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terapod

Characterisation of emitters and detectors for THz wireless links

Jess Smith & Mira Naftaly

Properties measured

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Emitters:

- Spatial beam profile
- Broadband frequency spectrum
- Power

Detectors:

- Frequency-dependent responsivity
- Spatial acceptance cone

Emitter spatial beam profile

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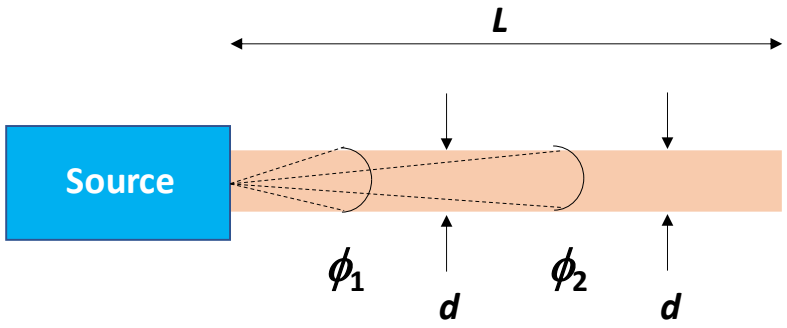
a

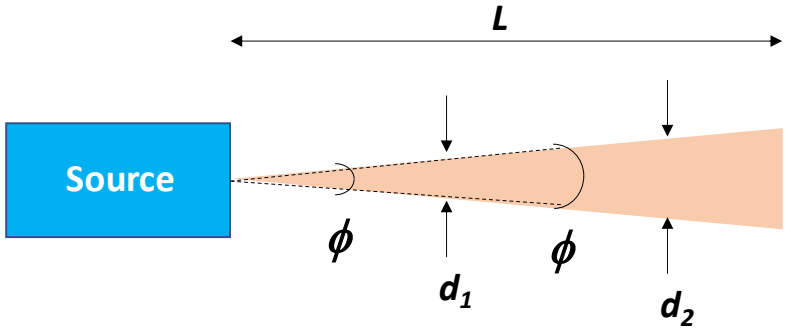


d = constant

$d/2L = \tan(\phi/2)$

Collimated beams have invariant diameter

b



ϕ = constant

$d/2L = \tan(\phi/2)$

Diverging beams have invariant angular distribution

Terahertz emitters are divergent sources

Emitter beam profile

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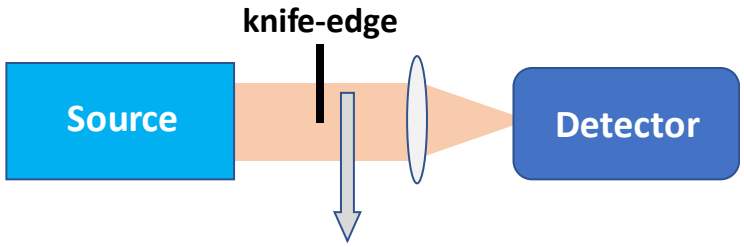
Measurement approach

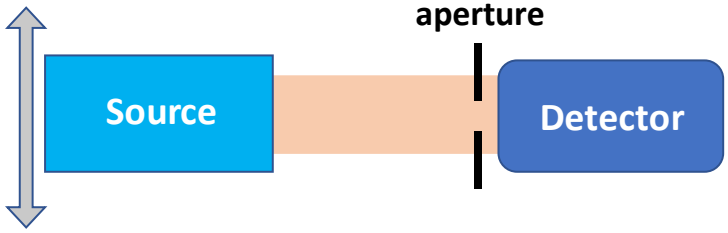
Does not reveal features or lobes

a



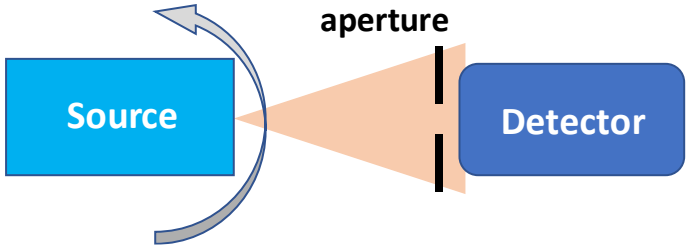
Suitable for collimated beams

b



Suitable for diverging beams

c



← **Method used**

Measurements in the far field

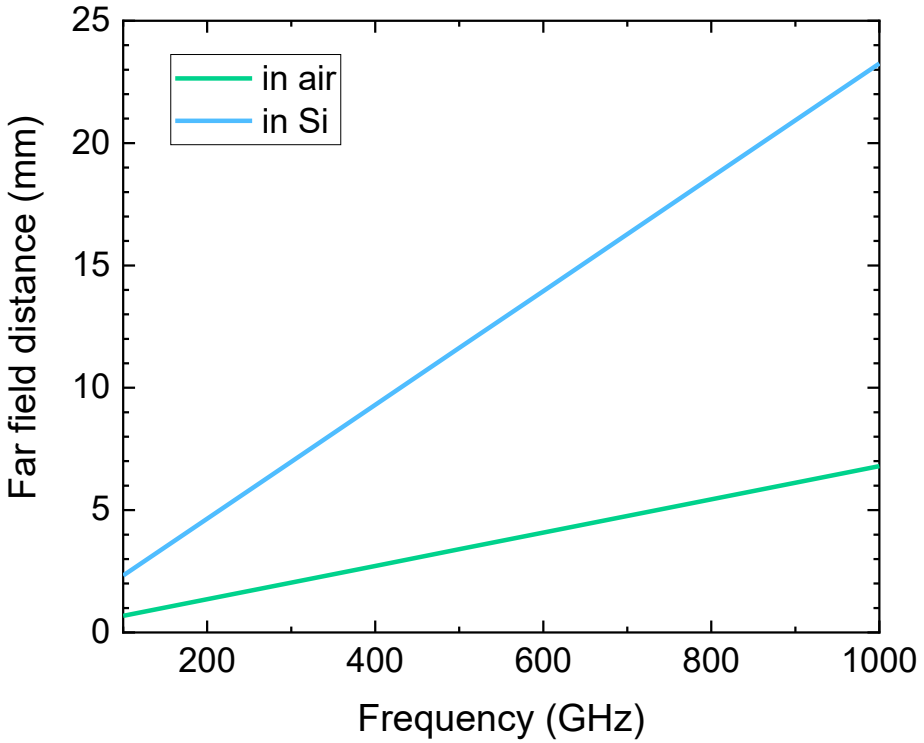
- Near field: the angular distribution of the field varies with distance from the antenna
- Far field: the angular distribution is distance-independent

➡ Emitter beam profile must be measured in the far field

Far field:

For $D < \frac{\lambda}{2}$ $\quad L_{far} > 2\lambda = \frac{2c}{f}$

For $D > \frac{\lambda}{2}$ $\quad L_{far} > \frac{2D^2}{\lambda} = \frac{2D^2 f}{c}$



