

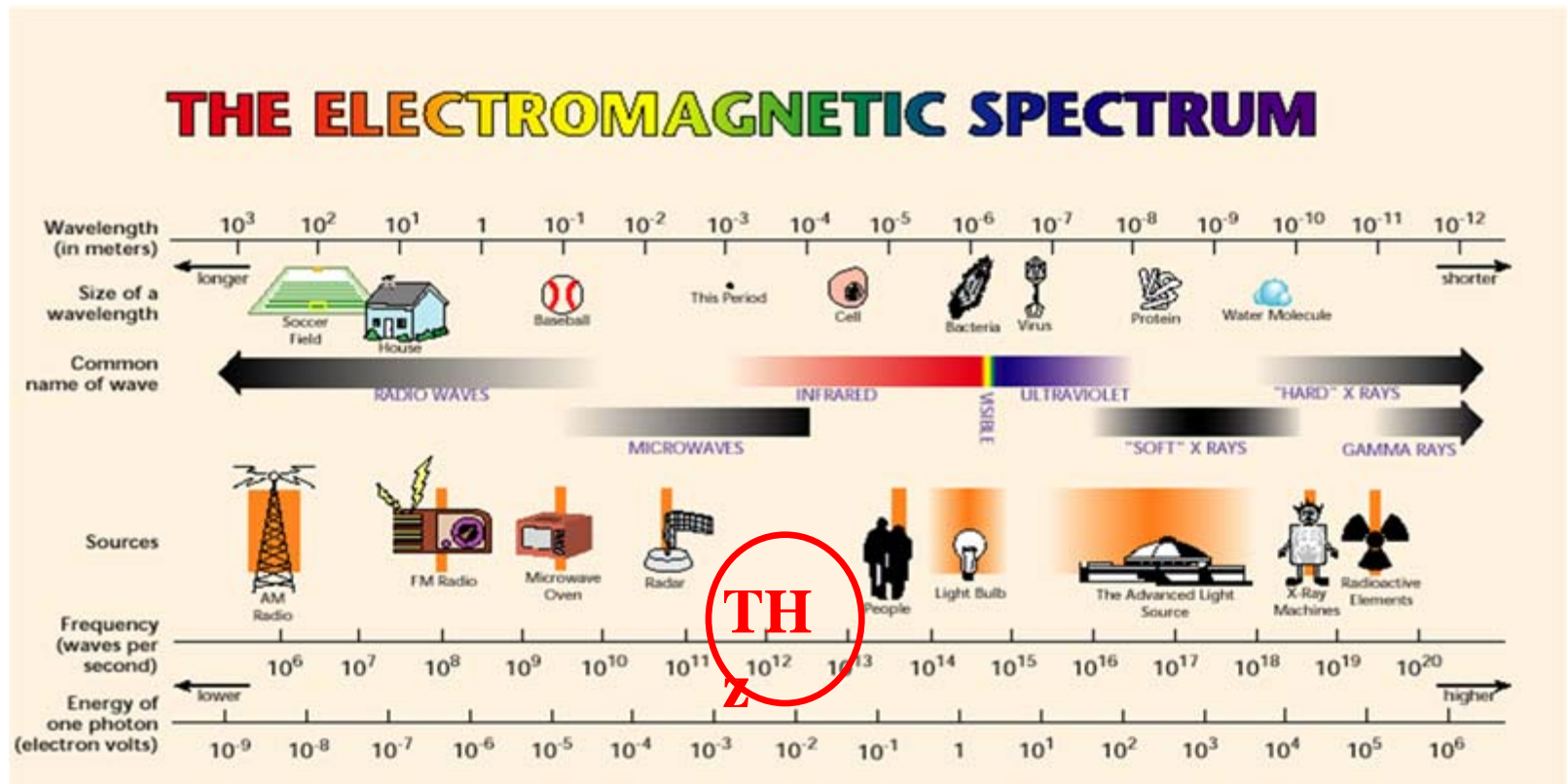
THz Beam Measurement A Practical Primer

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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 μm) to 30 THz (10 μm)

