Next generation of the sub-millimetre wave security camera

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

THz Videocam

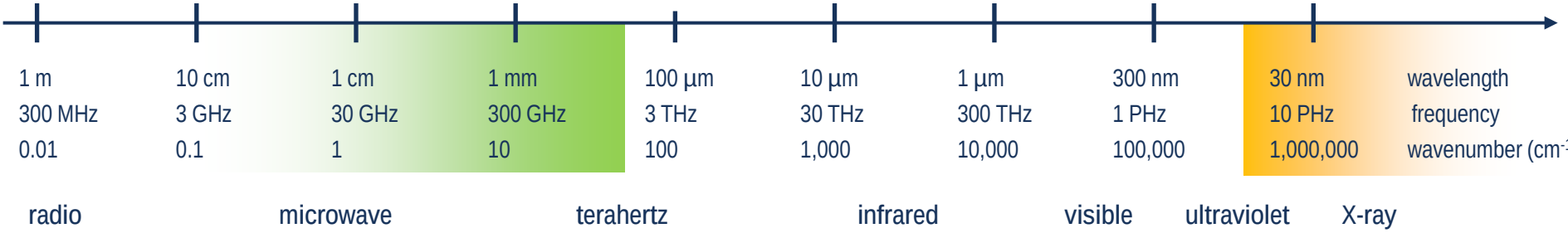
- Security body scanning: concept and actuality
- Realization of our camera(s)
  - Overview
  - Details of selected components
- Conclusion

basic concept of a „body scanner“

image of a person in a suitable wavelength band

conditions:

1. (partial) transparent clothing
2. contrast between hidden object (z.B. weapons, explosives etc.) and human body
3. best possible spatial resolution
4. avoid health and privacy issues



Actuality

L3 Provision ATD

Smith Detection Eqo

millimeter waves

Braun Conpass

X-Ray

ASE SmartCheck

1 m	10 cm	1 cm	1 mm	100 µm	10 µm	1 µm	300 nm	30 nm	wavelength
300 MHz	3 GHz	30 GHz	300 GHz	3 THz	30 THz	300 THz	1 PHz	10 PHz	frequency
0.01	0.1	1	10	100	1,000	10,000	100,000	1,000,000	wavenumber (cm^{-1})

Prospects and limits of established solutions

- high image quality
- mature technology
- in operation at airport
- no health issues

limited to near field (portal) because of insufficient spatial resolution and difficult illumination

Why cameras?

'camera' is synonymous with '**flexible**':

→ quasi-mobile operation (configurable)

perspective: thinking beyond

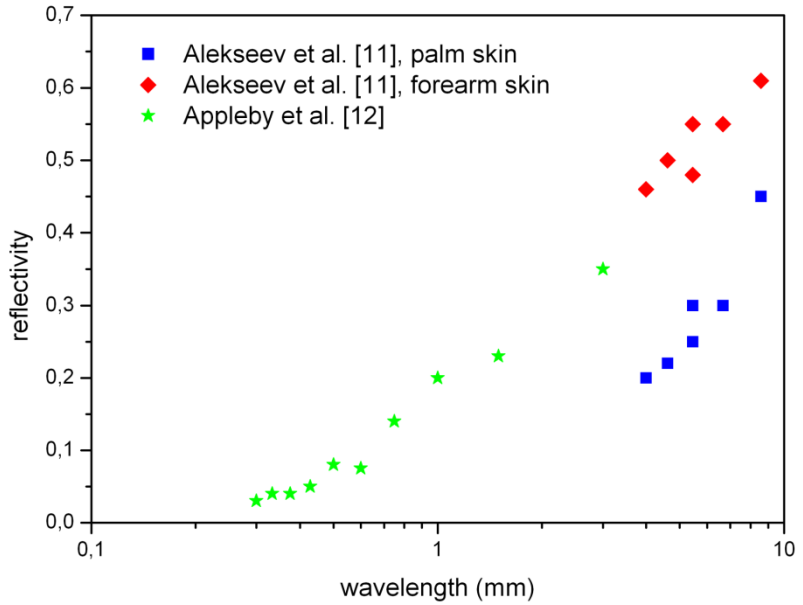
- detection **prior** endangering
- **temporary** installation

Active or passive?