Measurement distance = 60 mm

Emitter: photoconductive PIN diode

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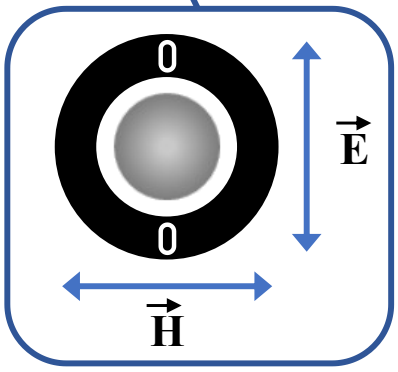
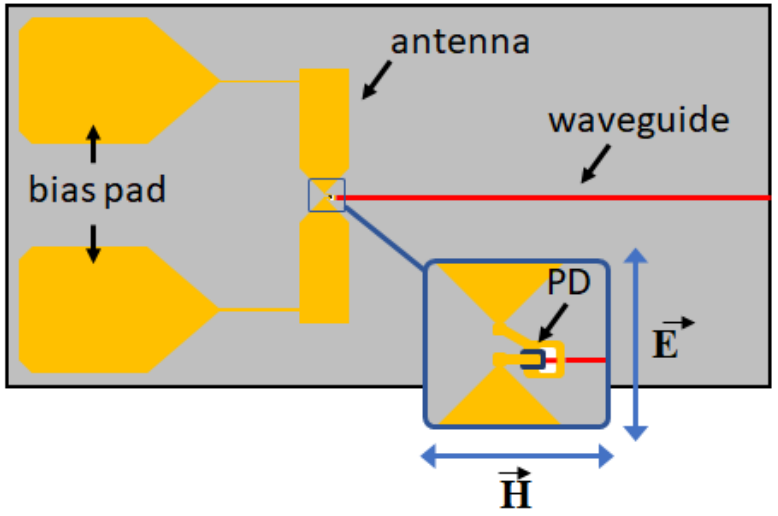
a