Courtesy- Advanced Light Source-Berkeley, CA

Measurement is Key to Success

If You Cannot Measure it, You Cannot Control it

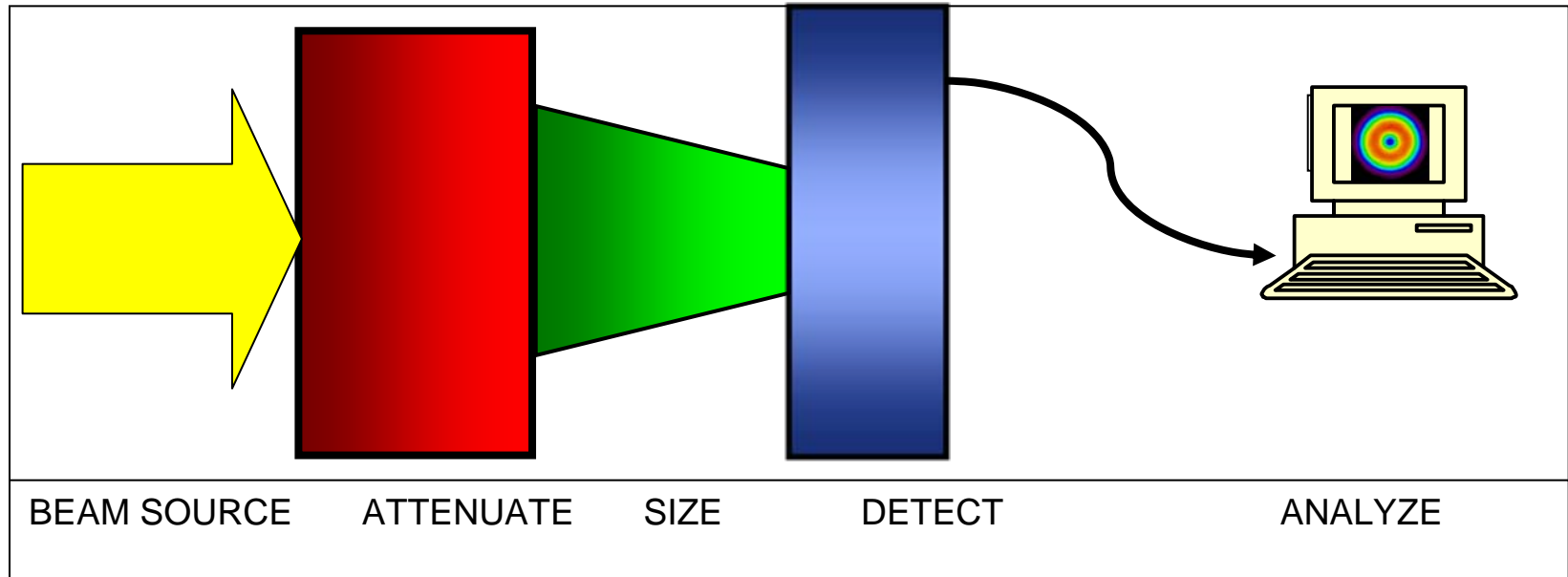
“If you can't describe what you are doing as a process, you don't know what you're doing.”

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 LiTaO_3 crystal
- Can be single element or array
 - Array has 124×124 $100 \mu\text{m}$ pixels
 - Up to 100 images per second
 - Sensitivity is $2.2 \mu\text{w}/\text{cm}^2$ or $70 \mu\text{J}/\text{cm}^2$
- Good Response across entire band



Microbolometers

- Generally Ferroelectric or Vanadium Oxide
- Not as stable baseline as Pyroelectric
- Sensitive to environmental temperature changes
- Smaller Pixels ($25\ \mu\text{m}$) than Pyroelectric ($100\ \mu\text{m}$)



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)



