THz Beam Measurement
A Practical Primer

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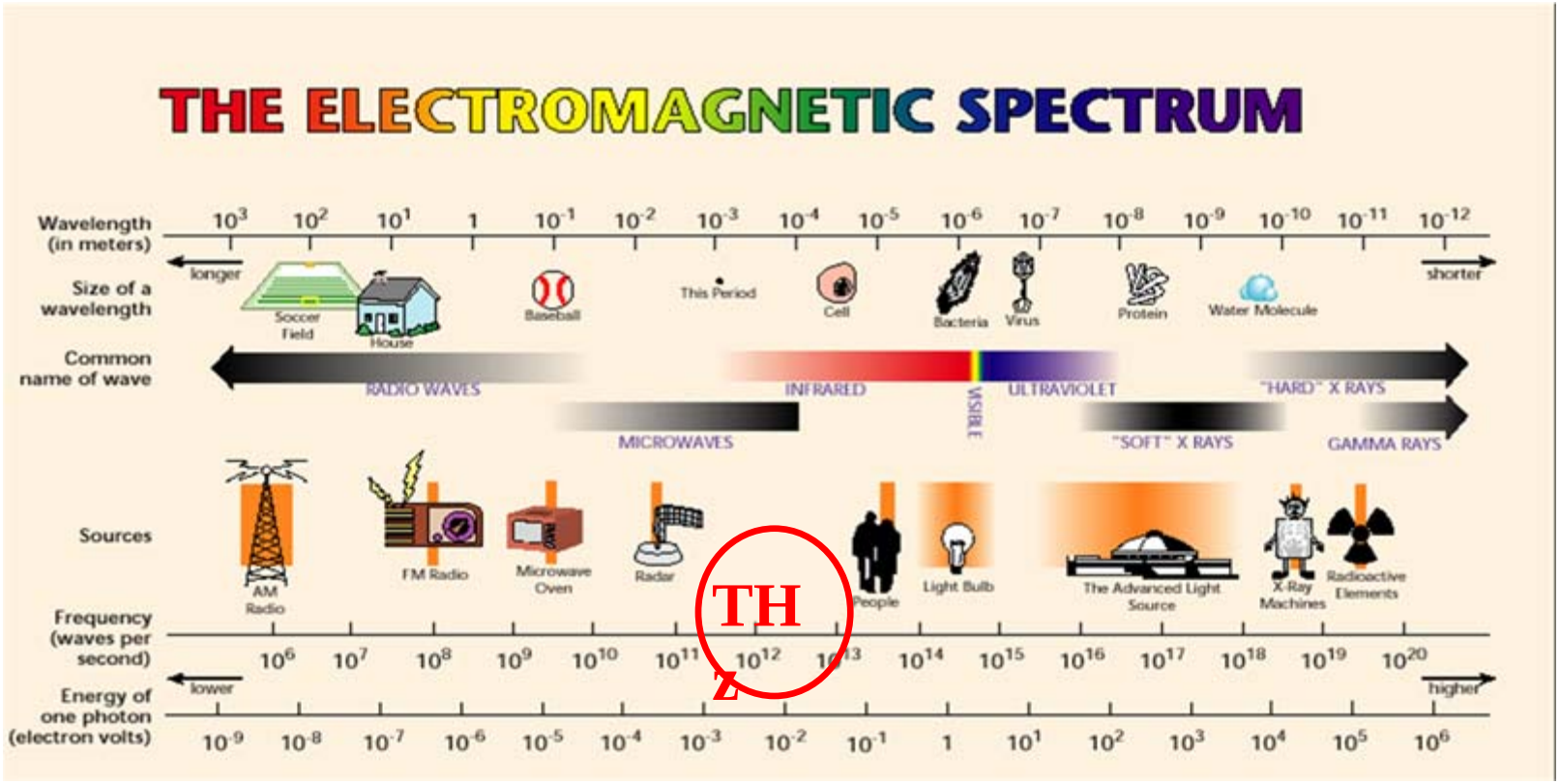
Outline

- THz Range available to the user
  - Wavelengths and Frequencies
- Tools to Image THz beams
- Optics- Type and Sources
- Cameras and Other Sensors
- Results

What is the THz Band?



