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Study of Electron Instabilities in Crossed Electric and Magnetic Fields

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Abstract

Crossed-field devices such as cross field amplifiers (CFA) are used in high power radar systems. In our research of cross field devices, electrons are injected into a crossed electric and magnetic field planar structure to observe the physical behavior within the system. The objective is to design and implement electronics to drive Gated Field Emission Arrays (GFEA) that have been fabricated by collaborators at MIT. This experiment will assist with the observation of electron behavior in the crossed-field vacuum environment. Understanding of the onset of electron beam instability in crossed-field devices is not complete. A predesigned controller board is used for electron injection device control to regulate high voltage, and current. An ATXMEGA192A microprocessor on the controller board is responsible for managing much of the input and output data. LABVIEW software communicates to this controller board and will be used to observe and record data for further analysis. Components such as opto-isolator boards, current monitor boards, and an isolation box will ensure the safety of both researchers and hardware.

Authors

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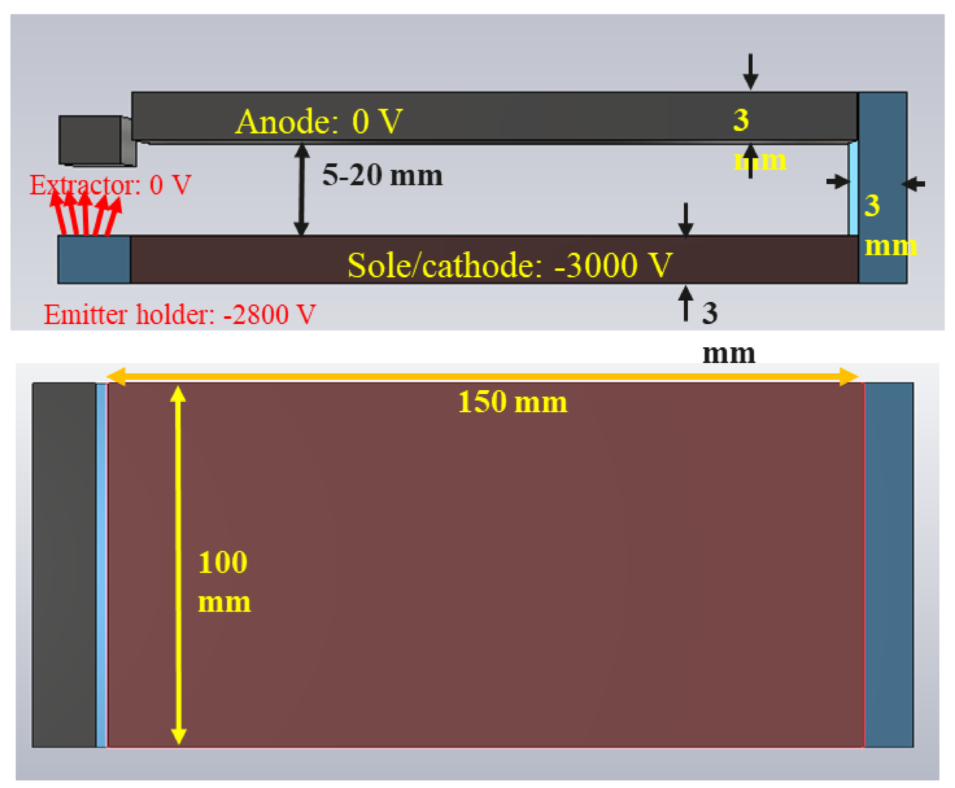
Introduction

