Holography + Beam Mapping Lab

Name:

August 10, 2022

TEAM NAME: [ ]

1 Station: Beam Map

The optical coupling couples light onto the detector and defines the detector beams [1]. One type of optical coupling used in CMB experiments is feedhorns with orthomode transducers (OMTs). Here the OMT antenna is part of the detector wafer, while the feedhorn sits just above the OMT. Unlike other coupling technologies where the antennae contribute to the detector beam, the feedhorn fully defines detector beam, while the OMT has four fins that split the polarization into two orthogonal polarizations (add a figure). This means that we can fully characterize the detector beams by measuring the feedhorn beams at room temperature using a beam mapper (while other technologies must be integrated with the detectors and tested cold).

The feedhorns must also couple to the optics in the telescope. In this design, three feedhorn arrays sit in the focal plane of the optics tube (see Fig. 1).

Goals:

1. Load the 90/150 GHz Mid-Frequency feedhorn array onto the rotary stage.
2. See a response in the real-time signal viewer.
3. Measure the feedhorn's beam at 3 frequencies (more if you want!).

Procedure: Follow the measurement Notebook for detailed instructions on operating the experiment. An overview is here:

1. Enter your team's name in the first cell.
2. Connect to the FPGA.
3. Customize your measurement:
   - Frequency between 80 and 125 GHz.
   - Range (how far you want the motor to rotate in 1 direction. For example, `range=30` would sweep the motor to $\pm 30°$.
   - Resolution: Start with `res=`$1°$.
4. Run the `take_data()` function.
5. Save data to analysis computer: run the final cell of the notebook to send your data to the Station 2 computer.

2 Station: Analysis

2.1 Notebook 1: Data Visualization

Now that you have some data, plot the beams! In Notebook 1, you'll first need to enter your team's name, as you did in the Beam Map Station.

Goals:

1. Plot your team's data at various frequencies.
2. Investigate how the beam size and shape changes with frequency.
3. From your data, estimate the on-sky resolution of the telescope.

Exercise 1: Plot the beam maps you've measured in the Beam Map Station, follow the instruction in Notebook 1 to plot your data and inspect the beams.

Lab Questions:

- Estimate the signal-to-noise of your beam.
- What happens at the edges of the beam?
- Plot the other frequencies that you've measured. What do you notice between the different beam maps (signal-to-noise, wide-angle shape, beam width, etc.)?

Exercise 2: Understanding Beams.

In this section, you'll dig into the measured beams of the feedhorns and understand how this impacts our telescope's performance.

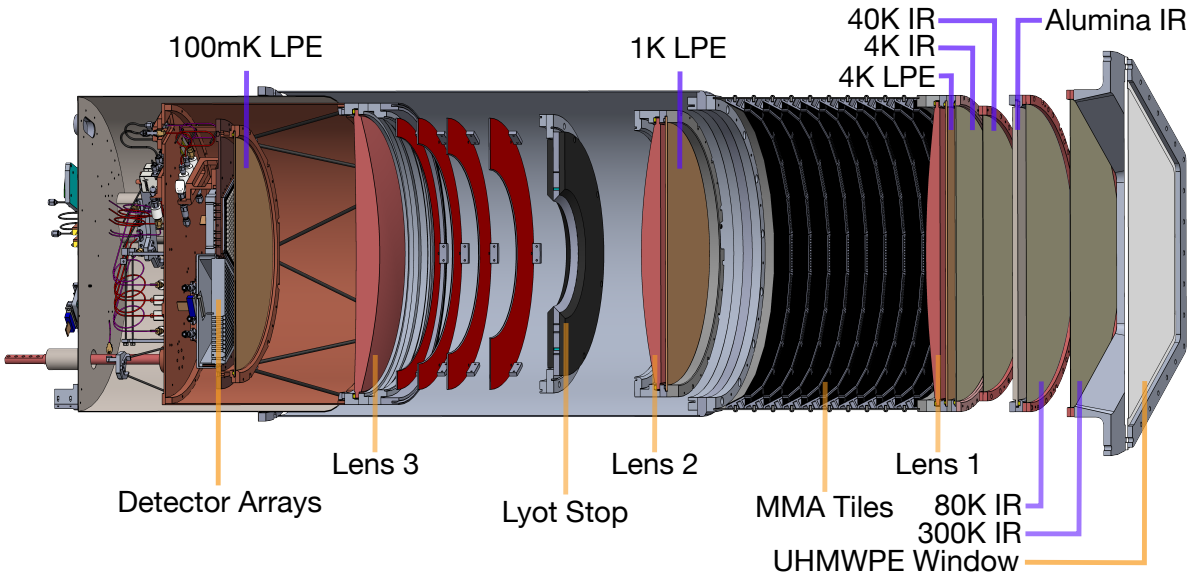


Figure 1: 90/150 GHz mid-frequency optics tube. The Lyot stop is an aperture which cuts off the beam at a specifically chosen radius. This defines our beam shape.

