

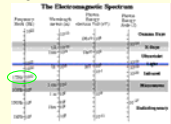
# Active Terahertz Imaging

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**Purpose:** Terahertz radiation can penetrate clothing and is non-destructive. Therefore, the THz region is of high interest for security purposes. The purpose of this research is to create terahertz images with an active source in order to study the applicability of such a setup as well as the accuracy of images produced.

## THz Region

- Falls between the far infrared region and the microwave region
- Extends from 100 GHz to 10 THz, in wavelength from 3 mm to 30  $\mu\text{m}$
- 1 THz =  $10^{12}$  Hz
- THz radiation passes through most non-metal materials
- This region of the spectrum has long been known as the "THz gap", however, recent interest in creating THz images has led to more research in this region

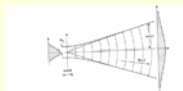


## Active Source and Detector

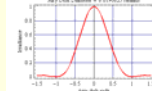
- The source emits electromagnetic waves with frequencies from 80 to 120 GHz
- The detector is a diode detector that is sensitive to radiation between 90 and 140 GHz
- Images were taken with the source emitting 0.120 THz (120 GHz) waves,  $\lambda = 2.5$  mm

## Beam Profile

- Intensity of the electric field of a beam from a coherent source is approximately Gaussian
- As the wave travels through space the beam spreads out due to diffraction
- For our setup spot size for a Gaussian beam would be  $\sim 8$  mm
- Because the mirror used in this setup is smaller than the beam diameter at the mirror, the Gaussian beam is truncated and power is lost behind the mirror
- The mirror acts like a uniformly illuminated circular aperture, this increases the spot size
- Spot size in our setup  $\sim 3$  cm



Gaussian Beam Propagation



Expected Irradiance Profile

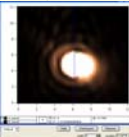


Image of the Beam

## Aberrations

- Will aberrations distort our images?
- Seidel Aberrations affect spherical mirrors, for example:
  - Spherical Aberration - peripheral rays focus at a different point than paraxial rays
  - Astigmatism - tangential and sagittal rays from off-axis points do not focus in the same plane
  - Coma - aperture zones that have different magnification create a comet shaped image
- Experimentally tested aberration effects of the mirror using a video camera (with no lens) and visible light
- How far off-axis can the object be positioned?



Optical axis

1.48°

2.53°



3.35°

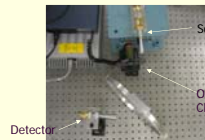
4.46°

6.70°

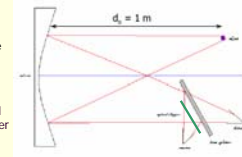
- At approximately 6° off-axis a 3 mm spot will blur to  $\sim 6$  mm, which may begin to affect our image resolution

## Experimental Setup

- Beam waist out of the source  $\omega_0 = 3.8$  mm
- note: beam waist is defined as the  $1/e^2$  point, where the beam irradiance intensity has fallen to 13.5% of the peak value
- Concave spherical mirror of focal length 0.5 m and radius 10 cm
- The mirror is controlled by a LabVIEW program which moves the mirror in a raster scan, to scan the object
- Voltage output of the detector at each pixel is converted to a digital signal by a NI DAQ Board and is sent to the LabVIEW program, which creates an intensity graph of the voltage outputs versus position (image)
- Object distance = 1 m, for a magnification of -1
- Optical chopper with lock-in detection cuts down on noise
- THz radiation leaves the source and reflects off the beam splitter to the mirror where it is reflected to the object and is then reflected back off the object to mirror, through the beam splitter to the detector
- Detected power is related to the THz reflection properties of the object and impacts the image quality



Detector



THz Imaging Setup



## THz Images

- Images taken at 0.120 THz



Object: Metal Optical Board with hole spacing 2.54 cm

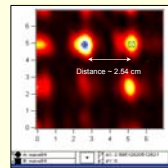


Image in Igor showing accurate hole spacing on the image



Object: Pliers

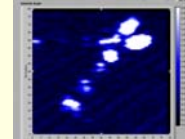


Image: Pliers

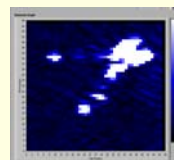


Image: Pliers



Object: Pliers with clothing

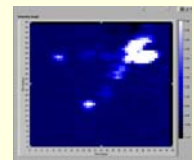


Image: Pliers with clothing

**Conclusion:** The experimental setup produced accurate images. The images show that THz waves will pass through clothing, creating an image of reflective objects beneath the clothing. However, a larger mirror would improve resolution by allowing Gaussian beam propagation, possibly producing images with more detail.

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