TERAPOD

WP4.1:
Device Characterization

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- This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 761579 TERAPOD.

Properties measured

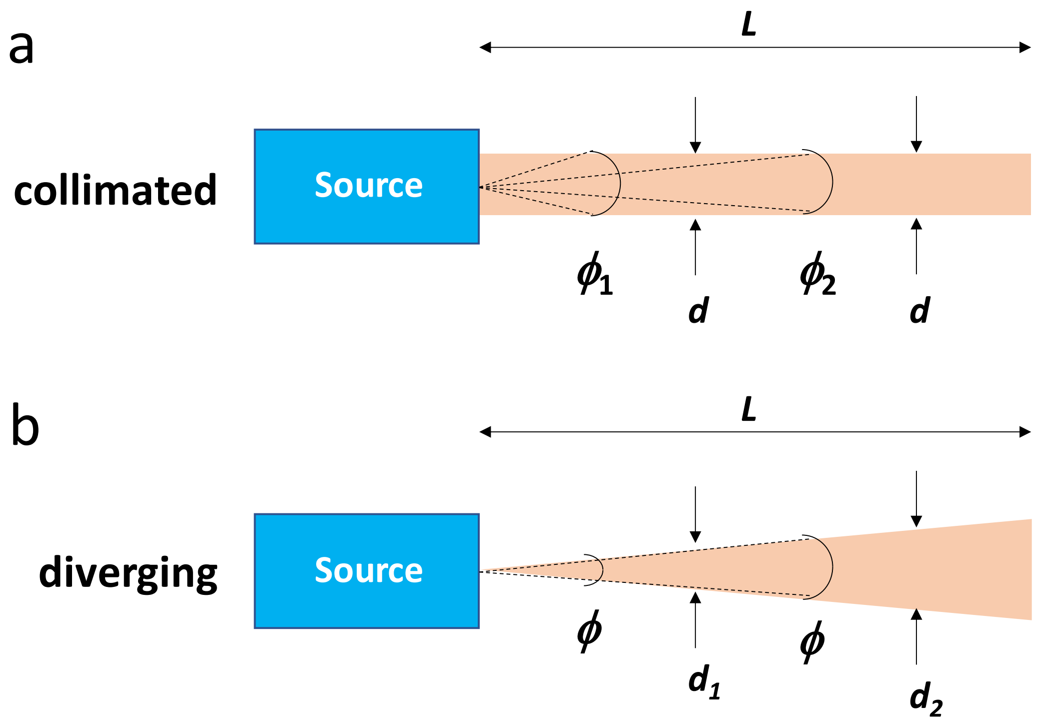
Emitters:

- Spatial beam profile
- Broadband frequency spectrum
- Power

Detectors:

- Frequency-dependent responsivity
- Spatial acceptance cone

Emitter spatial beam profile



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

Collimated beams have invariant diameter

ϕ = constant
$d/2L = \tan(\phi/2)$

Diverging beams have invariant angular distribution

Terahertz emitters are divergent sources

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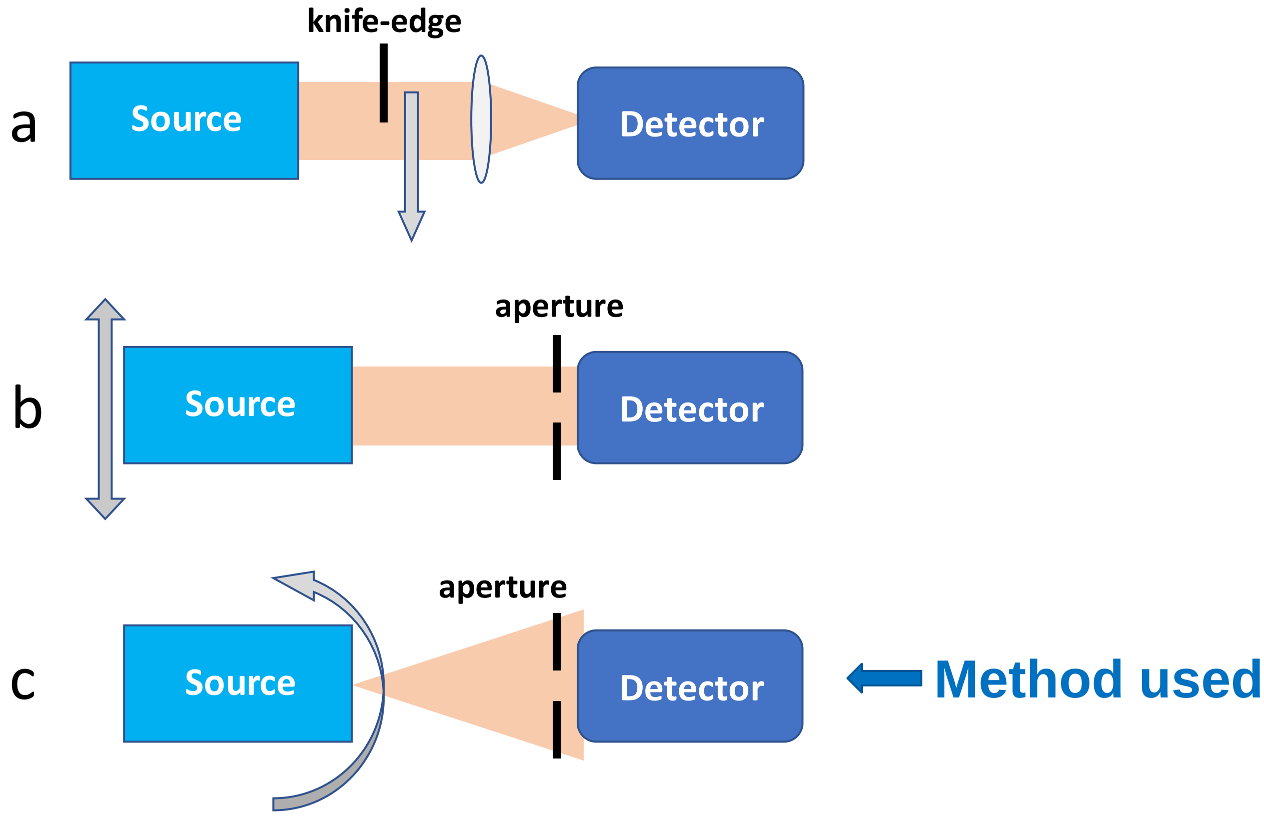
Emitter beam profile

Measurement approach

Does not reveal features or lobes

Suitable for collimated beams

Suitable for diverging beams



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:

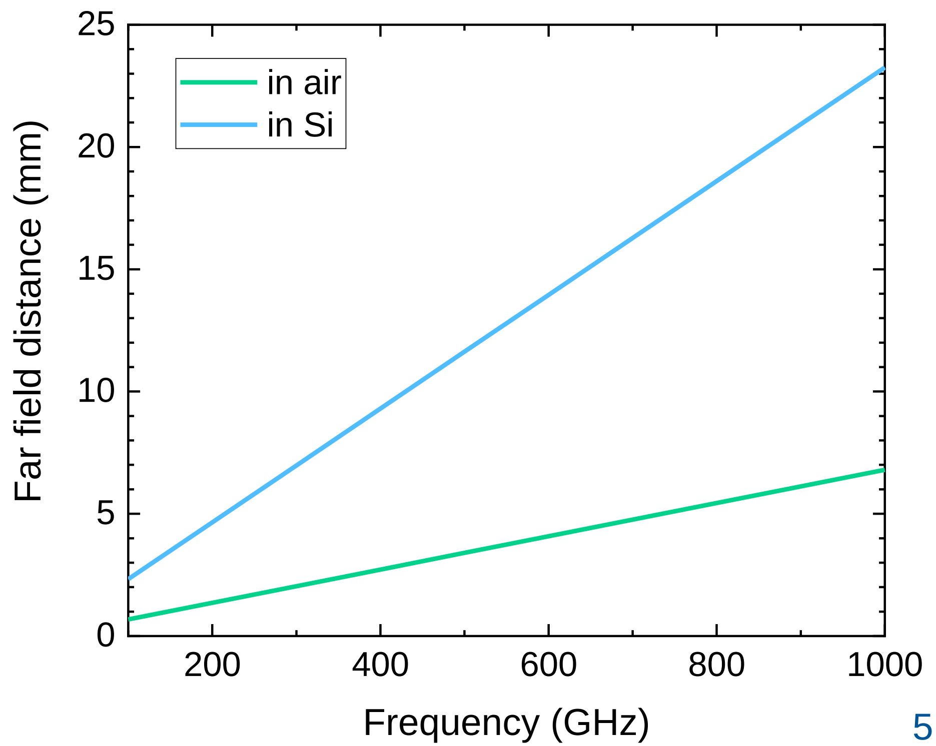
For

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

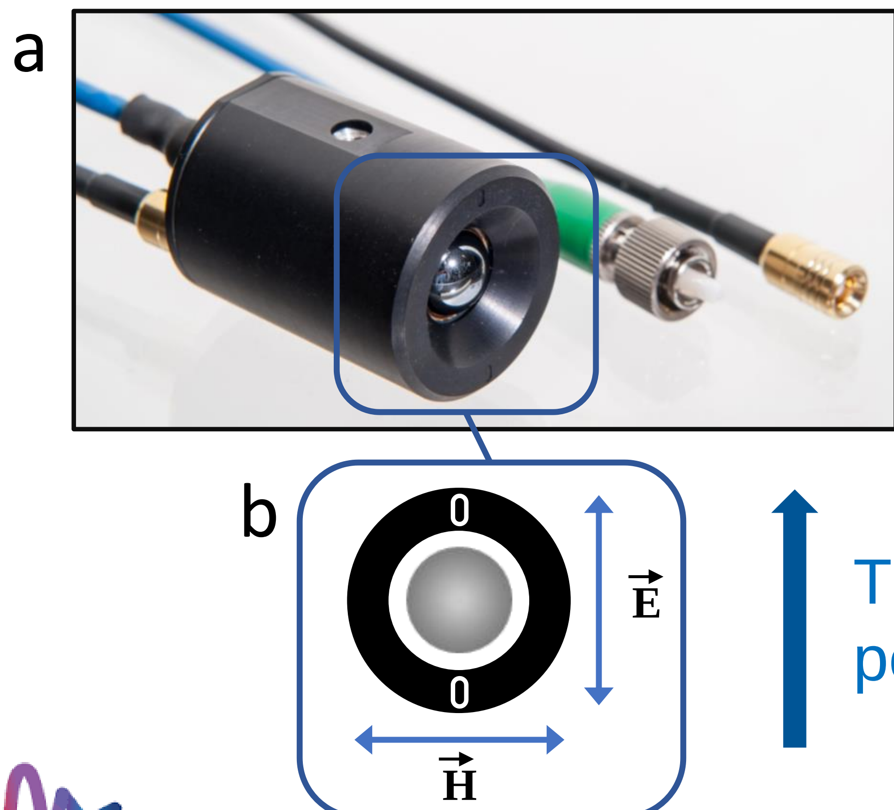
For

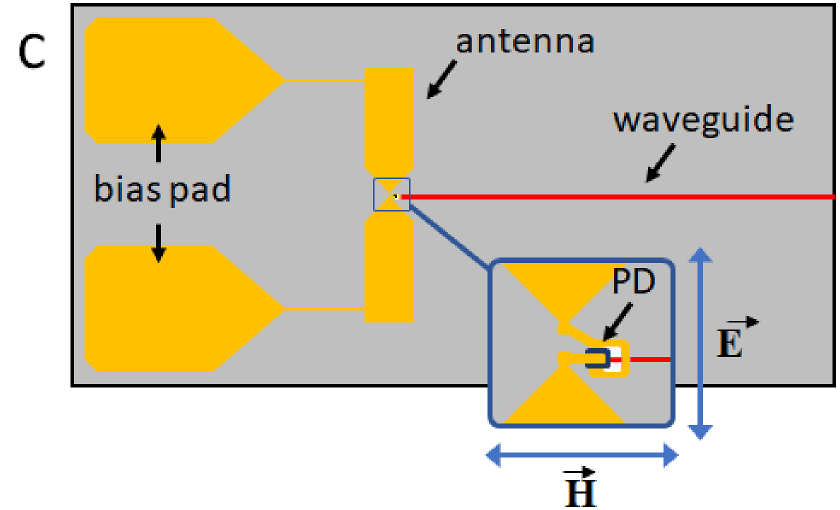
$$D > \frac{\lambda}{2} \qquad L_{far} > \frac{2D^2}{\lambda} = \frac{2D^2 f}{c}$$