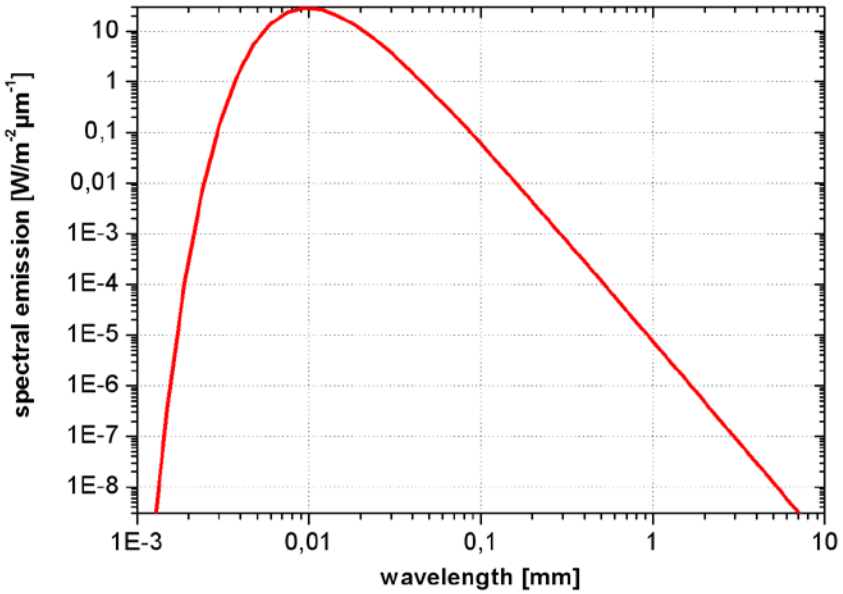
[11] Alekseev et al., Human Skin Permittivity Determined by Millimeter Wave Reflection Measurements, Bioelectromagnetics 28 (2007)

[12] Appleby et al., Standoff Detection of Weapons and Contraband in the 100 GHz to 1 THz Region, IEEE Transactions on antennas and propagation, 55 (2007)

reflectivity of human skin



thermal radiation of 35°C black body

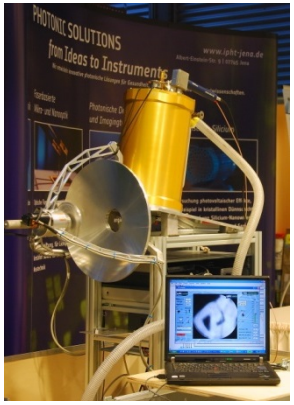


Indeed, a passive camera is a more simple approach

...in retrospect:

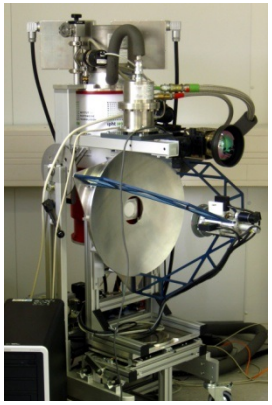
1st generation (2007):

- 1 sensor
- 25 seconds / frame
- liquid helium



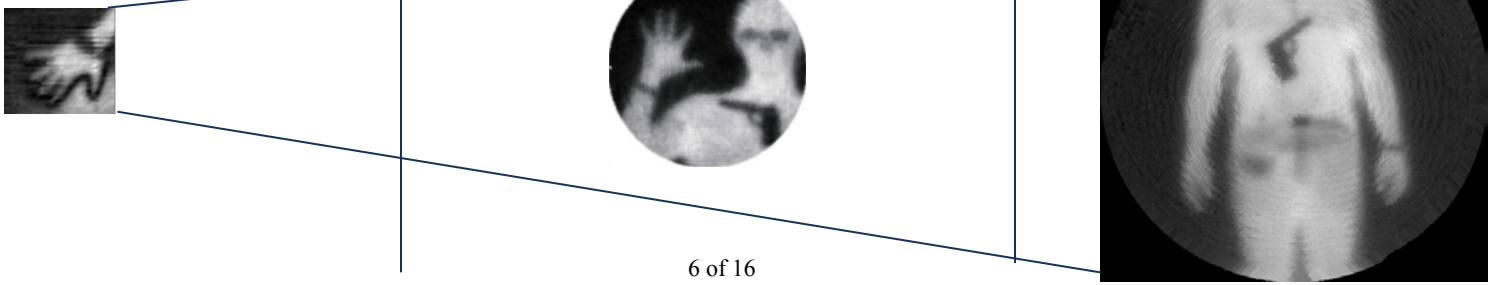
2nd generation (2009):

- 7 sensors
- 1 seconds / frame
- liquid helium



3rd generation (2010):

- 20 sensors
- 10 frames / second
- cryogen-free

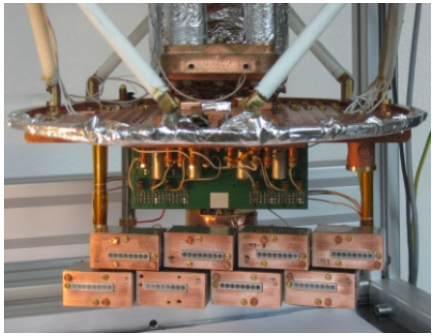


THz-Videocam TWO

integrated system concept with automated cryocooler TransMIT model PT4200 (air-cooled, 220V 4kW)