b

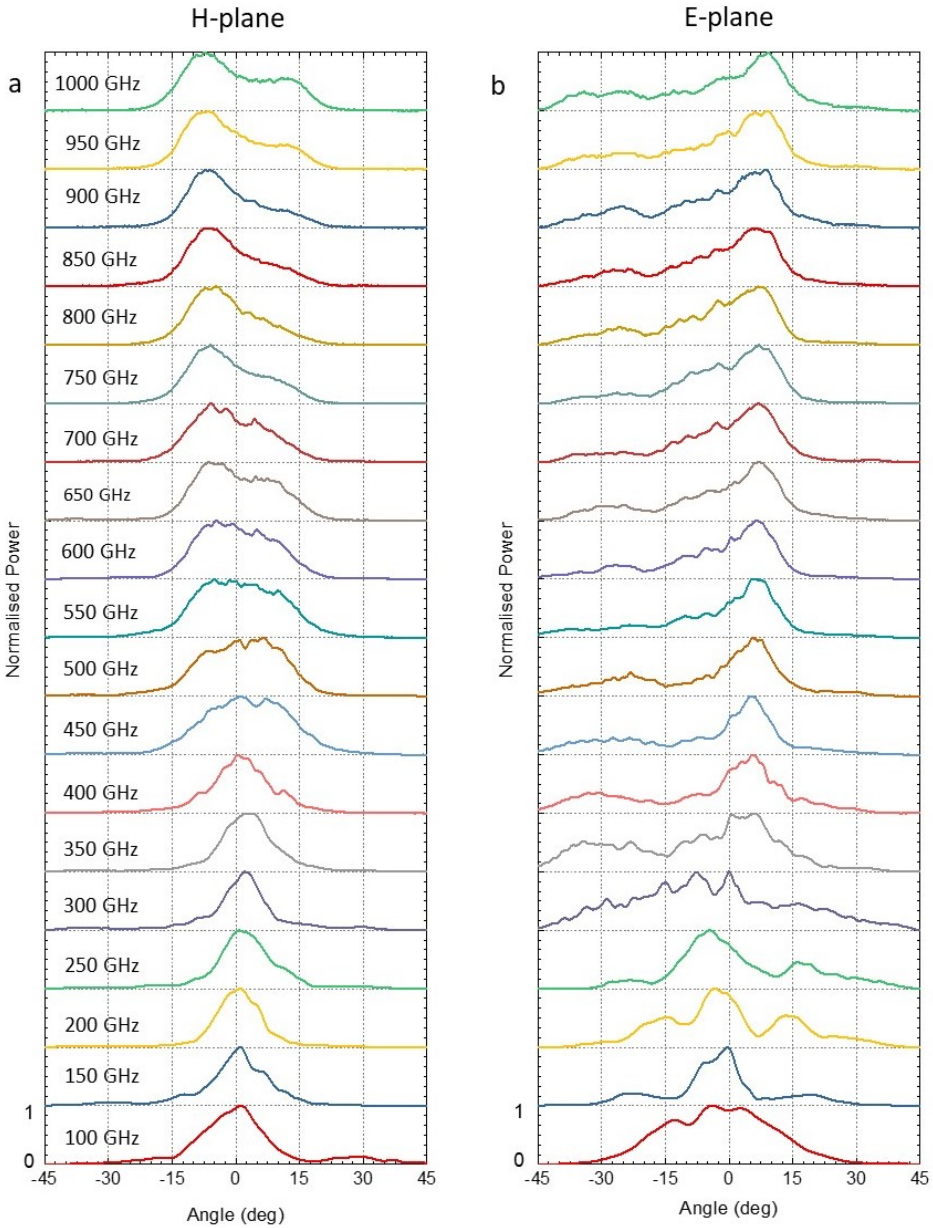


THz beam polarization

c



PIN diode beam profiles



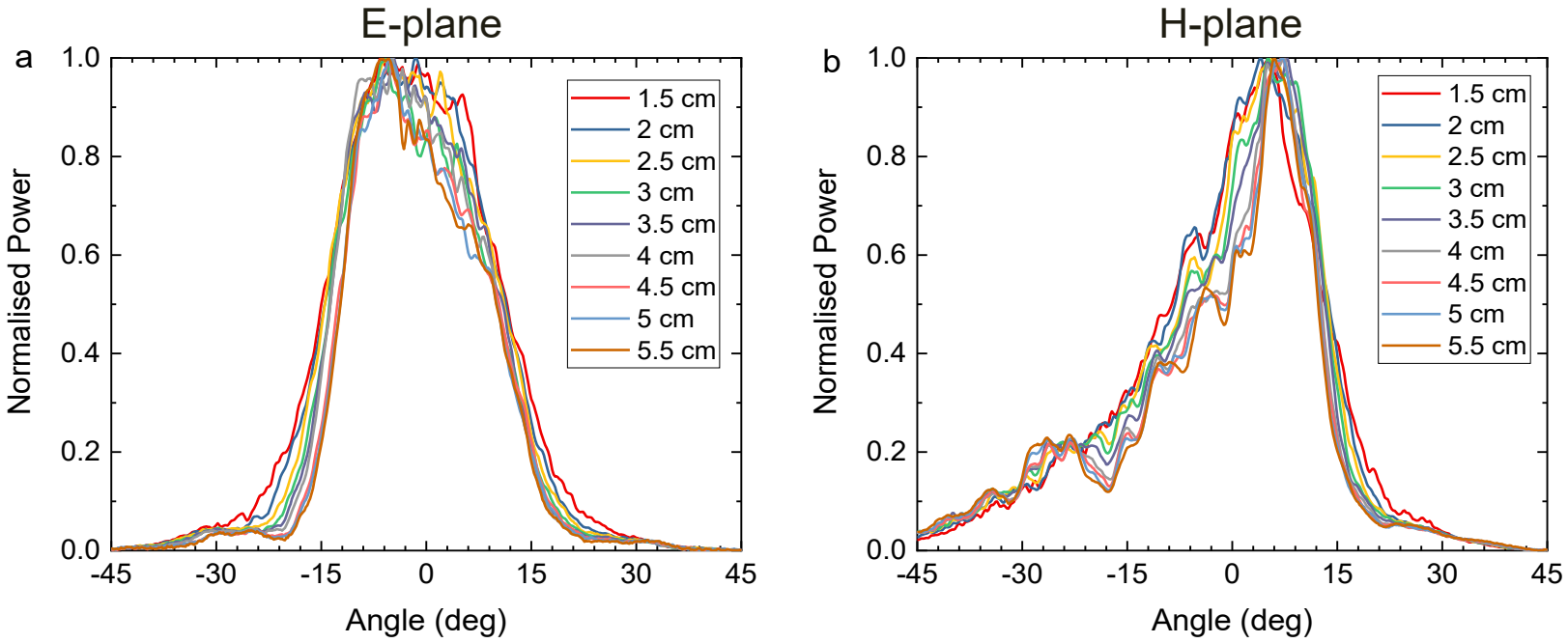
- All profiles deviate from Gaussian
- All are asymmetric
- Profiles are frequency dependent
- Profiles are polarization dependent
- Many have several lobes

Smith, J., Naftaly, M., Nellen, S., & Globisch, B. (2021). Applied Sciences, 11(2), 465.

Dependence of beam profile on emitter-detector distance

Testing the validity of the method

Emitter: PIN diode @ 600 GHz



The beam profile remains constant with emitter-detector distance

Emitter:
WR35 rectangular horn antenna

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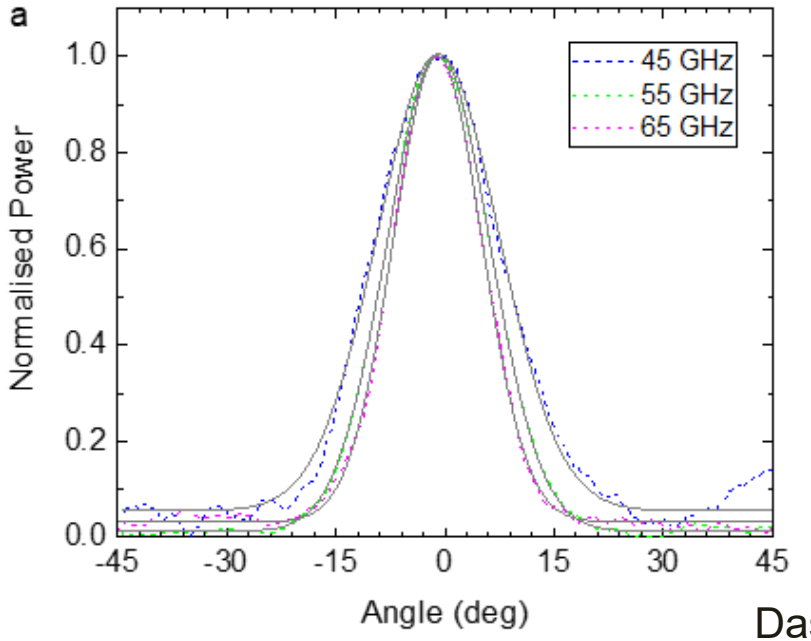
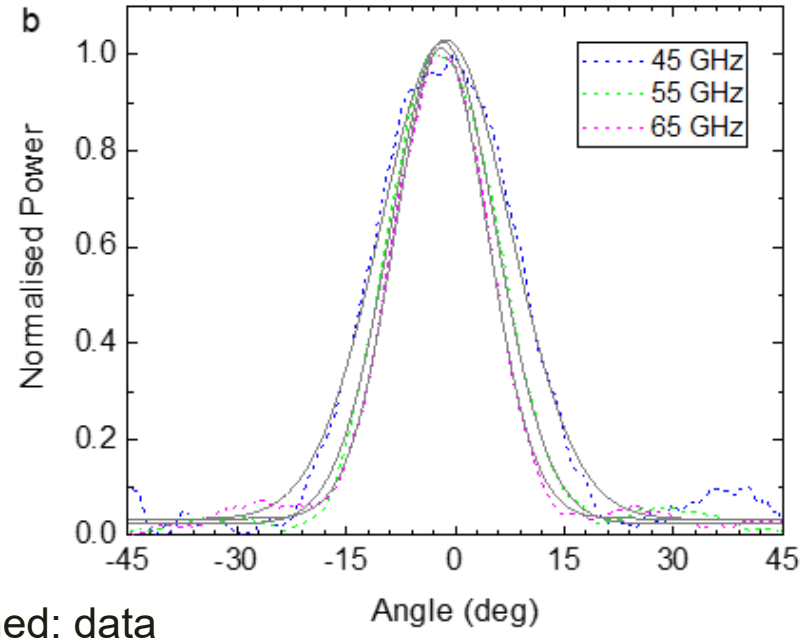
Source: signal generator Anritsu 69397A

