

Homeland Security, Medical,  
Pharmaceutical and Non-destructive  
Testing Applications  
of Terahertz Radiation

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TeraView  
Realising potential

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# Overview

- Introduction to terahertz
- Techniques – imaging and spectroscopy
- Applications of terahertz light

Medical

Non-destructive testing

Pharmaceutical

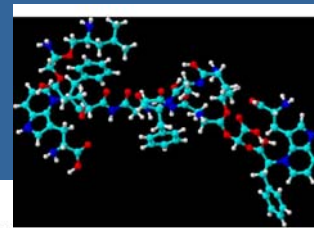
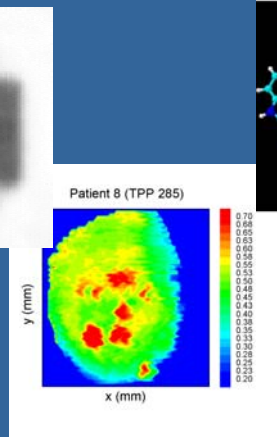
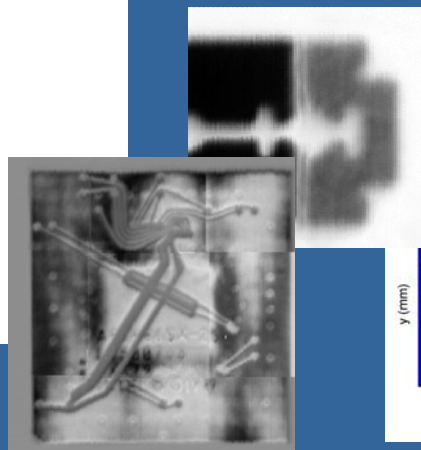
Security

- Conclusions

# TeraView

## The Terahertz Company

- Founded April 2001 Cambridge, England
- Exclusive focus on terahertz technology and applications – 30+ staff
- Close relationship with Cavendish Laboratory, Cambridge University
- Developed world's first portable terahertz imager & spectrometer
- Focus markets medical imaging, pharmaceuticals, security screening, non-destructive testing

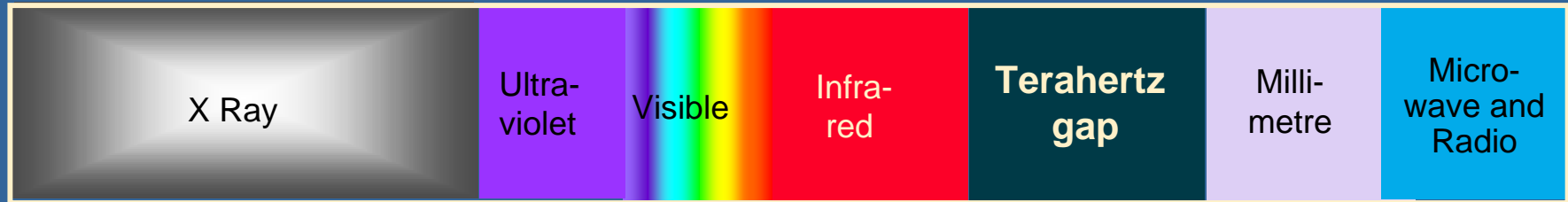


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# TeraView's TPI range



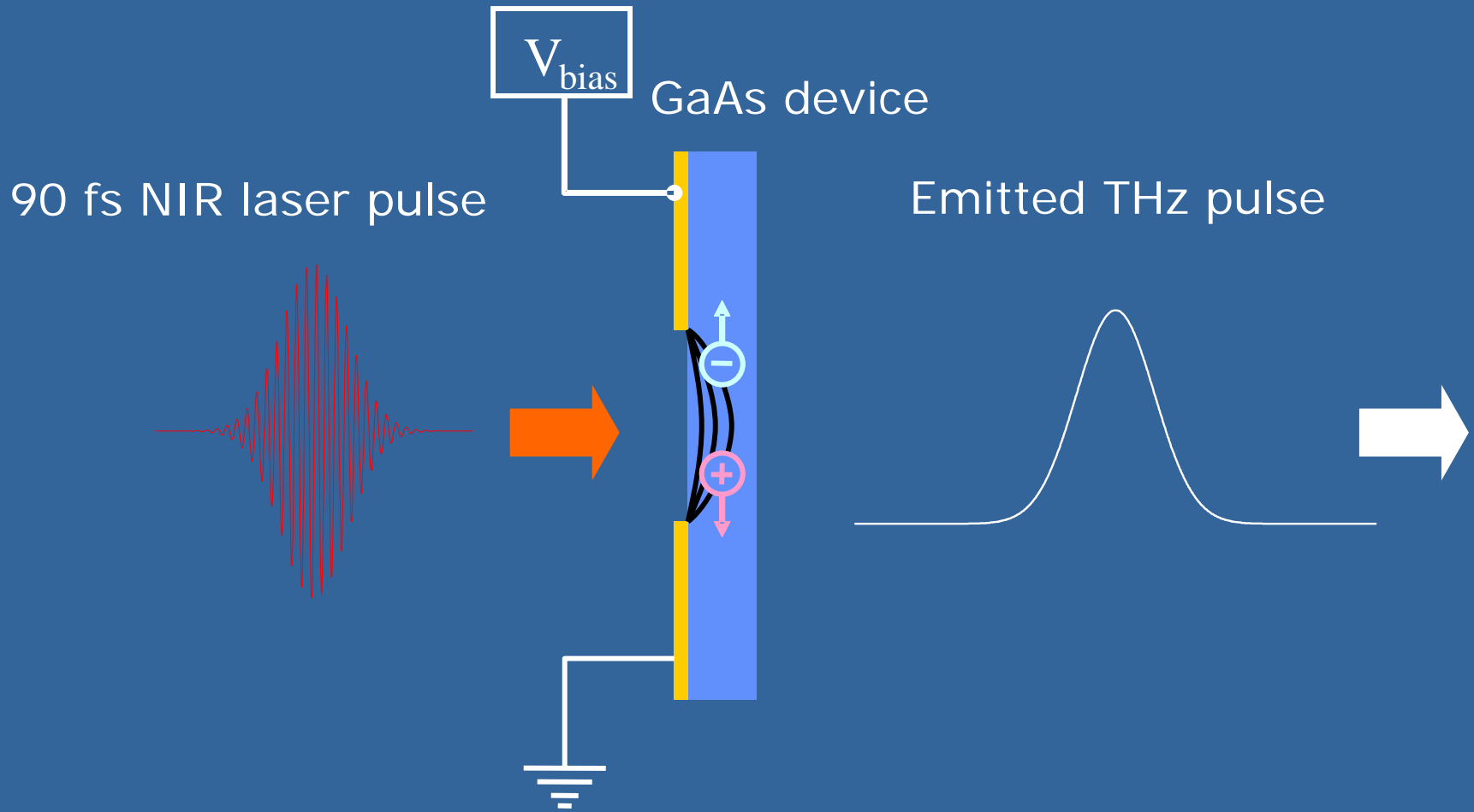
# What is Terahertz?



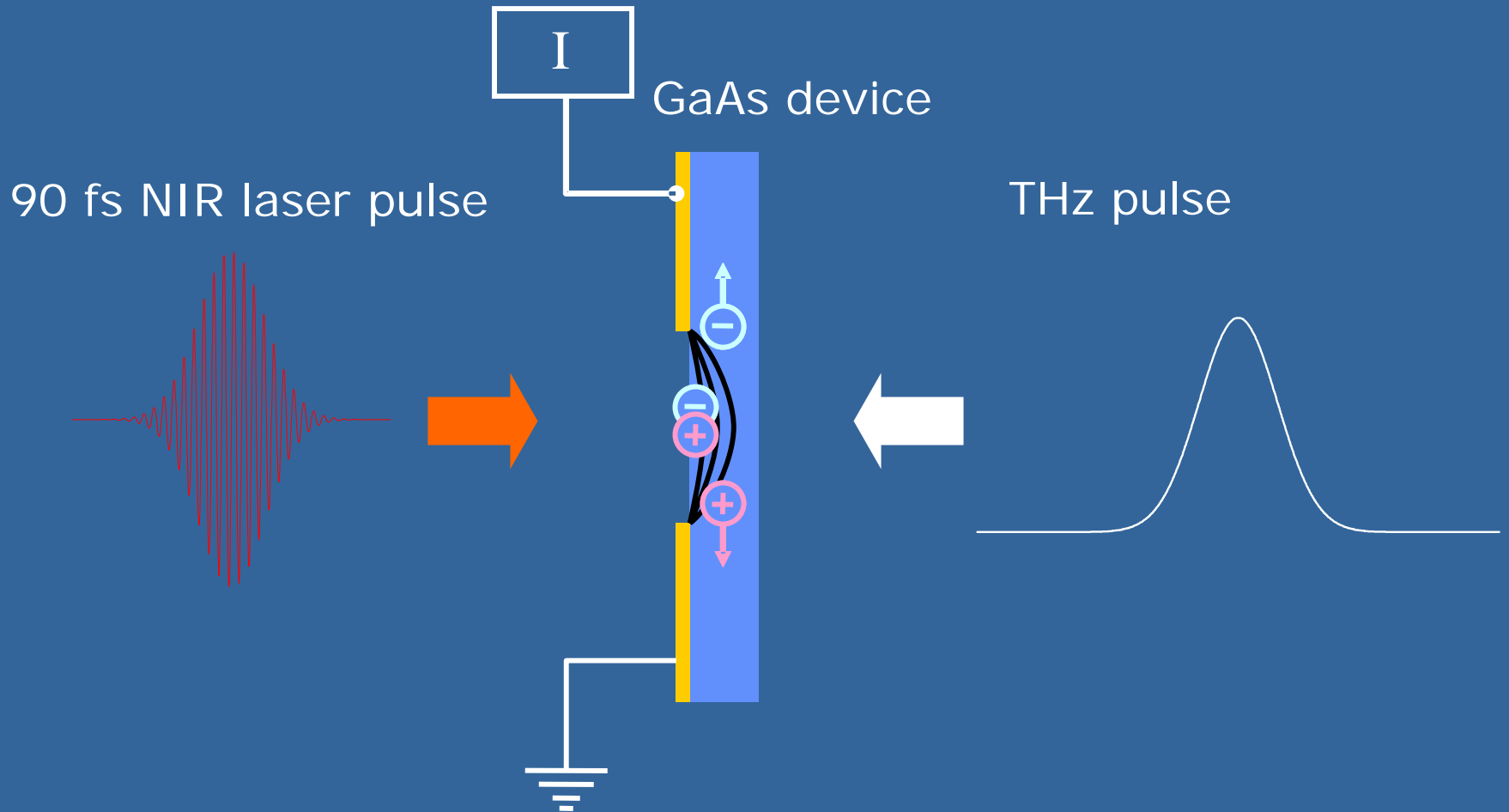
$10^{19}\text{Hz}$   $10^{18}\text{Hz}$   $10^{17}\text{Hz}$   $10^{16}\text{Hz}$   $10^{15}\text{Hz}$   $10^{14}\text{Hz}$   $10^{13}\text{Hz}$   $10^{12}\text{Hz}$   $10^{11}\text{Hz}$   $10^{10}\text{Hz}$