Measurement distance = 60 mm



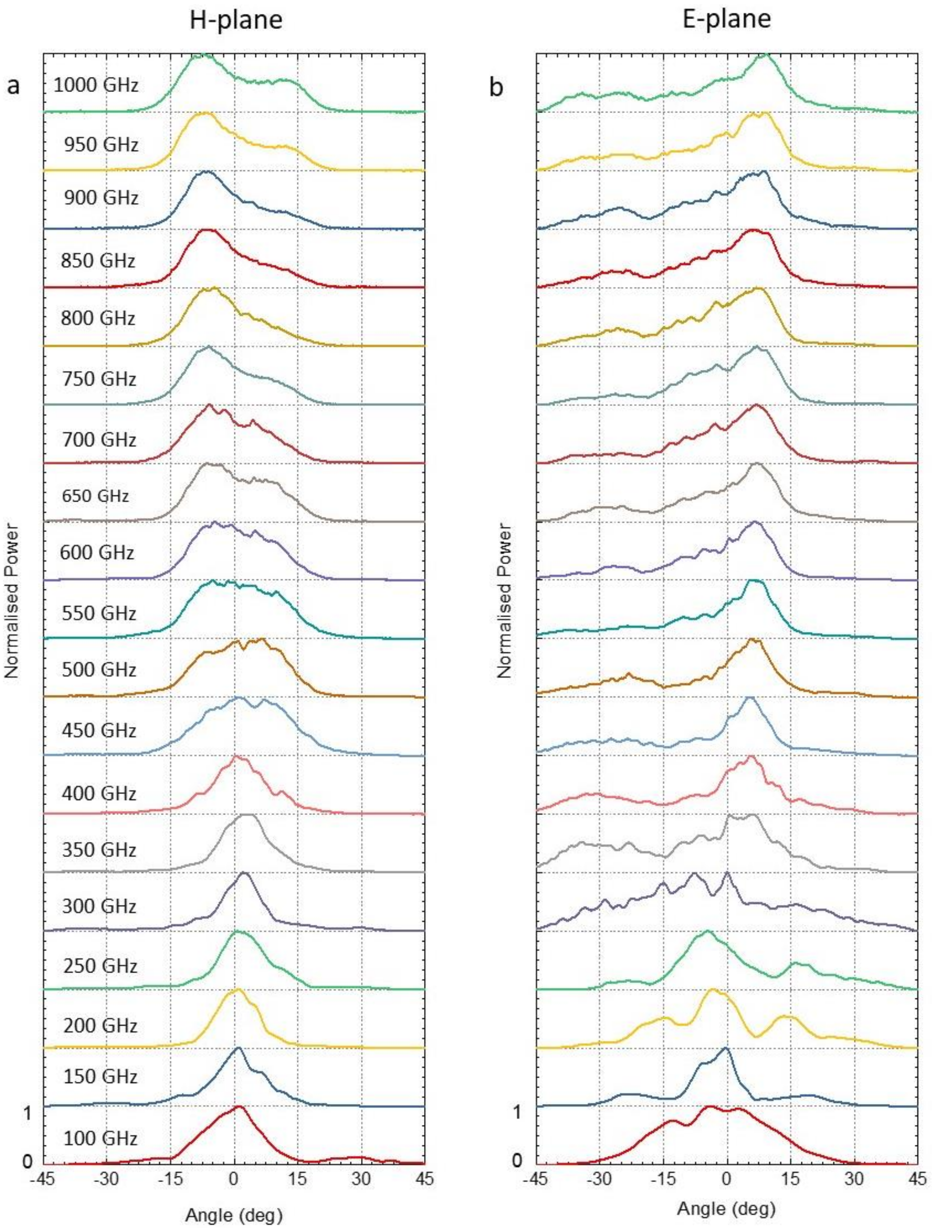
Emitter: photoconductive PIN diode





THz beam polarization

PIN diode beam profiles



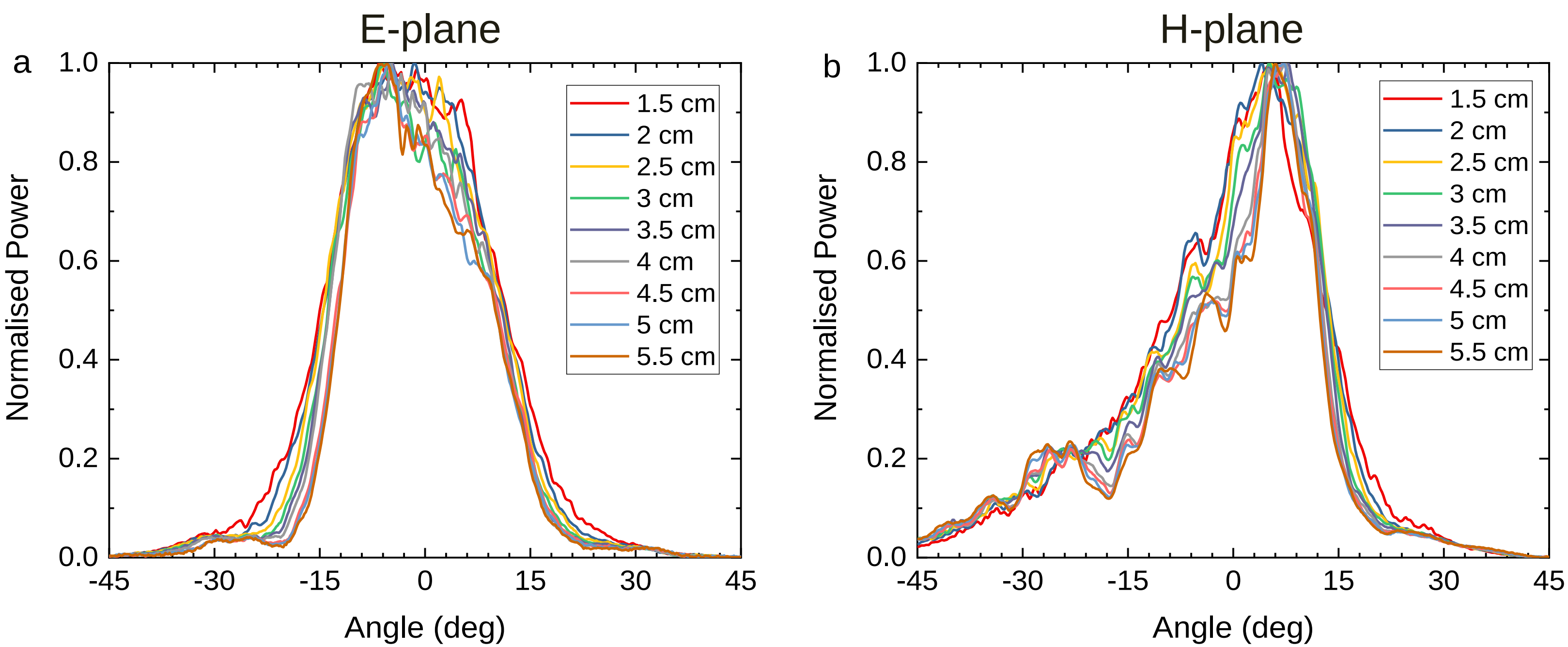
- All profiles deviate from Gaussian
- All are asymmetric
- Profiles are frequency dependent
- Profiles are polarization dependent
- Many have several lobes

