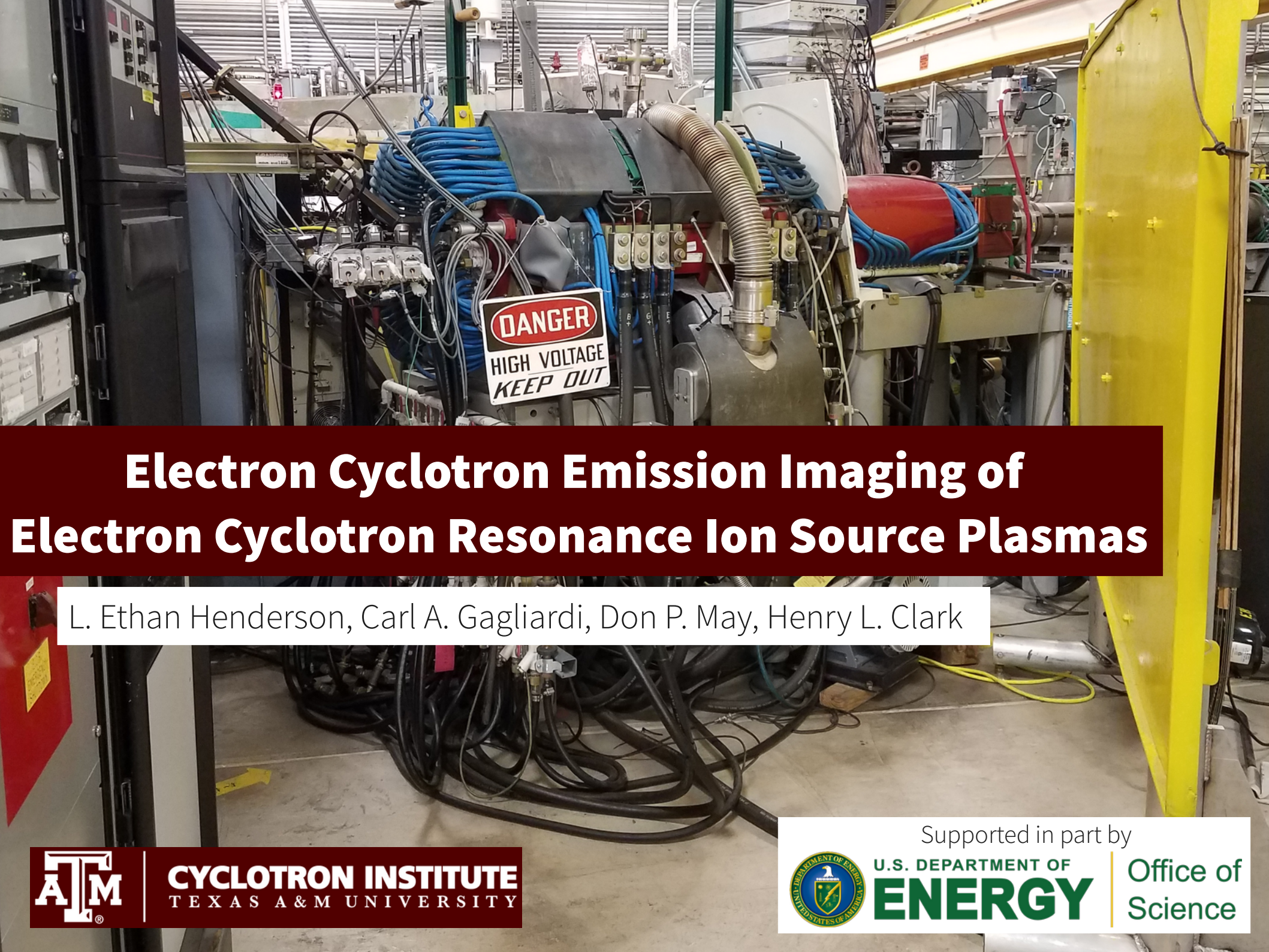

Electron Cyclotron Emission Imaging of Electron Cyclotron Resonance Ion Source Plasmas

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CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

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U.S. DEPARTMENT OF ENERGY
Office of Science

Outline

- Electron Cyclotron Emission (ECE) from plasma electrons
- K/Ka-band Microwave Camera for 6.4 GHz ECRIS
  - Primary Optic
  - Signal Processing
  - Receiver Electronics
- Research & Development Plan

Context

Previous Studies:

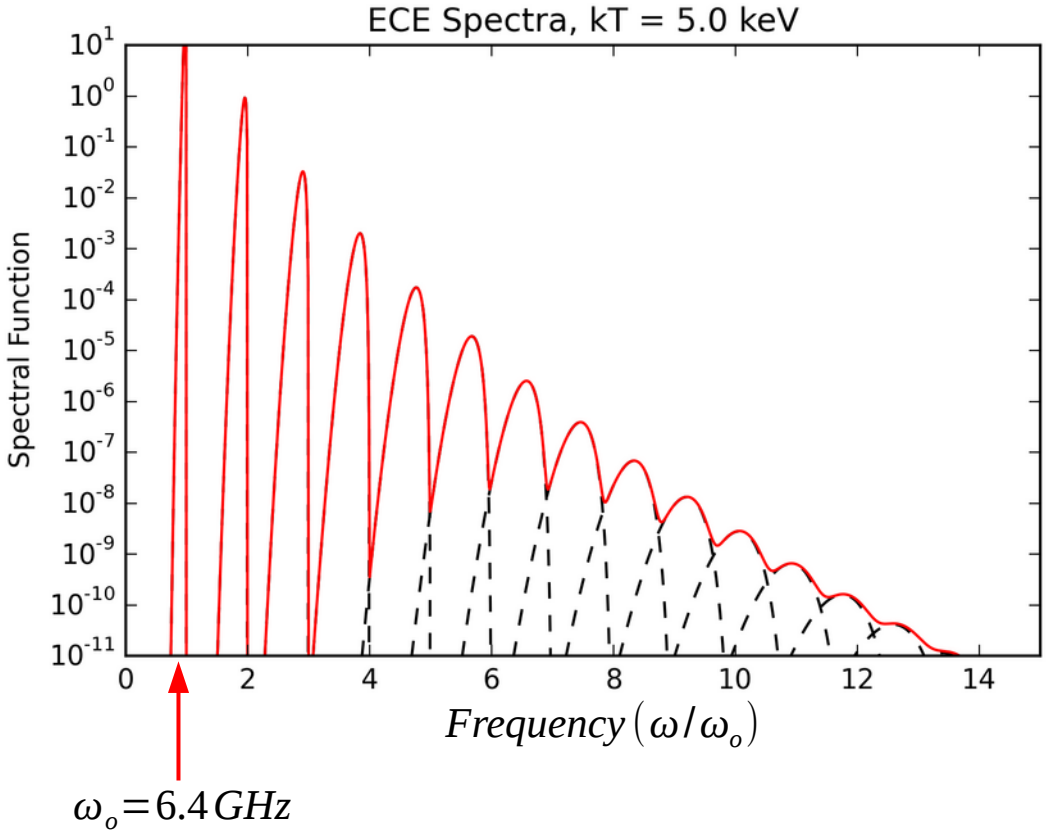
- Beam measurements
  → Ion populations
- X-ray & ECE bulk spectra
  → Ion populations
  → Electron energy spectrum
- Langmuir Probes
  → Plasma parameters