- Terahertz region 300 GHz – 10 THz (1 mm – 30 micron)
- Until recently – inaccessible due to lack of sources and detectors
- Key properties:
  - Penetrates clothing, leather, paper, plastics, packing materials
  - Materials identification using characteristic Terahertz spectra
  - 3-D imaging capability
  - Non-ionizing - no damage to body or cells

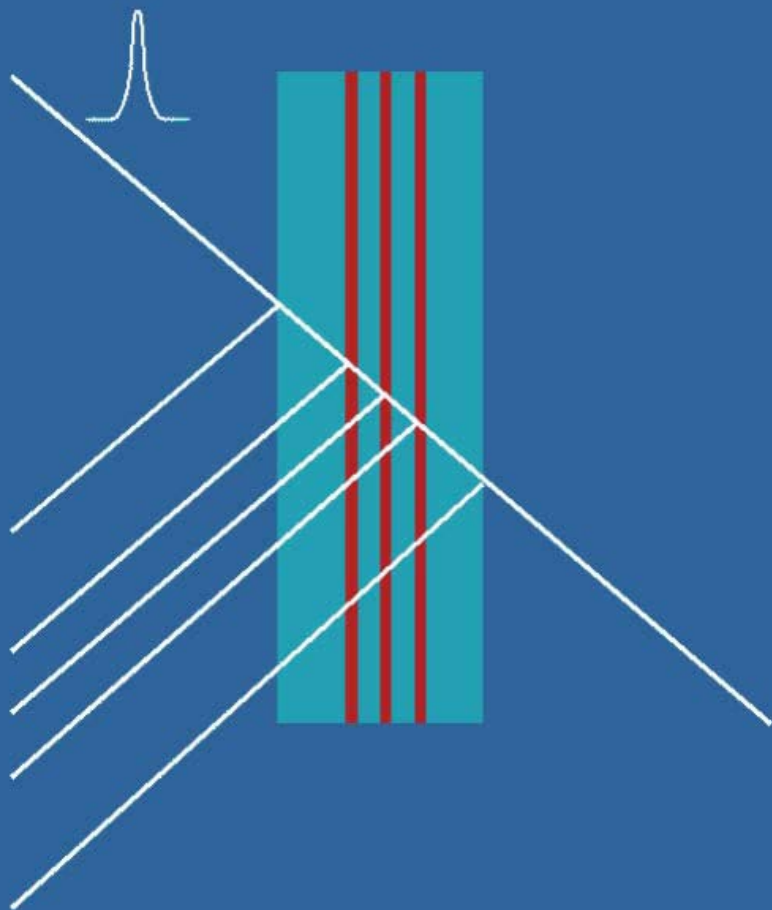
# Photoconductive THz generation



# Photoconductive THz detection



# Basics of THz Pulsed Imaging



- TPI provides for time of flight analysis, as well as producing spectral information.
- A proportion of the incident pulse will be reflected back whenever there is a change in the refractive index.
- Reconstruction of the multiple detected pulses permits depth profiling. X-Y raster scanning builds a 3D image.

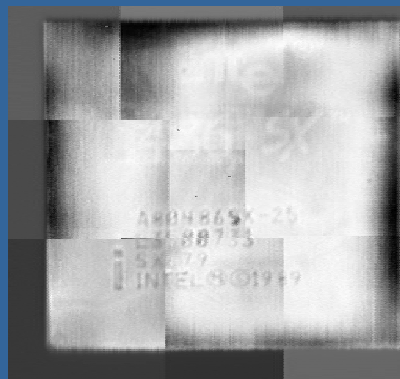


# Non-Destructive Testing – 3-D Terahertz Imaging of integrated circuit package



visible images

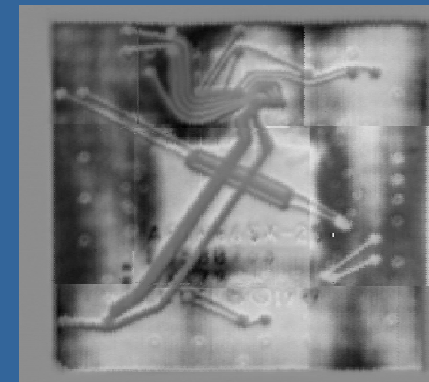
Terahertz images –  
seeing inside the chip



top surface



1mm deep



2 mm deep

# Medical Imaging

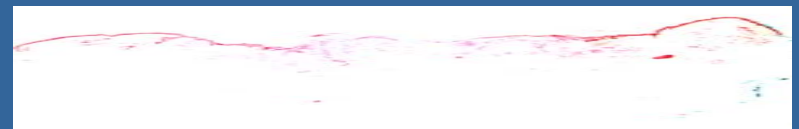
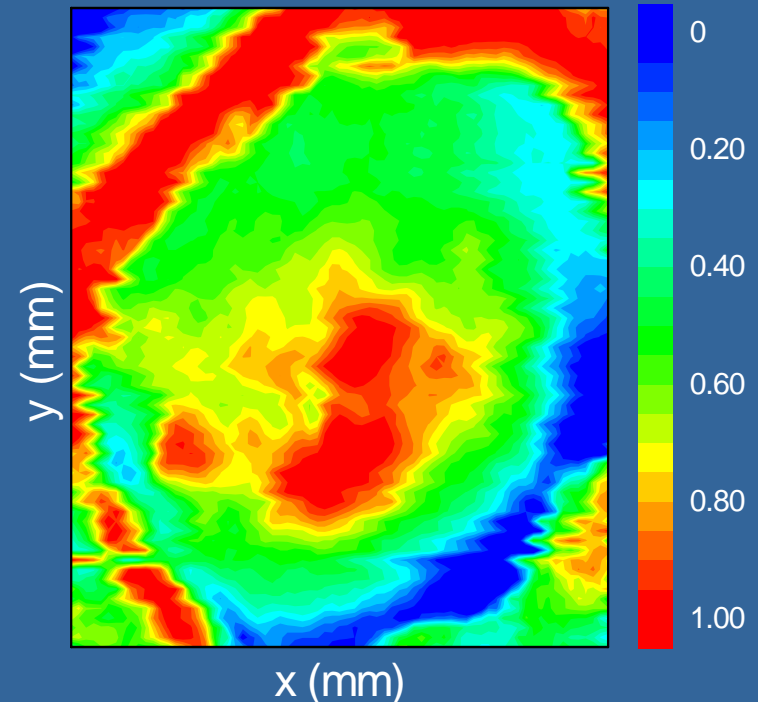
- **Applications**

- Skin cancer imaging – basal cell carcinoma
- Surgeon's aid – tissue typing
- Endoscopy – prostate & other cancers

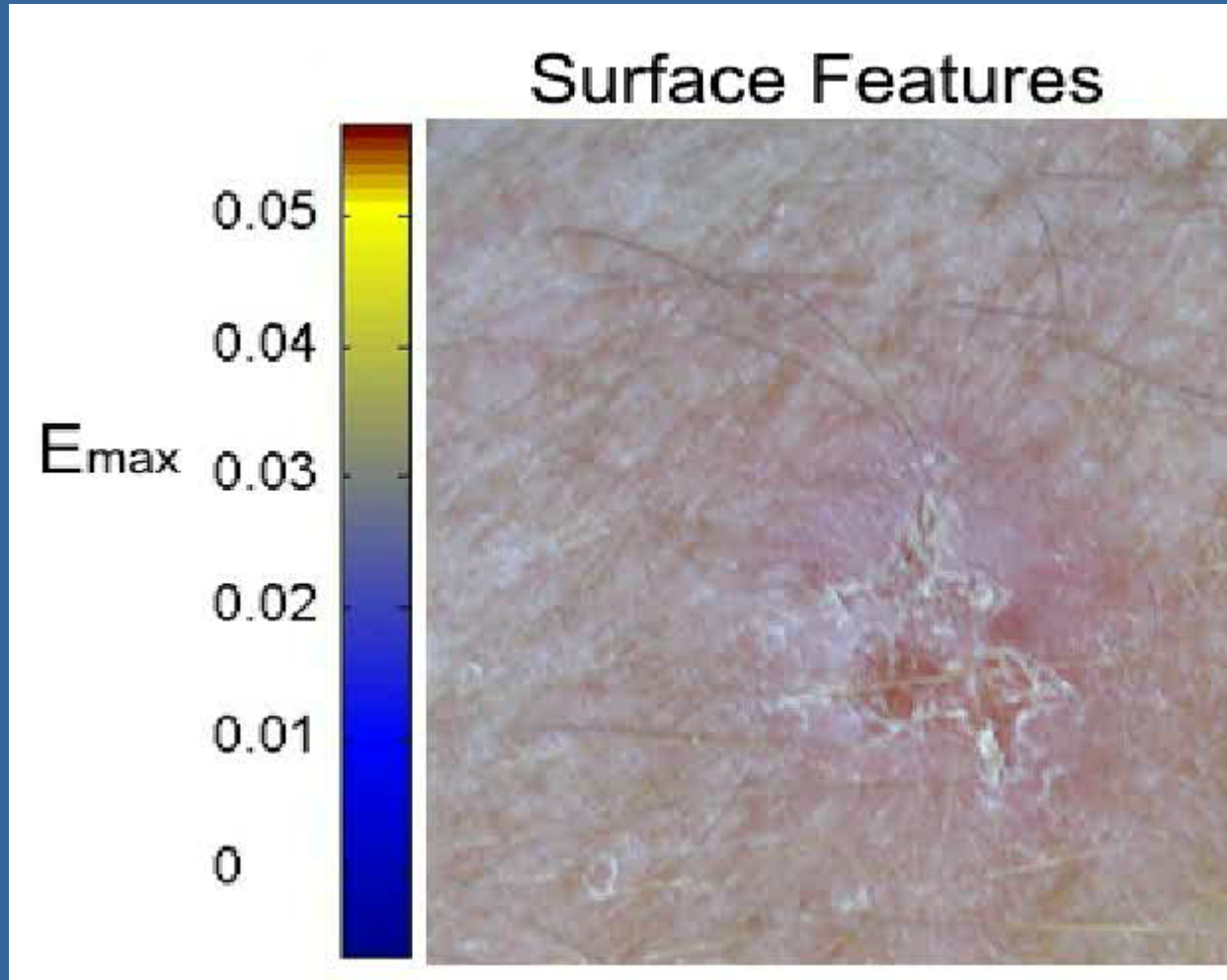
- **Status**

- Results very promising
- TPI Scan imager in use for clinical research
- Probe based systems under development

Patient 9 (TPP 285)