Lab Questions:

- From the model, what is the beam size, or Full-width Half-maximum?
- Where does the model fail to match your beam?

Exercise 3: Feed-horn Cross-Talk

Lab Questions:

- Was your beam map measured in the near-field or the far-field? (Hints: calculate d_F and estimate how far away the source was from the feedhorn array, d_M. If $d_M > d_F$ you're in the far-field.)
- What's the cross-talk from your measurement?

2.2 Notebook 2: Beam Systematics

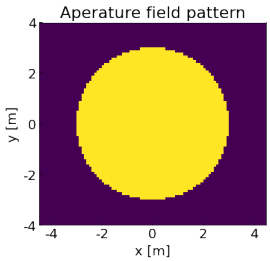
Lab Questions:

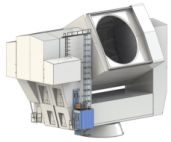
- What happens to the systematic contribution as you change the aperture stop size?
- What happens as you change the FWHM and ellipticity of the beams?
- What happens to the measured spectra as you change the telescope aperture size?

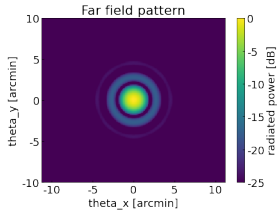
2.3 Notebook 3: Bonus Optics

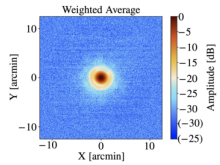
Check out this notebook if you have time!

2.3.1 Circular Aperture

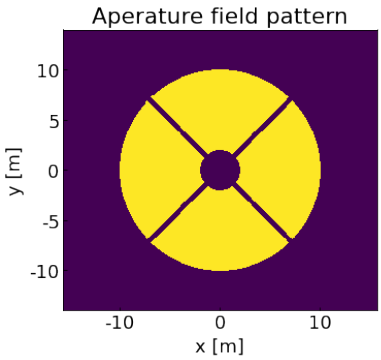


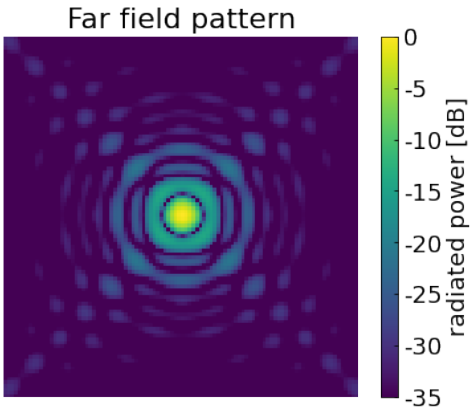




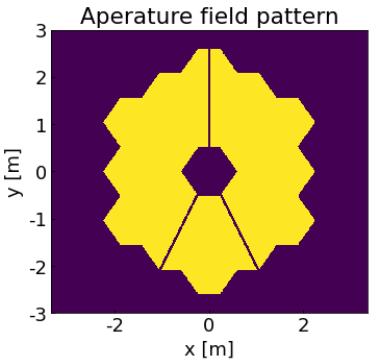


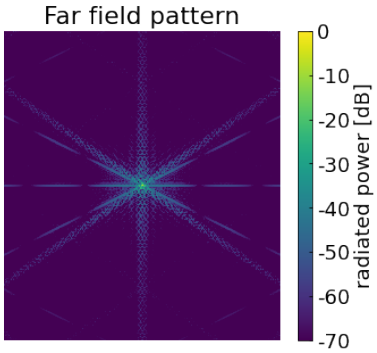
2.3.2 Circular Aperture with 4 Arms





2.3.3 JWST





3 Station: Vector Network Analyzer

3.1 Functions of a VNA

1. How can we measure the transmissivity of a material?
2. How about reflectivity?

3.2 Characterizing Optical Componants

1. Place some materials in between the source and receiver.
2. For example, how much power does the black metamaterial transmit? How much does it reflect? Why is this an optical material to coat the insides of an optics tube?