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

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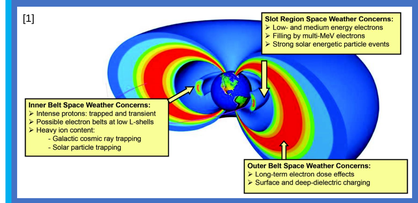
Key Points

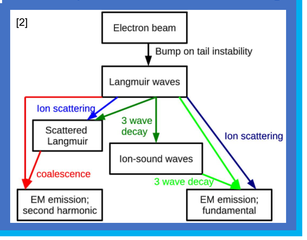
- Understanding fundamental plasma processes such as wave-particle interactions is of great importance to many of the subfields in plasma physics.
- Laboratory plasma experiments are a great way to gain insight on astrophysical phenomena.
- The proposed study aims to determine the efficacy of generating 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

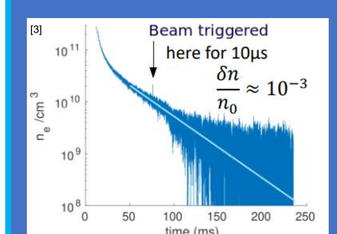


Type II and Type III radio burst are an important type of solar outputs as they are generated by beams of electrons and can be used to study electron acceleration, energy transport and the plasmas in which they travel through. However, the generation mechanism of these burst requires further understanding

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.

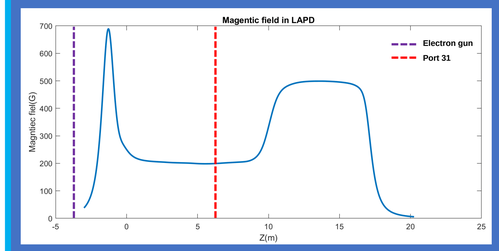


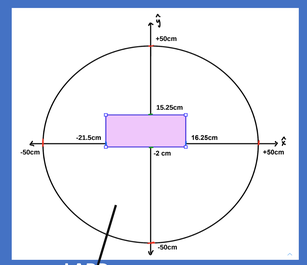
Plasma Conditions



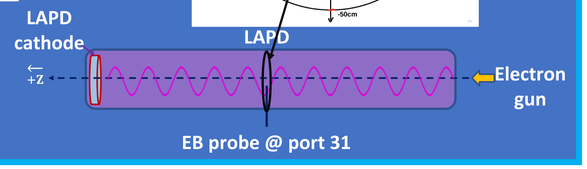
Electron beam is triggered at varying times after the plasma discharges as a way of varying the density of the plasma.

Experimental Setup

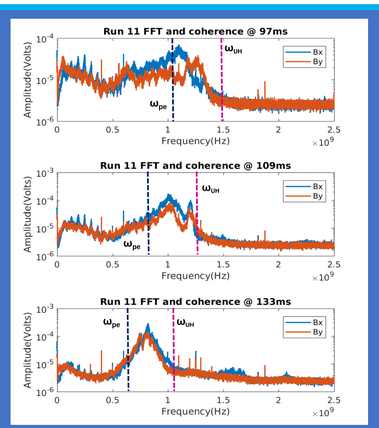




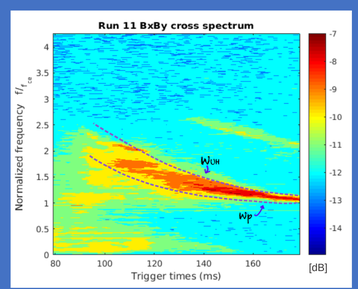
- 1 EB probe in, measuring Bx, By, Ex, and Ey
- Probe is positioned at (2,7.75) ←(xy in cm) & and port 31→ z = 7m
- Electron gun triggering times range from79-179ms (in 2ms increments)



Results & Discussion



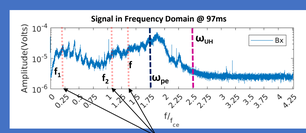
Earlier gun trigger times show more activity between the whistler (low frequency) and X-mode region.



Looking at the cross spectrum of the Bx & By illuminates the activity between the whistler and X-mode frequency range. This activity suggest potential non-linear 3 wave coupling.

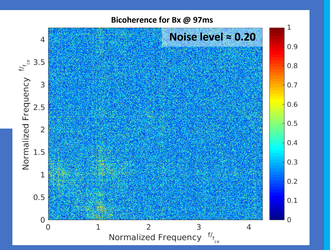
$$b(f_1, f_2) = \frac{\left|\sum_n F_n(f_1) F_n(f_2) F_n^*(f_1 + f_2)\right|}{\sum_n \left|F_n(f_1) F_n(f_2) F_n^*(f_1 + f_2)\right|}$$

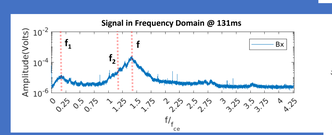
Bicoherence is used to measure the degree of three-wave coupling. (Take $F_n(f_i)$ to be the Fourier transform)



There appears to be some activity present in the low frequency region.

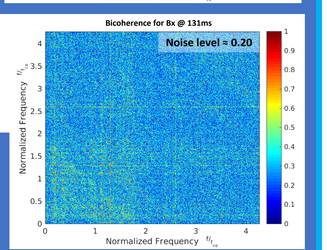
Recall: $f = f_1 + f_2$ ← frequencies

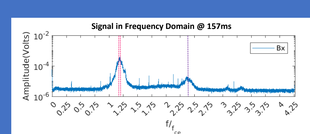




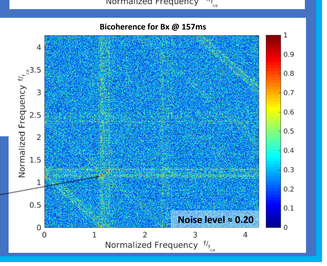
Grid patterns pop up with some of the indicated frequencies mapping out to activity in the frequency space of the signal.

One example from this grid patter is taking $f_1 \cong 1.2$, $f_2 \cong 0.2$, so f = 1.4. (These frequencies are plotted above)





Here in later trigger times there are indications of potential 3 wave coupling with the second harmonic of the plasma frequency

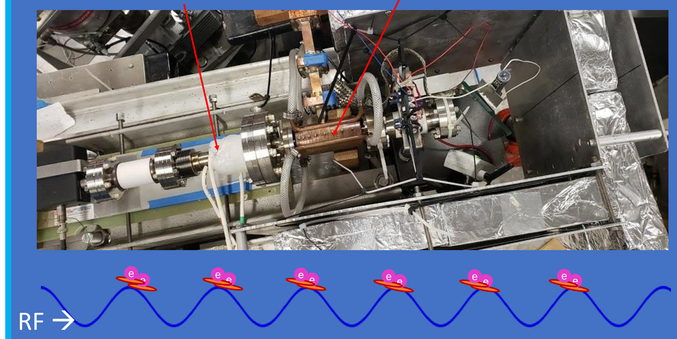


Conclusions

- 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 whistler and X-mode region are possible.
- Bicoherence analysis does suggest some interactions between waves at the plasma frequency may lead to emissions at the second harmonic.

Future Work

- Further bicoherence analysis is needed. Observations of the By and the electric field 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.



Acknowledgments

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References

[1] Reid, H. & Ratcliffe, Heather. (2014). A review of solar type III radio bursts. Research in Astronomy and Astrophysics. 14. 10.1088/1674-4527/14/7/003.

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