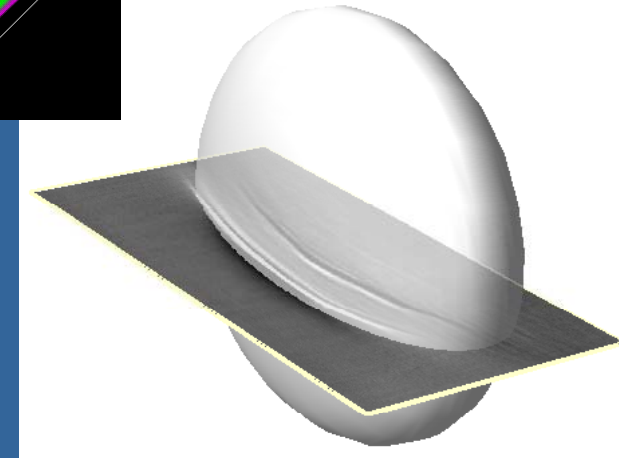
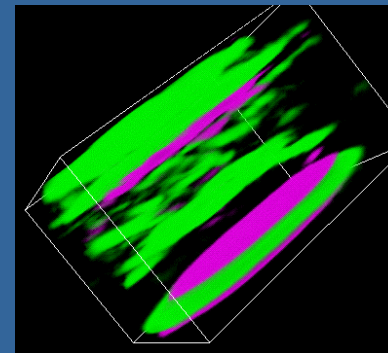
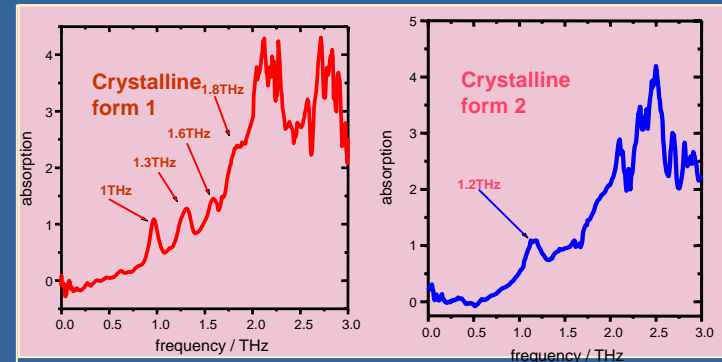


# *In vivo* surface and depth information

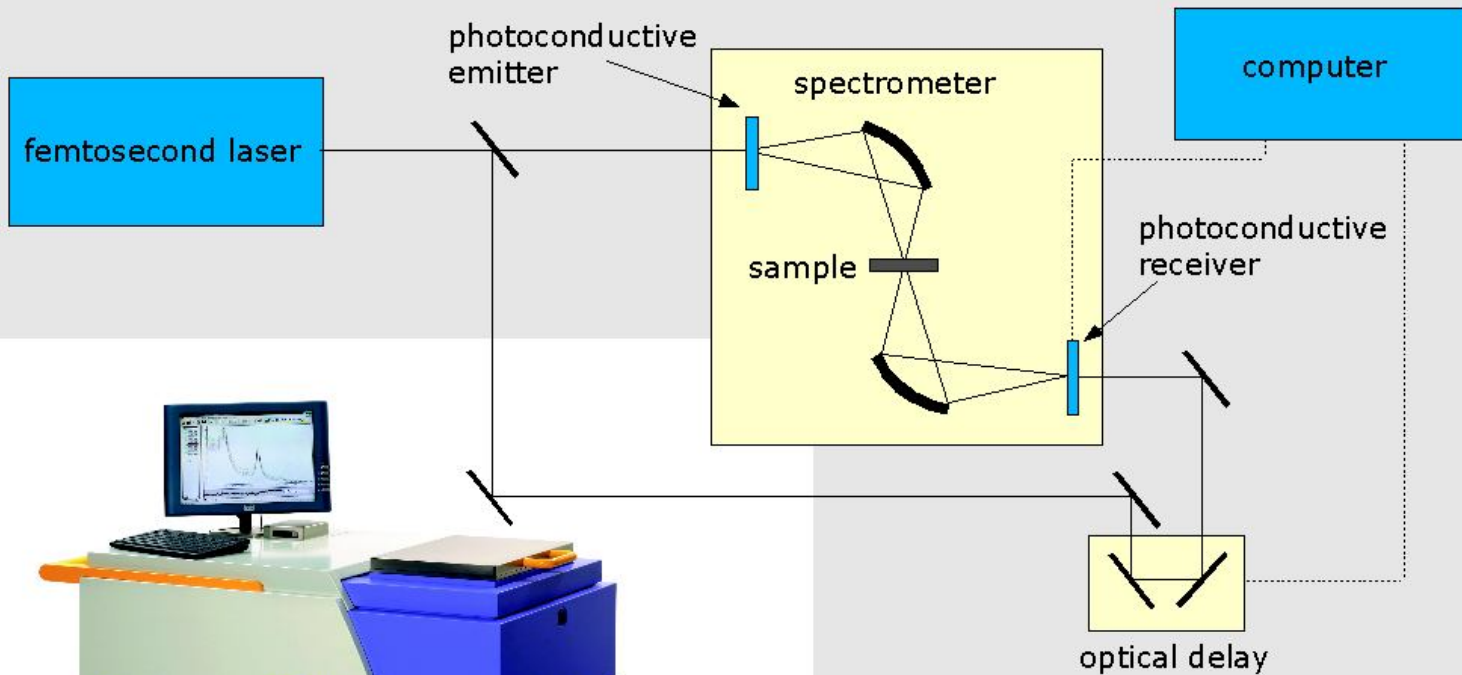


# Pharmaceuticals

- Applications
  - ◆ Process improvement
  - ◆ Polymorph screening
  - ◆ Tablet inspection
- Status
  - ◆ Reflection imaging system
  - ◆ Partnership with Bruker
  - ◆ Range of products available including reflection and transmission spectrometers

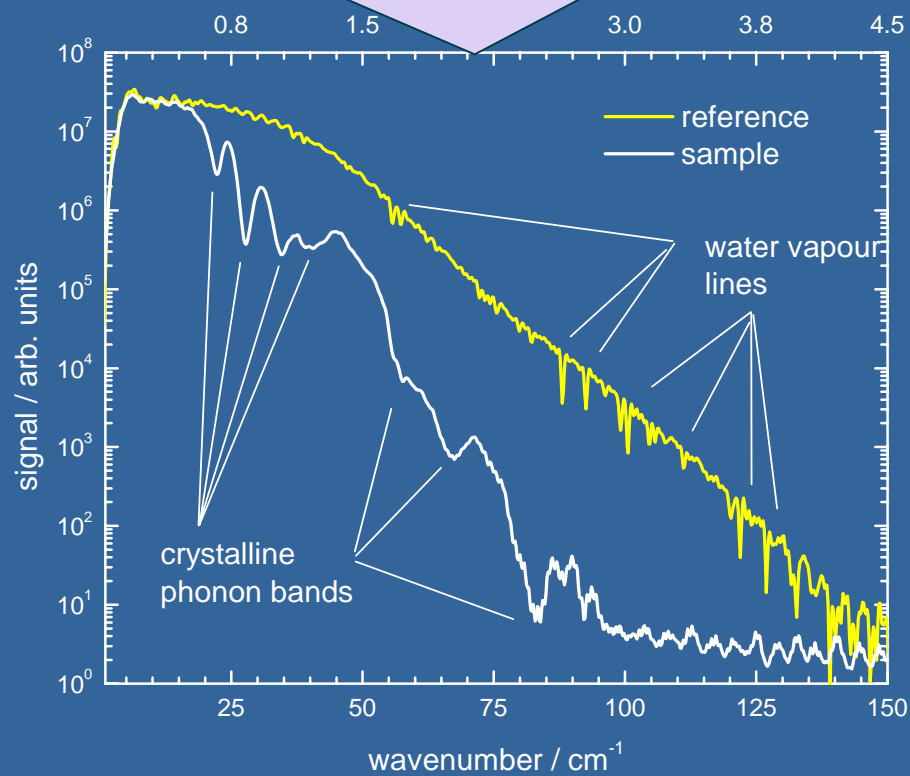
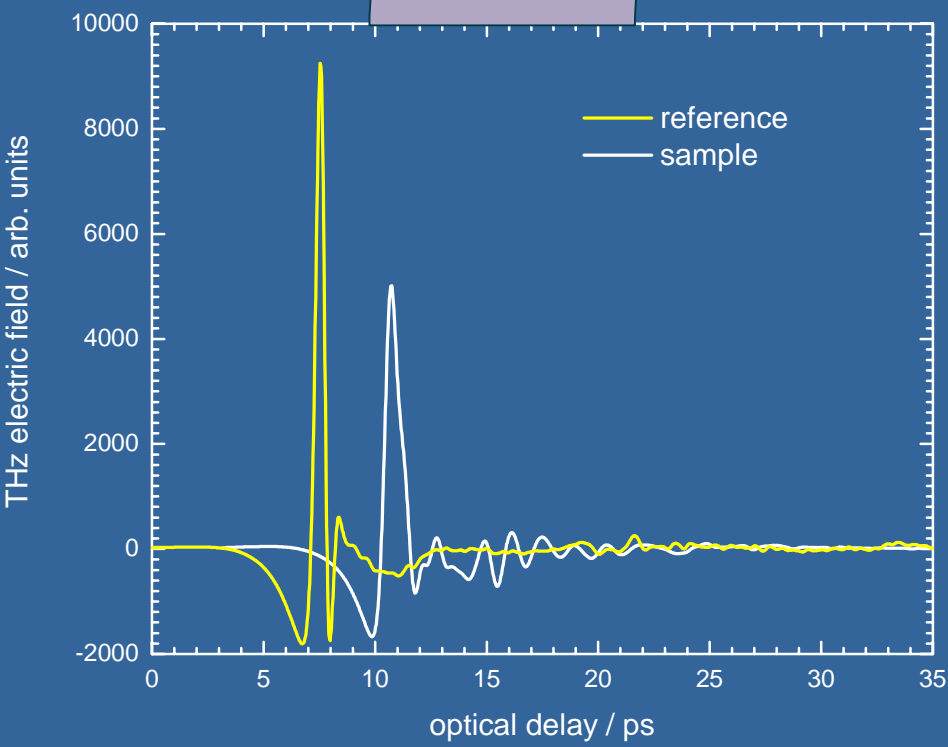
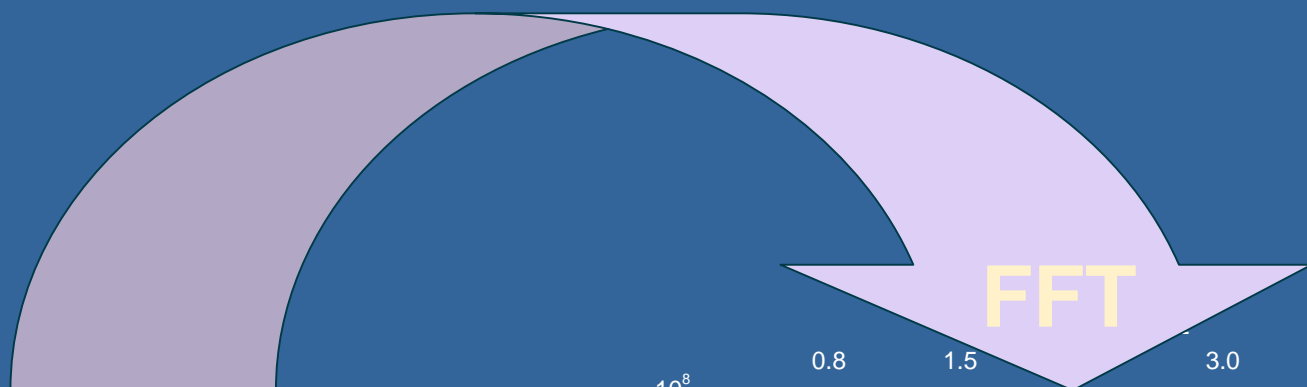


