Observations of Waves Generated by a 20keV Electron Beam in a Laboratory Plasma

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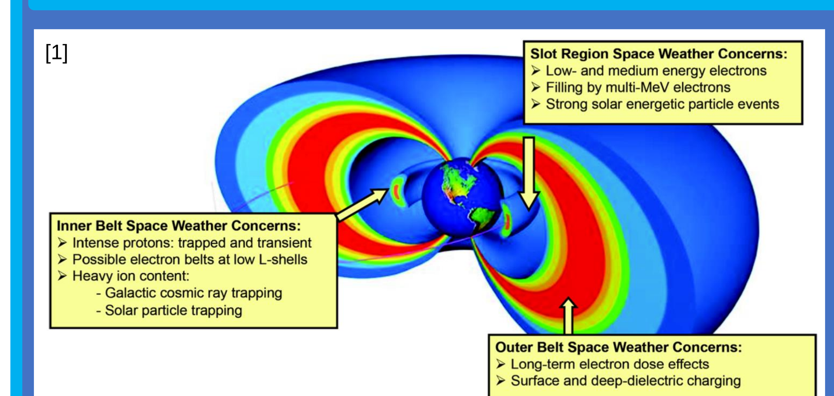
Key Points

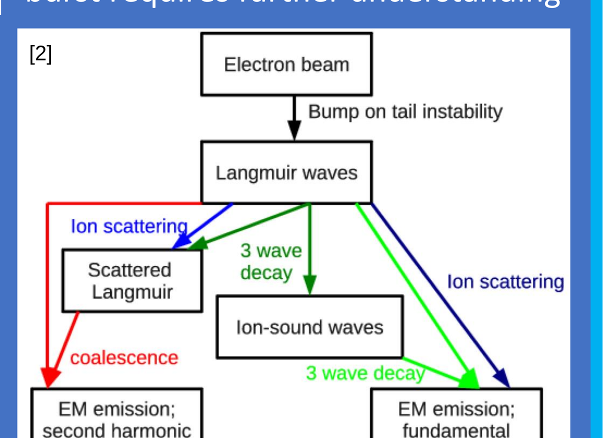
- ❑ Understanding fundamental plasma processes such as wave-particle interactions is of great importance to many of the subfields in plasma physics.
- ❑ Laboratory plasma experiments are a great way to gain insight on astrophysical phenomena.
- ❑ The proposed study aims to determine the efficacy of generating whistler waves in UCLA's Large Plasma Device(LAPD) in order to further our understanding of the wave-particle interactions present in our solar system.