ROHDE&SCHWARZ

linear array of 64 superconducting detectors



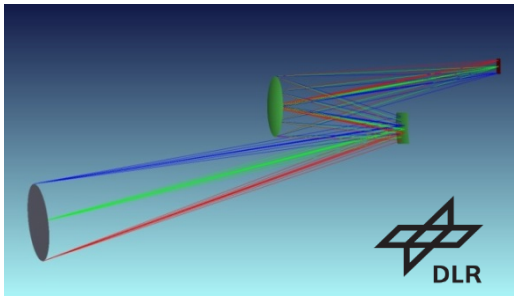
ipht jena

KIT Karlsruher Institut für Technologie

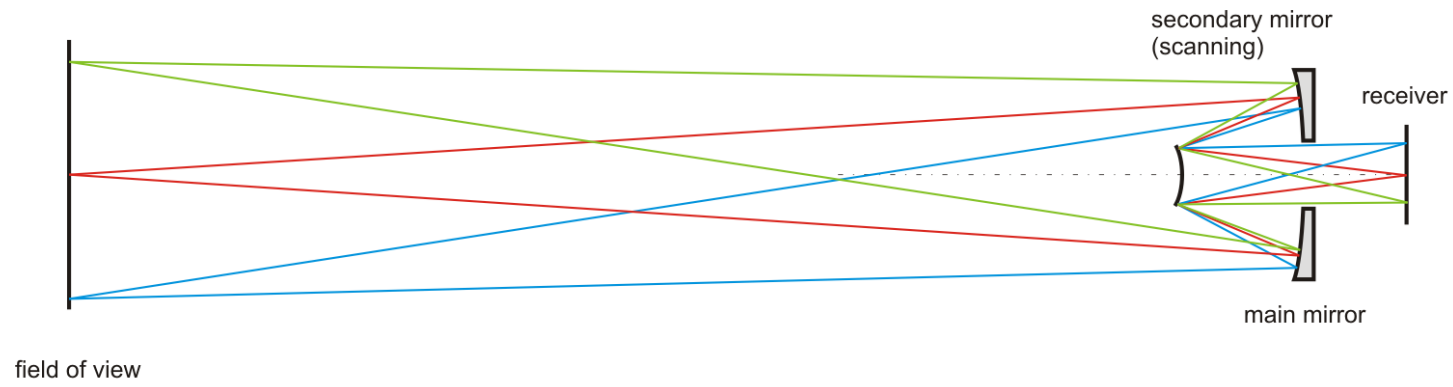
scanning apparatus for 25Hz utilising carbon fibre reinforced mirror