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TPI spectra 1000

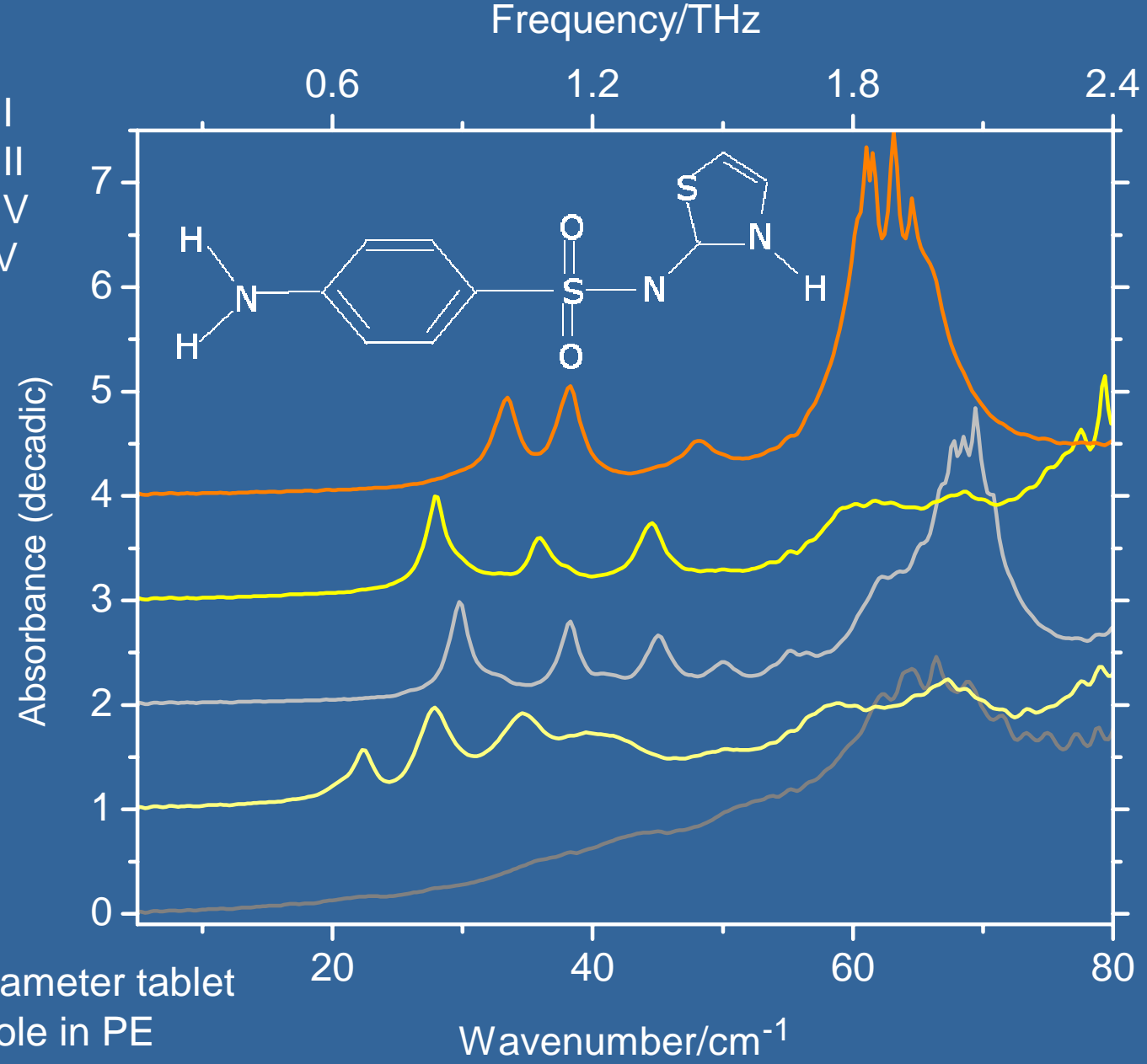




Terahertz Pulse Profile

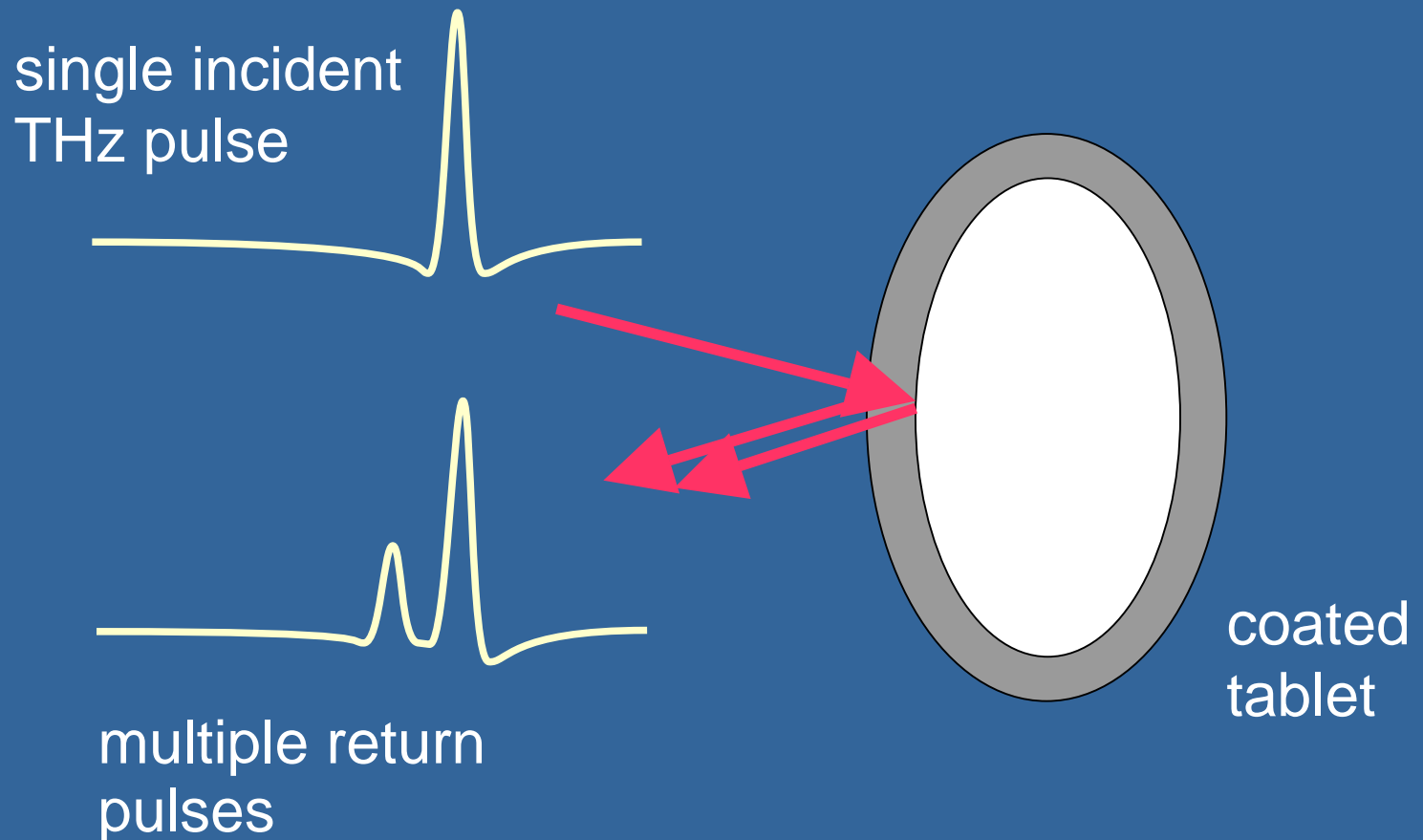
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- Form I
- Form II
- Form III
- Form IV
- Form V



Samples provided by Terry Threlfall, U. of Southampton

# Using terahertz pulsed imaging as a tool to investigate coating integrities

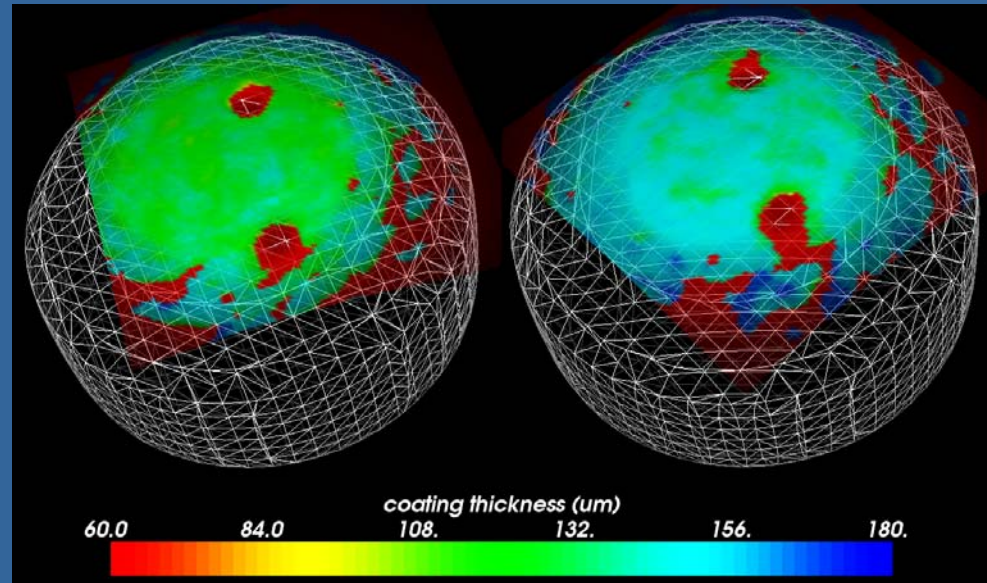
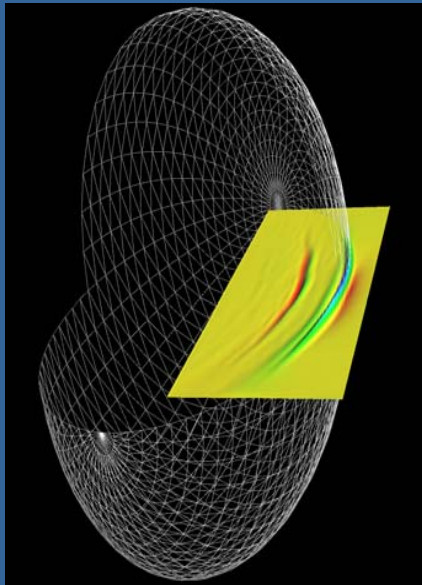


Reflected THz pulses probe coating structure



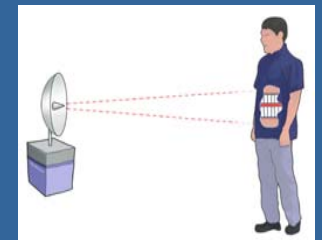
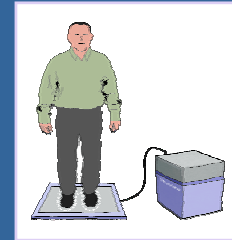
# Non-destructive mapping of coating thickness in pharmaceutical tablets

- Terahertz pulses reflect from each coating layer
- Time of flight and scanning over surface allows mapping of coating layers



# Security

- Checkpoint people screening for hidden weapons & explosives
- Stand-off detection of explosives
- Baggage screening for explosives
- Screening for biological & chemical agents
- 'white powder' detection



# Terahertz & Security: Key Issues

- **Signatures**

- ◊ Do threat materials have characteristic signatures?
- ◊ Are they distinct from confusion materials?