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

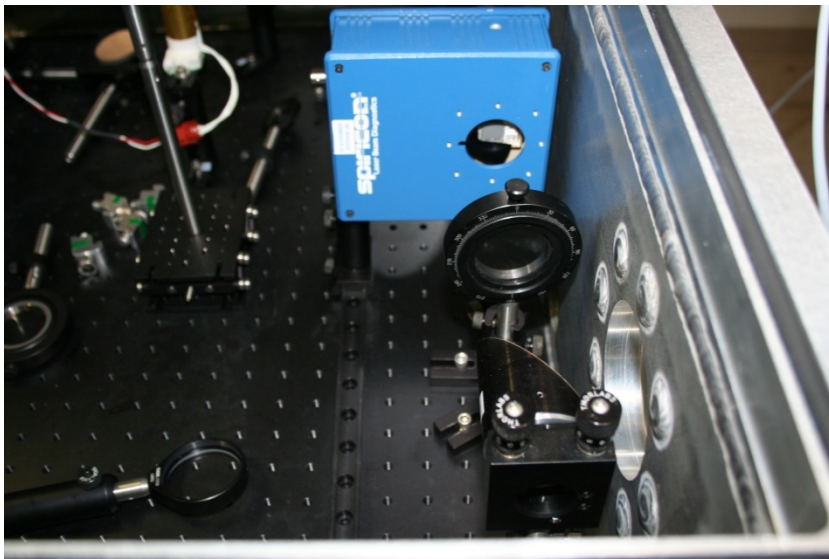


Other Optics

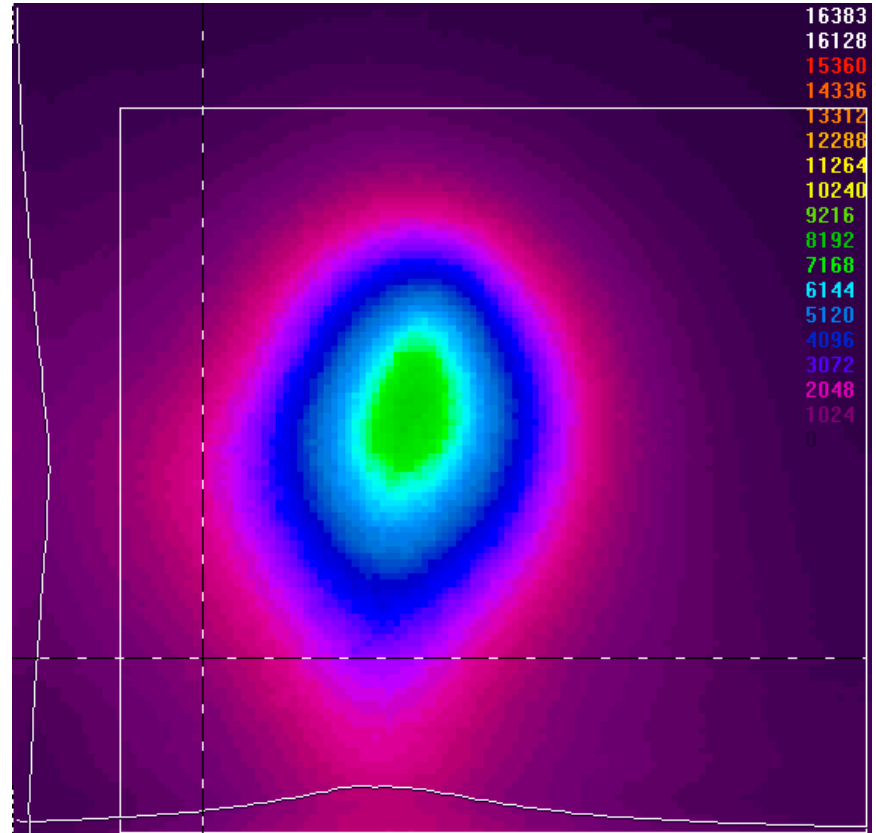
- Gold-coated parabolic ,ellipsoidal or toroidal mirrors
- For beam sizing –not imaging, (unless they are spherical)
- Off–axis parabaloids most common and easiest to use
- Relatively inexpensive