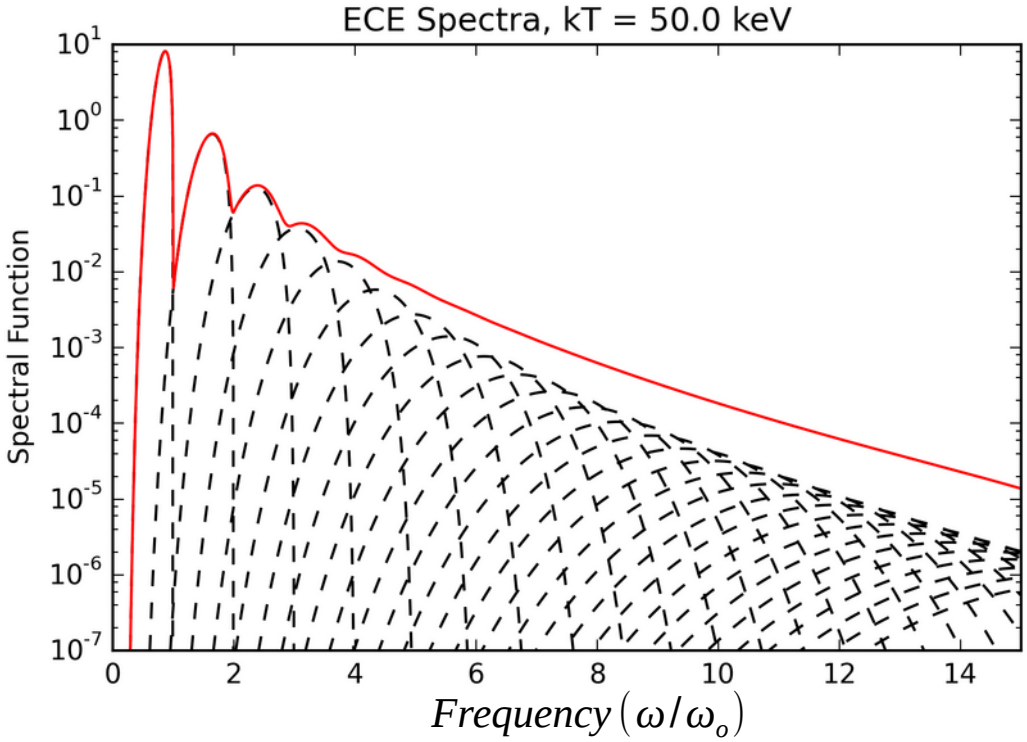
This Research:

- Spatially resolved ECE
  → T_e for electron population(s)?

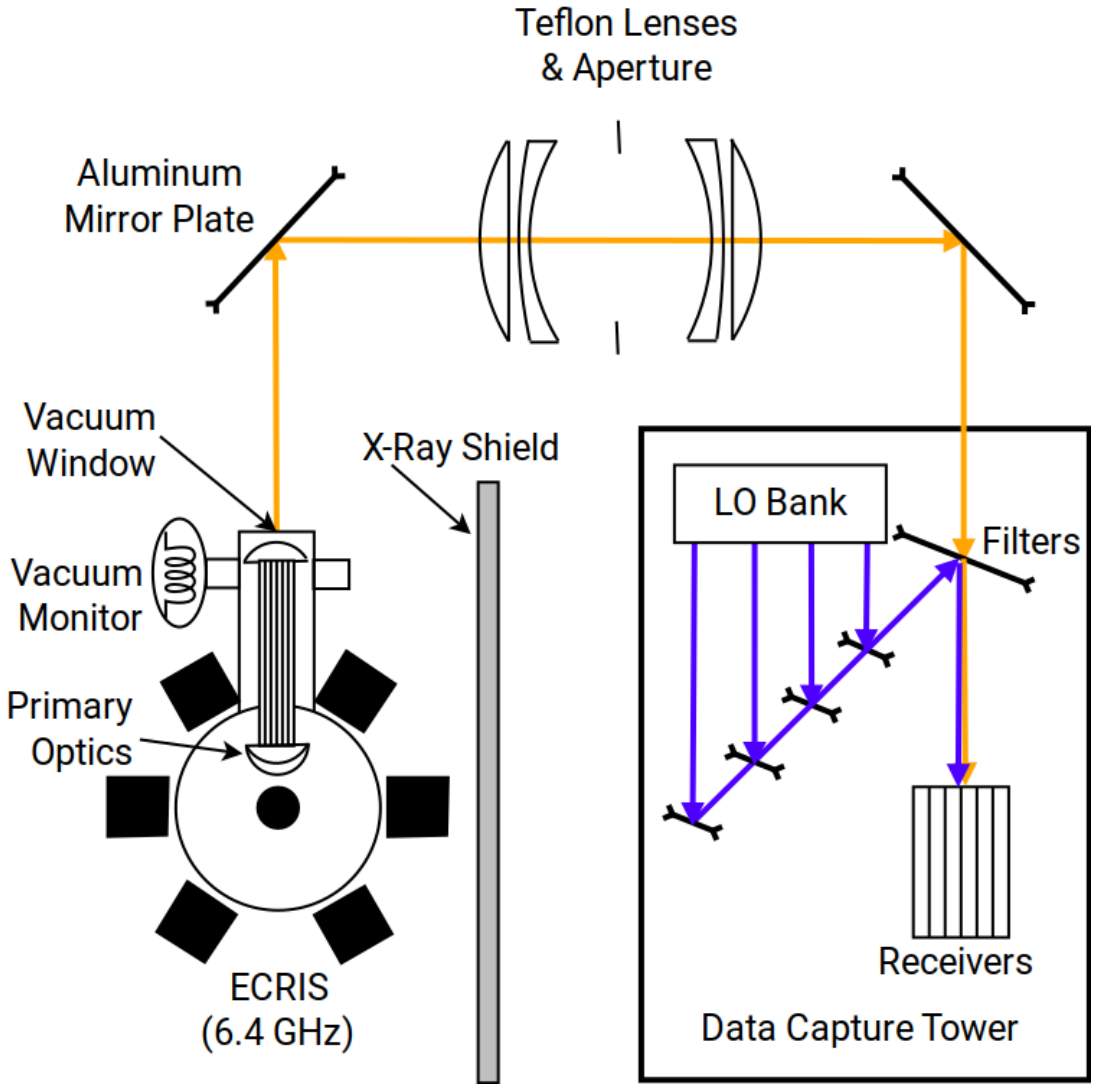
Context (Transparent Plasma)

