagte whereas electrostatic EBW does. Mode conversion theory suggests that vacuum EM wave may be coupled to EBW via X-B or O-X-B at plasma edge. So understanding coupling and mode conversion are prerequisites before launching any rf power. The present experiment addresses mainly these two issues. Moreover since the EBW is optically thick diagnostic potentiality of EBW emission will also be examined. So experiment aims to:

(a) Look for emission in ECRF: Accesibility issue
(b) Understand the mode conversion: Efficiency issue
(c) Check the diagnostic feasibility: Diagnostic issue

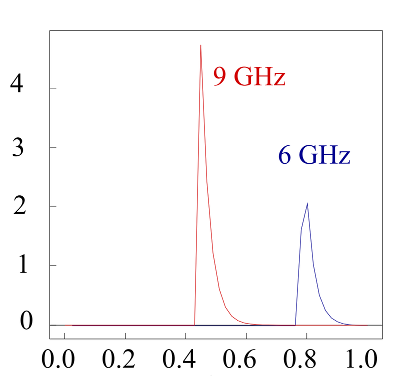
Ray Tracing and Fokker-Planck Shows the Current Drive Possibilities & Localized Heating



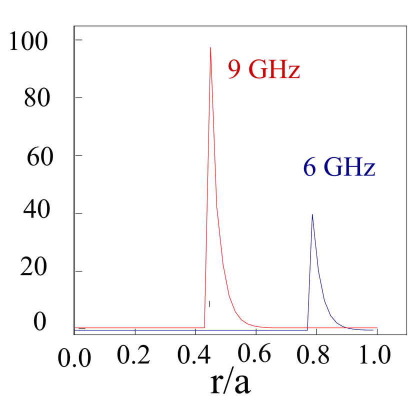
EBW Rays in MST



parallel index of refraction

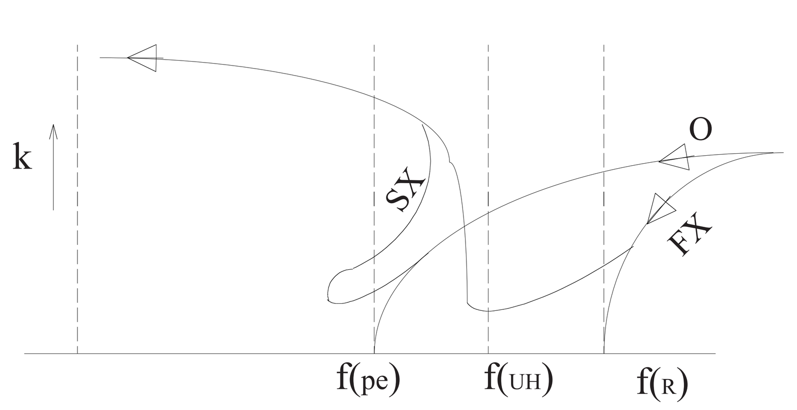


power density (power/volume)