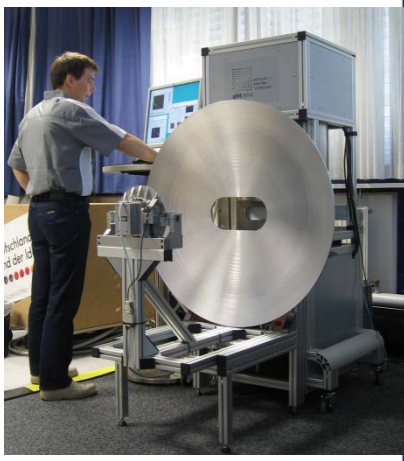
supracon

modular THz-optics



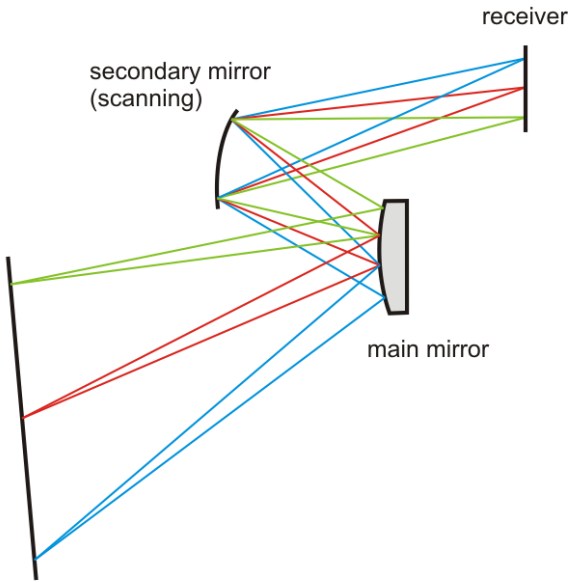
Modular optics



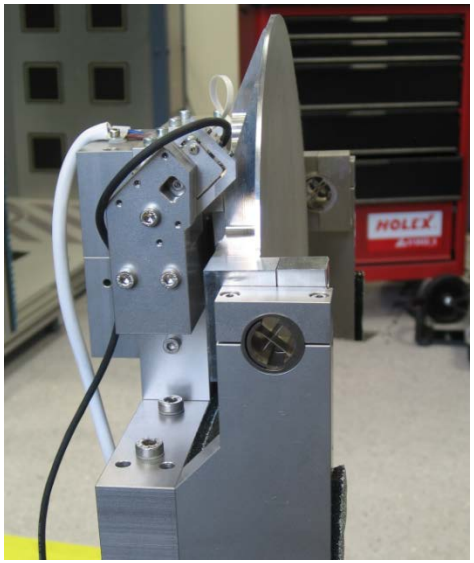


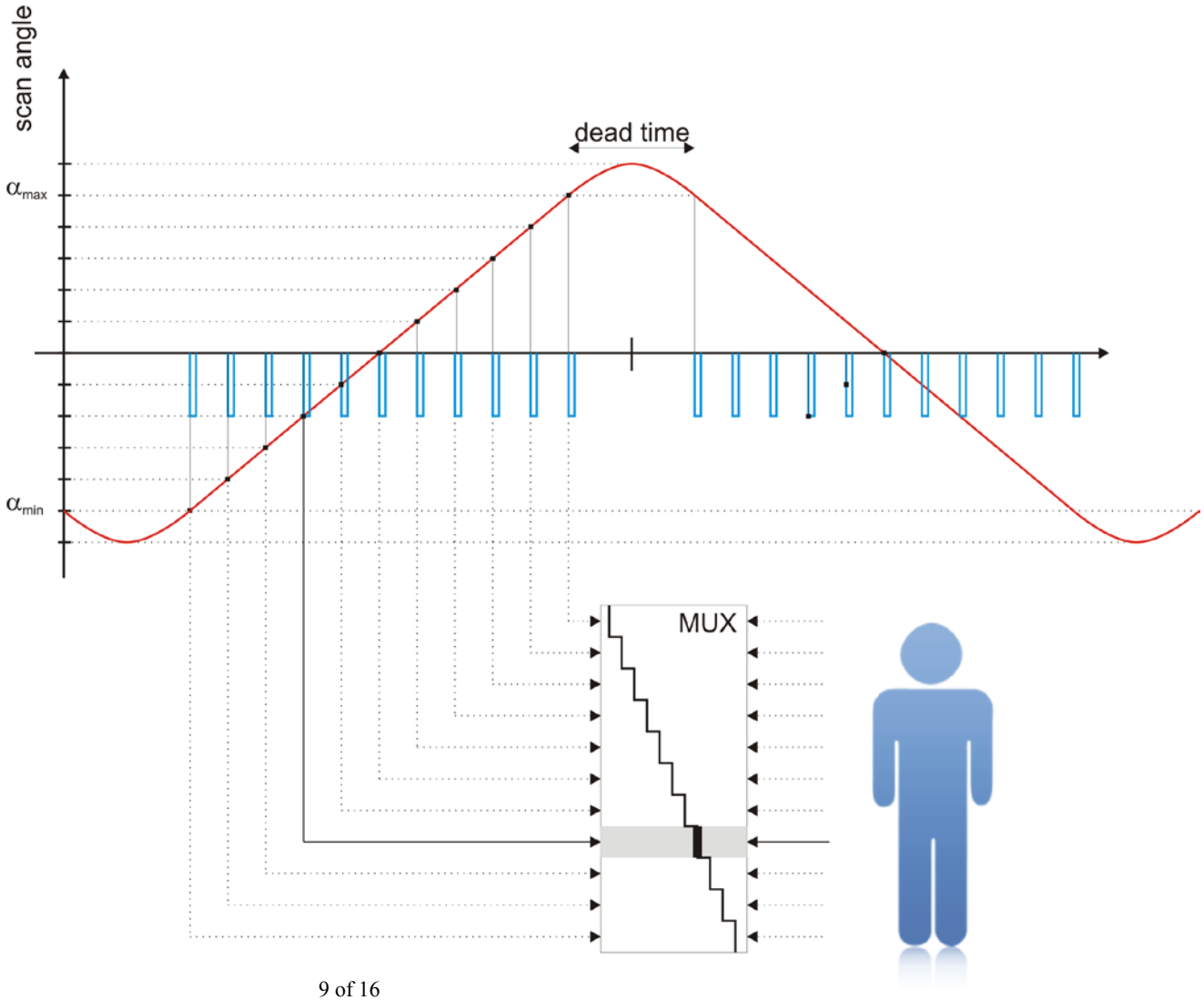
on-axis telescope as telephoto
off-axis telescope as wide-angle

- field of view 1 m × 2 m
- intended image resolution 128×256 pixel (1.5cm Nyquist sampling)
- image plane corrected for 25cm long receiver (tilted and curved)