Parallel to waveguide



Perpendicular to waveguide



Dashed: data
Solid: Gaussian fit

- Beam profiles are near-Gaussian
- Beam width increases with frequency

Emitter: photoconductive UTC

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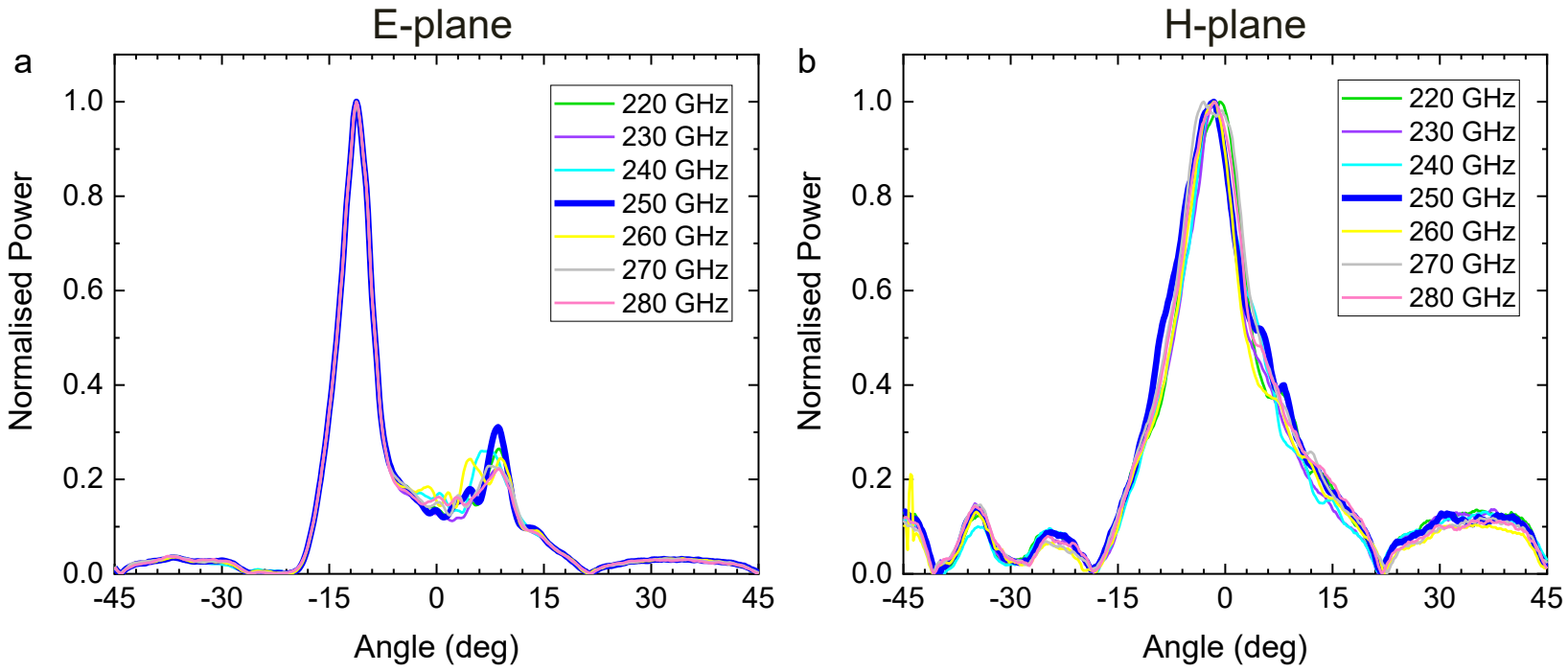
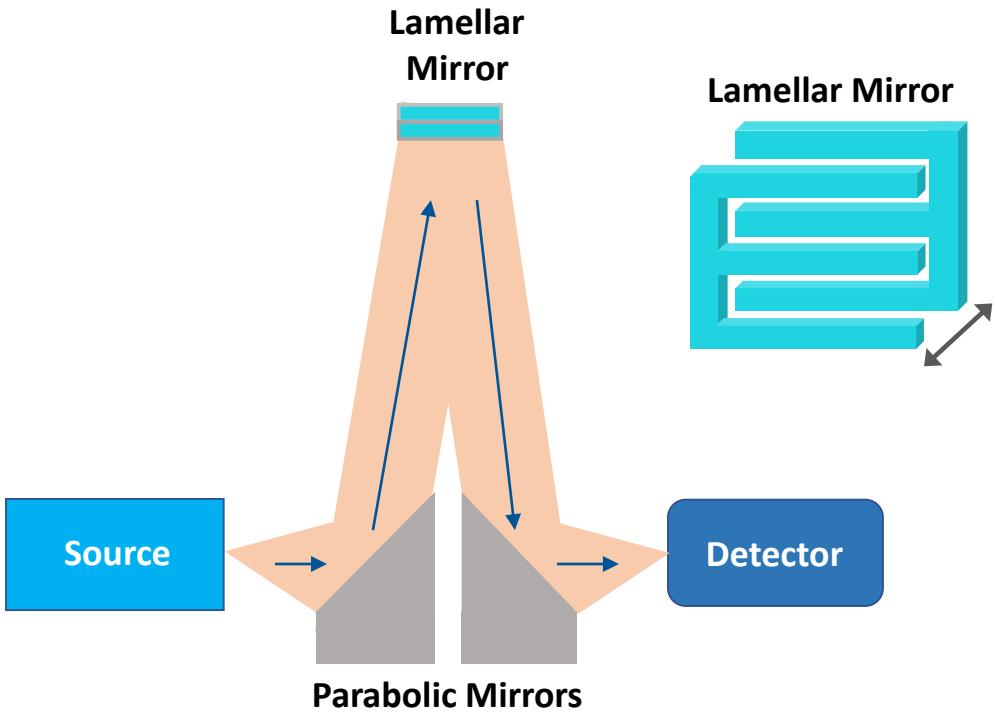
UTC optimised at 250 GHz



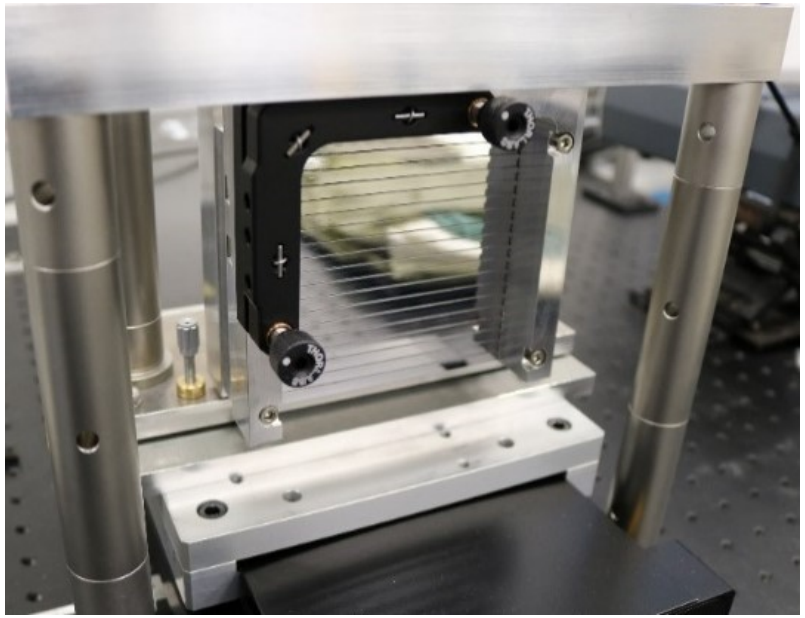
Strongly irregular beam profile, especially in the E-plane

