AUTOMATED TEST BED FOR PASSIVE MILLIMETER WAVE IMAGING

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Introduction

Passive Millimeter Wave Imaging (PmmWI):

- Non-invasive imaging technology that can detect ambient electromagnetic radiation in millimeter wavelengths (30-300 GHz)
- Particularly effective for applications including security and remote sensing as it can detect differences in thermal emissions from a distance
- The equipment used in this test bed detects millimeter waves in the W-band (75-110 GHz)

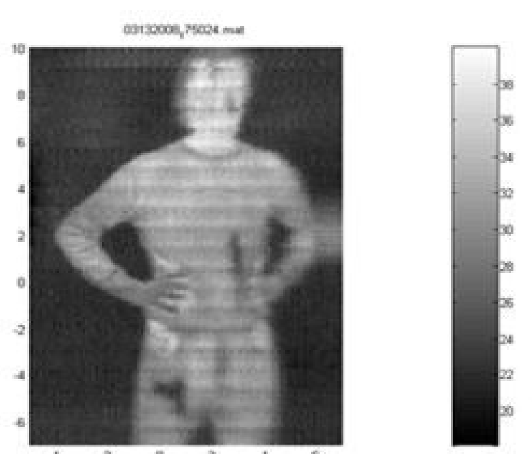

Fig. 1 NIST PmmWI image https://www.nist.gov/programs-projects/terahertz-imaging-and-sources

- Figure 1 displays PmmWI used in security applications
- Contrary to active millimeter wave imaging, PmmWI does not actively illuminate the target

Objectives:

- Construct an automated PmmWI test bed for evaluating lens iterations & system architectures to optimize image resolution and minimize distortion

Problem Statement

- Current millimeter wave imagers for security applications use components that are extremely bulky, expensive, only effective at close range, and require active illumination
- A test bed is required to evaluate the properties of inexpensive, lightweight lenses that could be used in compact imaging systems

Methodology

- Assembled linear motion stages to sweep the radiometer and electrical chopper in three dimensions
- Using CAD software, designed then 3D printed custom mounting and adapters for lenses, millimeter wave sources, and millimeter wave detectors
- Utilized radar absorbing material (RAM) to minimize scattering