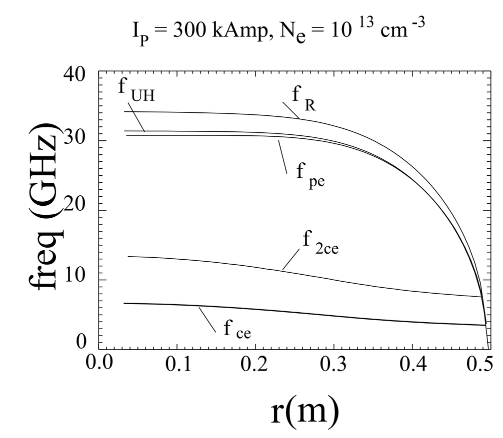


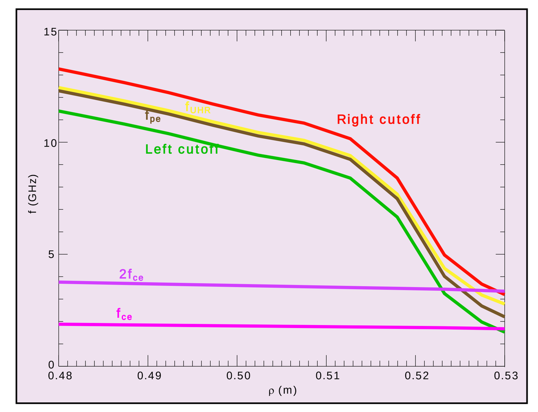
poloidal current density

MODE CONVERSION SCHEME



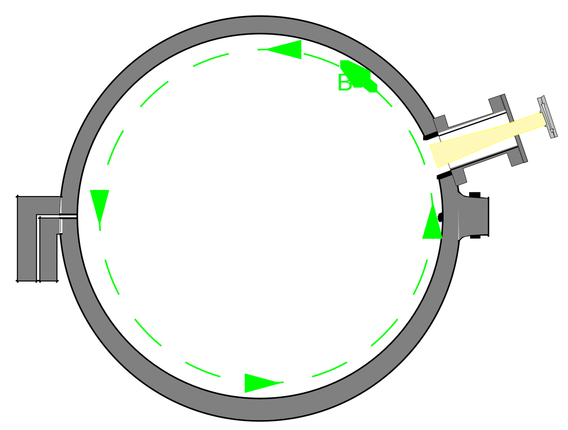
Characteristic frequencies in the ECRF on MST

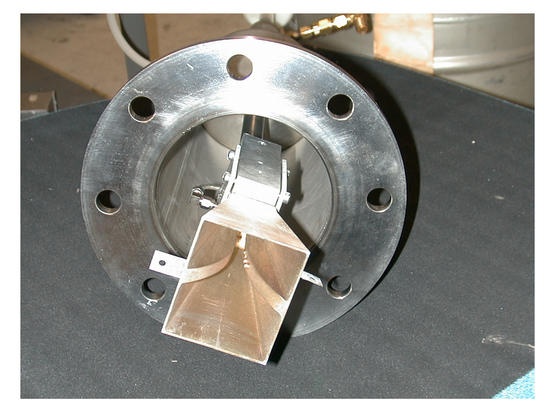




* f(ce) < f(pe) ...... MST is overdense for EM waves
* f(ce) = f(uh) at the very edge of MST.

Experimental set-up for EBE

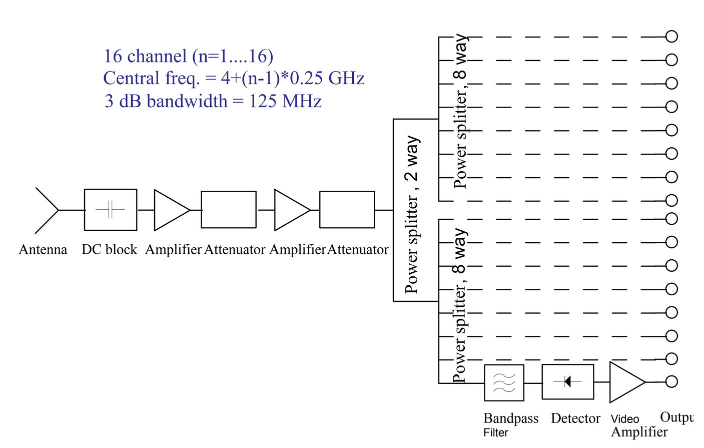




Antenna Specification

Bandwith: 3.8-8.4 GHz
Polarization: Linear
Directivity: 13-17 dB
Location: 15 deg poloidal from horizontal mid plane
Antenna looks at either O or X mode polarization.
$\Delta n_{||} = 0.5$