300 GHz (1000 um) to 30 THz (10 um)

Courtesy- Advanced Light Source-Berkeley, CA

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Measurement is Key to Success

If You Cannot Measure it, You Cannot Control it

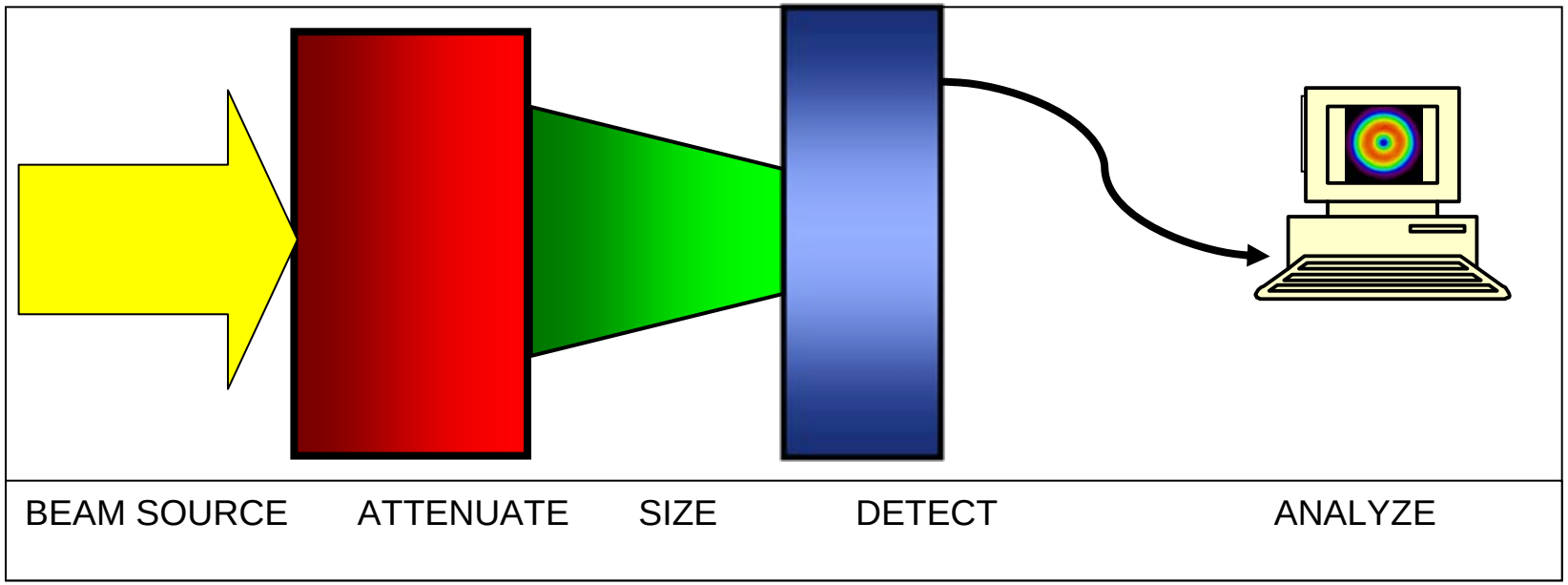
"If you can't describe what you are doing as a process, you don't know what you're doing."

W. Edwards Deming (1900-1993)

How is THz measured?

- Single element detectors- Pyroelectric
  - Acceptable for the Wavelength/Frequency Range
  - Does not yield any information about spatial energy
- Array detectors-Pyroelectric or Bolometer
  - Pyroelectric- more stable-larger pixels (100 µm)
  - Microbolometer- less stable-smaller pixels (25 µm)
- Power/Energy meter
  - Only displays power or energy

Simple Block Diagram for Measurement



THz Detectors

- Pyroelectric
  - Based on $LiTa0_3$ crystal
- Can be single element or array
  - Array has 124 x 124 100 um pixels
  - Up to 100 images per second
  - Sensitivity is 2.2 µw/cm^2 or70 µJ/cm^2
- Good Response across entire ban

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Microbolometers

- Generally Ferroelectric or Vanadium Oxide
- Not as stable baseline as Pyroelectric
- Sensitive to environmental temperature changes
- Smaller Pixels (25 µm) than Pyroelectric (100 µm)

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Optics- The Missing Link

- For imaging ***sources,*** optics not necessary
  - UNLESS- beam is too big for array
- For imaging scatter from ***target***, optics are required
  - Same as in photography
- Optics have different characteristics
  - Polyethylene, Picarin* & Silicon most popular

    *Microtech Instruments, Inc.