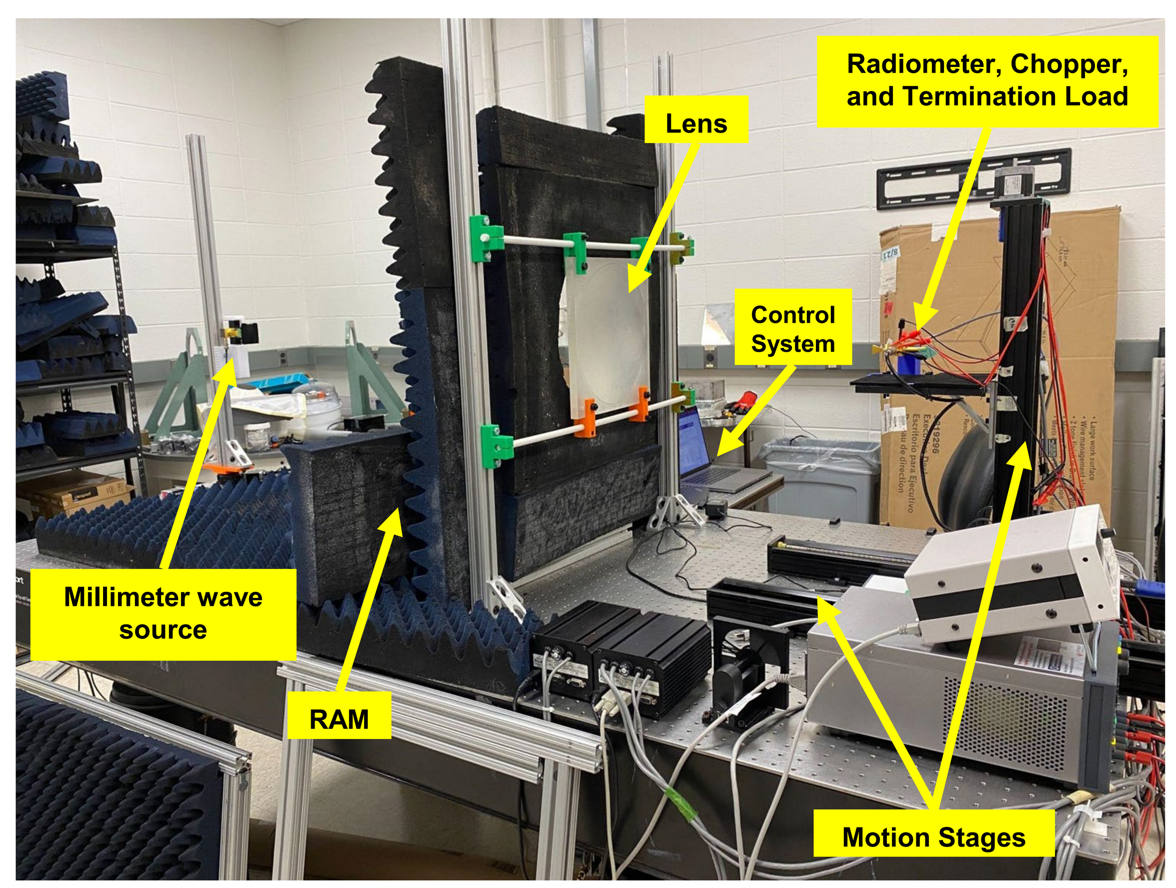

Fig. 2 Automated test bed experimental setup

- Wrote algorithms for motor control and data processing and built a custom application with a user-friendly GUI in MATLAB to perform both linear and raster scans
- Wrote a software lock-in amplifier to extract data from an extremely noisy signal

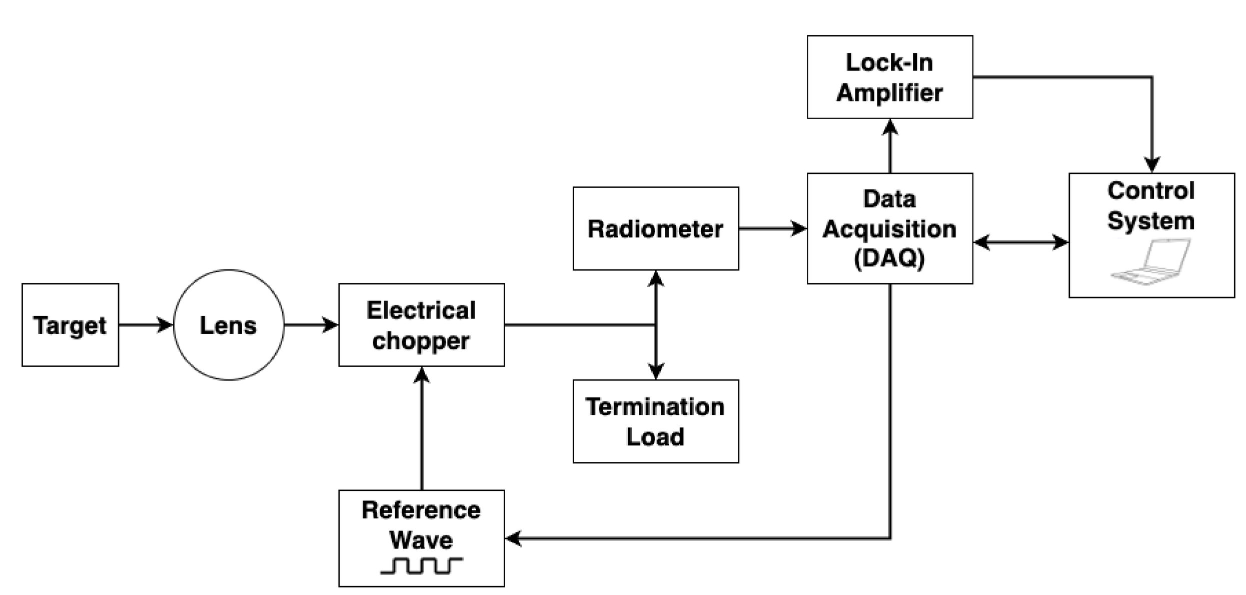

Fig. 3 System diagram of data collection, control and processing

- Performed linear scans to analyze point spread functions (PSF)
- Performed raster scans to analyze diffraction patterns at the focal point

Results and Discussion

- Simulated data in Figure 4 shows the relative signal intensity at each position in the focal plane
- Demonstrates an airy disk diffraction pattern