Motivation

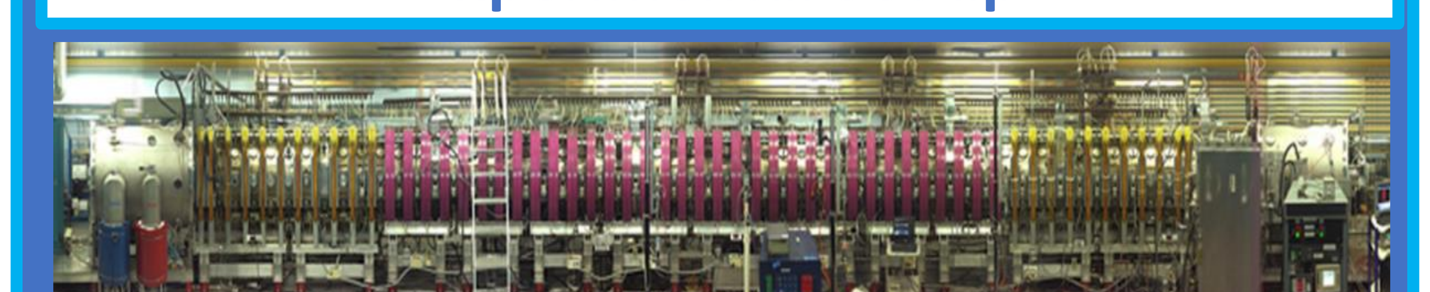


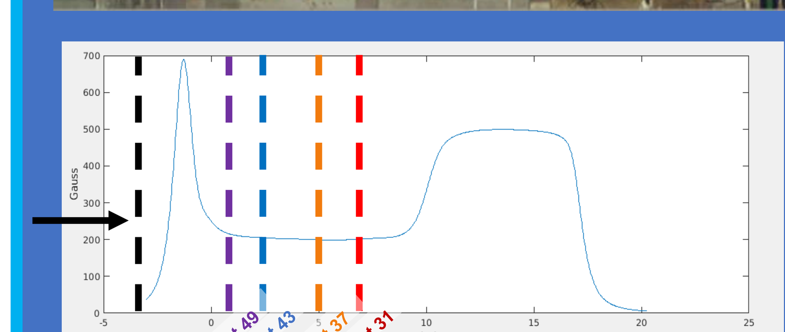
Type II and Type III radio burst are an important type of solar outputs as they are generated by beams of electrons and can be used to study electron acceleration, energy transport and the plasmas in which they travel through. However, the generation mechanism of these burst requires further understanding

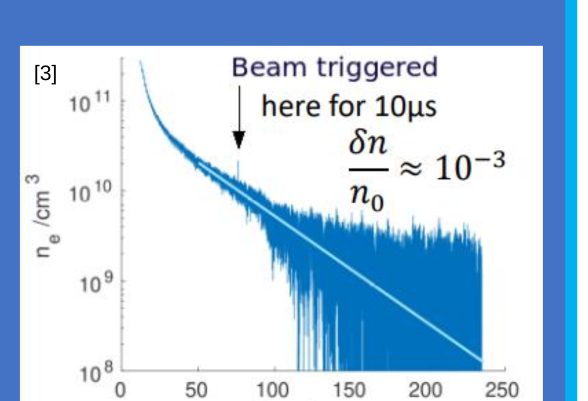
High energy electrons from either solar wind or from human caused high altitude nuclear explosions may become trapped inside the Van Allen radiation belts and persist there for long periods of time. Spacecrafts in the regions may be suspectable to damage from these trapped electrons. A proposed solution is using spacecraft to carry compact electron beams or antennas to remediate the trapped electrons.



Experimental Set up







- ❑ EB probes are place in various locations of the testing area.
- ❑ EB probes are 3D.
- ❑ Operating in the plasma afterglow, operating regions range from $2.75\,\frac{f_{pe}}{f_{ce}}$ - $.55\,\frac{f_{pe}}{f_{ce}}$

Electron beam is triggered at varying times after the plasma discharges as a way of varying the density of the plasma.

Results & Discussion

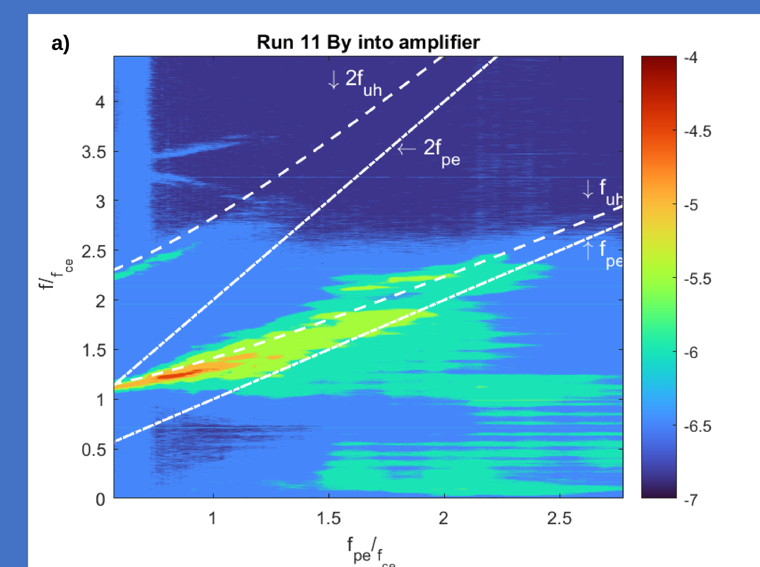


Figure a) The spectrum for By at run 11 illuminates the activity between the whistler and X-mode frequency range. This activity suggest potential non-linear 3 wave coupling. There also appears to be emission of a 2[nd] harmonics for the main mode just under the upper hybrid frequency in regions where fpe/fce < 1.