ECE Spectra → Electron Pop. Rel. Density & Abs. Temperature



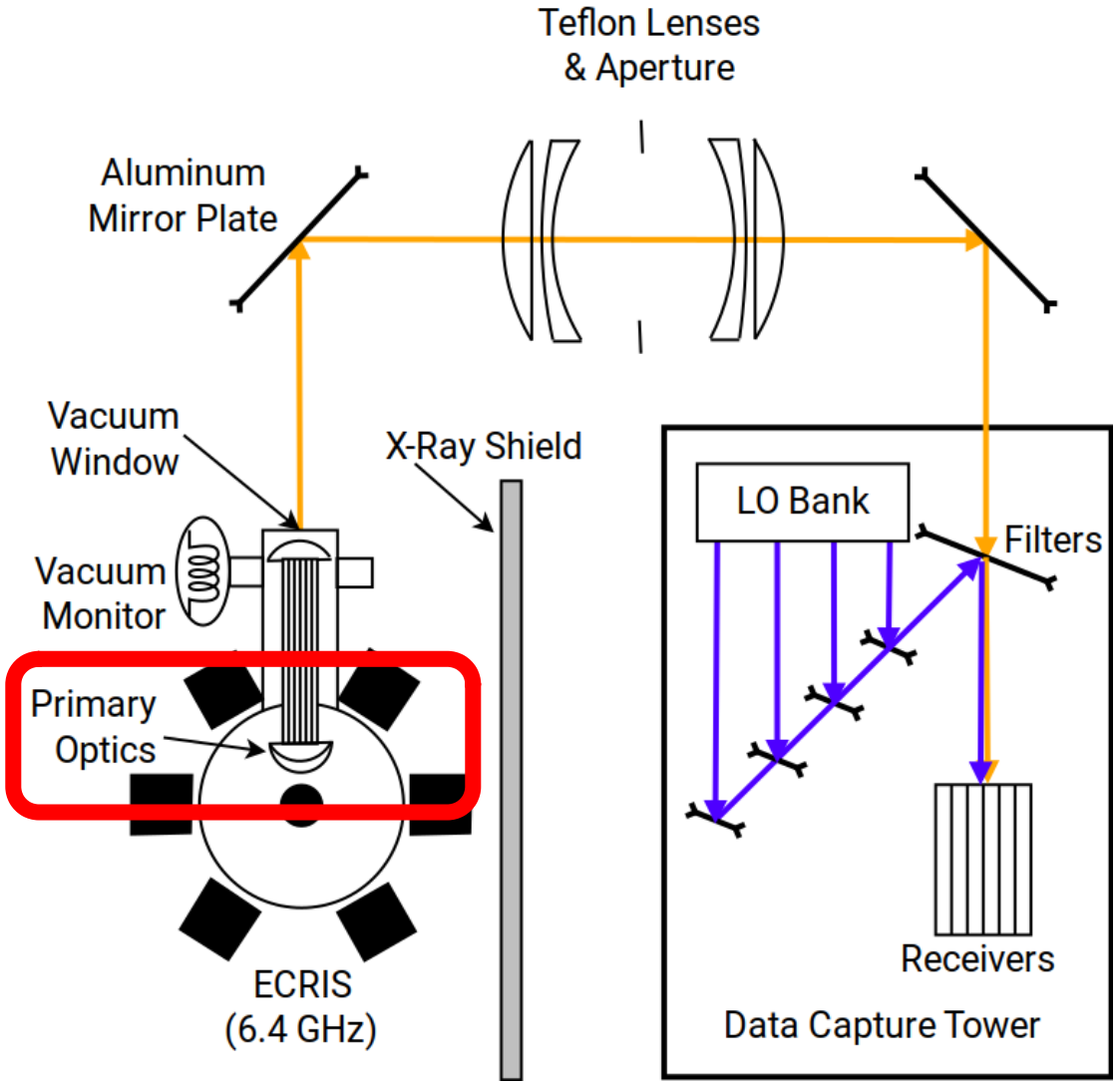


Camera Overview



NOT TO SCALE

Camera Overview - Primary Optic



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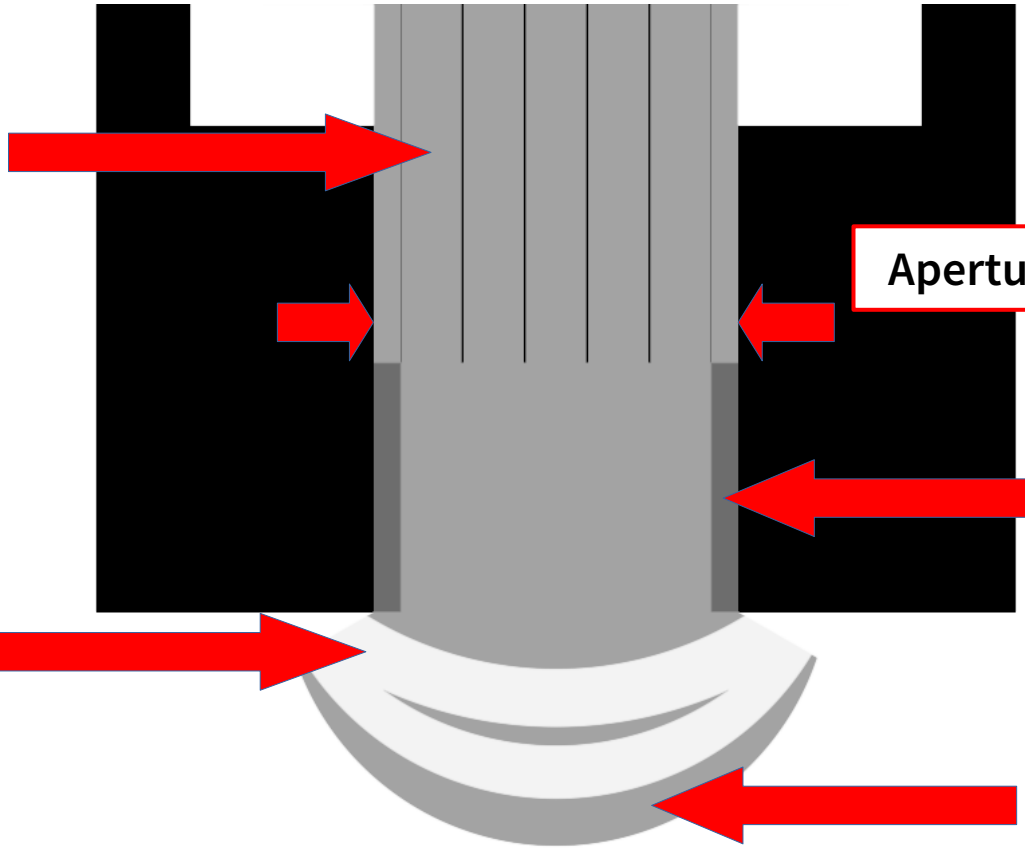
Primary Optic