Broadband emitter spectrum

Measurement instrument: lamellar interferometer

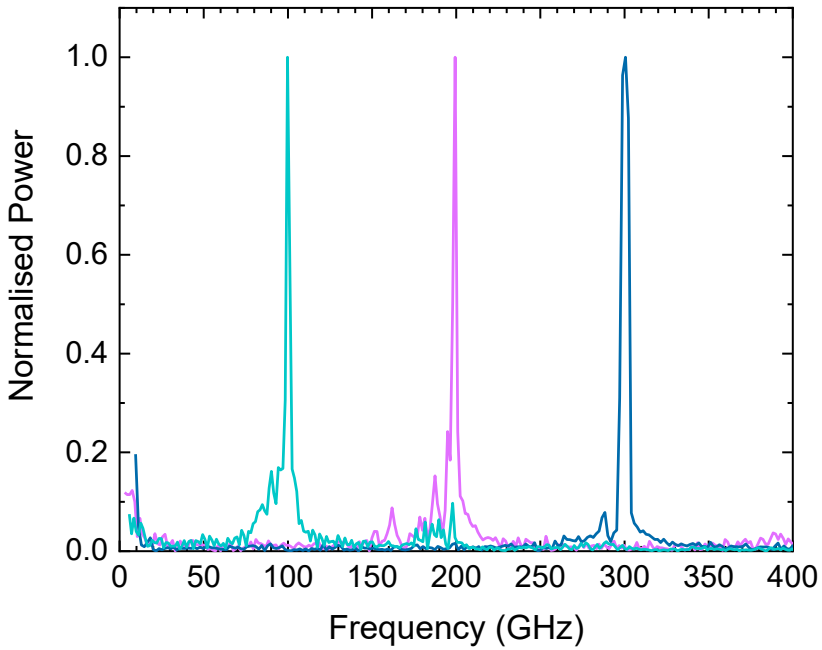


Lamellar mirror at NPL



Maximum frequency resolution: 0.75 GHz

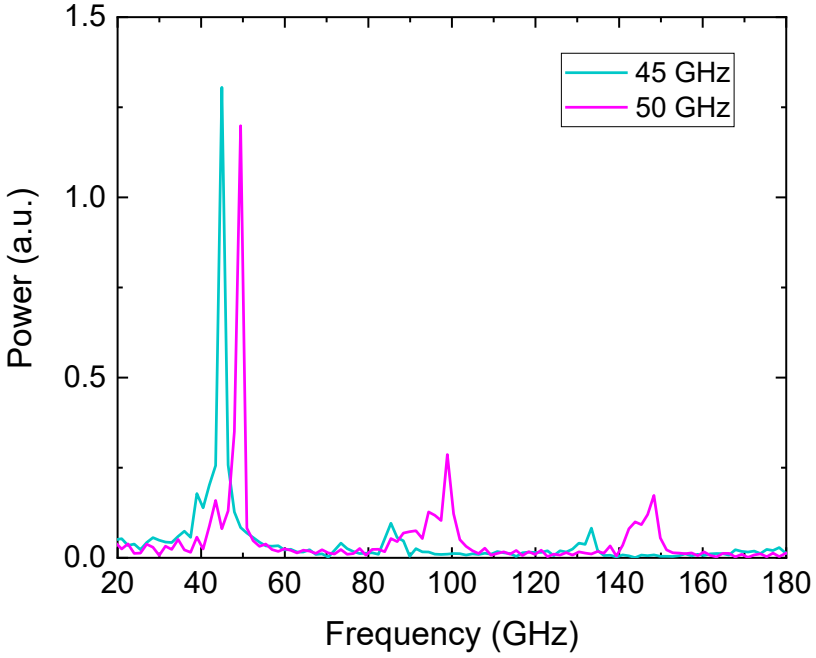
Emitter: photoconductive PIN diode

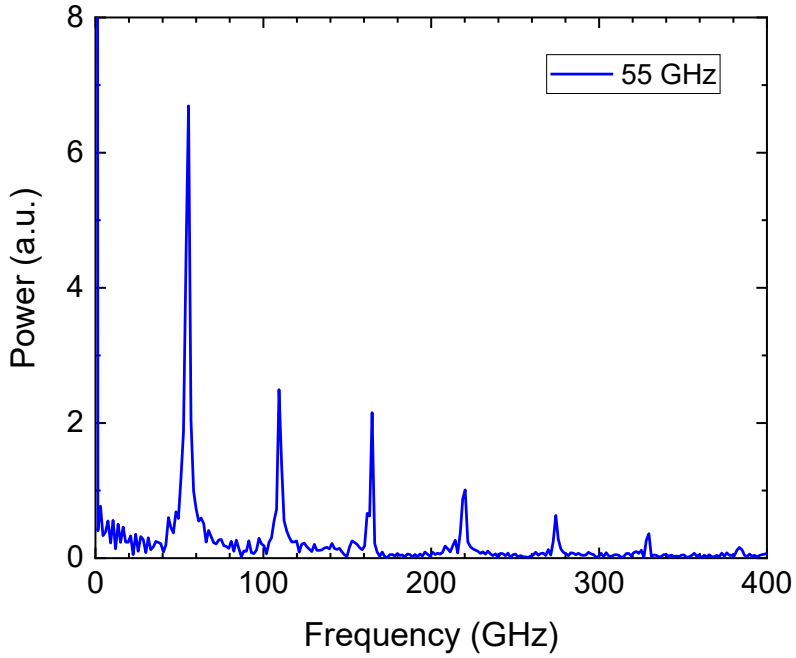


- Narrow-band spectrum is confirmed
- There are no harmonics or other features

Emitter:
WR35 rectangular horn antenna

Source: signal generator Anritsu 69397A

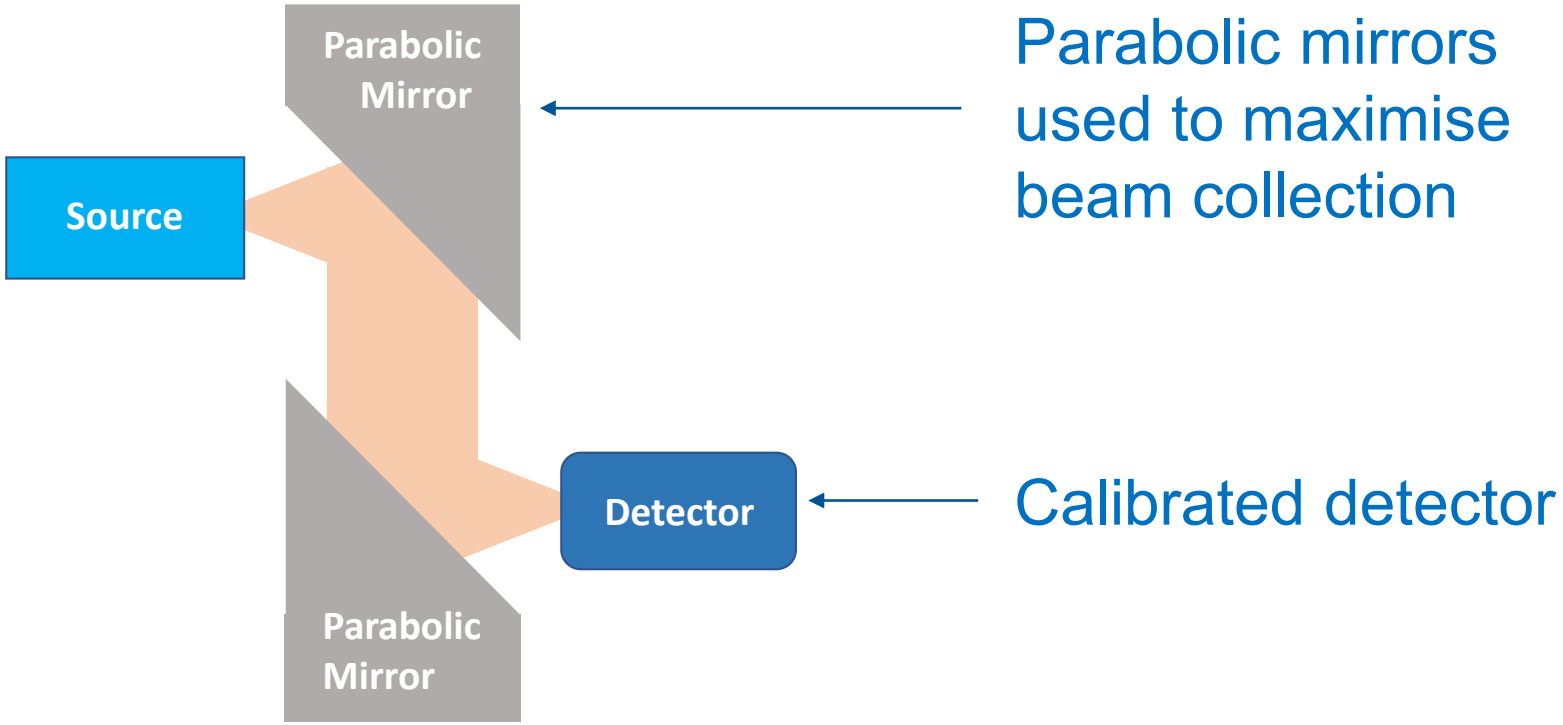




- Measurement technique reveals harmonics that are not detectable using waveguide-based methods