Scanning scheme



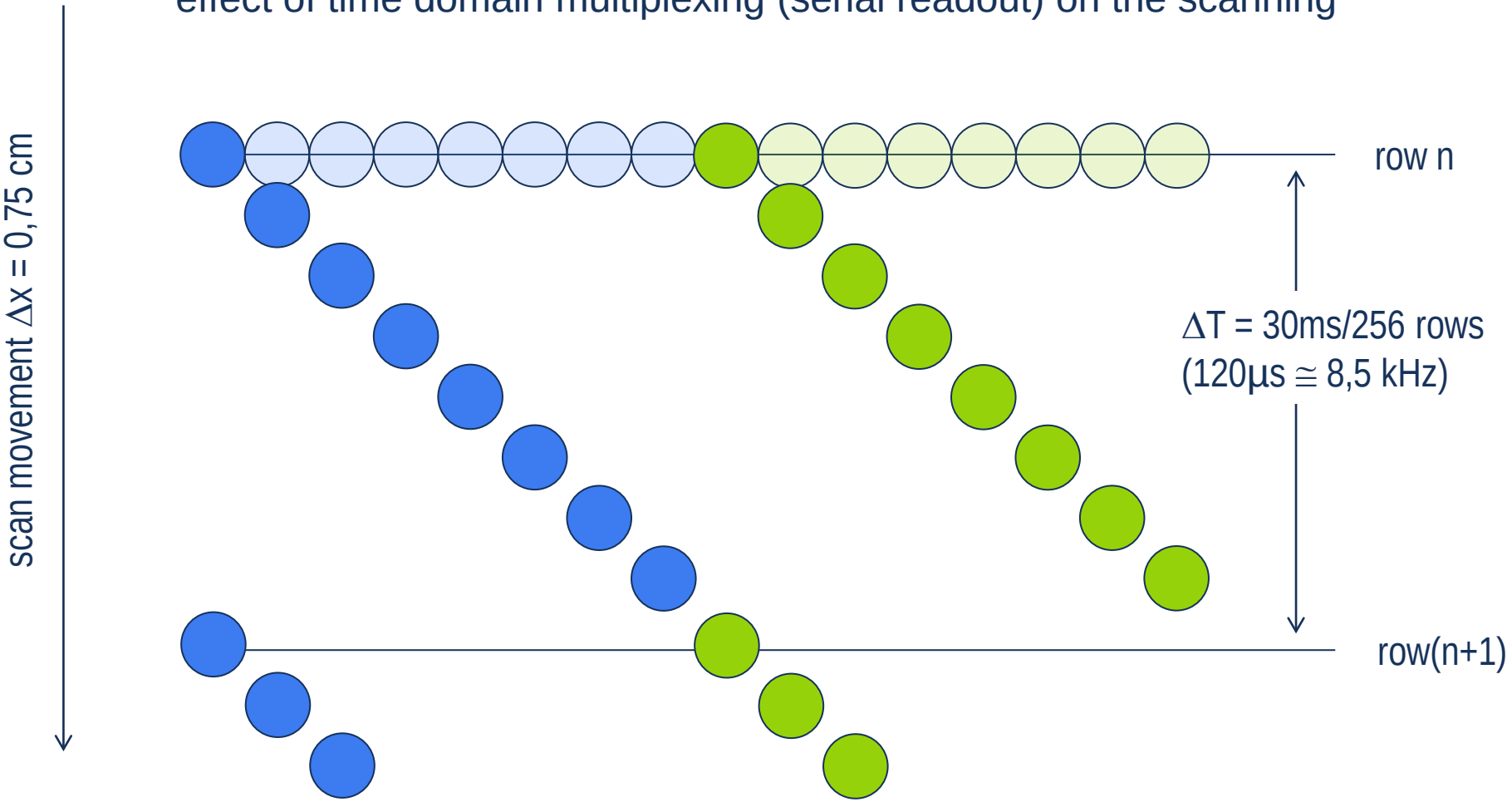


@ 25Hz:

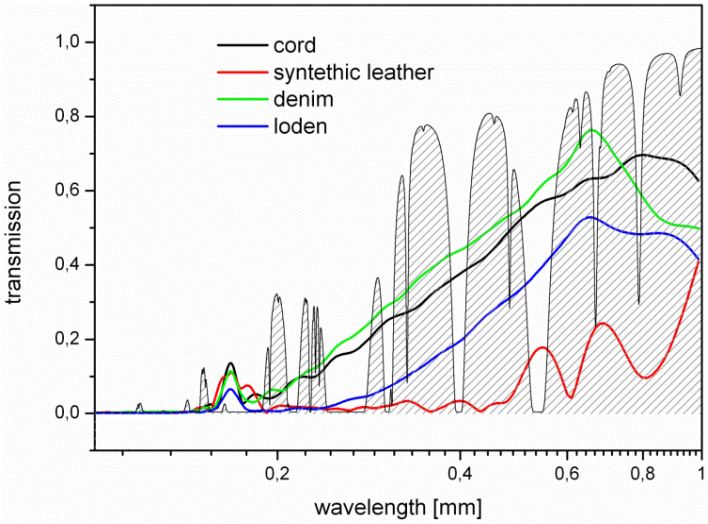
frame-time: 40 ms
dead-time: 2 ms
image: 38ms

Scanning scheme

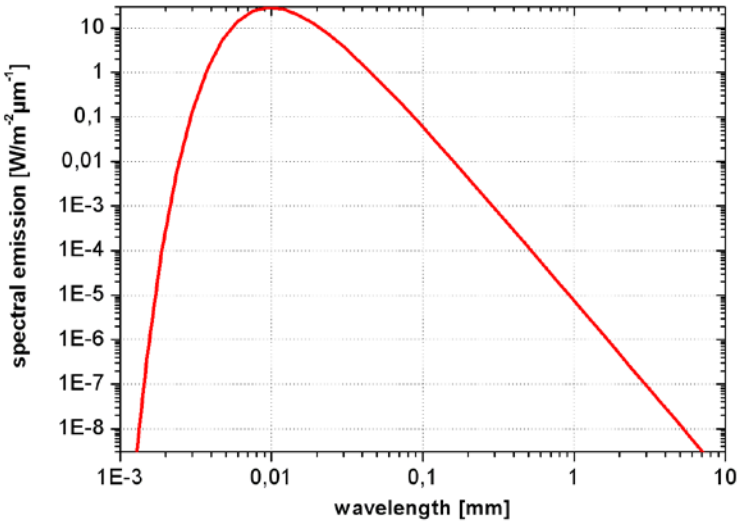
effect of time domain multiplexing (serial readout) on the scanning