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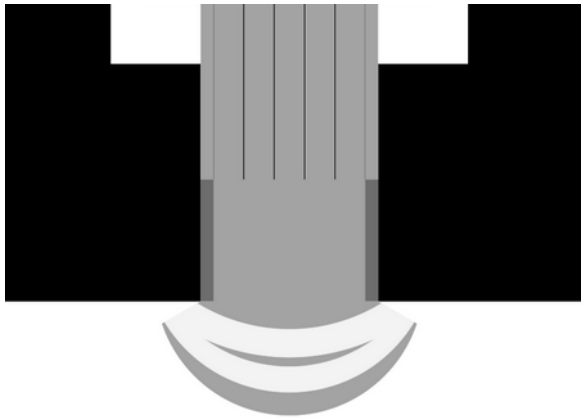
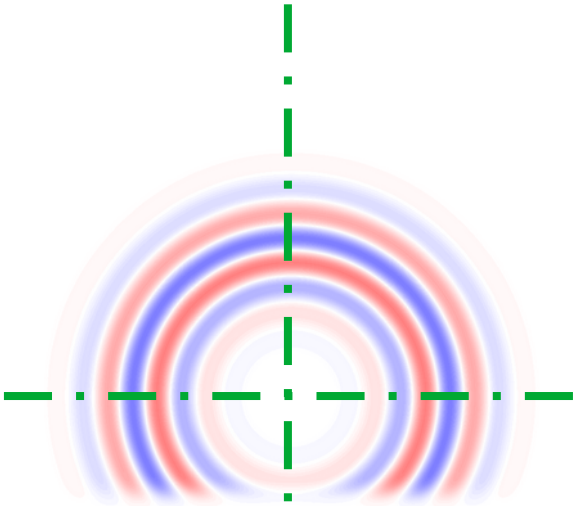
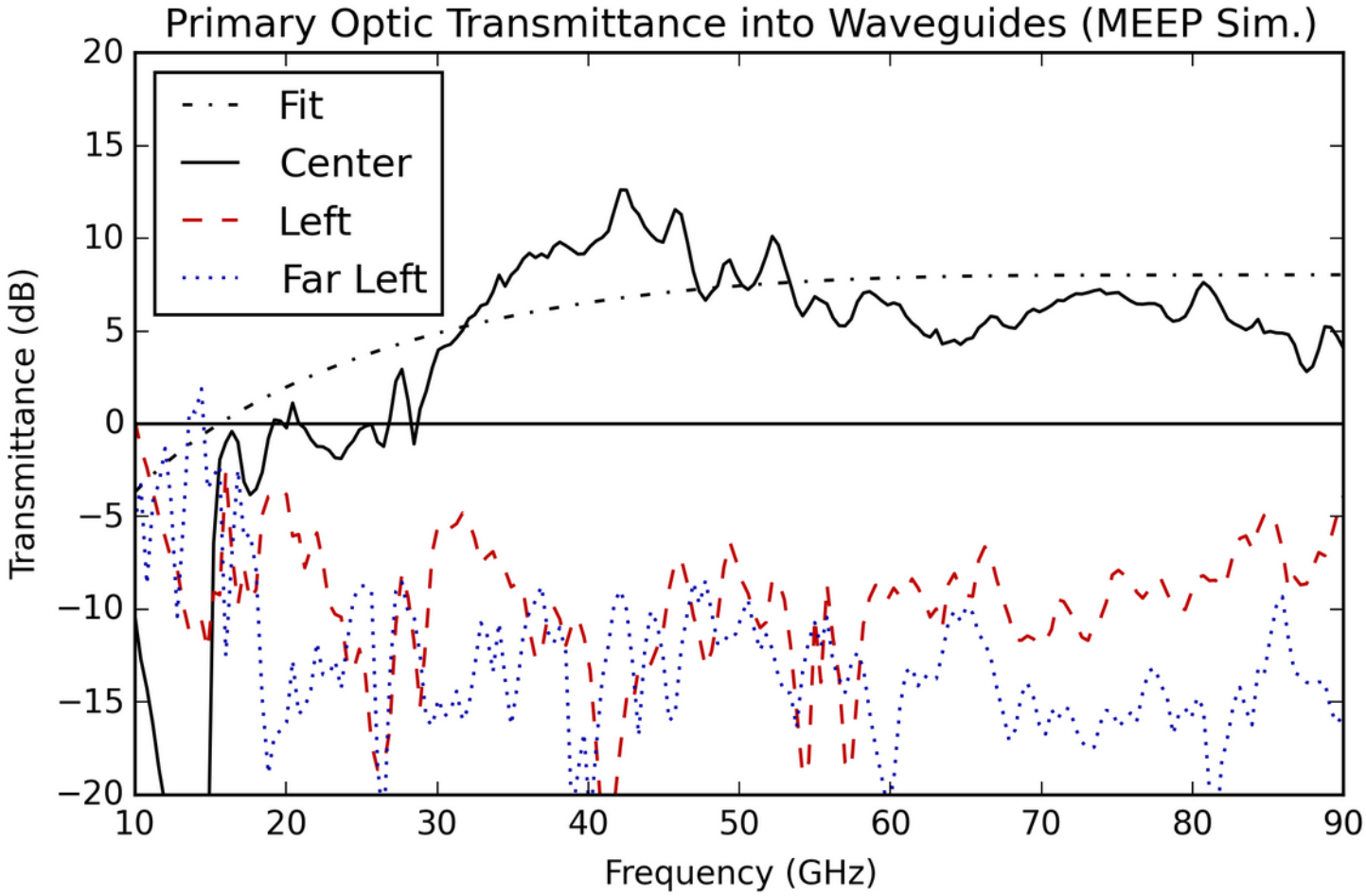
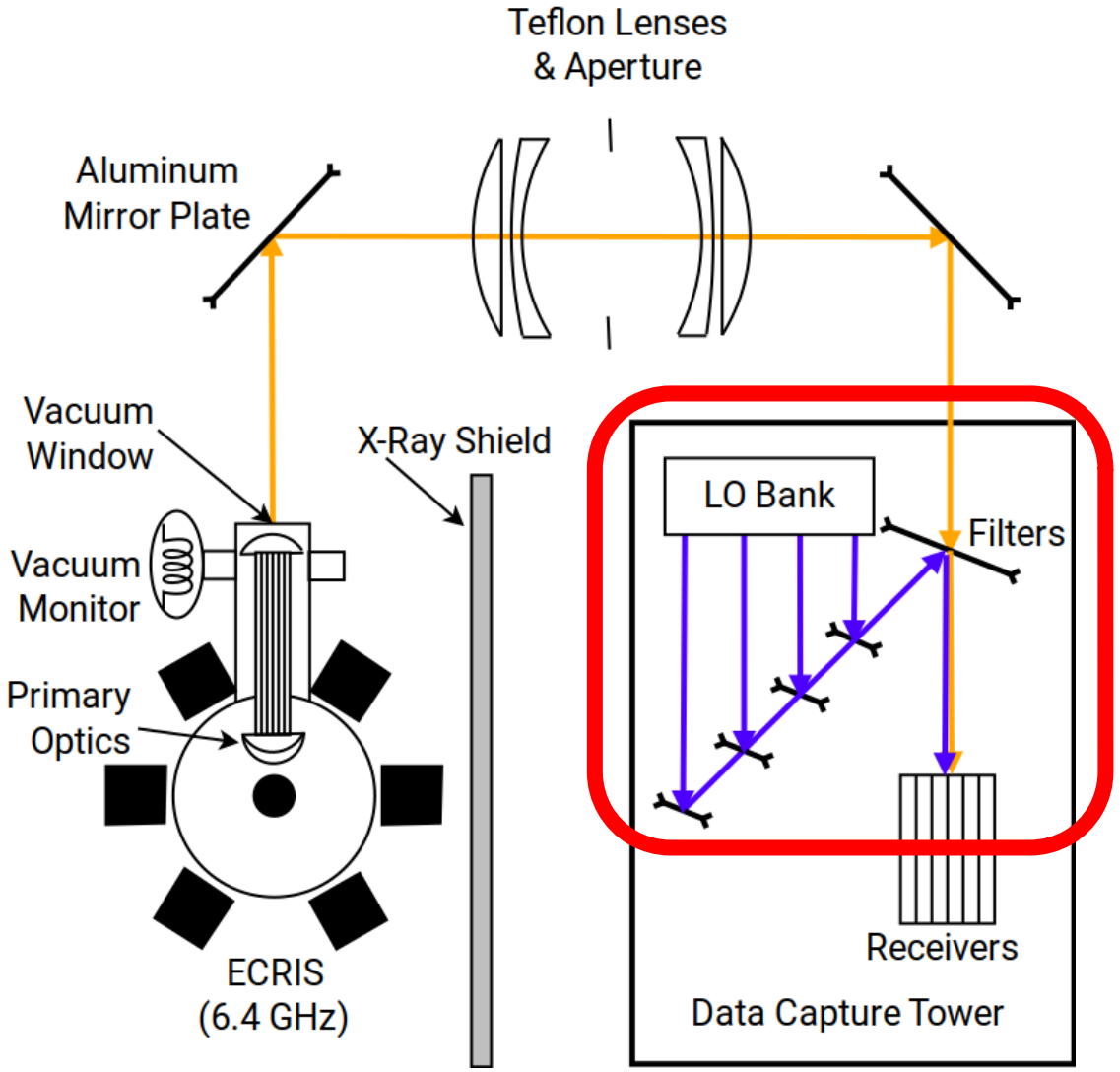
Point Source Simulation (via MEEP)