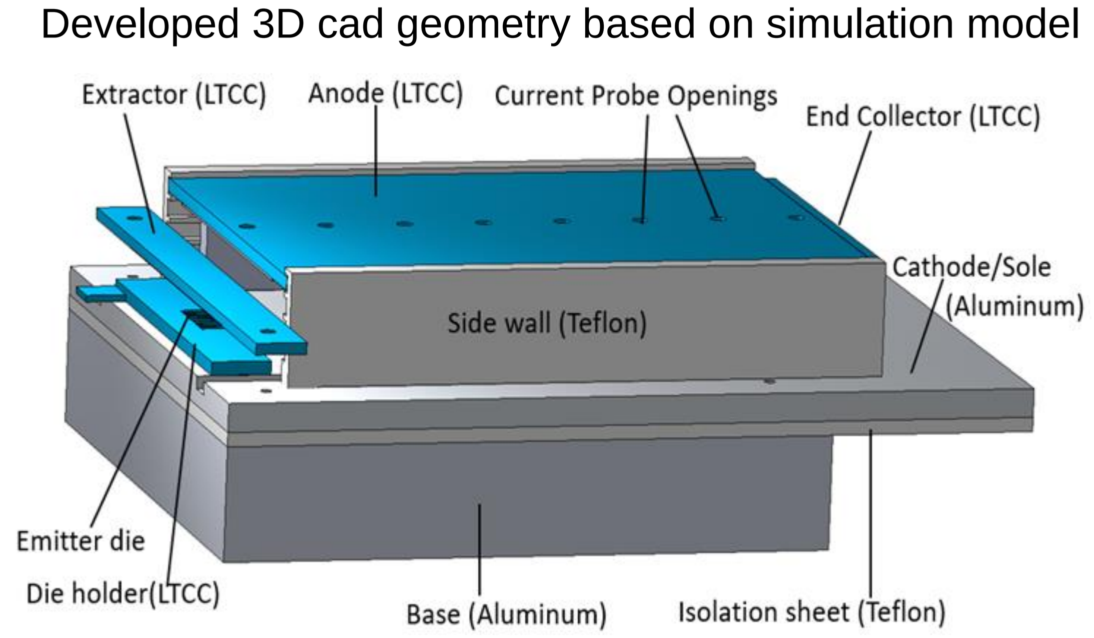
The research goal is to study the onset of instabilities in electron beams in Crossed-Field configurations. Many devices such as microwave oscillators (magnetrons) and test equipment (mass spectrometers) use the electron motion in crossed electric and magnetic fields to emit high-powered waves. Experiments are performed using a simple planar Cross Field configuration that utilizes Gated Field Emitter Arrays (GFEA) as the electron source. The objective of this study is to develop a driver circuit system for the experiment.

Experimental Model

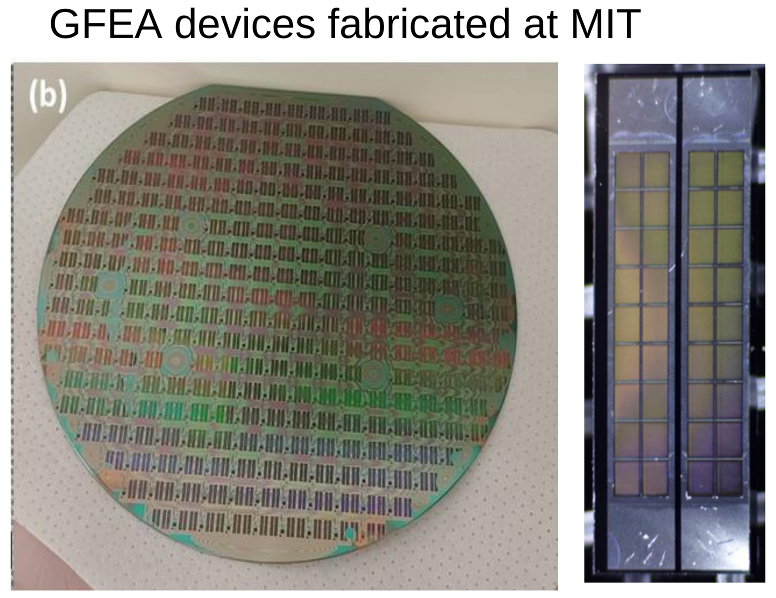
Planar crossed-field simulation model



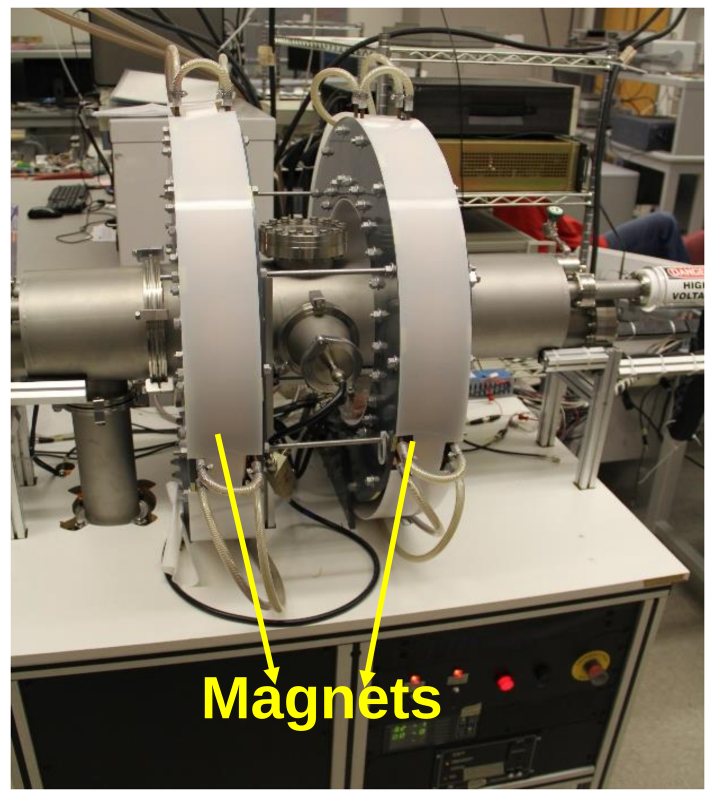
Developed 3D cad geometry based on simulation model