- The number and strength of harmonics are frequency-dependent

Emitter power

Measurement method

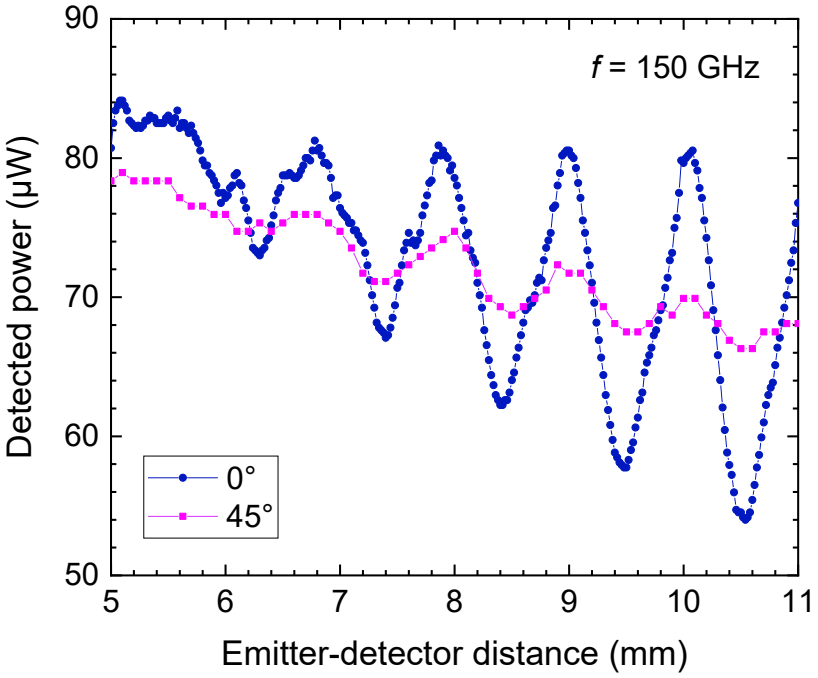


Power meters:

- Pyroelectric detector – SLT, calibrated by PTB
- Golay cell – Tydex, calibrated against the pyroelectric

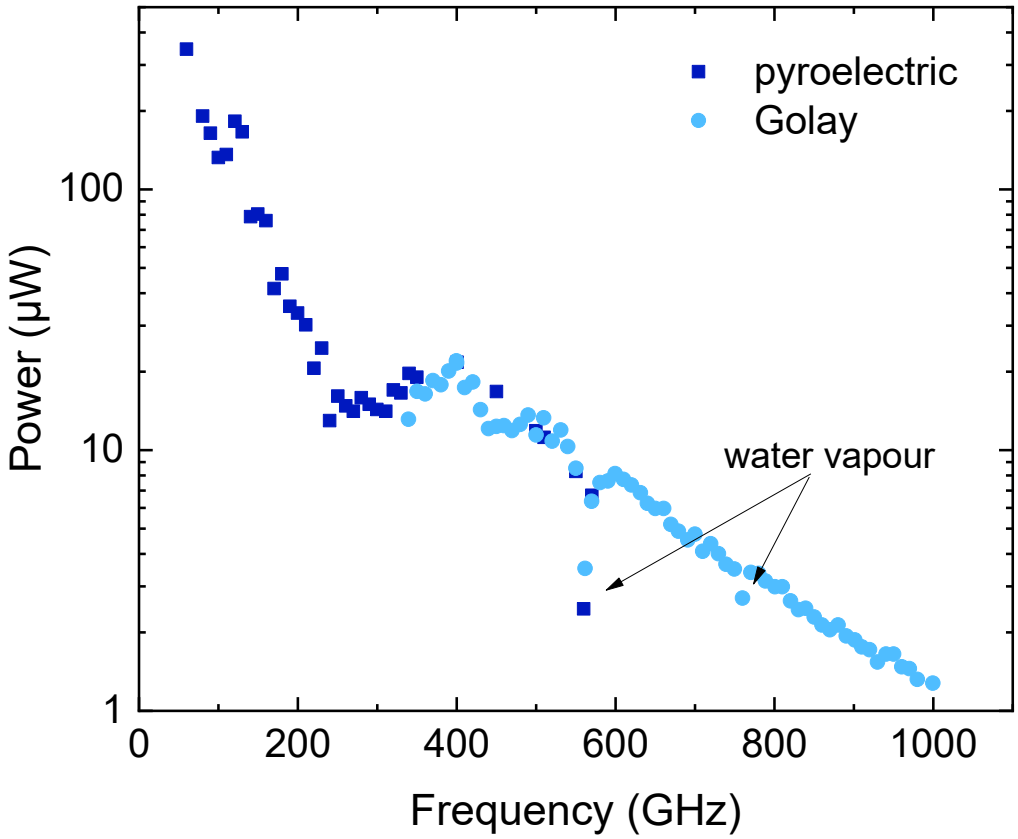
Standing waves

- Standing waves are a severe problem in power measurements
- Are ubiquitous and extremely difficult to eliminate
- Manifest as a sinusoidal variation of the detected power with the emitter-detector distance
- The distance between two power maxima is *c*/2*f*
- Can be reduced by tilting the detector at 45° to the beam axis