Camera Overview - Signal Processing



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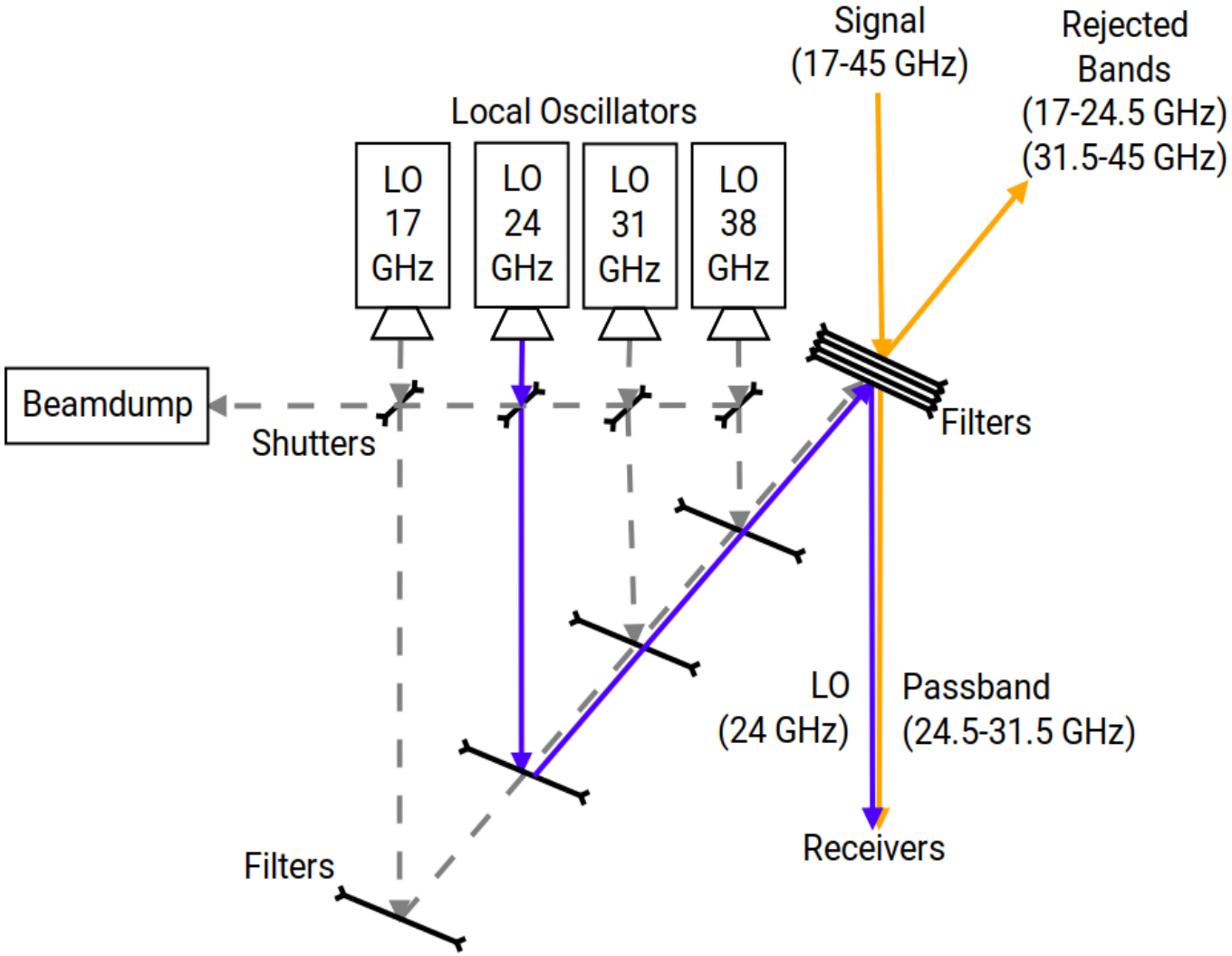
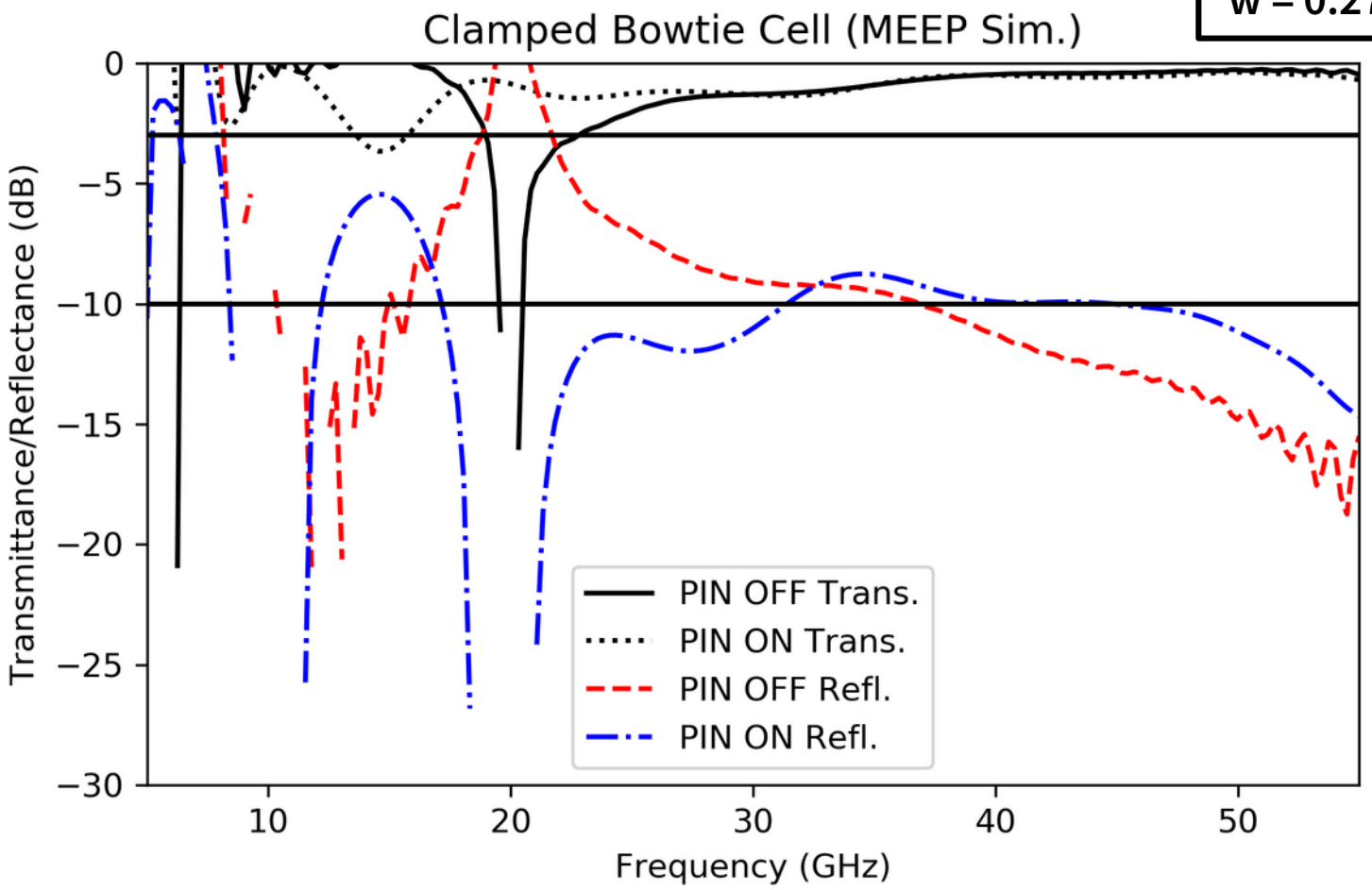
Quasi-optical Bandpassing

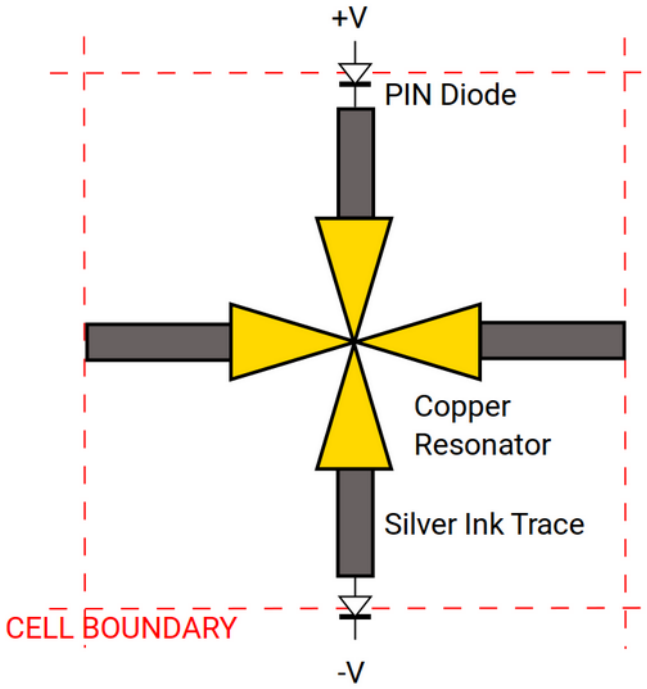


Electronically Variable Reflective Surfaces (EVRS)

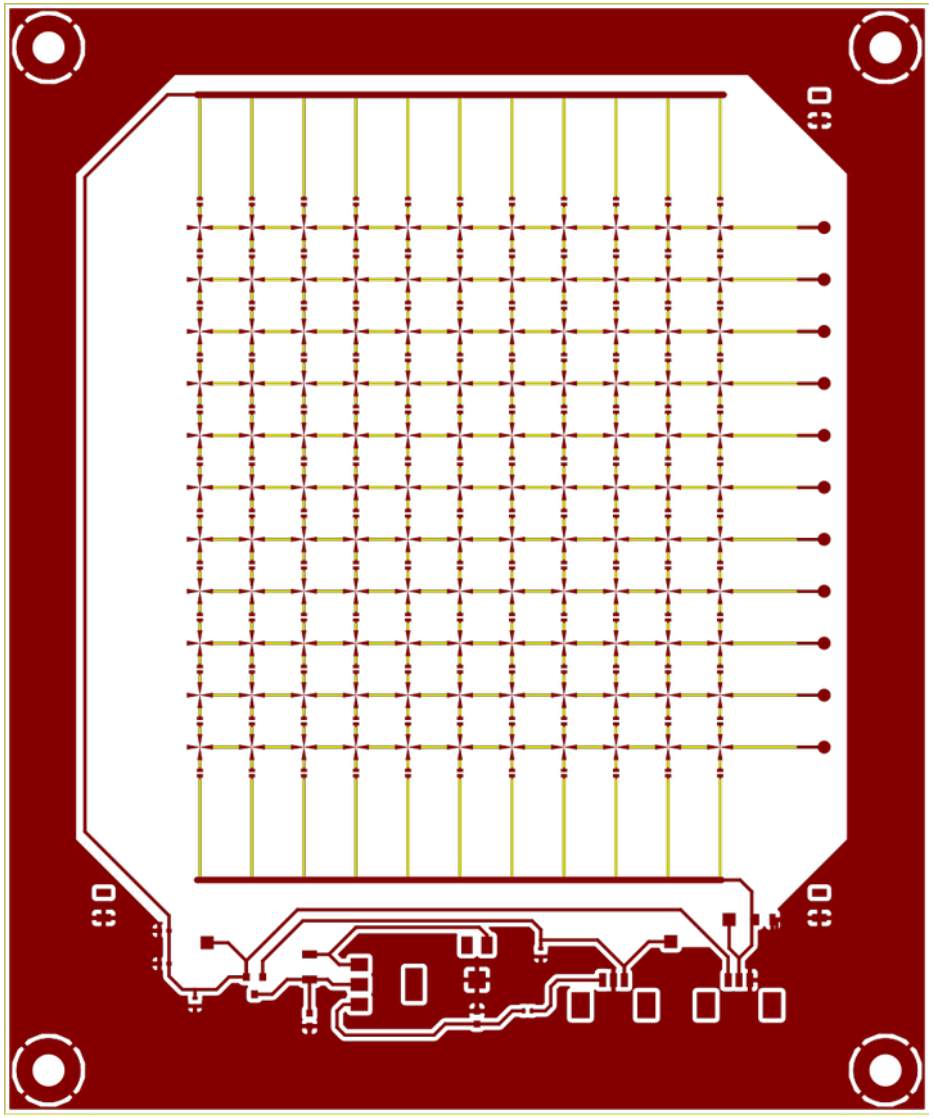
a = 0.55 cm
w = 0.275 cm



Electronically Variable Reflective Surfaces (EVRS)