Achievable performance

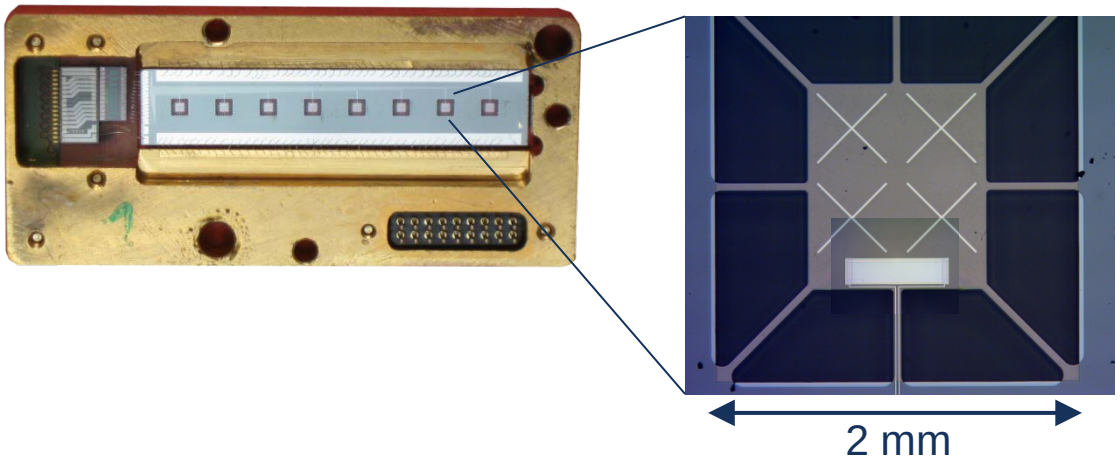


- compromise between spatial resolution and transmission
- horn-coupled detector with bandwidth 0.8 – 0.91 mm
- coupling efficiency including filters about 40%

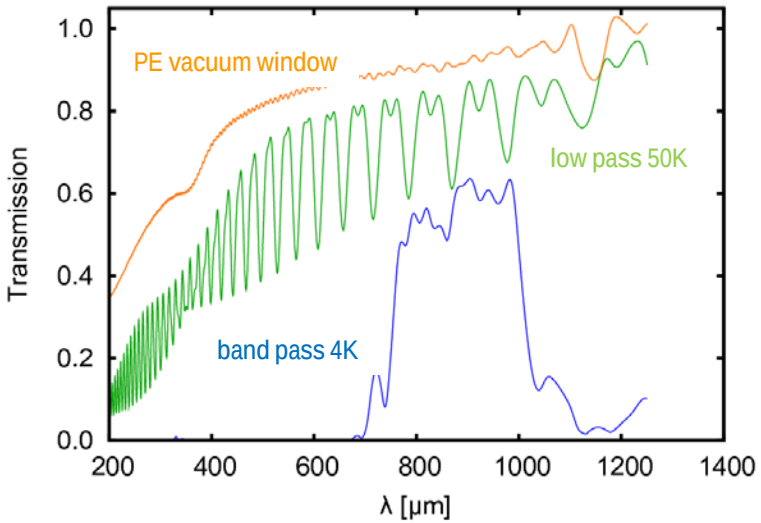


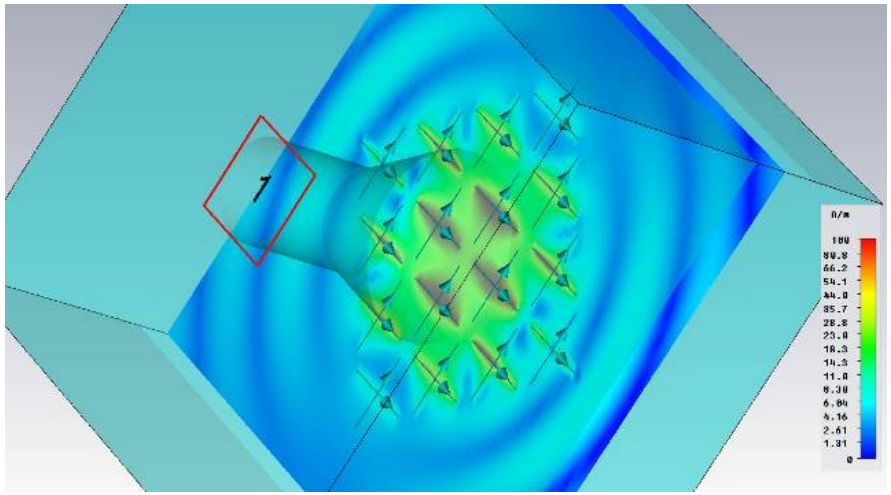
- solving Planck's equation (200 pW @ 295K)
- background-limited NEP $1 \cdot 10^{-15}$ W/√Hz
- human body (310K) stands out with about 18pW (ΔT=15K)
- bandwidth is limited by scanning approach to about 8.5kHz at 25Hz frame rate
- achievable thermal resolution (theoretical) **ΔT=0,16K (≤7bit)**

