THz Synthetic Aperture Slides
Pulsed THz Spectrometer

Angle & polarization diversity

CW Swept Frequency

Two port s-parameter measurements
0.045 – 0.780 THz

Pulsed THz Imaging System

8” x 8” 2D scanning

Funded by NSF MRI, Murdock Foundation, & ONR
# Processing Approaches for 3D THz Spectroscopy

<table>
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<th>Optical Lens</th>
<th>Time-gating</th>
<th>Synthetic aperture processing</th>
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<td><strong>Advantages</strong></td>
<td>Optical focus determined by lens (good depth resolution)</td>
<td>Ability to produce multiple images/depths from sensor data*</td>
<td>Ability to produce multiple images/depths from sensor data*; coherent gain from sensor combination</td>
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<tr>
<td><strong>Disadvantages</strong></td>
<td>Requires mechanical scanning for multiple depths</td>
<td>Reduces spectral resolution; material properties (phase speed) must be known or assumed</td>
<td>Complexity; material properties (phase speed) must be known or assumed</td>
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*Can scan in x-y to produce 2D image data*
NEAR-Lab Measurement Capability

**Pulsed THz Spectrometer**
- Angle & polarization diversity
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- Two port s-parameter measurements
  - 0.045 – 0.780 THz

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Synthetic Aperture Processing using a Virtual Image Source

N x N sensor array (raster scan in x,y)

Illumination from “virtual sources” formed at focal point

Synthesize image at $z_0$ using coherent addition of sensors:

$$
\sum_{m=1}^{N} \sum_{n=1}^{N} E(x_n, y_m, f) \quad F_{mn}(r_{jk}) \quad e^{-2i k_0 R_{mn}(r_{jk})} \quad ^2
$$

where $F_{mn}$ is a tapering window, and $R_{mn}$ depends on choice of $z_0$
- Image of single steel ball-bearing (3.9 mm)
  - Synthesized image has better resolution achieved from coherent gain (multiple sensor combination)
  - Synthesis is depth dependent (image at $z_0 = 10 \text{ mm}$)
Pellet with Embedded Scatterers

- Two ball bearings (3.9 mm) embedded in polyethylene (PE) pellet
  - Targets offset in depth and lateral position
  - Imaging equation adjusted for phase introduced with PE
**Depth-Dependent Images using Synthetic Aperture Processing**

**Imaging geometry**

*mnth sensor (50 x 50 sensors)*

- Movies show images formed at progressive depths $z_d$
- Depth resolution proportional to wavelength (get’s better with higher frequency)

250 GHz

500 GHz