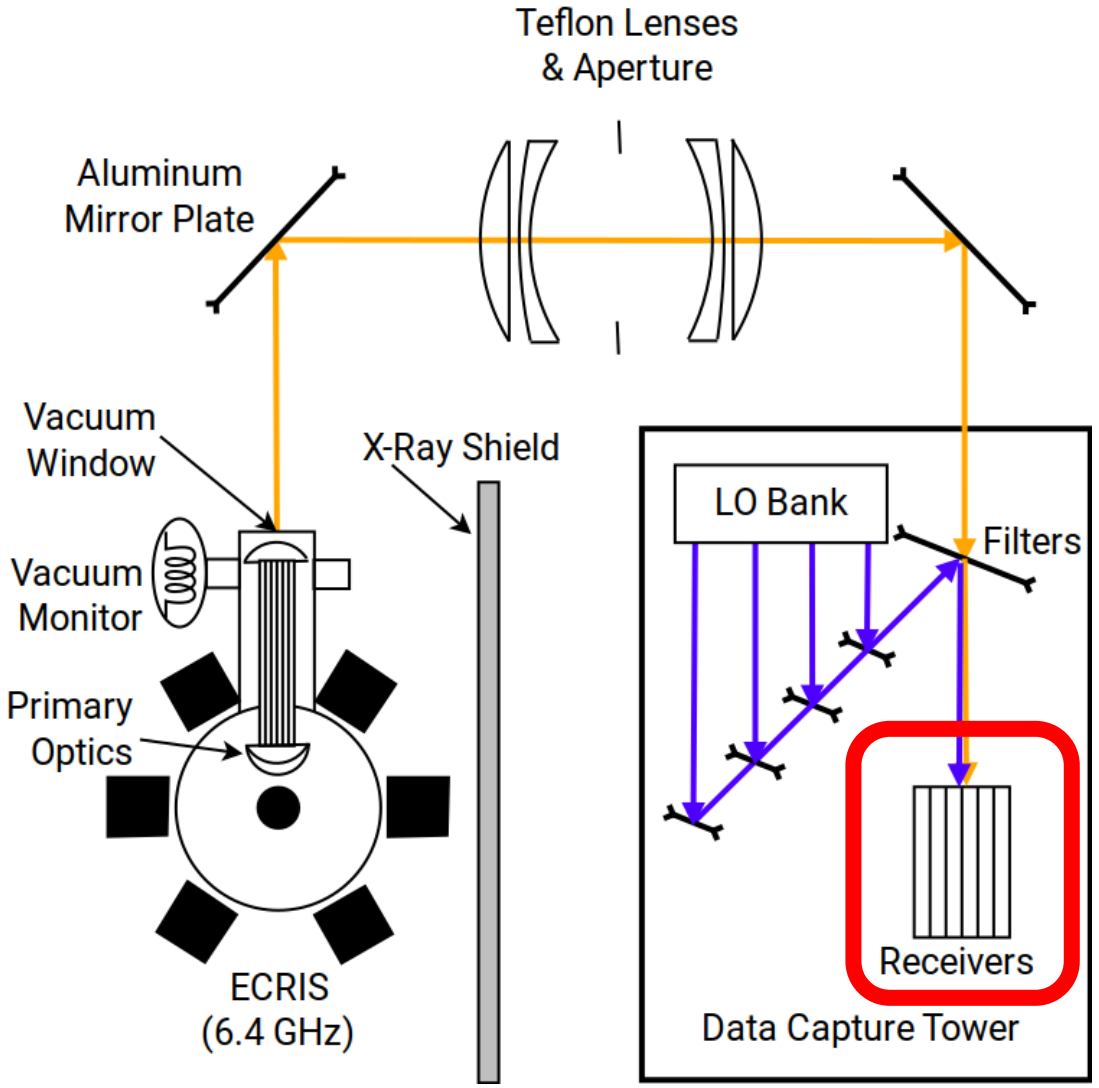
Cell Size
~3mm to ~6mm



Array Type		Power Supply
Shutter	(~2” x 2”)	~8 V @ ~2 mA
Filter	(~6” x 6”)	~24 V @ ~6 mA

Reflective state	Non-reflective state
No bias current	0.675V@100µA per cell
Diode R(AC) = 3 kΩ	Diode R(AC) = 20 Ω

Camera Overview - Receiver Array



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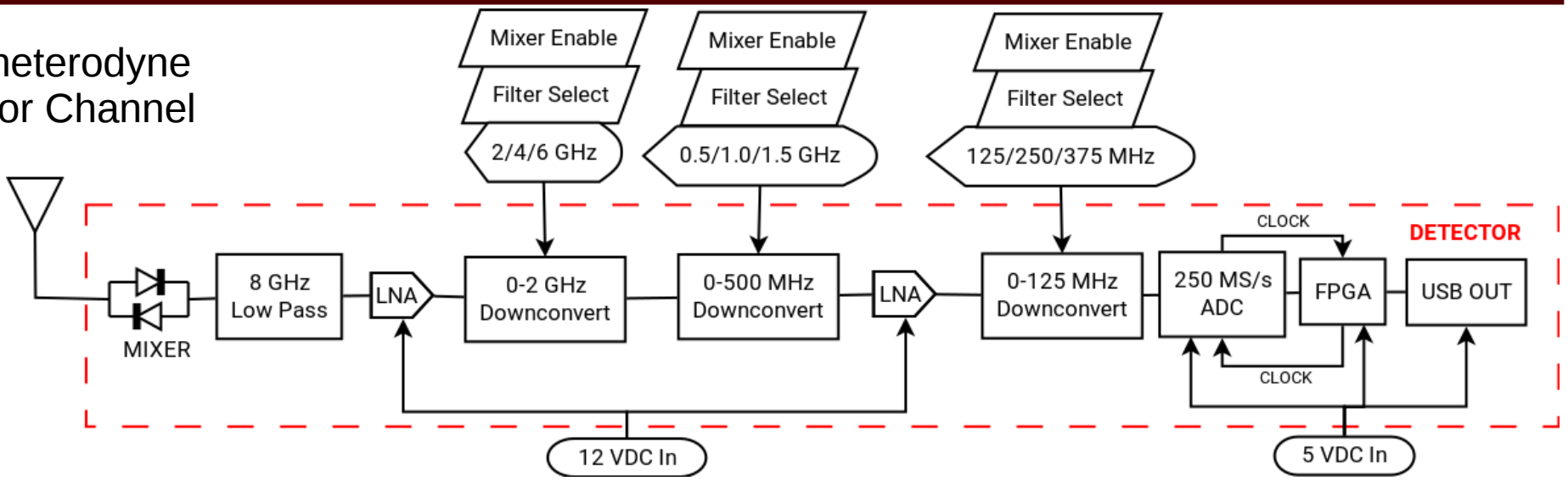
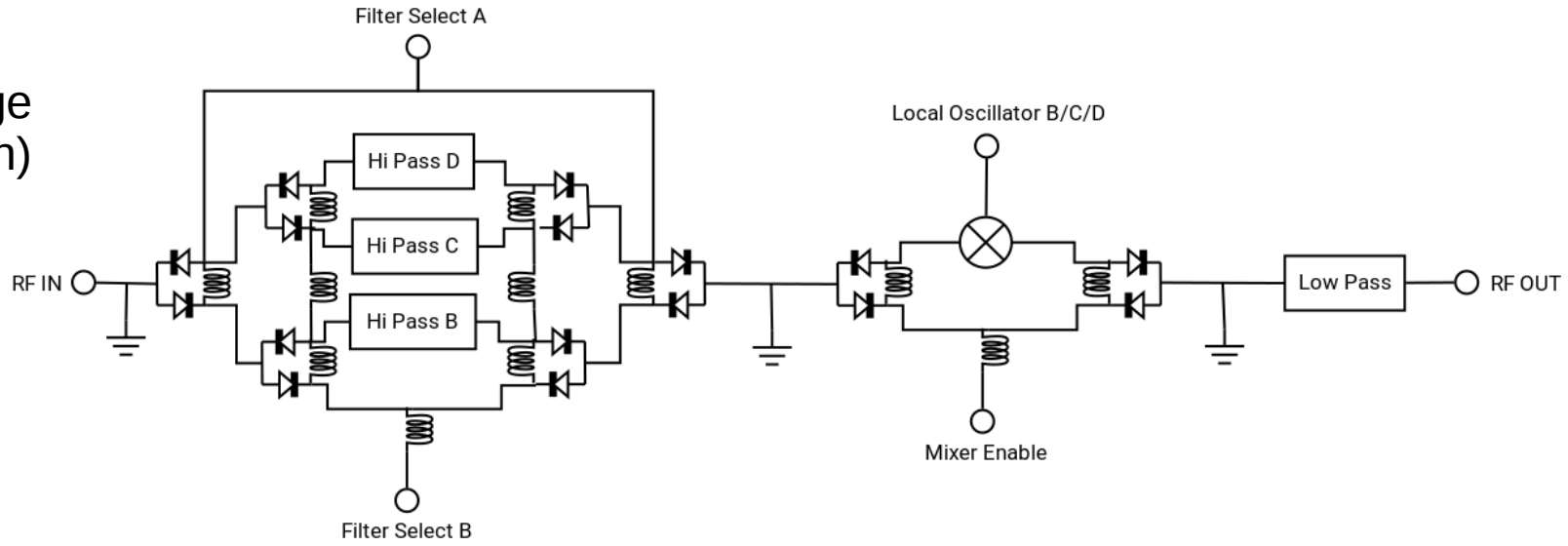
Receiver Electronics