16 Channel Radiometer schematic

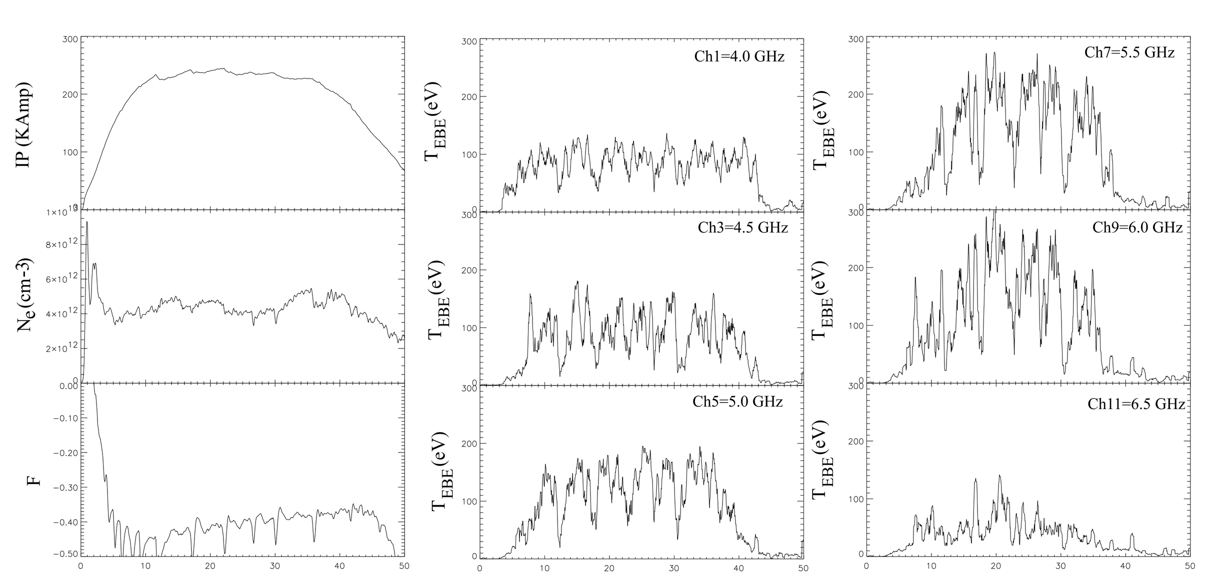


Radiometer performance

Calibration: Radiometer was calibrated using eccosorb kept at room and LN2 temperature along with chopper arrangement. Lock in amplifier was used to measure low signal.
System Temperature: It ranges from 1000 to 3000 deg K for different channel
Resolution: Theoretical resolution is 33 deg K
Sensitivity: It ranges from 10mv/ev to 30v/ev; linear when T(hot) >> T(sys)
Dynamic range: appx. 4 order was achieved.

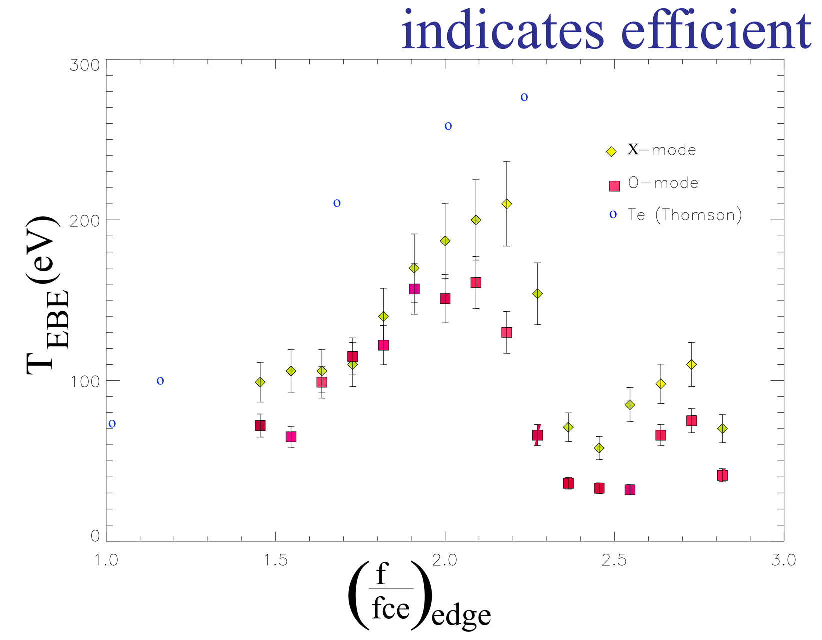
Error sources: How black the eccosorb was? How much antenna pattern was covered during calibration? Background microwave radiation, Stability and noise of video amplifier, sensitivity of lock in amplifier.