Imaging Results

- Typical set up including Polarizer
- Beam Image

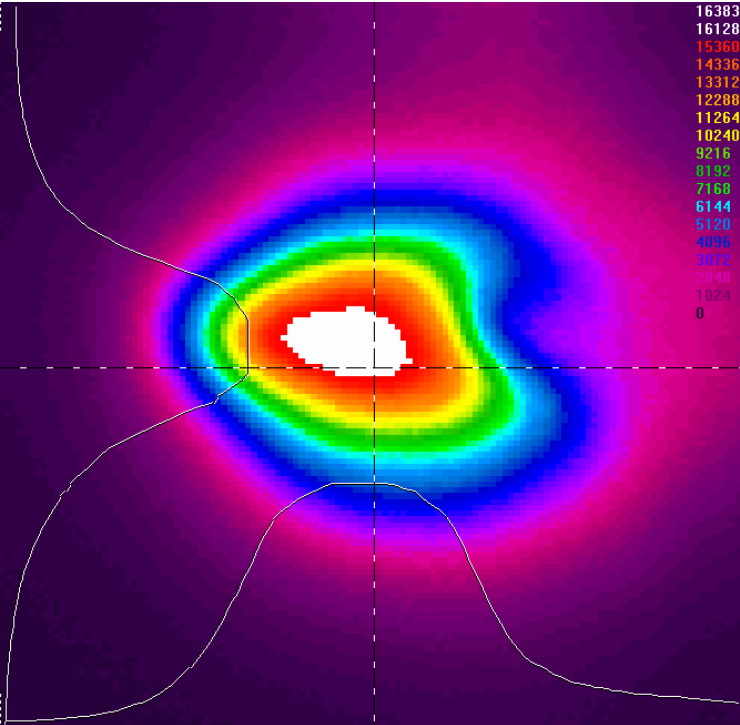


Courtesy- Thomas Jefferson National Accelerator Facility

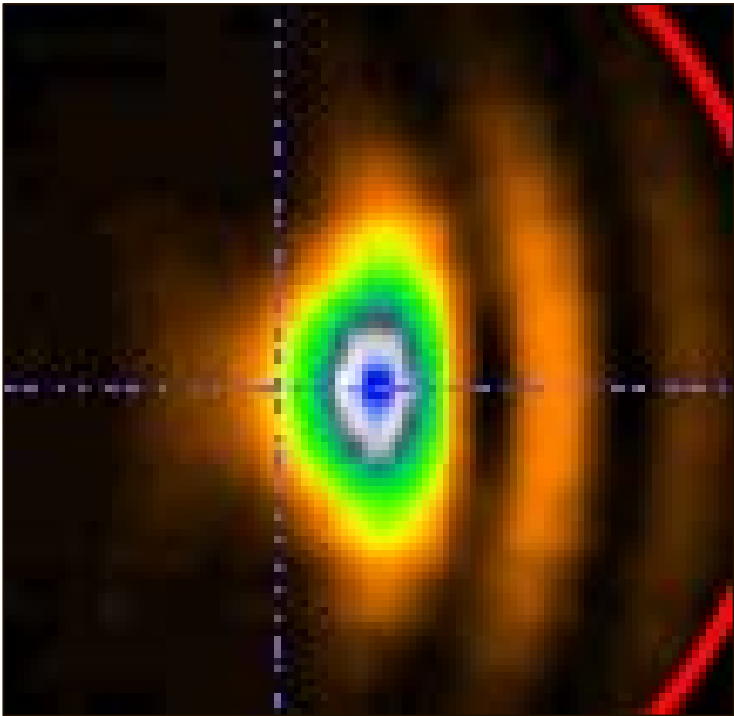


THz Beam Profile Near a Focus

Measured



Calculated



Courtesy- Thomas Jefferson National Accelerator Facility

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.

A Beam Profiler for Every Application

LBA-PC

Scientific/Technical Applications
Widest Selection of Cameras
High Accuracy
ISO Compliant
Patented UltraCal for ISO Baseline
Multiple Cameras - Up to 4 per Application

BeamStar

Industrial Applications
Low Cost
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