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

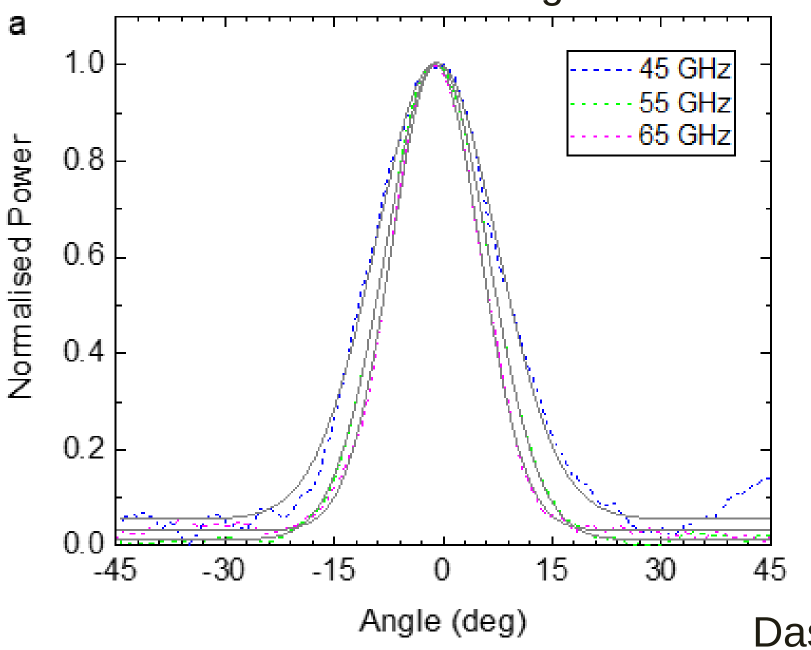


The beam profile remains constant with emitter-detector distance

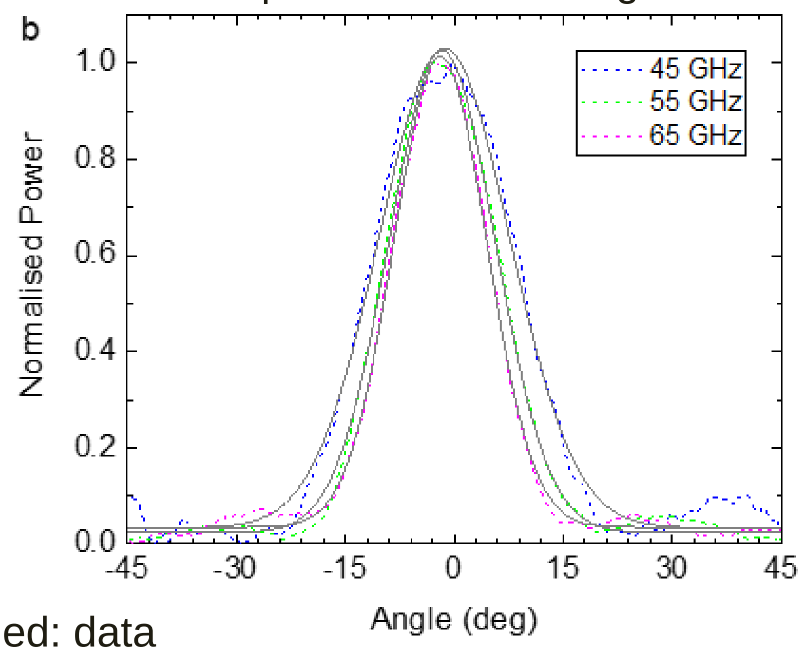
Emitter:
WR15 rectangular horn antenna

Source: signal generator Anritsu 69397A

Parallel to waveguide



Perpendicular to waveguide

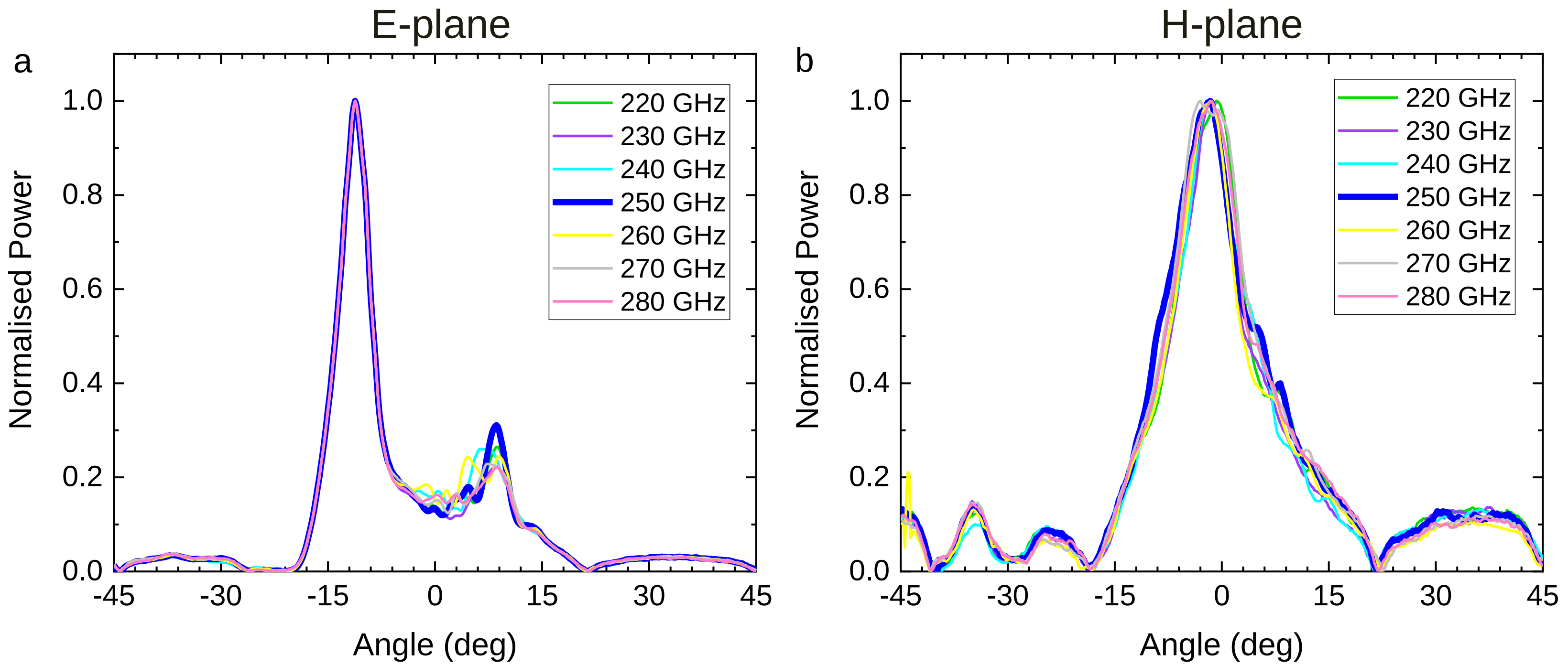


Dashed: data
Solid: Gaussian fit

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

Emitter: photoconductive UTC from UCL

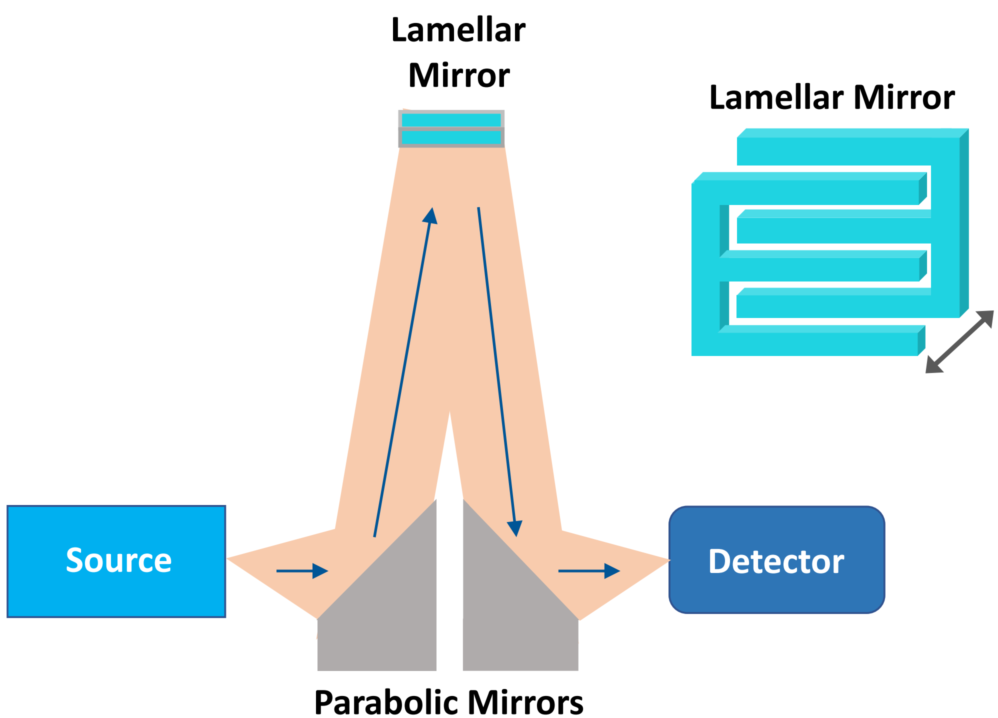
UTC optimised at 250 GHz