Intensity of radiation received at different channel, if considred thermal, are of blackbody level



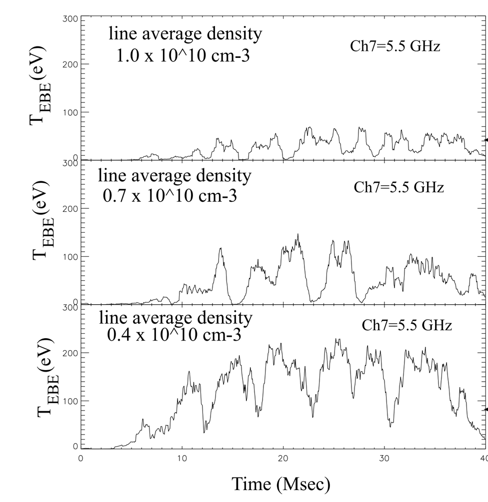
* If radiation received assumed thermal, the radiation equivalent temp is close to plasma temperature
* Huge temperature fluctuation during sawteeth observed
* Radiation temperature goes up to 200-220 eV

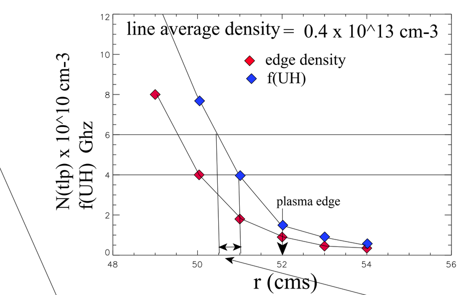
Comparison of radiation and Thomson temperature indicates efficient mode conversion

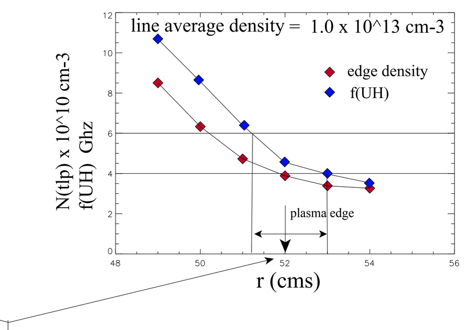


* $T_{(EBE)}$ for X-mode is higer than $T_{(EBE)}$ for O-mode
* $T_{(EBE)}$ for X-mode is up to 80% of Te (Thomson)
* $T_{(EBE)}$ for O-mode is up to 60% of Te (Thomson)
* 2nd harmonic overlaping happens at 2.15, not at 2.0

Emission critically depends upon density gradient at edge





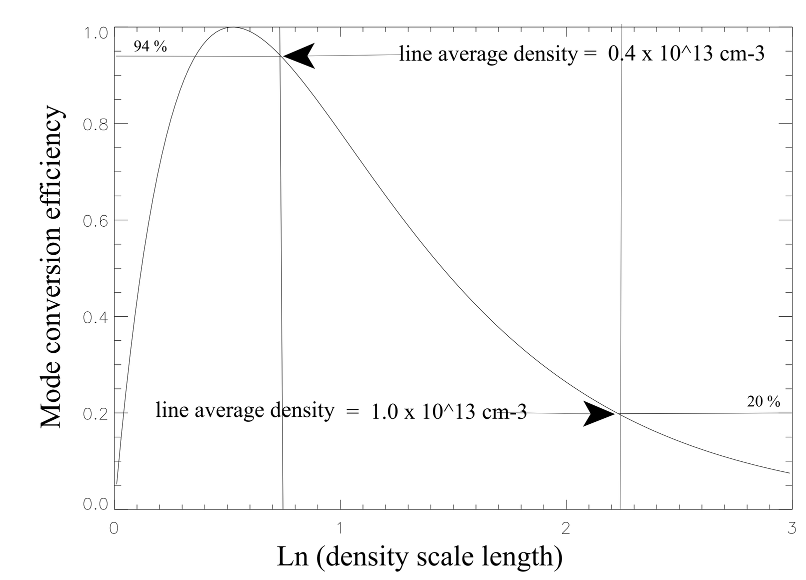


Higher density
EBE signal decreases

* Density gradient scale lengths are 0.75, 2.25 cm
* Low line average density--> stepper density gradient ----> higher EBE temperature..... indicates the mode conversion critically depends on density gradient

Mode conversion theory predicts conversion efficiency depends on density scale length at f(UH)