Optics- Characteristics

Polyethylene

- Offers the best performance at frequencies below 1 THz and above 7 THz
- Not transparent in visible and near-IR
- Polymer not hard like glass optics- has variations- may cause aberrations in imaging
  - Available in 2” (50 mm) diameter biconvex or spherical 60 mm focal length

Optics- Characteristics

- Polished Tsurupica (Picarin)
  - Tsurupica is highly transparent in THz and visible spectral ranges
  - Refractive index of Tsurupica is the same for THz and visible light (n=1.52)
    - Available as Plano-convex, aspheric, Bi-convex, and spherical in 30 and 45 mm sizes, with focal lengths from 50-180mm(other focal lengths available on order)

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Silicon Lens

- Silicon Lenses
  - “Harder” than polymer lenses
  - Can be machined to better tolerances
  - High purity Si results in less Aberrations
  - Very High Refractive Index in THz region results in losses & possible internal reflections

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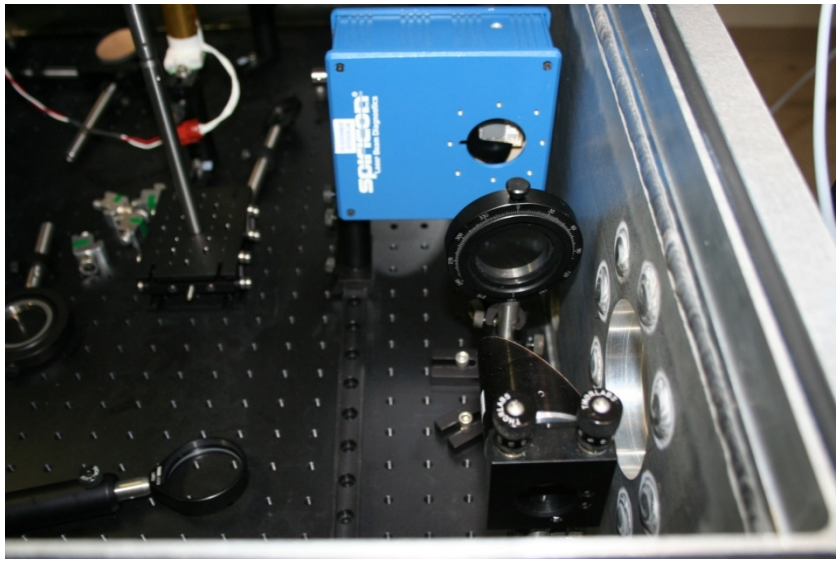
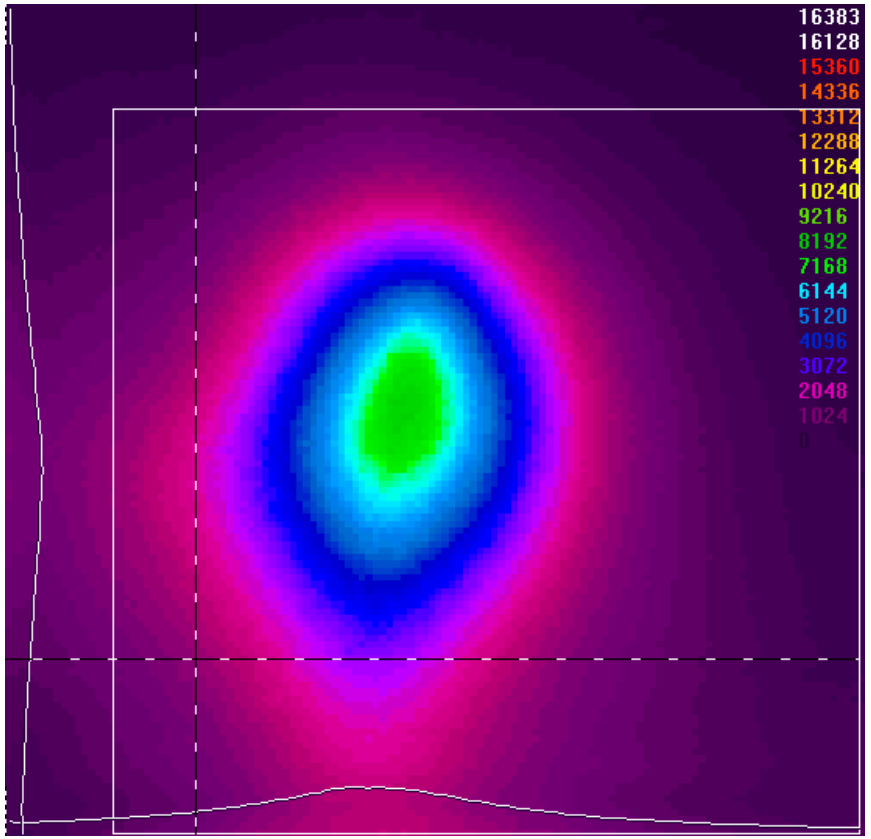
Other Optics

- Gold-coated parabolic ,ellipsoidal or toroidal mirrors
- For beam sizing –not imaging, (unless they are spherical)
- Off–axis parabaloids most common and easiest to use
- Relatively inexpensive