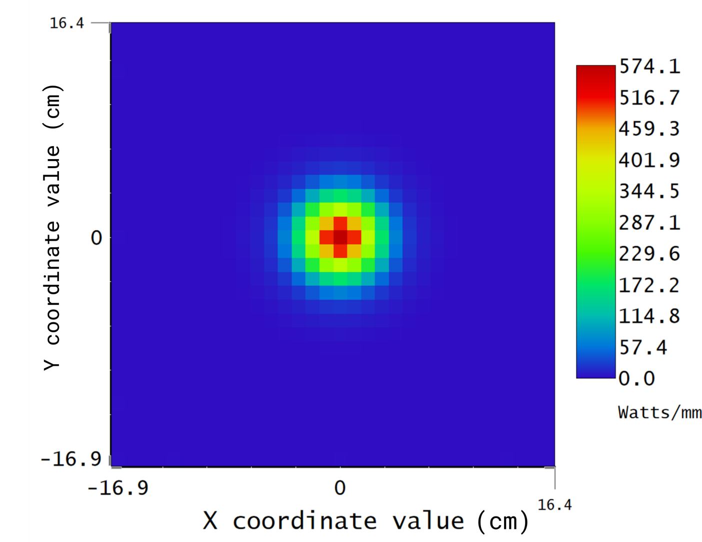

Fig. 4 Simulated focal plane scan

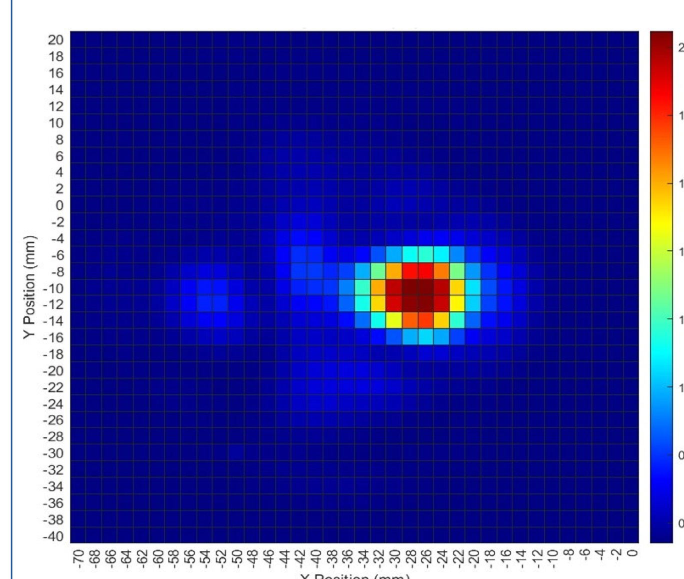

Fig. 5 Experimental focal plane scan

- Experimental result of raster scan across a lens in the focal plane shows an airy disk diffraction pattern
- Some scattering visible

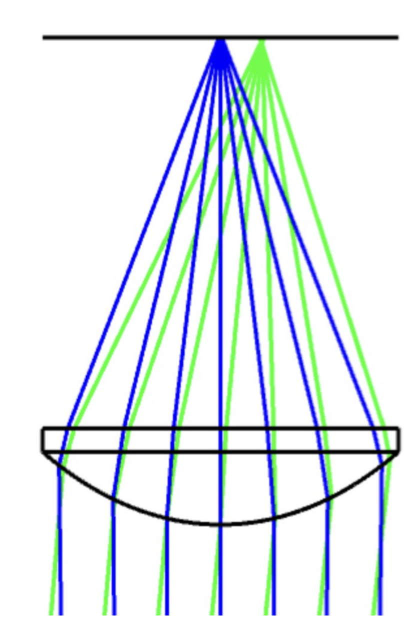

Fig. 6 Simulated ray traced cross section of focal plane

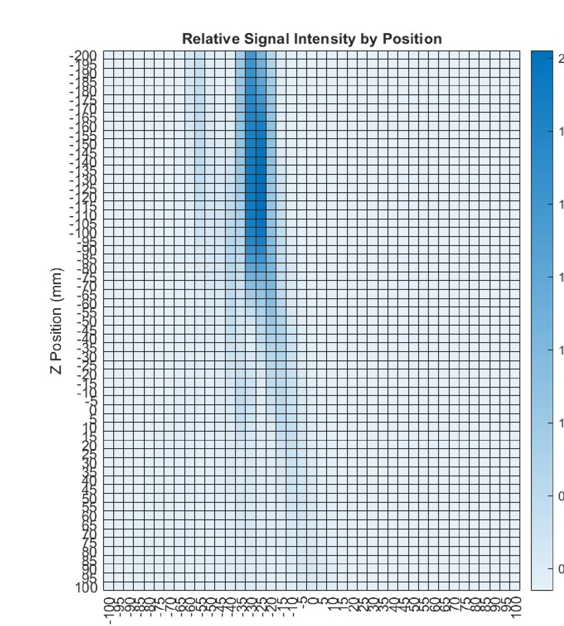

Fig. 7 Experimental cross section of focal plane

- Figure 6 simulates the focal point of the lens from a cross sectional view
- Figure 7 is the experimental result of a cross sectional scan taken along the optical axis
- The depth of focus of the lens is represented by the points in which the signal is most intense
- Scattering is visible to the left of focal axis