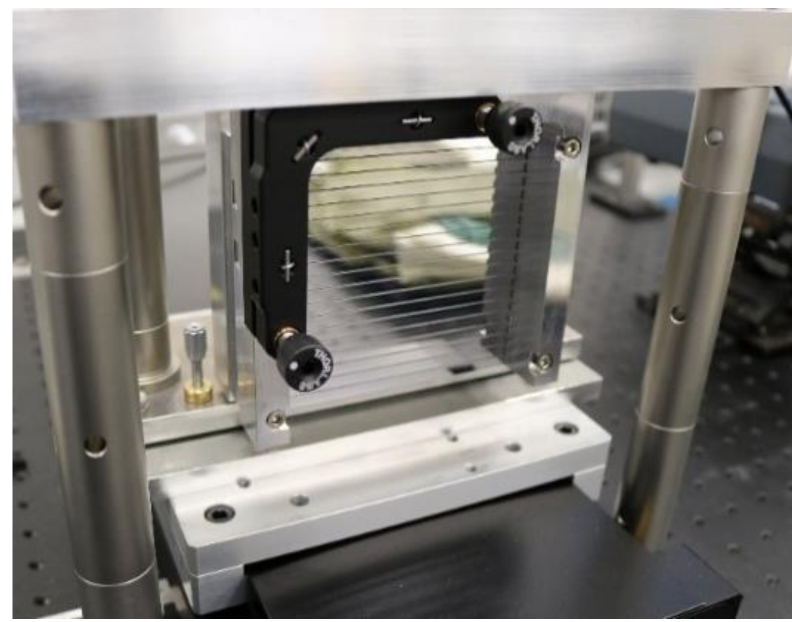
Strongly irregular beam profile, especially in the E-plane

Broadband emitter spectrum

Measurement instrument: lamellar interferometer

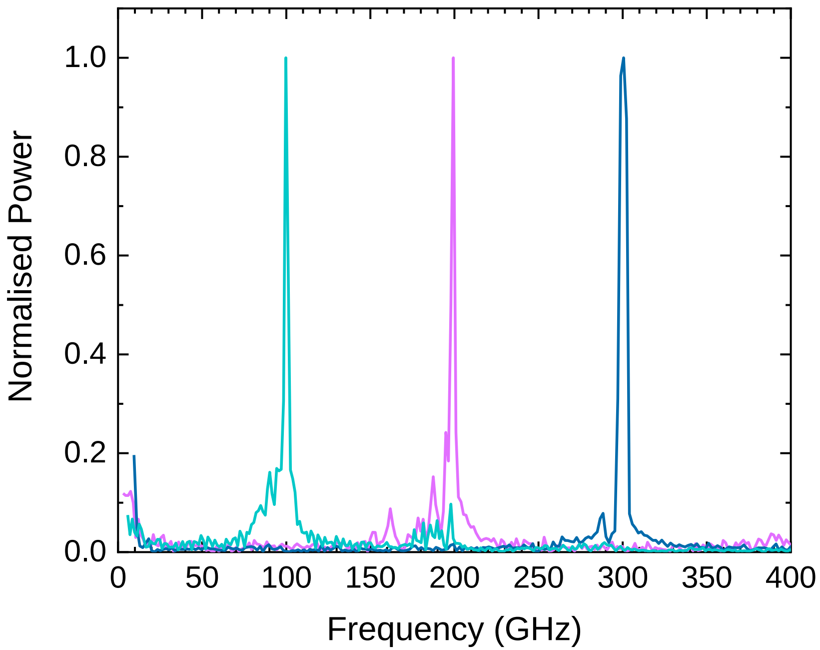


Lamellar mirror at NPL



Maximum frequency
resolution: 0.75 GHz

Emitter: photoconductive PIN diode



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

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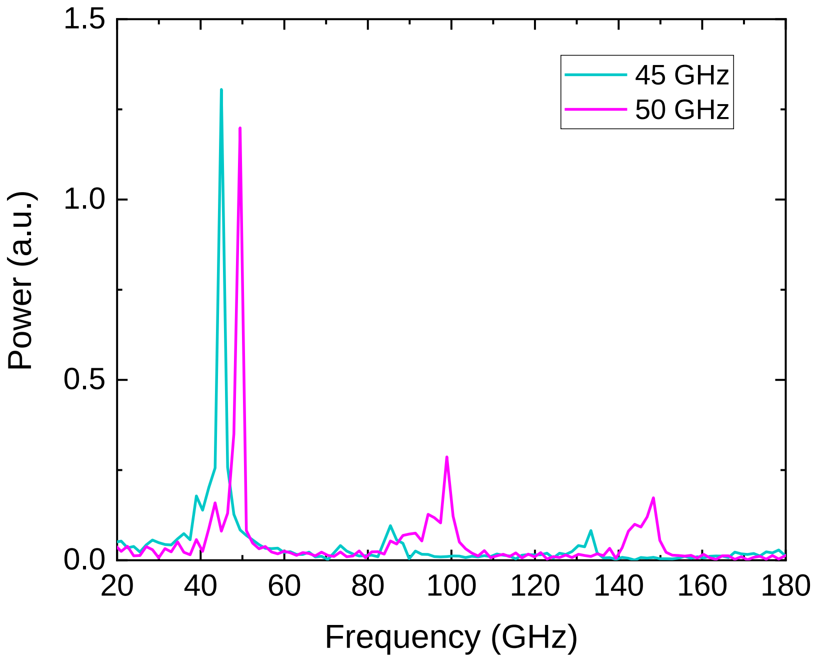
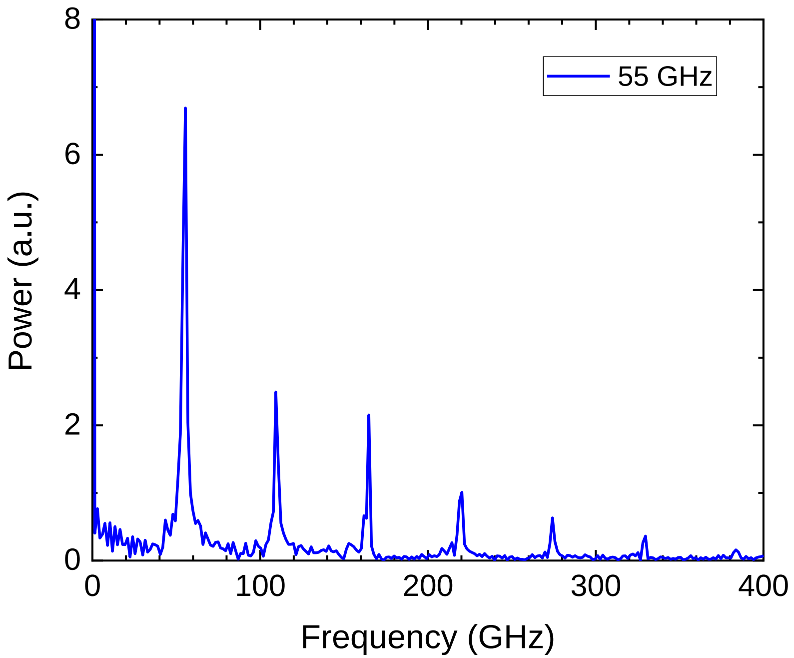
Emitter:
WR15 rectangular horn antenna