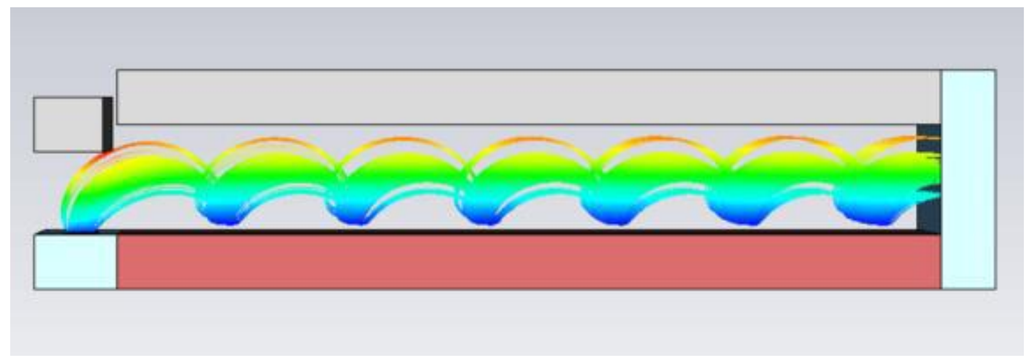
GFEA devices fabricated at MIT



Test chamber system for crossed field device experiment



Particle tracking simulation of a planar crossed field device



Intended CFD Testing

Once completed, the CFD test system will be able to:

- Examine electron beam propagation under a crossed electric and magnetic.
- Examine electron beam stability thresholds experimentally.
- Allow comparison with theory and simulation.

Circuit Development for CF Device

Opto-coupler circuit (Isolates GFEA drivers at 3 kV)

- Contains input and output sides with four different channels to measure floating potential.
- The circuit is designed to take 0-20 V through the input side.
- The circuit mainly focuses on the LOC110 chip that uses two phototransistors to mimic an input signal to the output side.

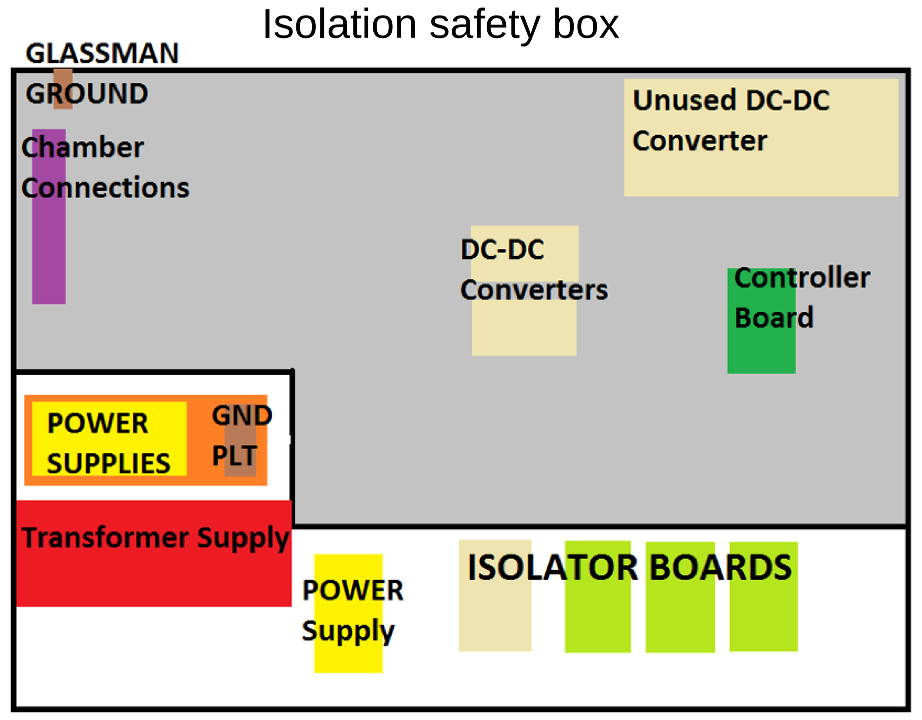
Isolation Box

- Allows critical components to be referenced to a floating voltage of several thousand volts.
- The CFD control signals come from LabView, Isolation is established to reference the new ground.
- Ensures user safety with a micro switch that acts as an emergency shut-off.