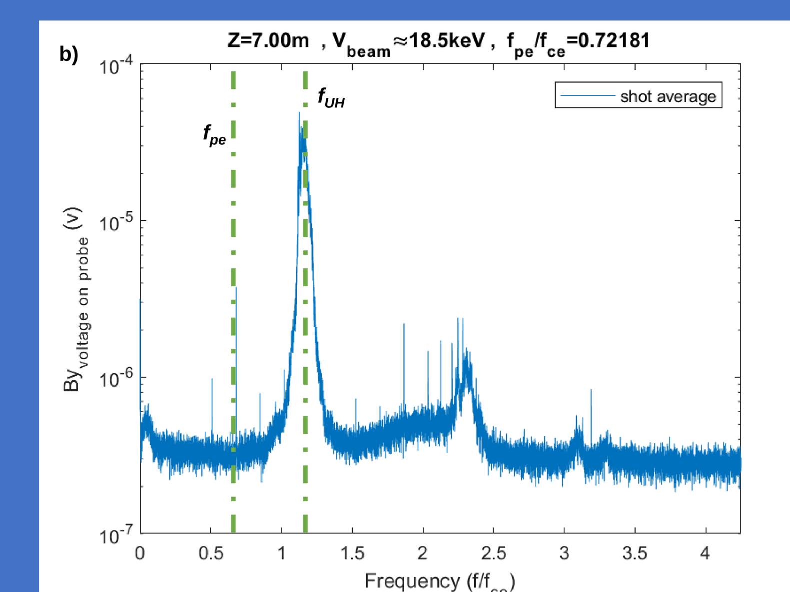


Figure b) The spectrum at f_{pe}/f_{ce} = 0.72181 reveals clear emission at the 2[nd] harmonic of mode.

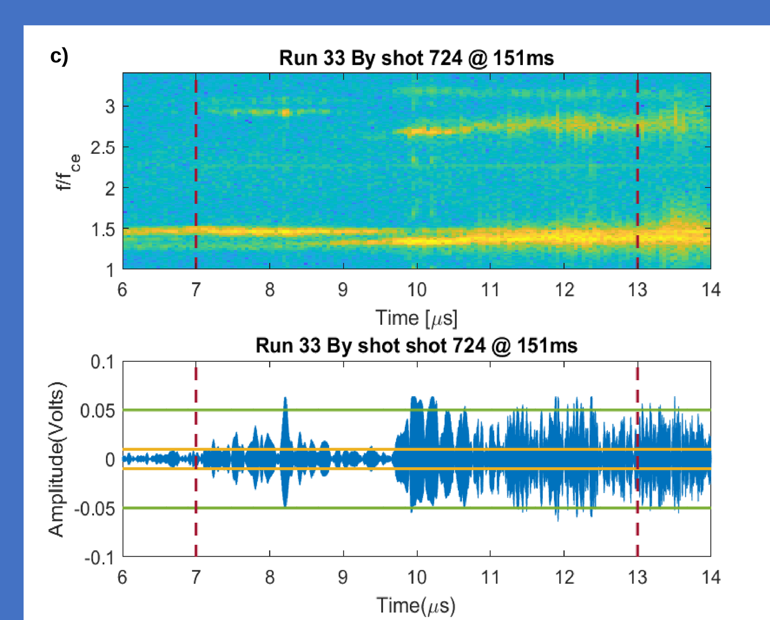


Figure c) A time dependent analysis of the spectrum indicates a potential amplitude threshold of the fundamental mode for 2[nd] harmonic emission. The green horizontal line in the bottom panel is the average peak voltage for the signals at 151ms. The yellow horizontal line is the average rms voltage for the same background density