Source: signal generator Anritsu 69397A

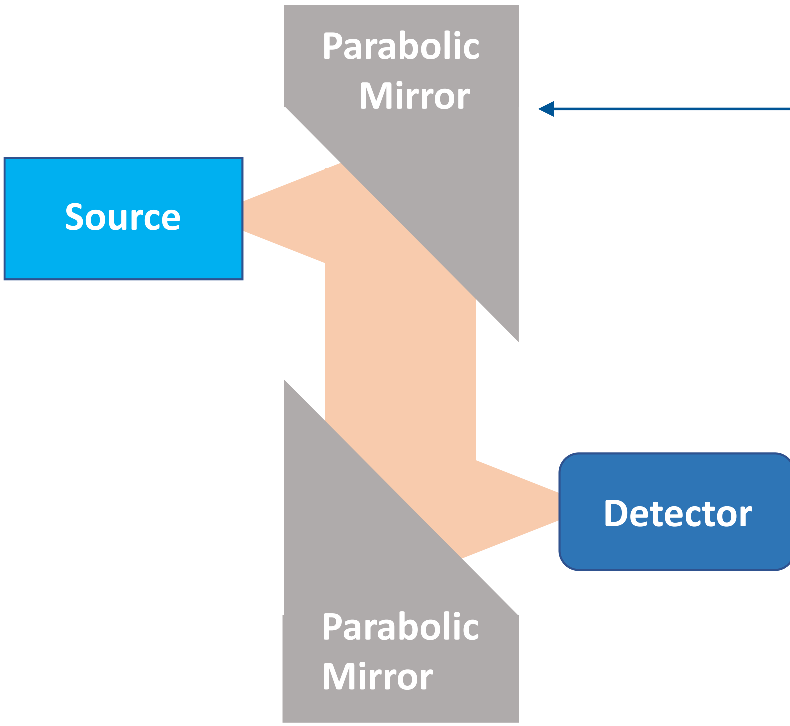




- Measurement technique reveals harmonics that are not detectable using waveguide-based methods
- The number and strength of harmonics are frequency-dependent

Emitter power

Measurement method



Parabolic mirrors used to maximise beam collection

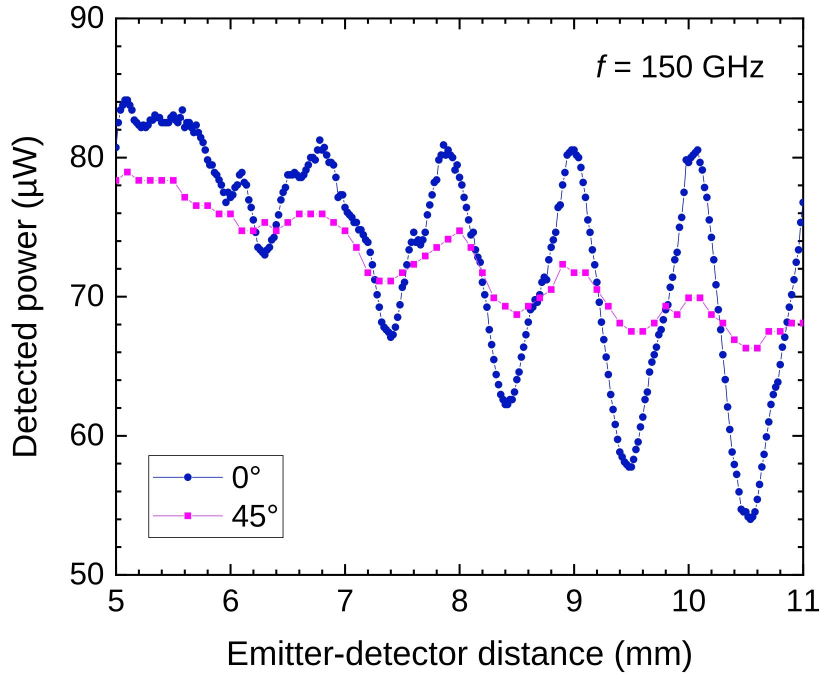
Calibrated detector

Power meters:

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

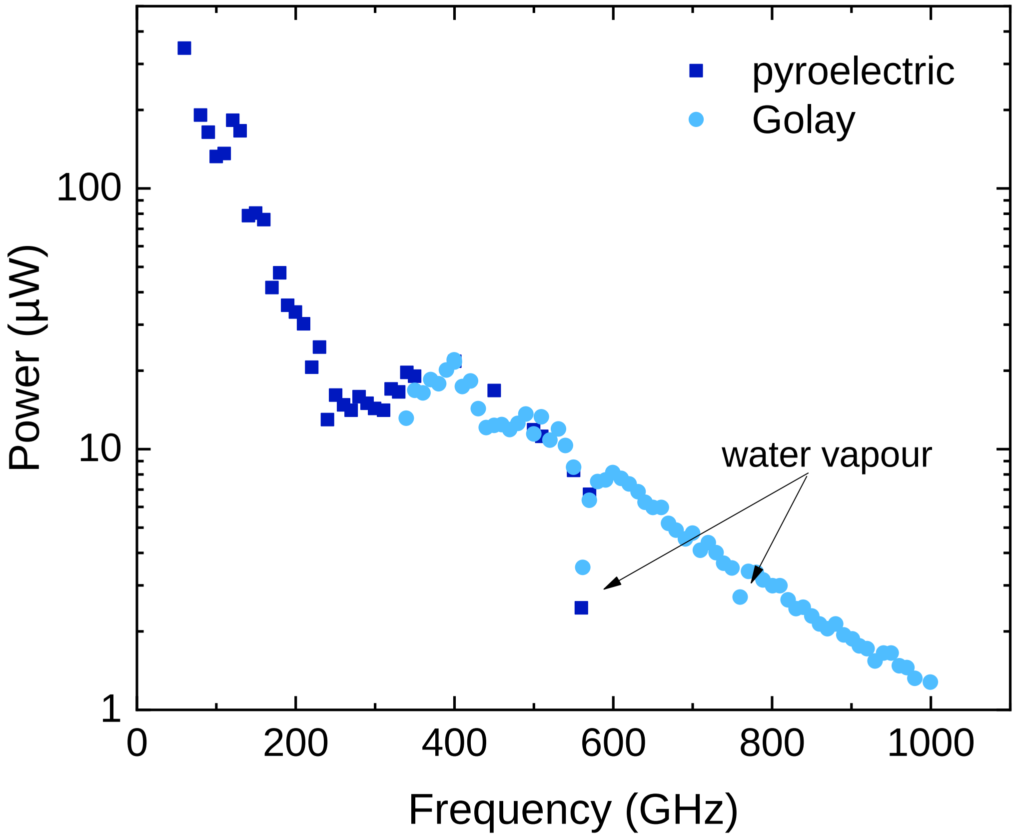
Standing waves

- 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/2f*
- Can be reduced by tilting the detector at 45° to the beam axis