Current Monitor

- Consists of three current monitors the gate, emitter, and collector.
- The monitors are crucial to visualizing the desired behavior of electron beam propagation.
- LabVIEW is used to communicate with the current monitor boards through serial communication.
- A proper data transfer rate is prioritized for the controller board to read and analyze data properly into LabVIEW.

Isolation safety box

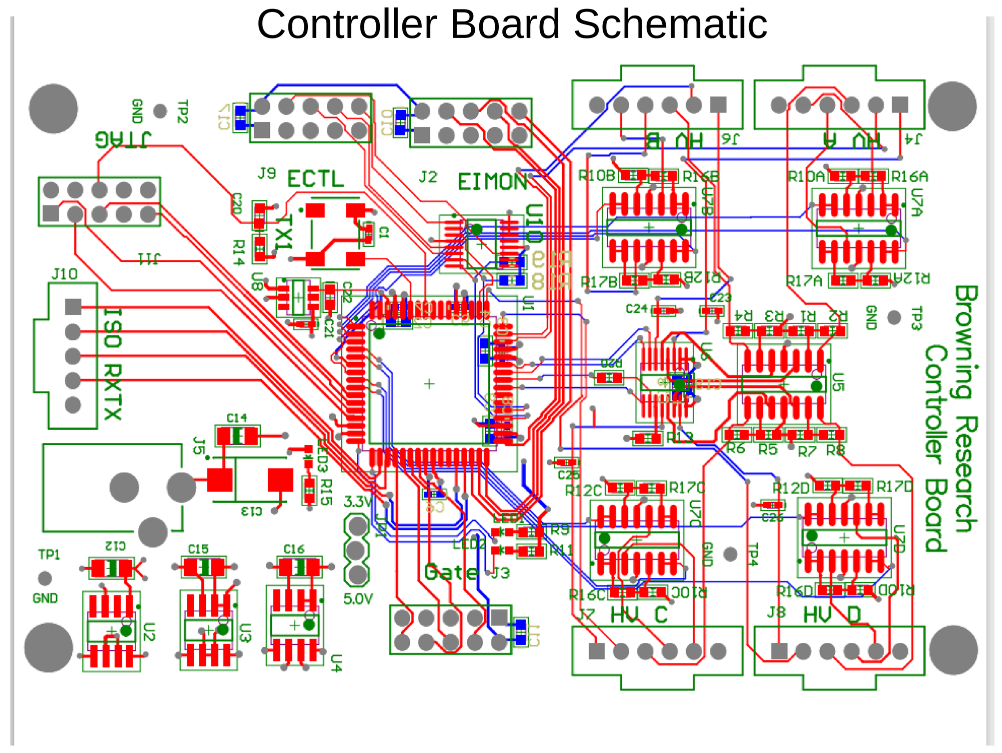


Controller Board for CF Device

The microcontroller board utilizes features for the CF device.

- Communication is established with LabVIEW through two available SPI interfaces.
- Special op-amp configuration allows 1-5 V control that multiplies by 100 for the high voltage DC-DC converters.
- The CPU manages current data for the gate current, emitter current, and collector current.

Controller Board Schematic



RESULTS & ANALYSIS

- The CFD requires floating drive electronics to turn on and off the electron course (GFEAs).
- A driver system using previously developed opto-coupler and current monitor boards are being repurposed for this experiment.
- Testing and integration of these components into a floating HV isolation system are ongoing.
- The controller board requires further programming configuration to optimize data management.
- The current monitor boards are currently being used to analyze data without the controller board but are not an efficient use of resources.

CONCLUSION

- Crossed-Field Devices such as Magnetrons are highly efficient and robust for use in radar and industrial heating.
- Understanding fundamental device physics is critical.
- The CFD under study will compare theory, simulation, and experiment to extend our understanding of these devices.
- Once updated, the controller board will allow proper utilization of the CFD.
- The controller board and HV isolation opto-coupler system are under development.

ACKNOWLEDGEMENTS

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