- **Barriers**

- ◊ Will terahertz penetrate clothing and other barriers?

- **Reflection**

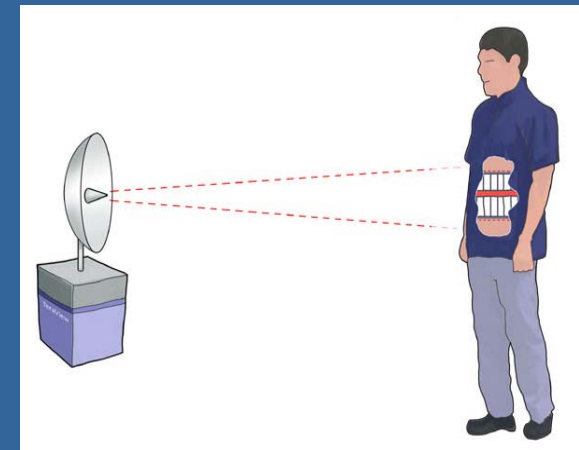
- ◊ Can signatures be detected in reflection?

- **Distance**

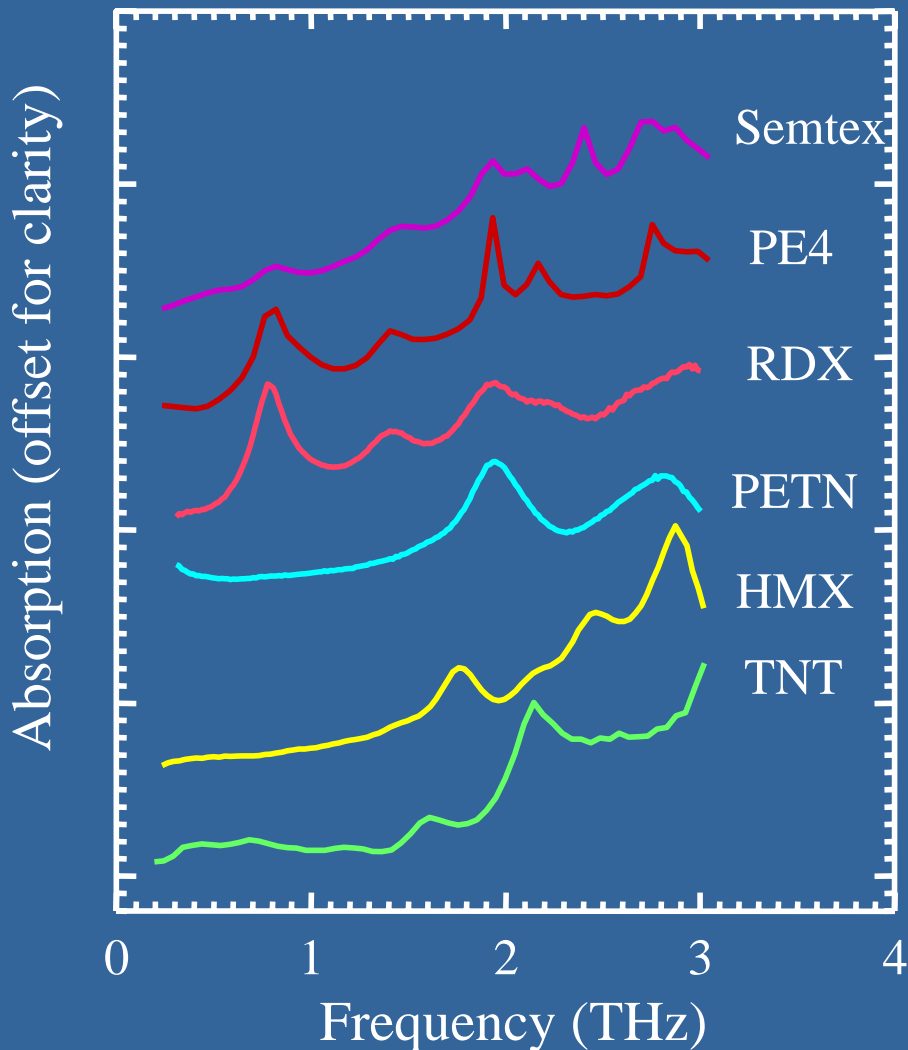
- ◊ Can we see (at least) 10 metres?
- ◊ Source power/ detector sensitivity
- ◊ Atmospheric absorption

- **Systems**

- ◊ Can we design practical systems?
- ◊ What sources and architectures should we use?



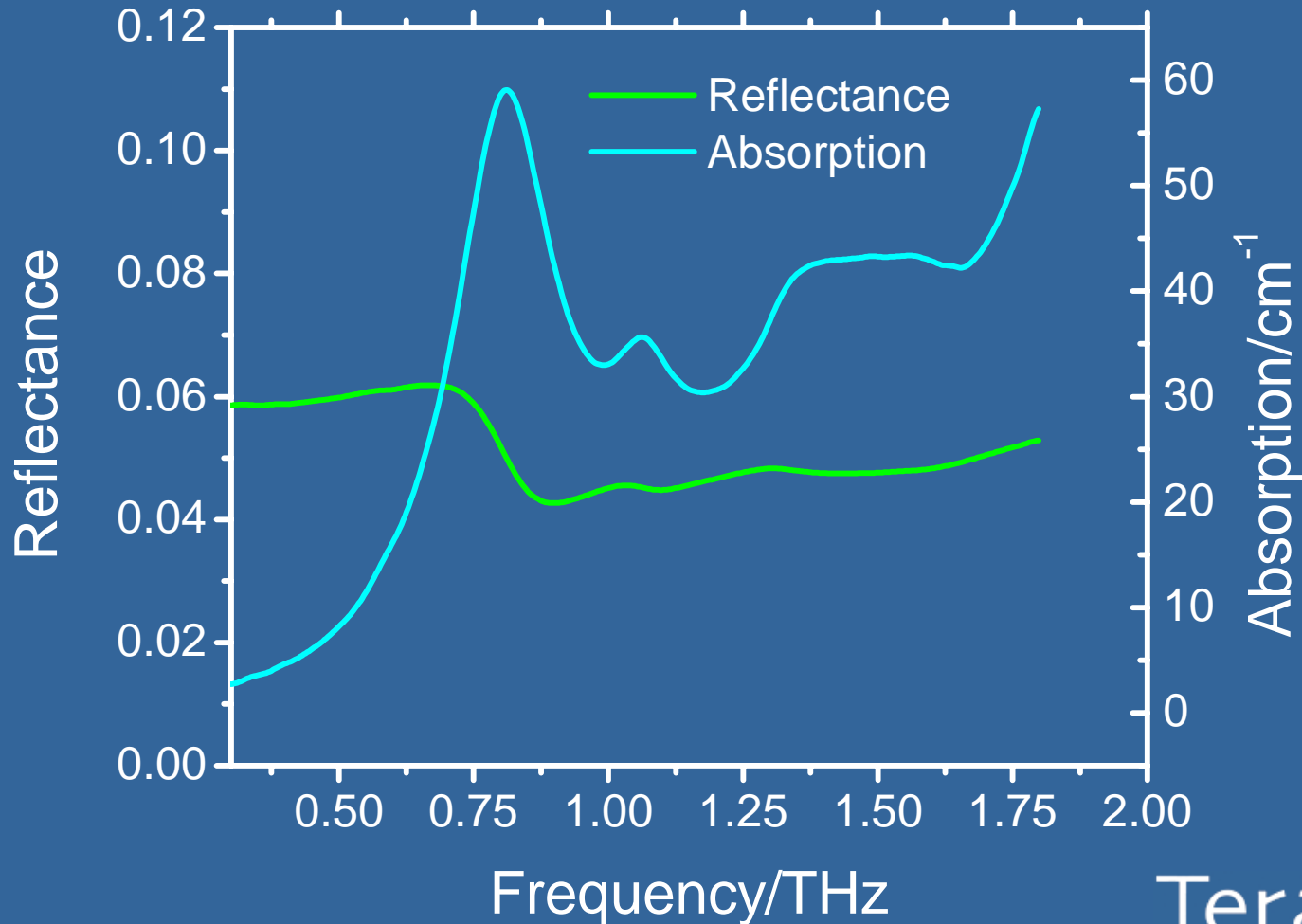
# Terahertz spectra of explosives



- Terahertz transmission spectra
- Energetic compounds and explosives
- All show characteristic features at terahertz frequencies
- Note:
  - Most features above 0.5 THz
  - Barrier material absorption limits practical range to 3THz

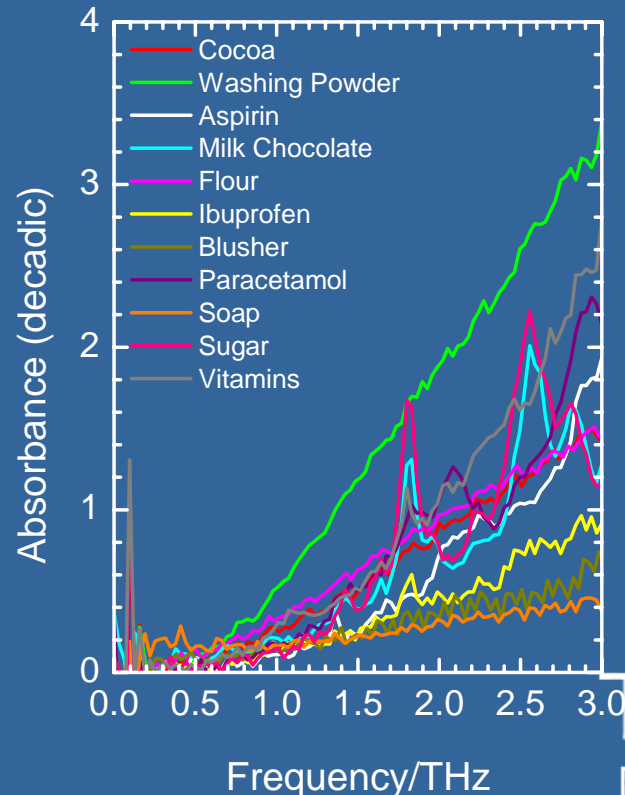
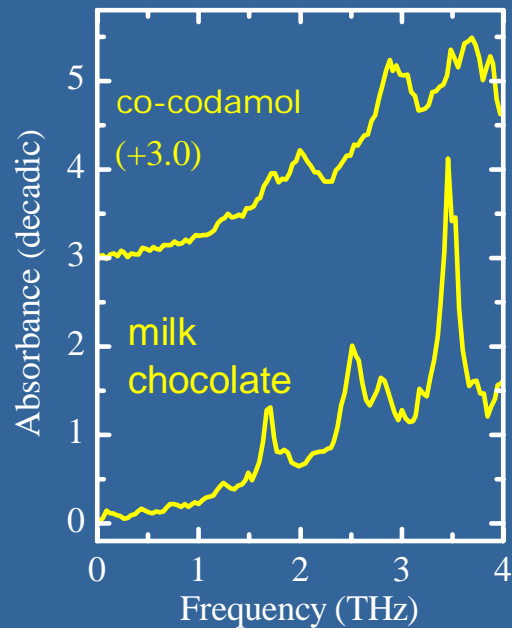
# Semtex-H reference measurements