Theory Predicts:



$$T = 4\exp(-\pi\eta)(1-\exp(-\pi\eta))$$

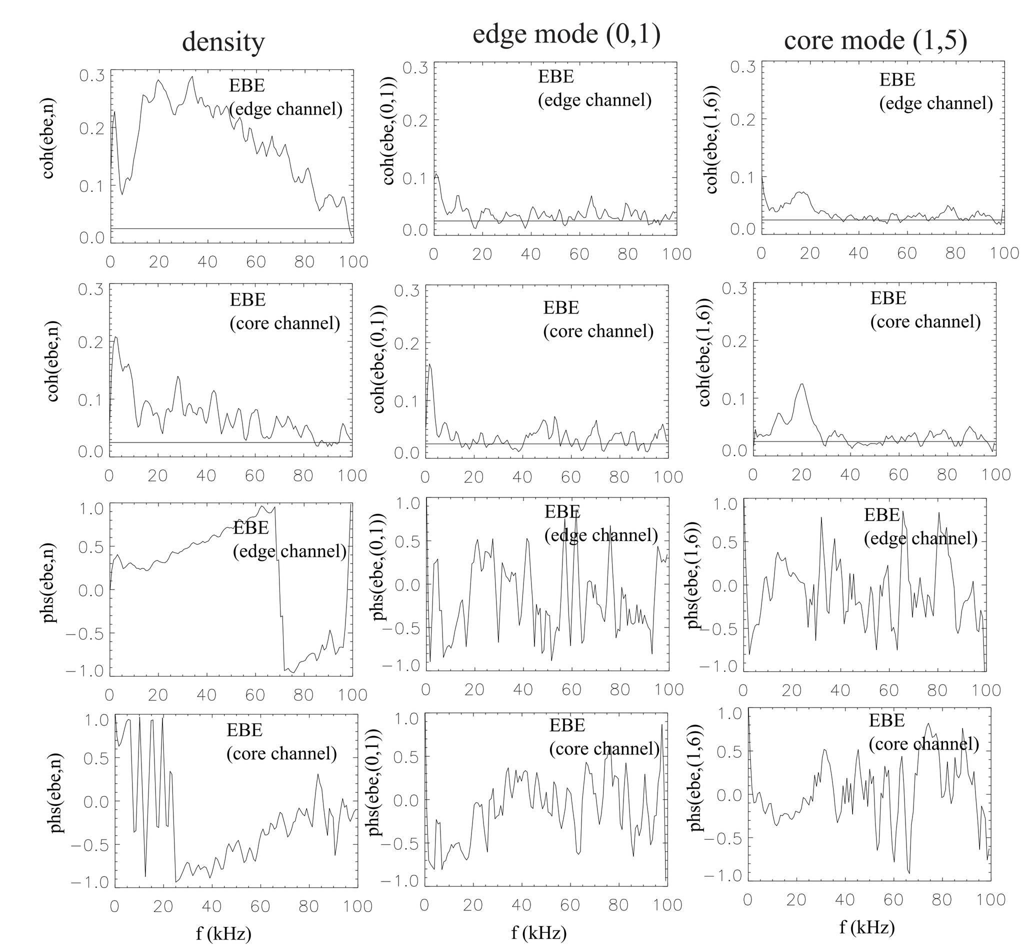
$$\eta = \frac{(\omega_{ce})_{x=x_{UHR}}}{2^{1/2}c} L_n$$

Ref:
A.K.Ram and S.D. Schultz
Phys. of Plas., Vol-7,p-4084,yr-2000

where, T= transmission coefficient, L = density scale length

T(exp.) = 80%
T(th.) = 94%

Corelation also shows a density dependence



* High coherance of ebe with n confirms the dependence of mode conversion on n.
* Coherance of core mode (1,6) with ebe indicates radiation originates from the core.
* No corelation of edge mode (0,1) with ebe was observed.

RESULTS AND CONCLUSION

* Blackbody radiation in ECRF has been observed
* We speculate the emission is due to XB or OXB
* Radiation for X-mode is higher than of OXB
* Mode conversion critically depends on density gradient
* Mode conversion efficiency (XB) upto 80% was observed
* Shift of 2nd harmonic frequency was noticed
* EBW seems a plausible heating candidate for MST
* Using EBE for diagnostic needs local (at edge) density control