- Figures 8 and 9 show simulated and experimental point spread functions (PSF) of lens

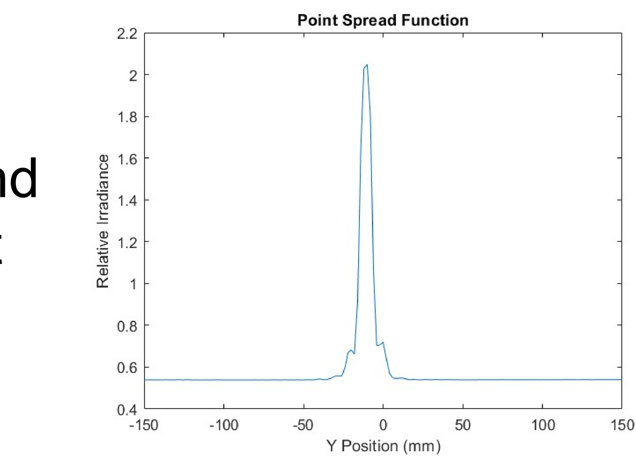

Fig. 8 Experimental PSF across X-axis

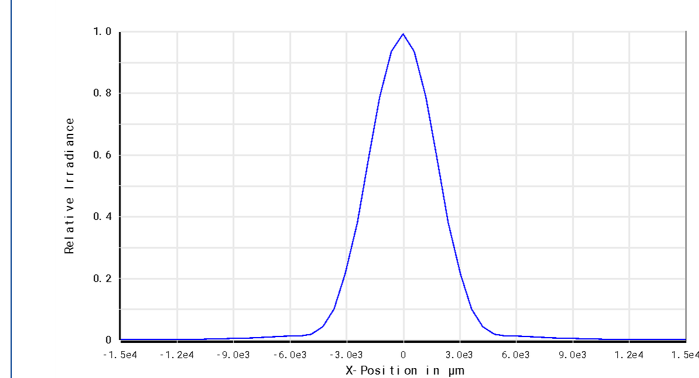

Fig. 9 Simulated PSF across X-axis

- PSF is a one dimensional scan across the lens
- The focal point is shown at the point of peak irradiance

Future Work

- Scattering needs to be further reduced and other confounding variables should be addressed
- Test lightweight lenses designed specifically for mm wavelengths

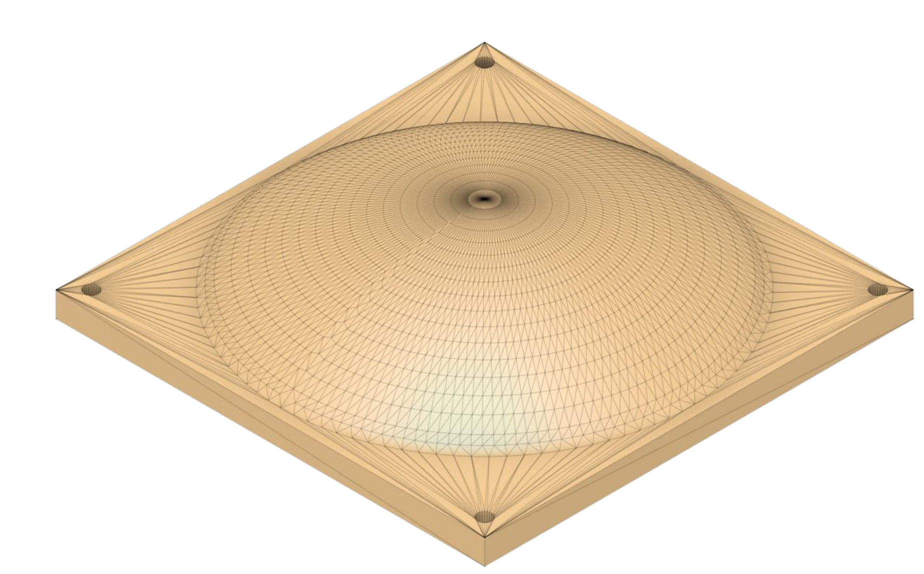

Fig. 10 CAD model of a future millimeter wave lens design

- Calibrate radiometer using RAM submerged in liquid nitrogen in order to image objects without active illumination

Acknowledgements

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