- Absorption and reflection spectra of Semtex calculated from measurements in transmission spectrometer



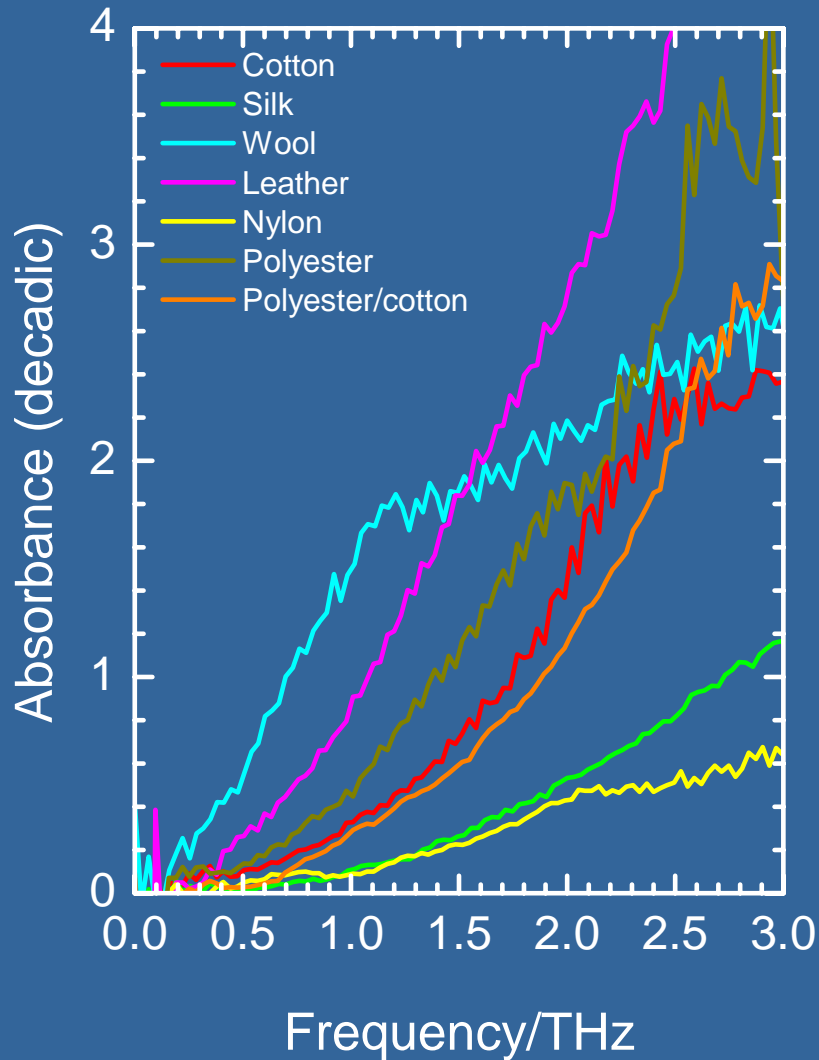
# Measurements of potential confusion materials

- TeraView has measured a library of terahertz spectra of common materials - developed with support of UK Department of Trade & Industry
- Also includes many pharmaceutical compounds
- No significant confusion found between explosives and harmless materials



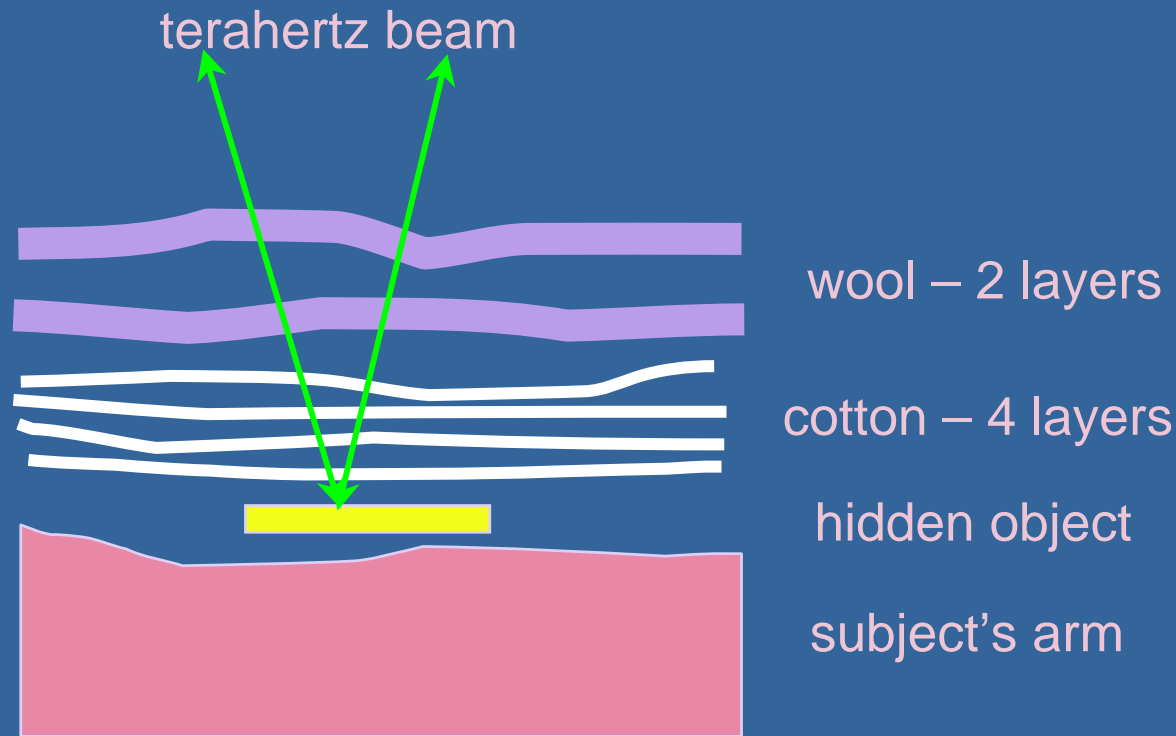
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# Clothing & Barrier Materials



- All clothing materials are partially transparent
- Absorption increases with frequency
- Limits useful frequency range to 2-3 THz

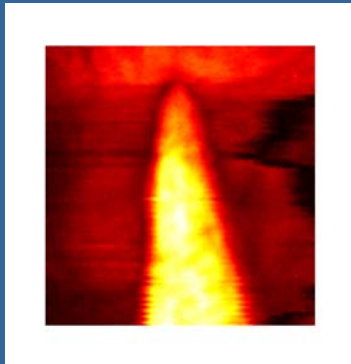
# Detecting metals, non-metals and explosives hidden in clothing



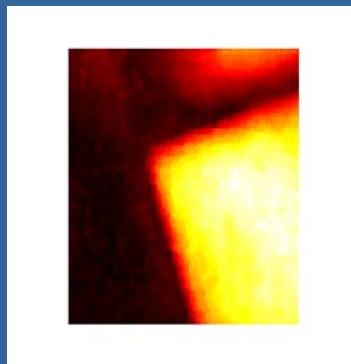


# Detecting metals, non-metals and explosives hidden in clothing

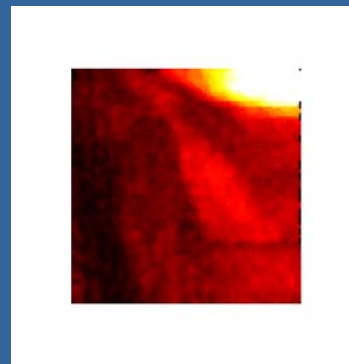
image



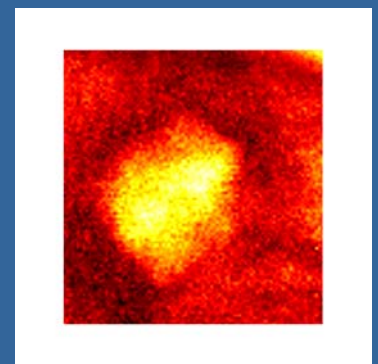
metal  
scalpel blade



ceramic

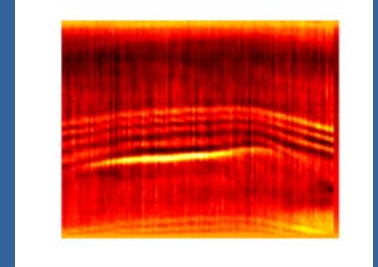
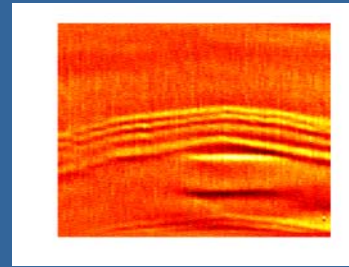
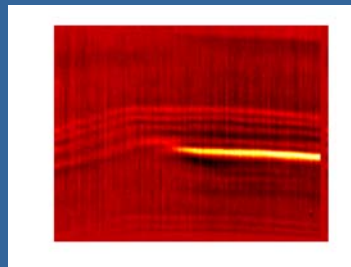
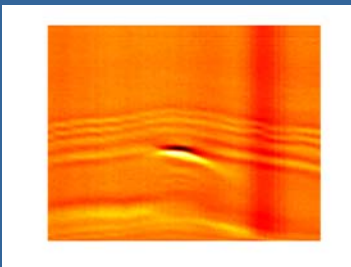


plastic



sheet explosive

depth  
profile



Terahertz images of objects (approx 1cm across) hidden under 2 layers of wool and 4 layers of shirt material