Detector technology: TES

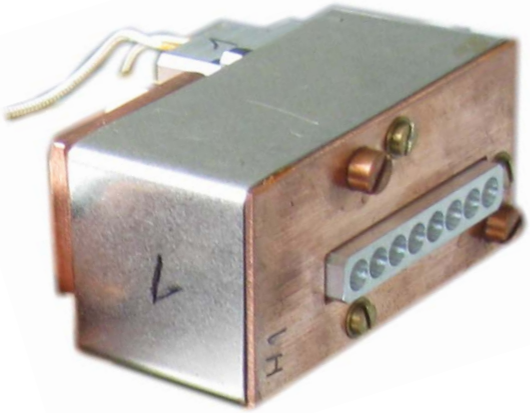


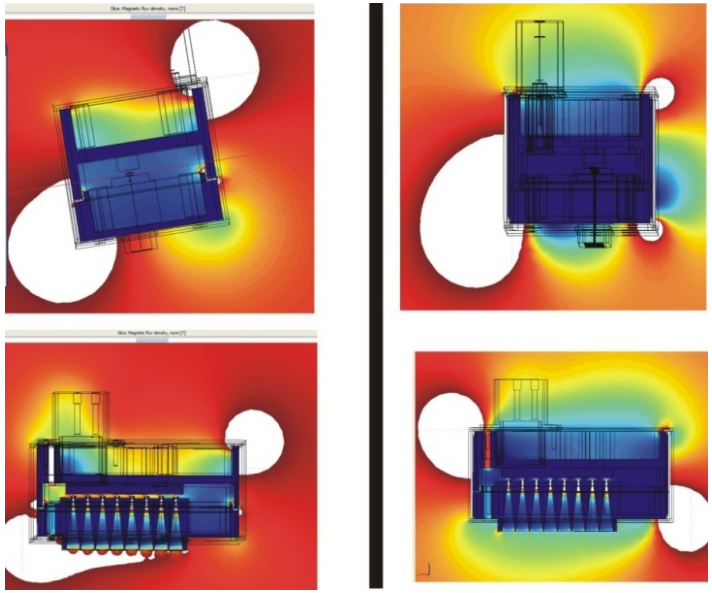
- superconducting bolometer based on 1µm thick siliconnitrid-membrane
- working temperature ~0,5 K
- absorption in impedance matched dipole-antenna array (λ/2)
- bandpass-definition through a set of cryogenic filters