Superheterodyne Detector Channel



Heterodyne Stage (Downconversion)



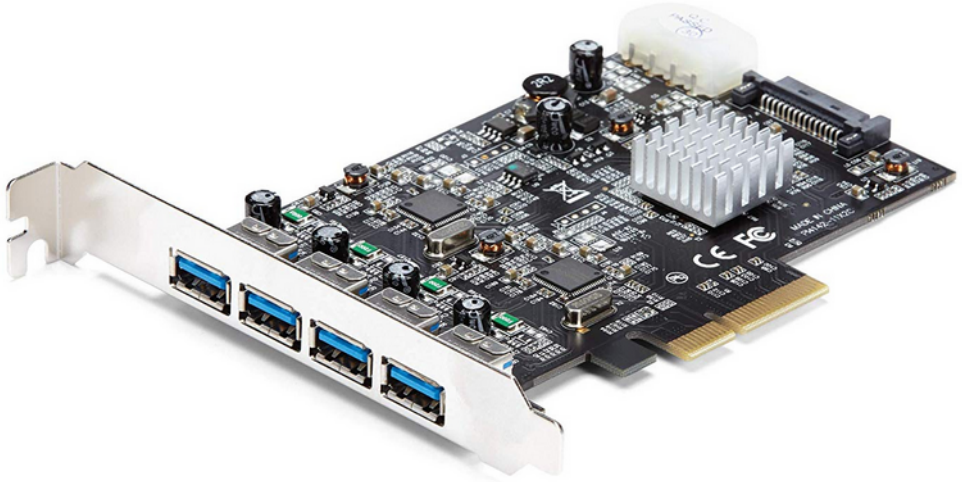
Receiver Framerate

ADC 12 bit @ 250 MS/s (Ti ADS4129)

2 µs sample per band (500 kHz resolution)

→ 0.54 ms full spectrum capture

→ 1.860 kHz “full-color” fps



Startech PEXUSB314A2V
4x USB 3.1 to PCIe

3.0 Gbit/s samples + 1.0 Gbit/s metadata per channel

→ 25x USB 3.1 dedicated channels (5 Gbit/s)

MOSFET rise/fall time ~100 ns

Arduino Nano (20 MHz ATMEGA4809) controller

→ 5 MHz filter power cycle max

→ ≤1 MHz switching states

Component Development

Single Component Testing:

- Anechoic Chamber w/ Turntable

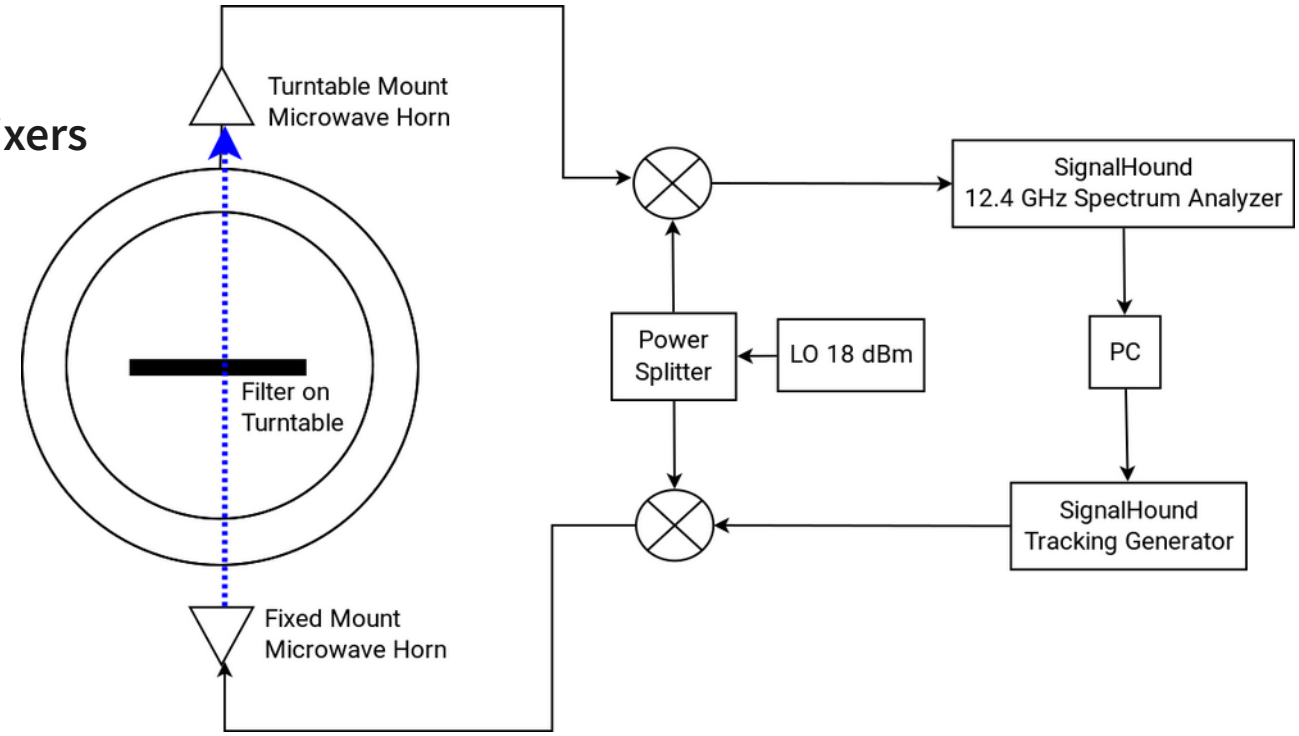
  (Mounting Hardware 3D-printed PLA)

- Network Analyzer (12.4 GHz)

  with step-up/step-down mixers

System Calibration:

- Frequency Response Curves for Individual Components



Outlook

Component Development

- Fall 2020 – EVRS Testing
- Spring 2021 – Optics Testing
- Summer 2021 – DAQ Setup

Full system

- Summer 2021 – Earliest First Light Opportunity

Initial Measurements

- Core vs. Shell Electron Temperature
- Observe Ignition & Afterglow Dynamics

Thank you!