Emitter: PIN diode
Detector: pyroelectric

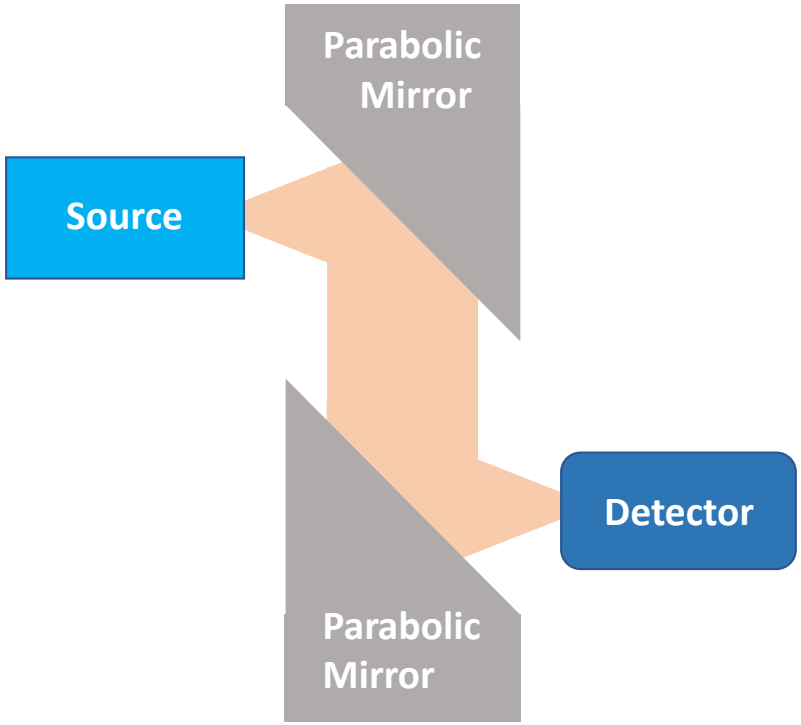
Emitter: photoconductive PIN diode



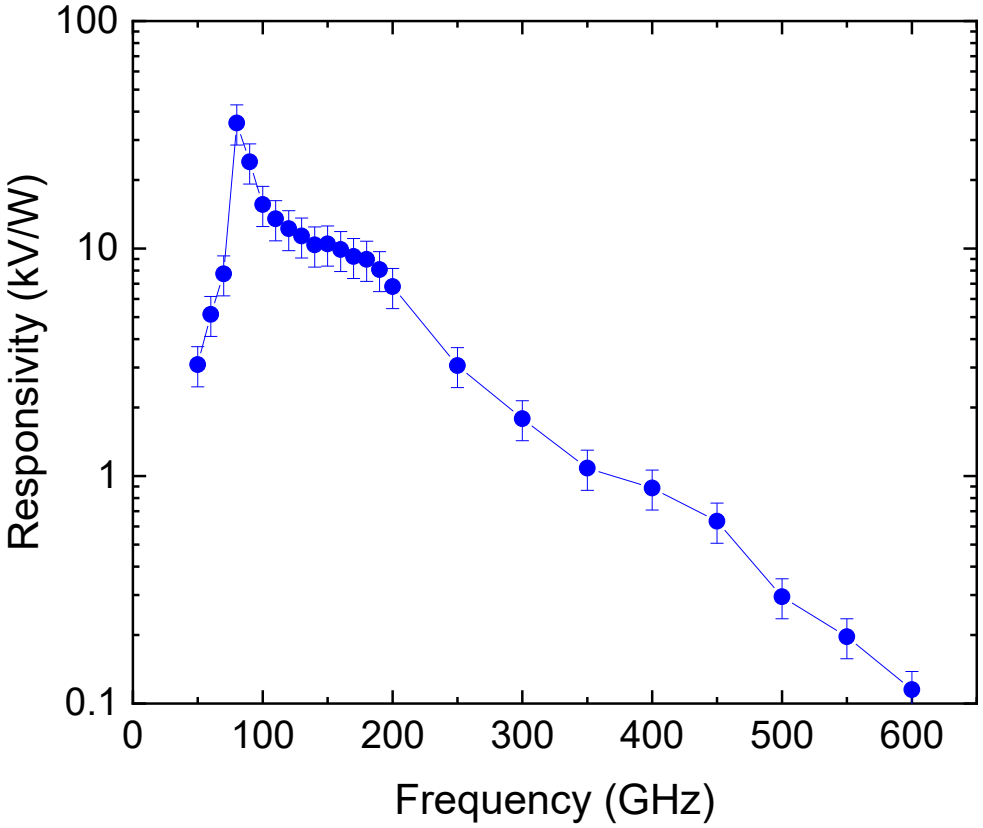
Detector frequency-dependent responsivity

Measurement method

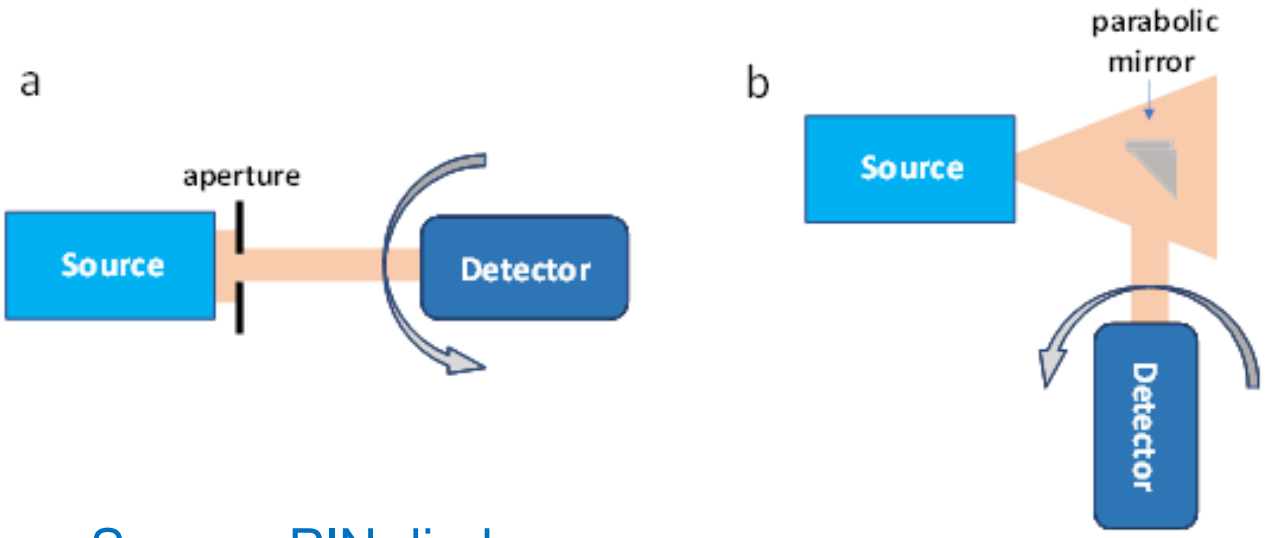
- Measure the frequency-dependent power of the emitter using a calibrated detector, to calibrate the emitter power
- Measure the same power under the same conditions using the detector under test
- Calculate the unknown detector responsivity from the known emitter power



Detector:
quasi-optical detector (ACST)