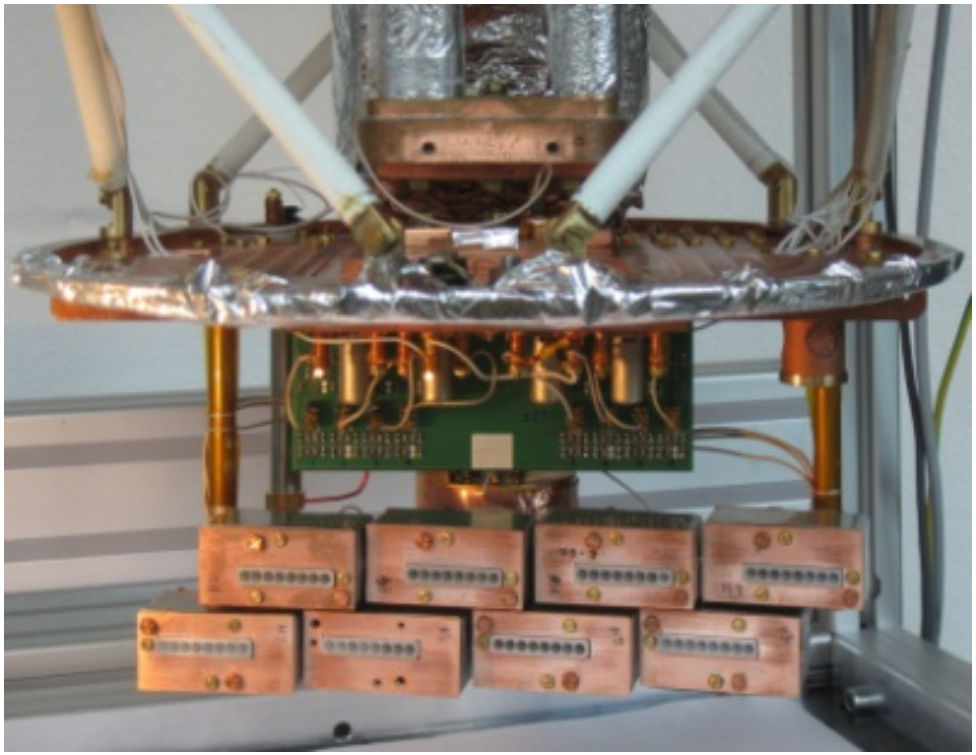




Linear array



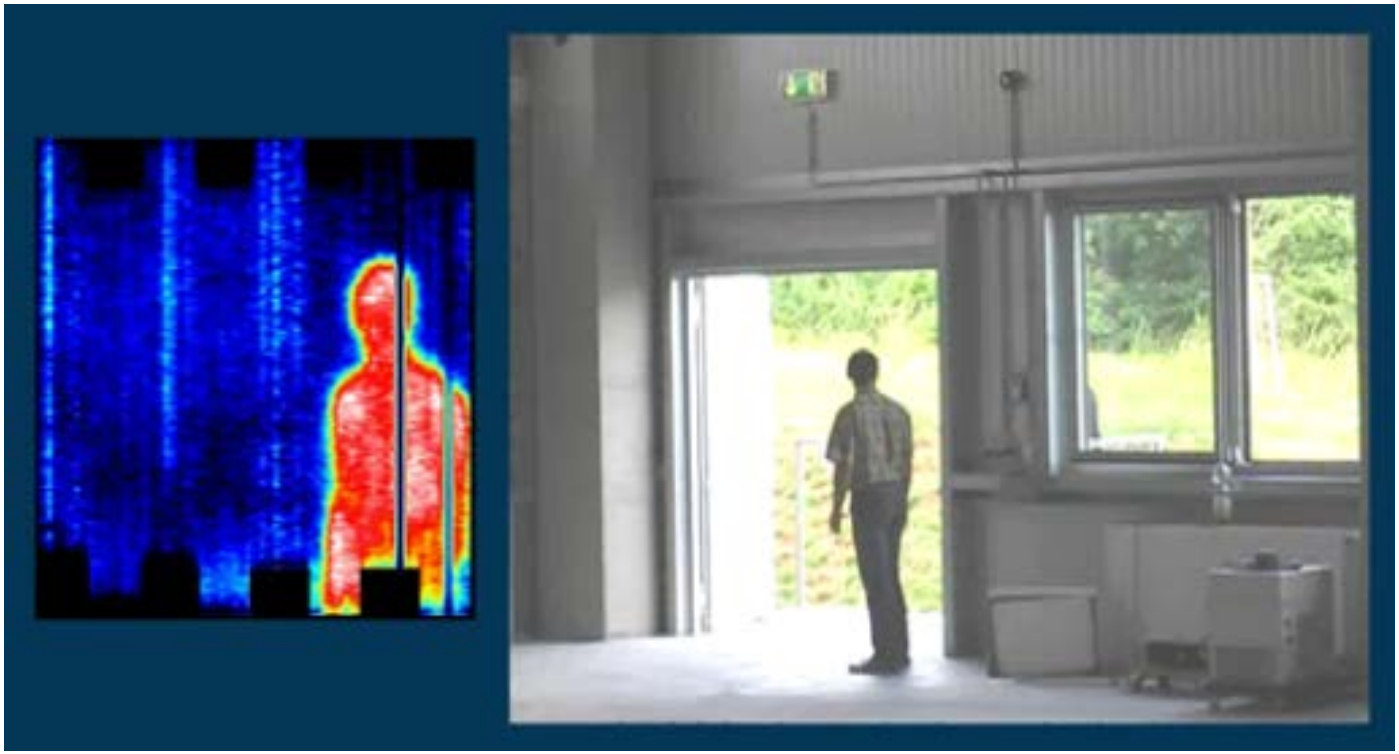




- 8 sensor modules with 8 pixel each
- cryogenic setup with vibration isolation
- optimised magnetic shielding (superconducting + cryoperm)
- first milestone (6/2013): 64 pixel
- final stage of completion: 128 pixel

THz footage

(Click to view video in a separate window, return manually to slide No. 15)



- „*first light*“ 20.6.2013
- 25Hz, object distance 20m
- hidden money bag and plastic bottle (soft drink)

Summary of progress

parameter	**‚THz-Videocam'**	**‚THz-Videocam TWO'**
working frequency (wavelength)	0,34THz (870µm)	
frame rate	10 Hz	25 Hz
spatial resolution (diffraction limit)	1,7cm	1cm
object plane	∅1,2m (1,1m^2)	2m x 1m (2m^2)
distance	(8,5±1,5)m	(4-20) m
field of view (FOV$_{max}$)	0,14 rad	max. 0,58rad x 0,32rad
receiver	20 pixel circular array	64 pixel linear array
scan	spiral (5 traces), effective about 100×100	linear, 256×64
power supply	water-cooled compressor 380V/6kW	air-cooled compressor with 220V, power supply 4kW

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Acknowledgement

- to colleagues from IZEW for accompanying research
- to Federal Ministry of Education and Research for financial support
- to action forces and security officials for instruction and valued advice

and last but not least:

to the audience for listening...