Emitter: PIN diode
Detector: pyroelectric

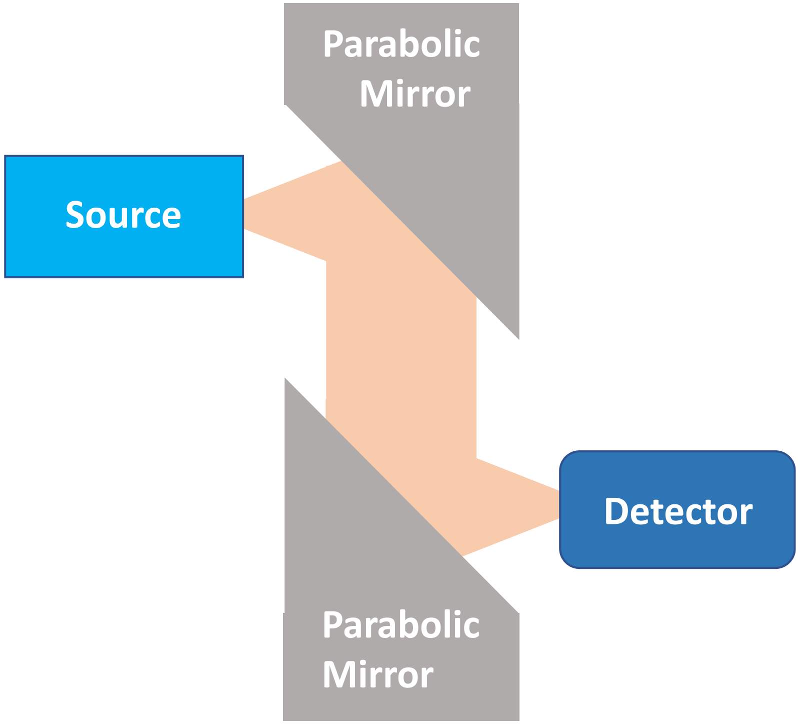
Emitter: photoconductive PIN diode



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



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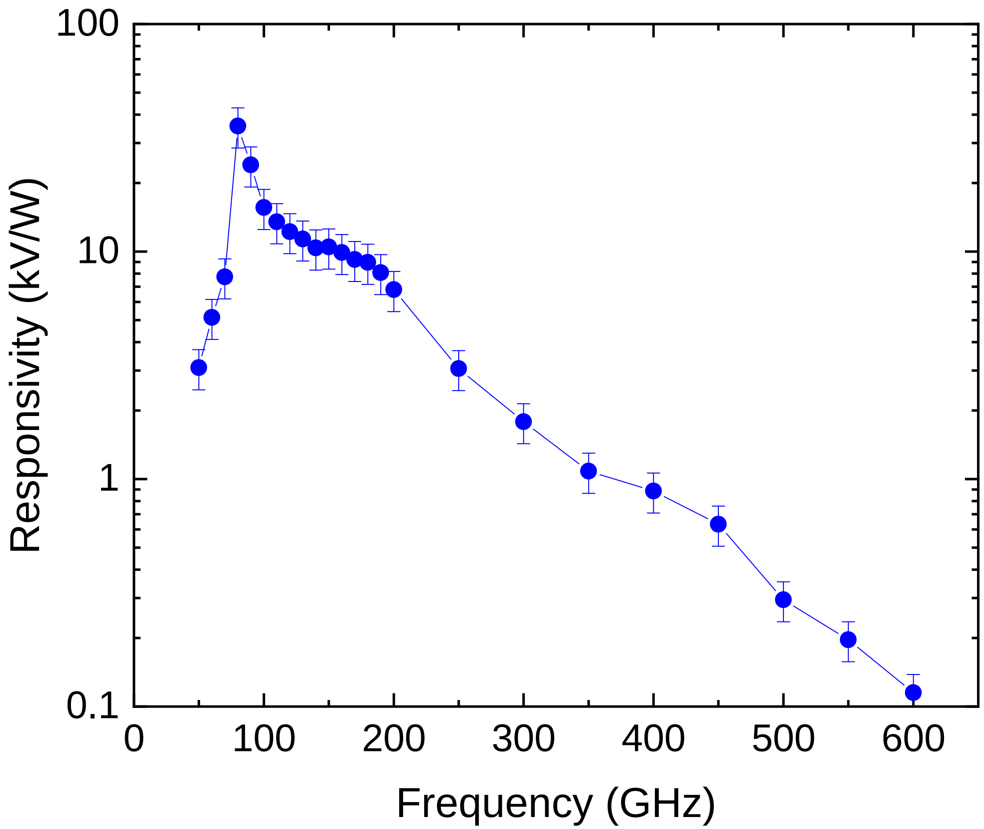
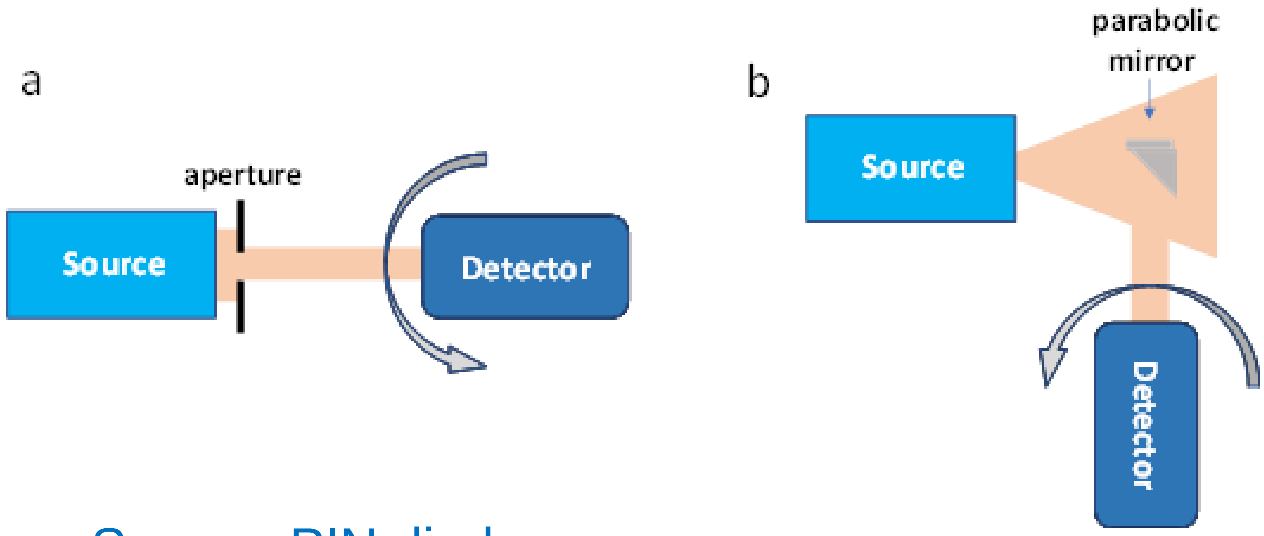
Detector:
quasi-optical detector from ACST