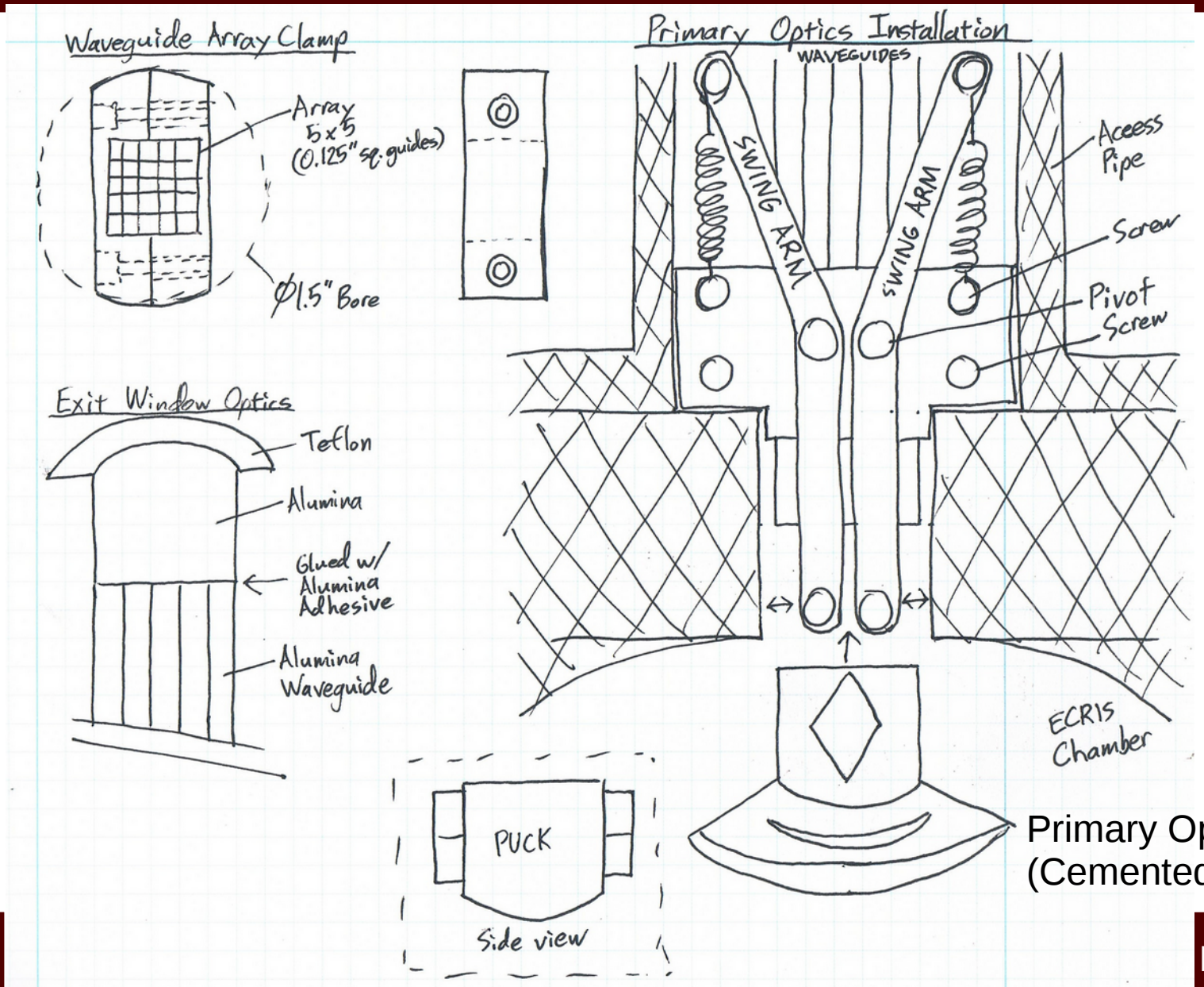
Research Group

- Carl Gagliardi
- Henry Clark
- Don May

Funding Sources

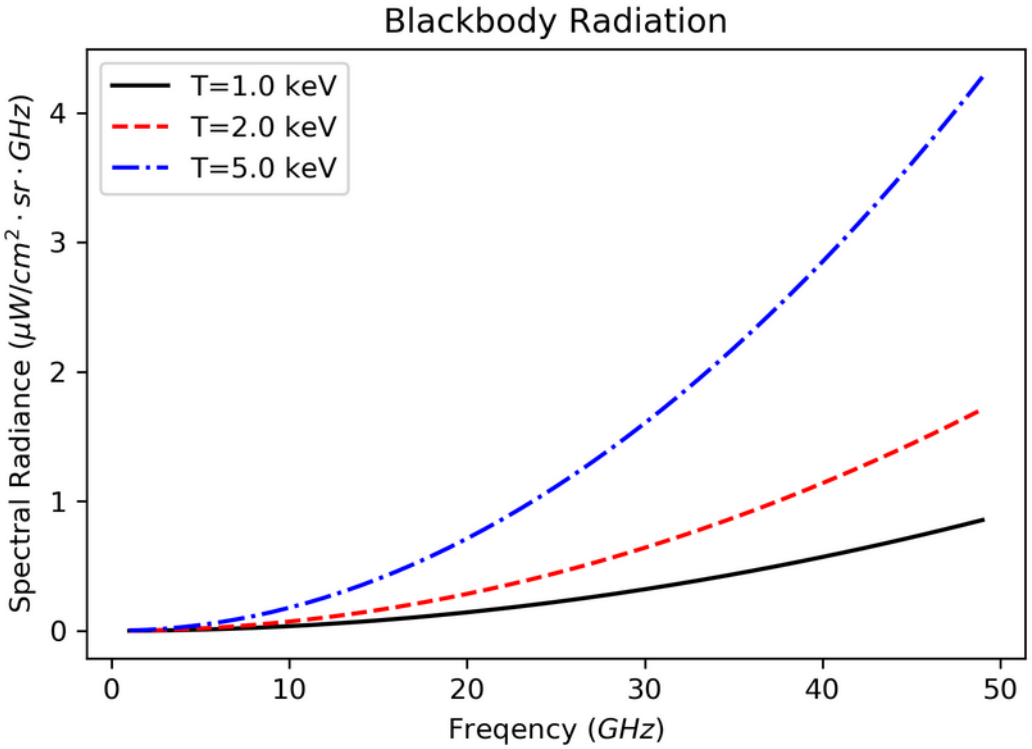
- Texas A&M University, Cyclotron Institute
- Dept. of Energy, Office of Science, Award No. DE-FG02-93ER4077

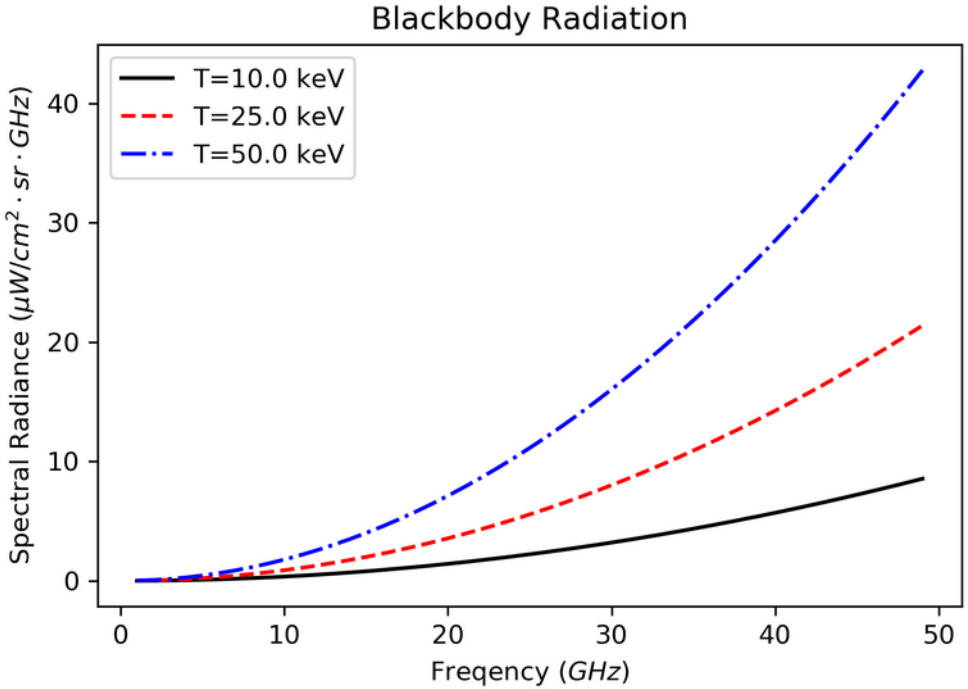
Primary Optic Installation



Primary Optic
(Cemented)

Limiting Case - Opaque Plasma





Receiver Array - Local Oscillator farm