# Terahertz detection of sheet explosive underneath clothing

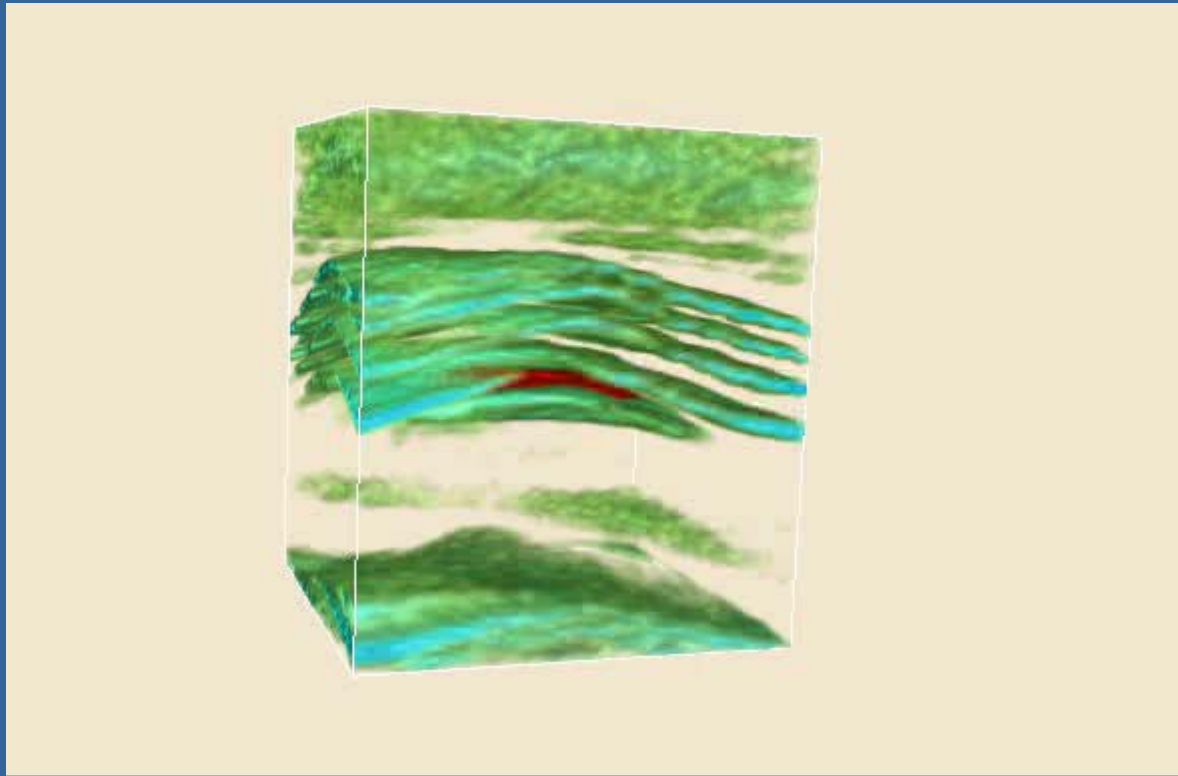
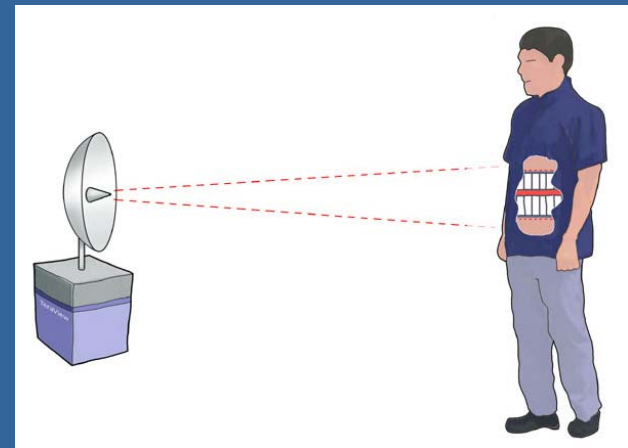


Image of 1cm square piece of SX2 sheet explosive against skin, hidden under two layers of woollen jumper and four layers of cotton shirt material –

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# Ongoing development programmes

- Objective: move from proof-of-principle to prototype ...
- ... and then to fieldable system
- Two projects:
  - ◆ People Screening Hand Wand
  - ◆ Stand-off Explosives Detection



# People Screening Wand

- Terahertz wand to detect metal & non-metallic weapons and explosives
- Marketing partnership with Smiths Detection
- Initial prototype under construction
- Detection techniques and algorithms being developed

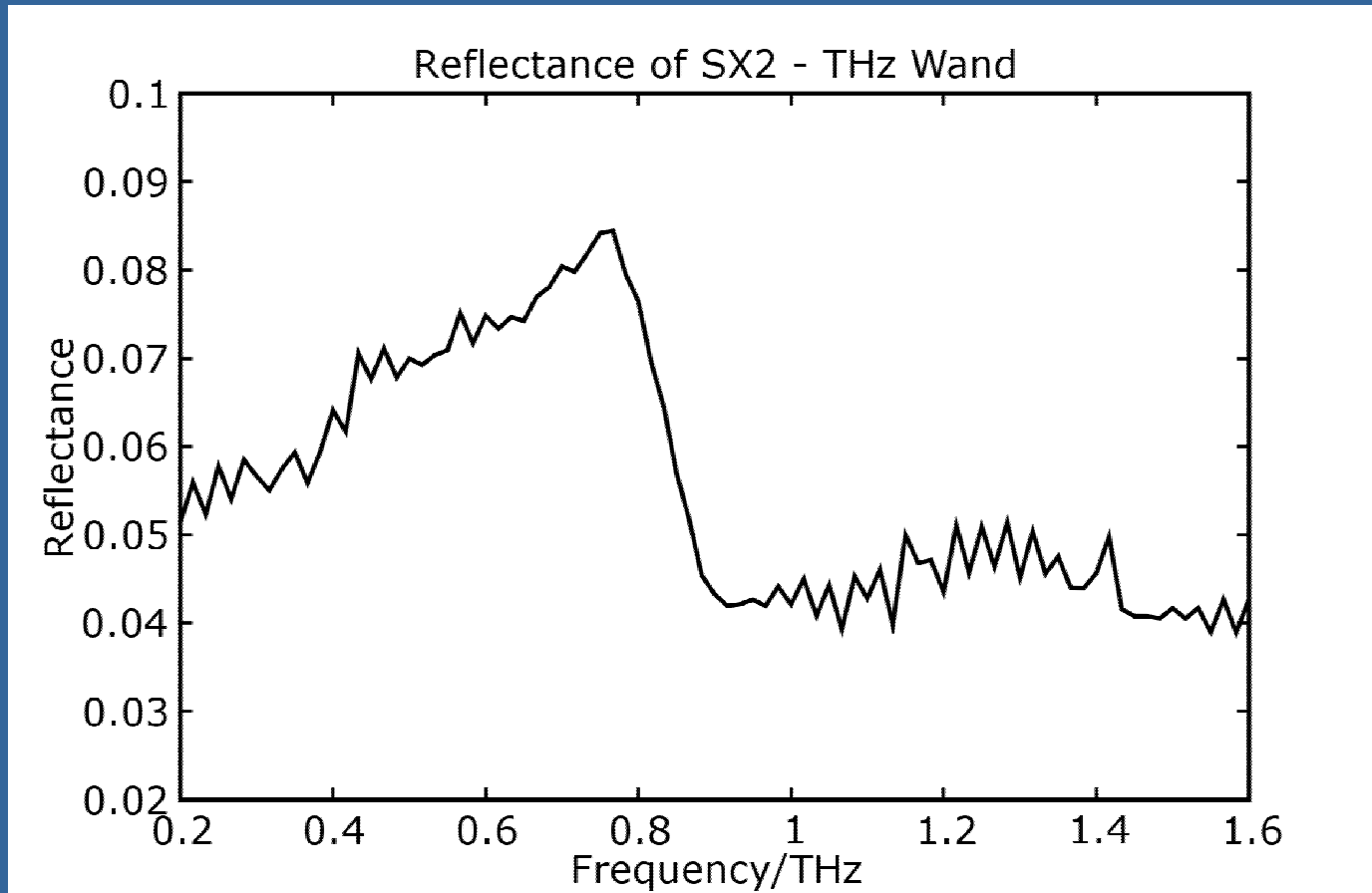


smiths

Smiths Detection

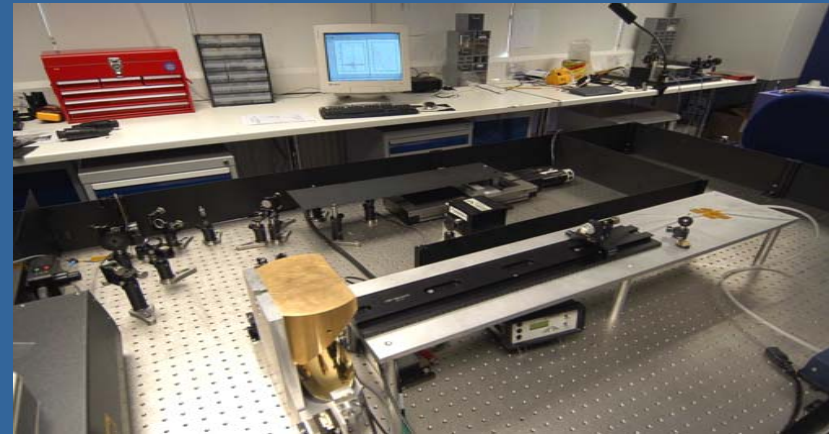
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# Terahertz reflection spectrum from Hand Wand – raw data

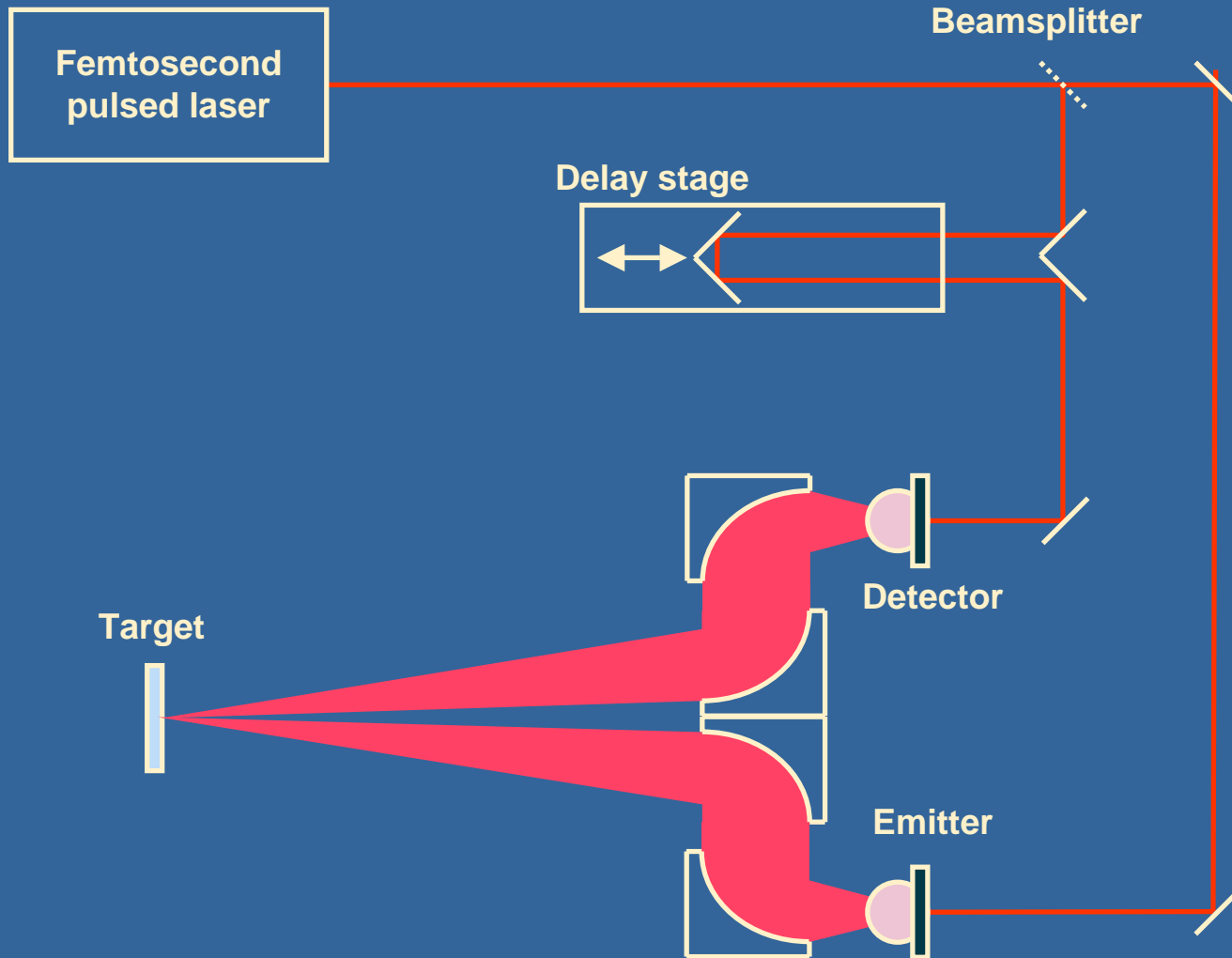


# Stand-off Explosives Detection

- Stand-off Explosives Detection
  - ◆ Programme funded by UK Home Office PSDB, with US participation
  - ◆ Laboratory prototypes under construction
  - ◆ Initial target 1m
  - ◆ Source & detector development to achieve larger stand-off distances
  - ◆ Development of detection techniques and algorithms