Detector spatial acceptance cone

NPL National Physical Laboratory



Source: PIN diode
Collimated beam diameter: 6 mm

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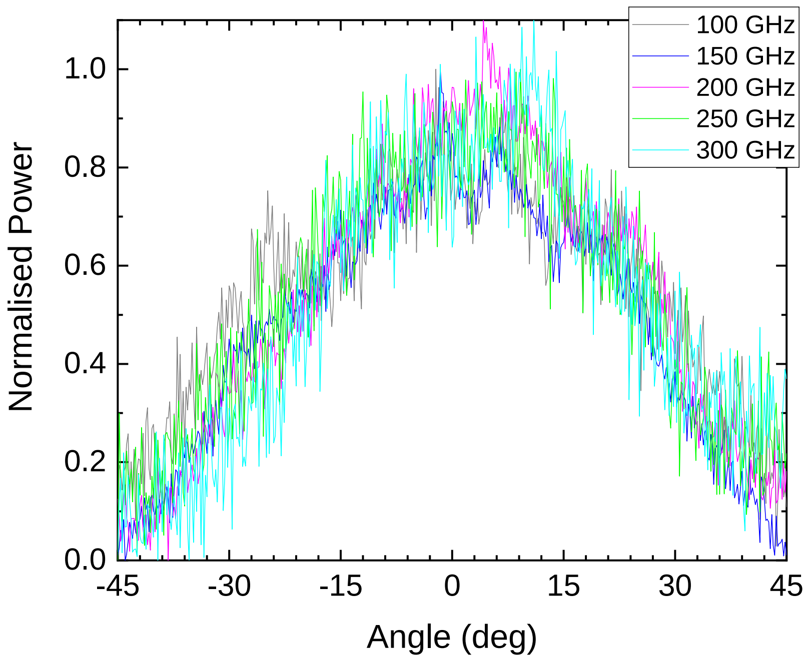
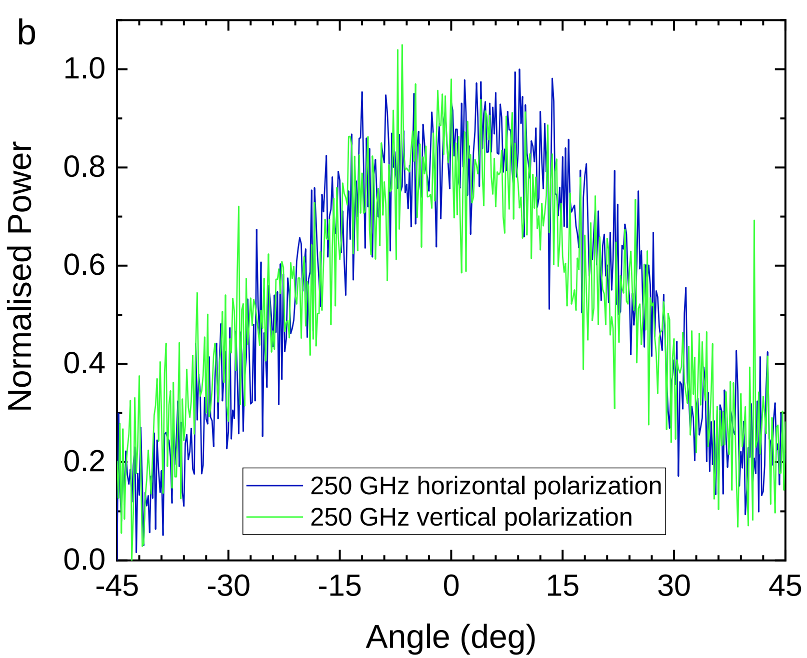
Detector: pyroelectric detector (SLT)

Detector aperture: flat absorber, 10 mm diameter



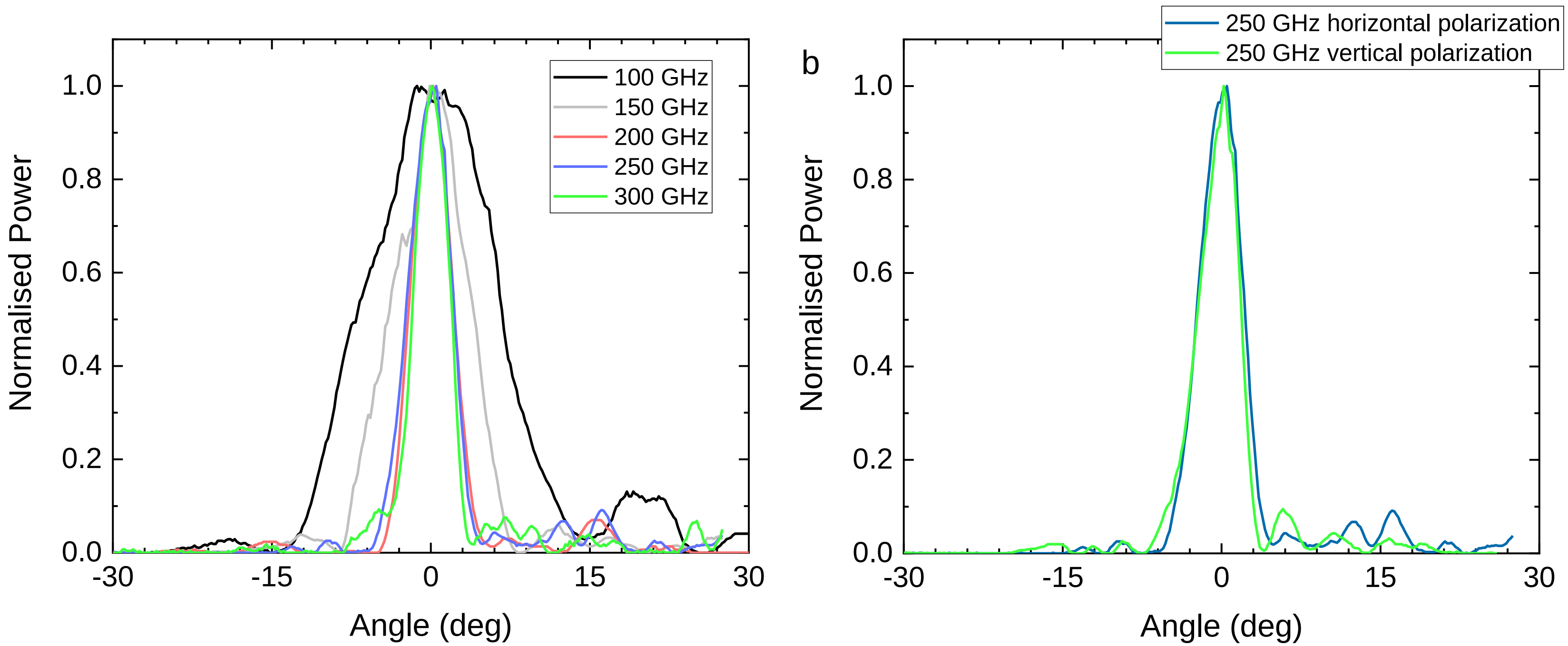


Acceptance cone: 50°

No polarization dependence

Detector:
quasi-optical detector from ACST

Detector aperture: hemispherical Si lens; 12 mm diameter



Acceptance cone:

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

No polarization dependence

Thank you for your attention!!

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