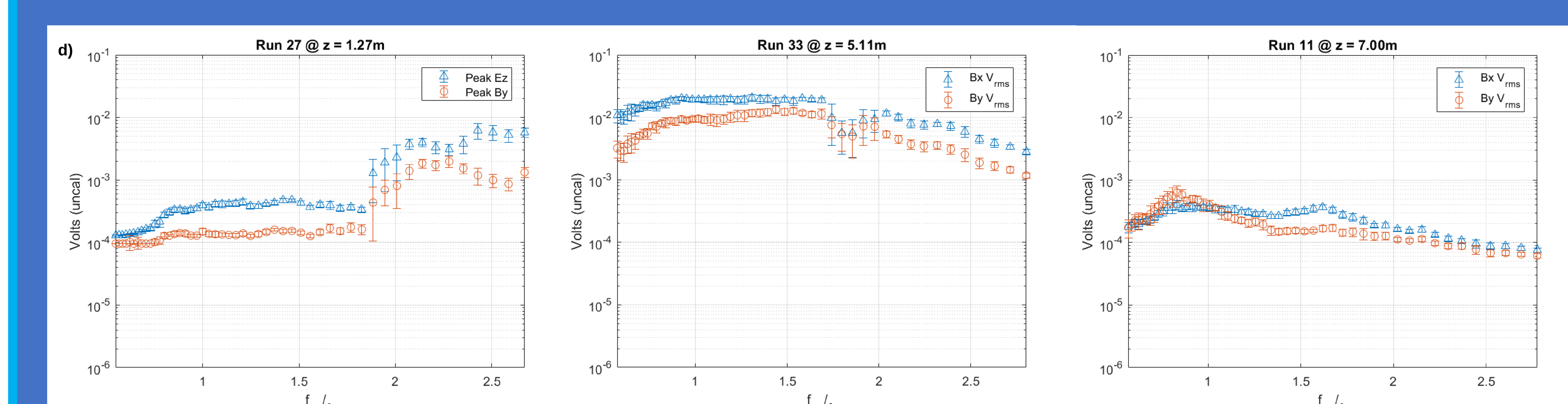


Figure d) Across various probes along the machine and spanning all operating background densities, there appears to be an amplitude threshold in which once the fundamental mode reaching such critical amplitude, emission of its 2[nd] harmonics is observed.

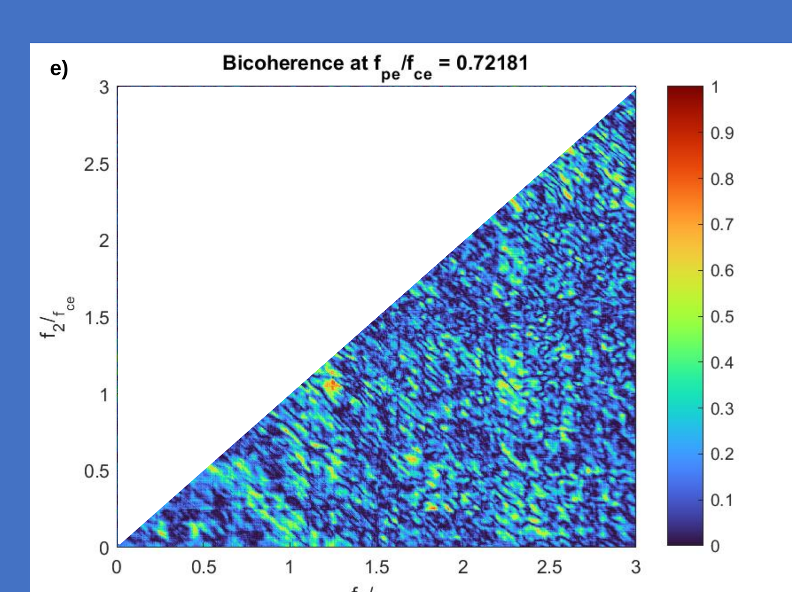


Figure e) A bicoherence analysis indicates potential 3 wave interaction between the main peak and the fundamental (seen in the figure b)

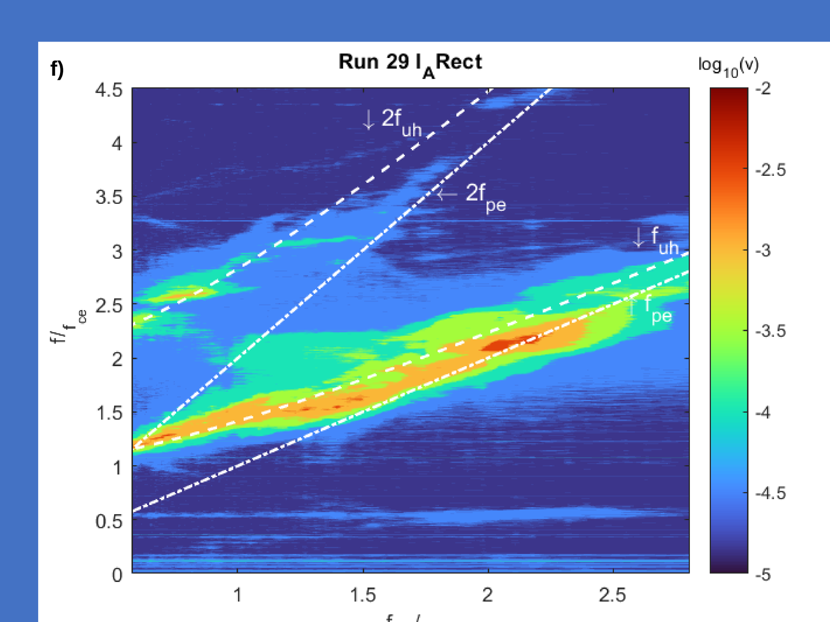


Figure f) Antenna place on the outside of the chamber also captures robust x-band emissions and emissions near $2f_{UH}$ in regions where fpe/fce < 1, further indicating some sort of non-linear interactions.