Imaging Results

- Typical set up including Polarizer
- Beam Image





Courtesy- Thomas Jefferson National Accelerator Facility

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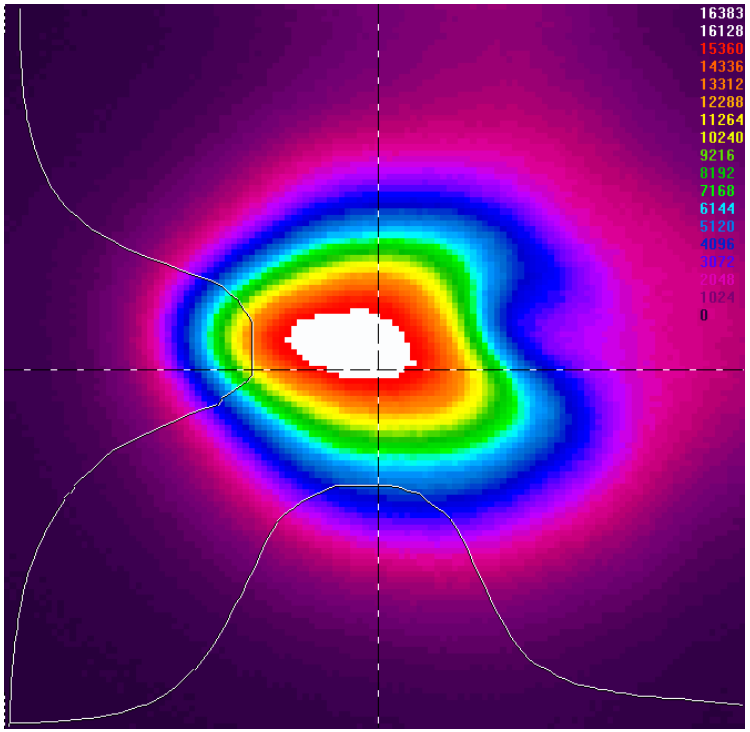
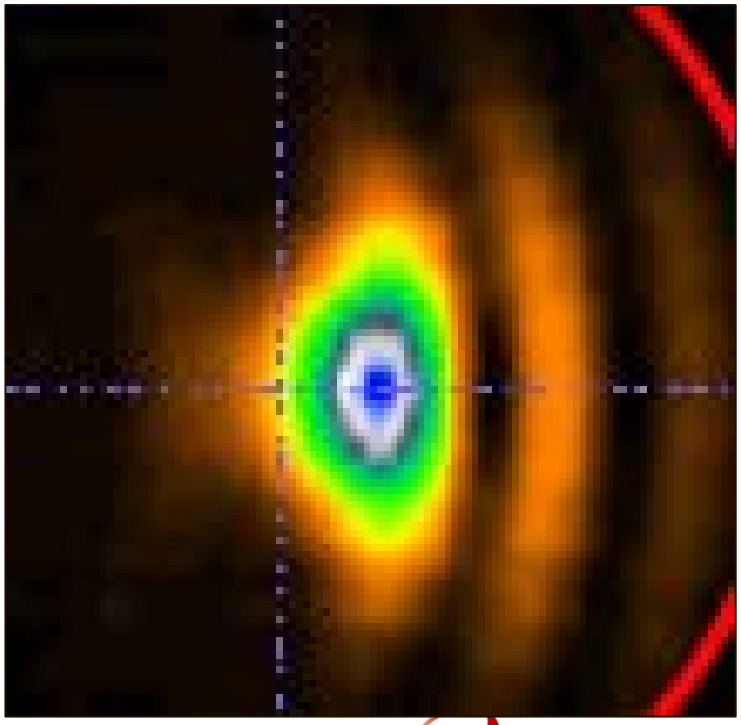
THz Beam Profile Near a Focus

Measured



Calculated



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Frequently Asked Question:

- Q: So, how DOES a Bolometer measure THz energy, when its bandwidth ends much lower?
- A: Bolometers are thermal sensors
  - Any photons absorbed will produce temperature rise and thus a signal.
  - Absorption efficiency at long wavelengths not great for VOx microbolometer arrays, but is definitely higher than PY III.
  - Drawback - pixel size is well below the diffraction limit in THz spectrum

Summary

- Imaging THz SOURCES is well understood, and can be done with pyroelectric cameras
- Imaging of TARGETS can be done by bolometers, providing care is taken when using them.
- Because human eye responds logarithmically, they are acceptable for image interpretation.

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Patented UltraCal for ISO Baseline
Multilpe Cameras - Up to 4 per Application

BeamStar

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Easy to Use
USB and Firewire Cameras
Automatic Exposure Control
Manual M2 Capability

BeamGage

Most Versatile
Flexible for Simple or Complex Applications
Easiest to Automate
End Users can Augment Calculations/Display Results
Interfaces with Ophir Power/Energy Meters
Connects to Networked & Multiplexed Cameras
Multiple Copies May Run Simultaneously