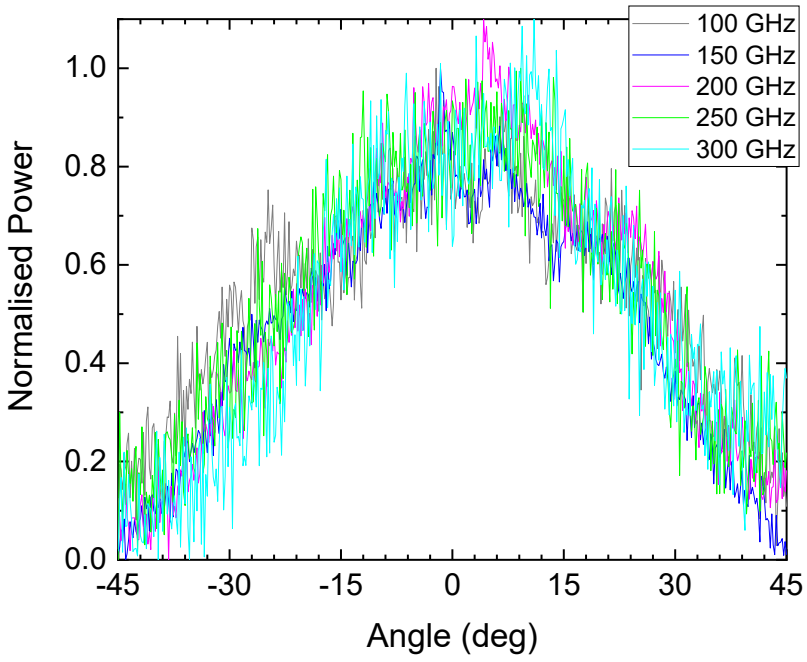
Detector spatial acceptance cone

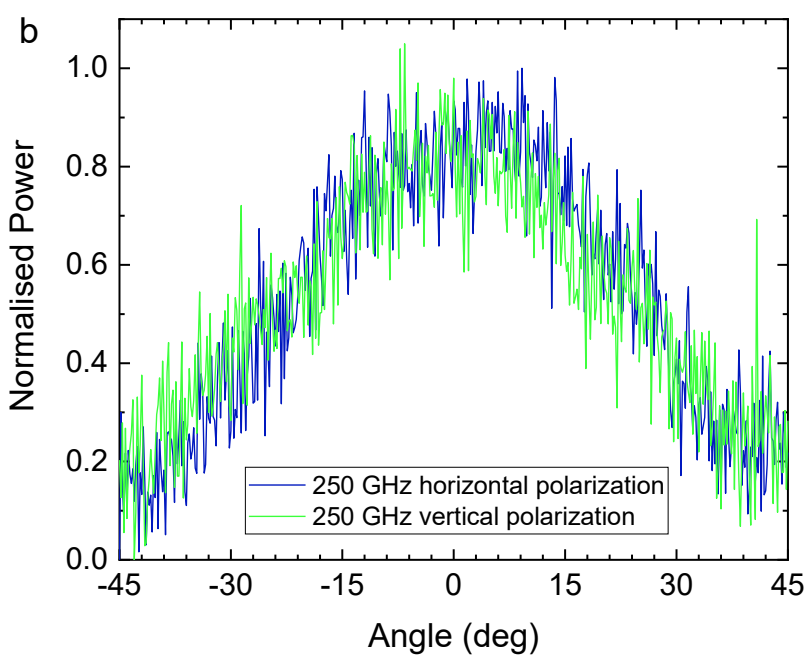


Source: PIN diode
Collimated beam diameter: 6 mm

Detector: pyroelectric detector (SLT)

Detector aperture: flat absorber, 10 mm diameter



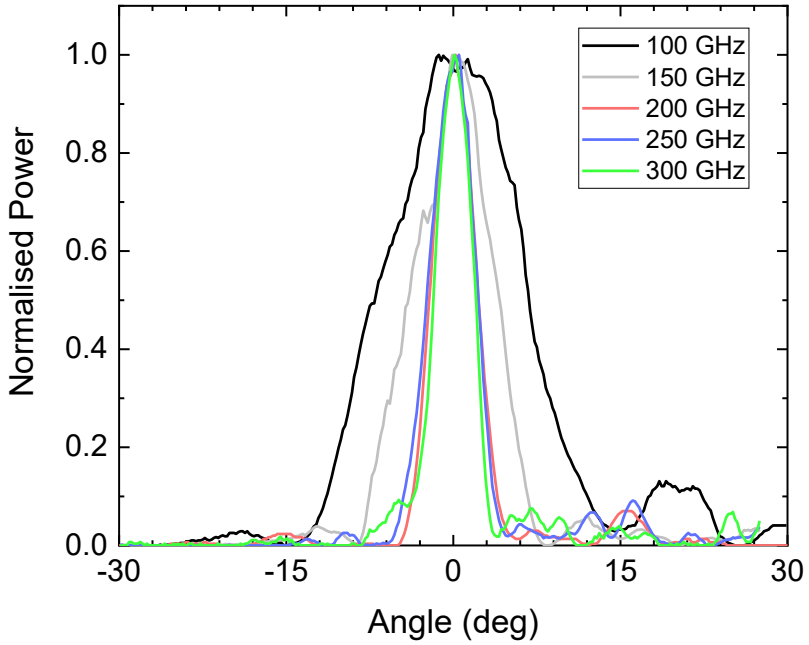


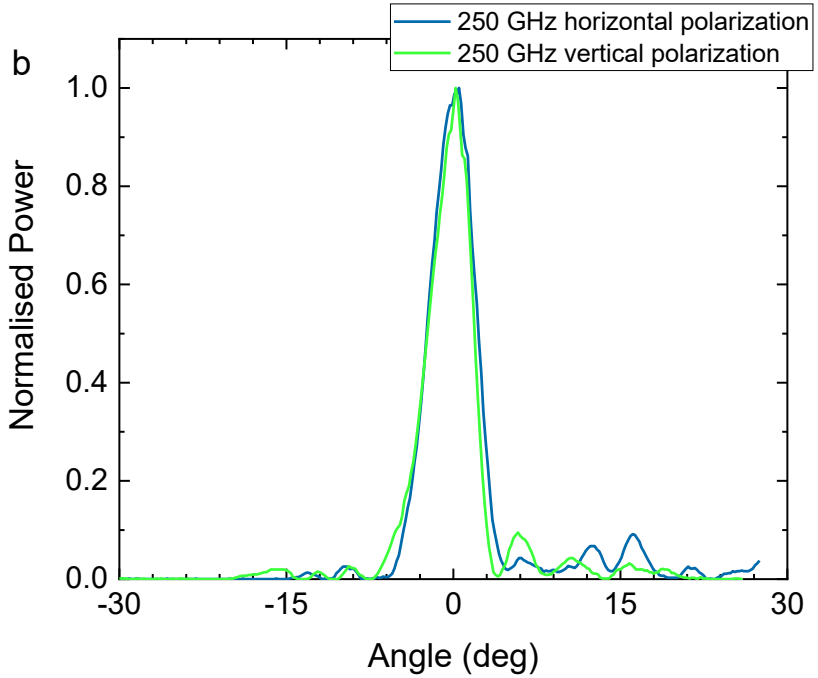
Acceptance cone: 50°

No polarization dependence

Detector: quasi-optical detector (ACST)

Detector aperture: hemispherical Si lens; 12 mm diameter





Acceptance cone:

- 14° @ 100 GHz
- 8° @ 150 GHz
- 5° ≥ 200 GHz

No polarization dependence

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Thank you