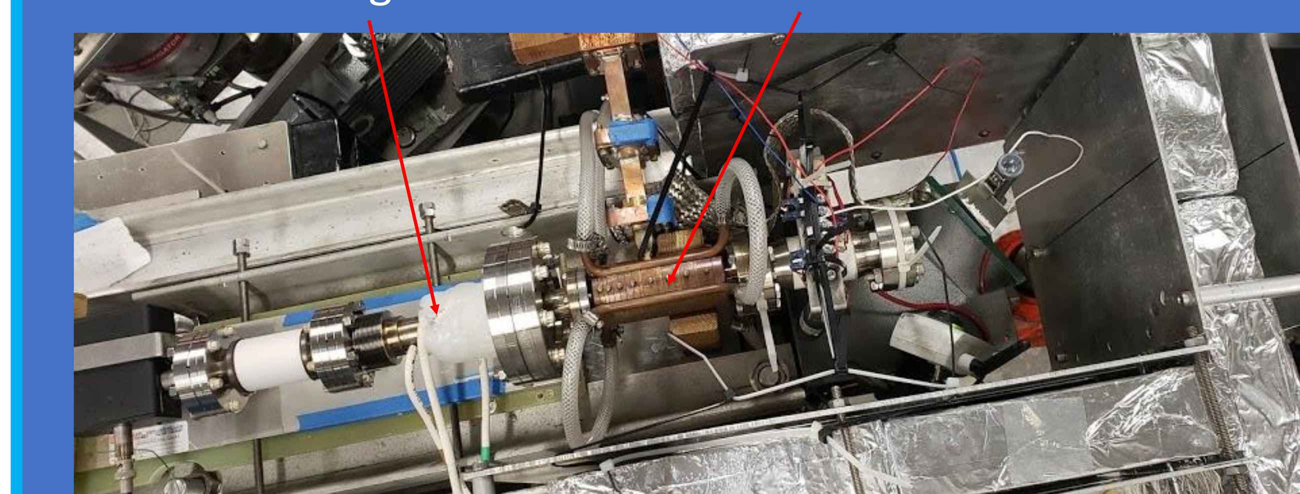
Conclusions

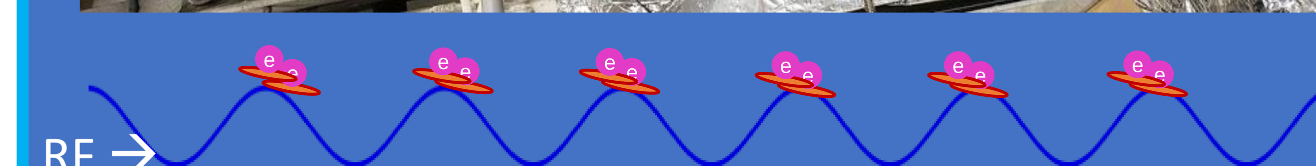
- ❑ Robust wave emissions in the X-band mode.
- ❑ Activity in the low frequency region suggestive of Whistler wave presence.
- ❑ Results indicate that 3 wave coupling between the X-mode and harmonics could be happening.
- ❑Bicoherence analysis does suggest some interactions between waves at the upper hybrid frequency may lead to emissions at the second harmonic.

Future Work

- ❑ Further bicoherence analysis is needed. Observations of the Bx and electric field are underway.
- ❑Further investigation into information about the wave vector at the second harmonic.
- ❑ For practical application in radiation belt remediation, a 1MeV electron beam is required. Thus, early stages of this beam in LAPD is currently under way.

Electron gun Linear Accelerator





Acknowledgments

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[3] Dorfman, S., "Plasma and Radio Wave Generation by an Electron Beam in a Laboratory Plasma", vol. 2019, 2019.