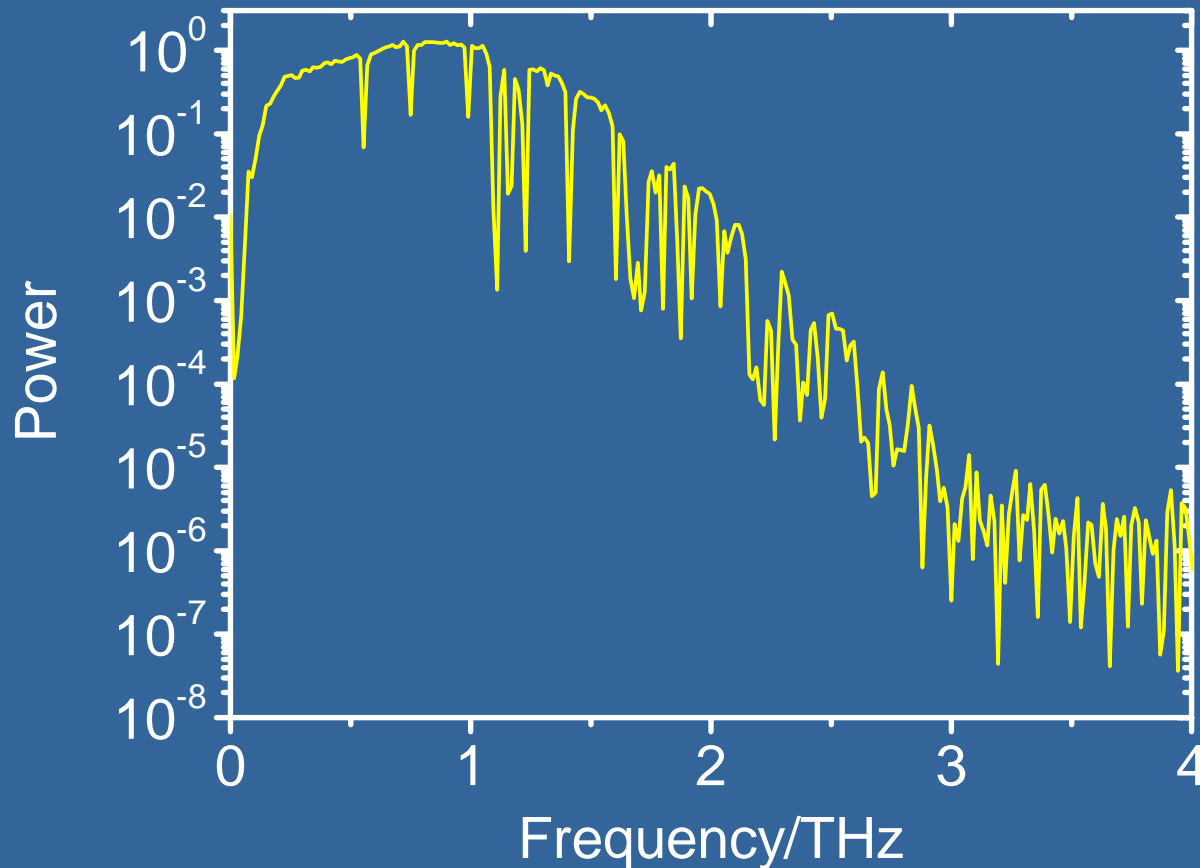


# Experimental system



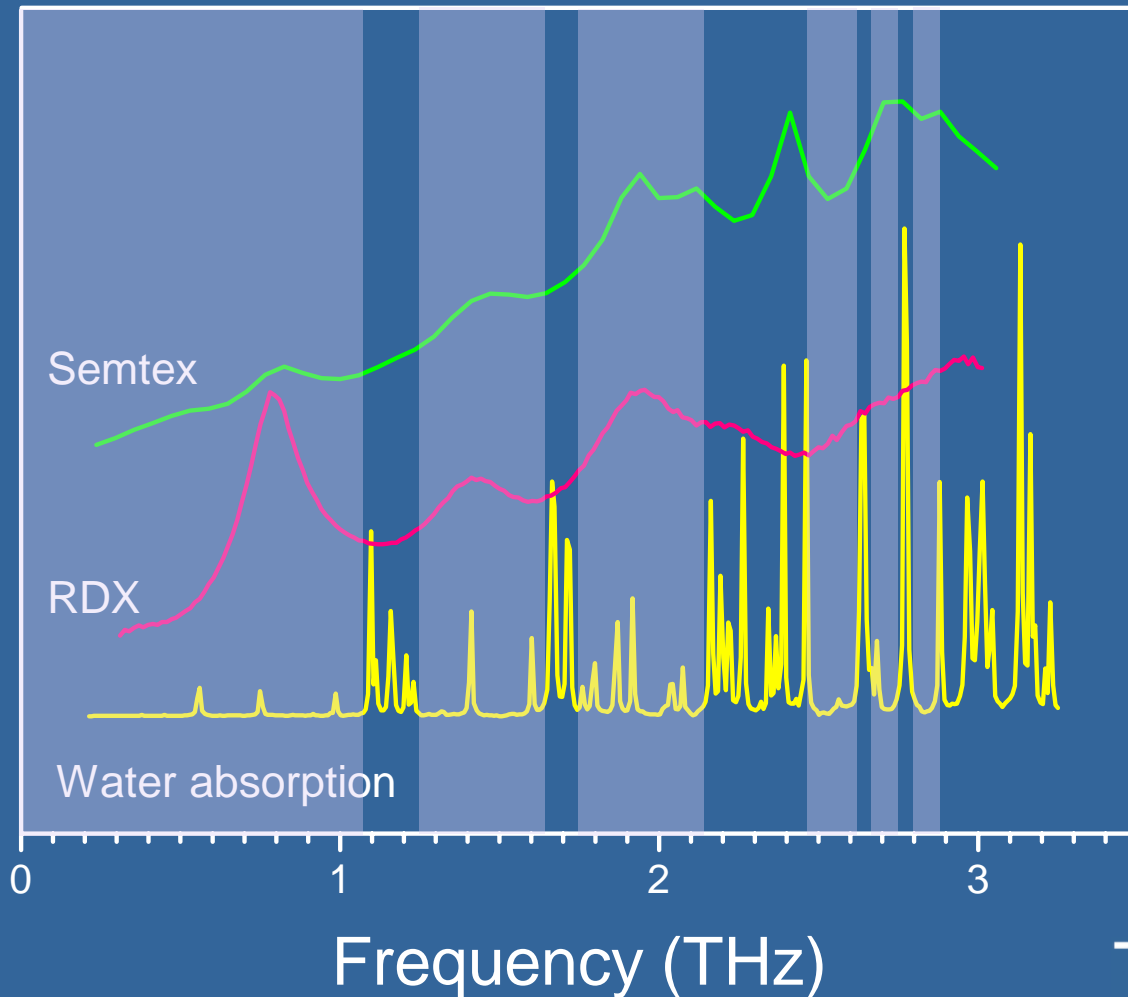
# Experimental System in Operation

- Response of stand-off THz system
- Target 1m
- Path Length over 2m



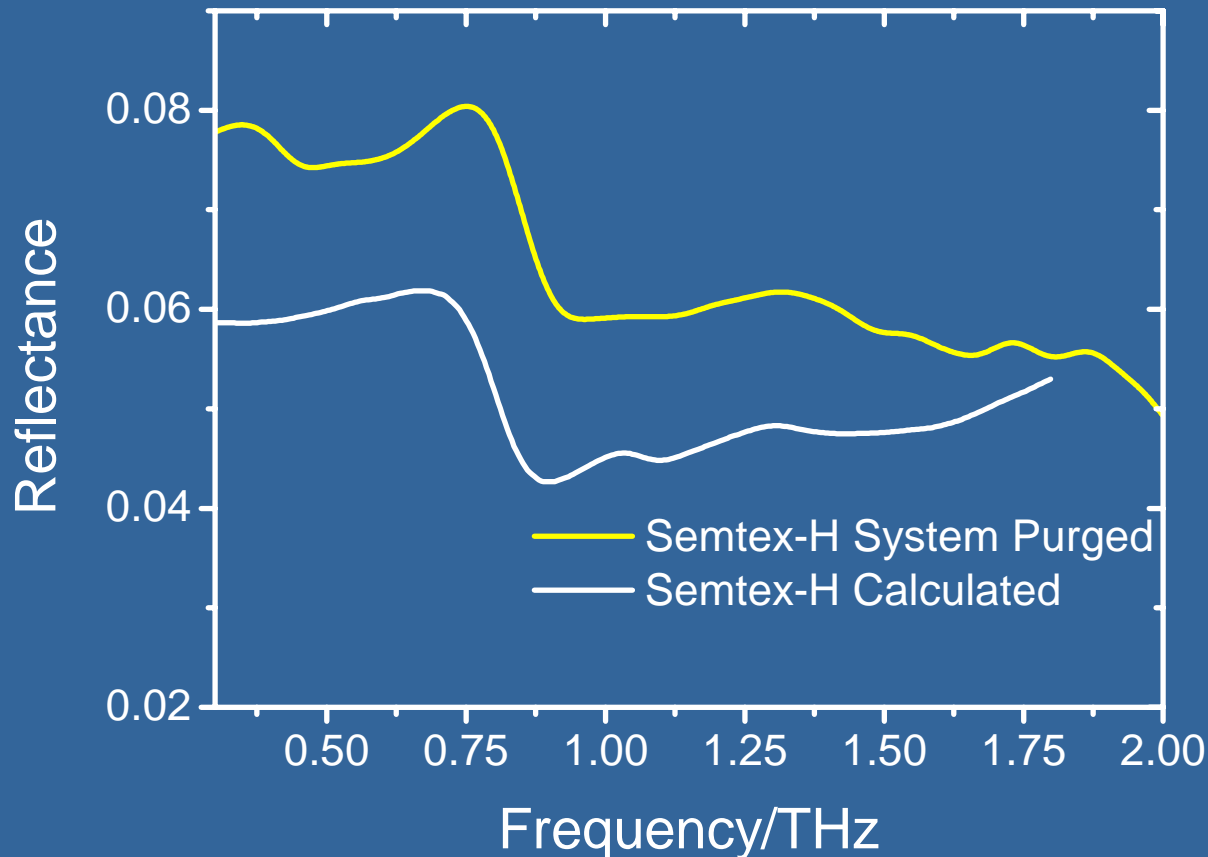


# Water windows correspond to spectral features of explosives



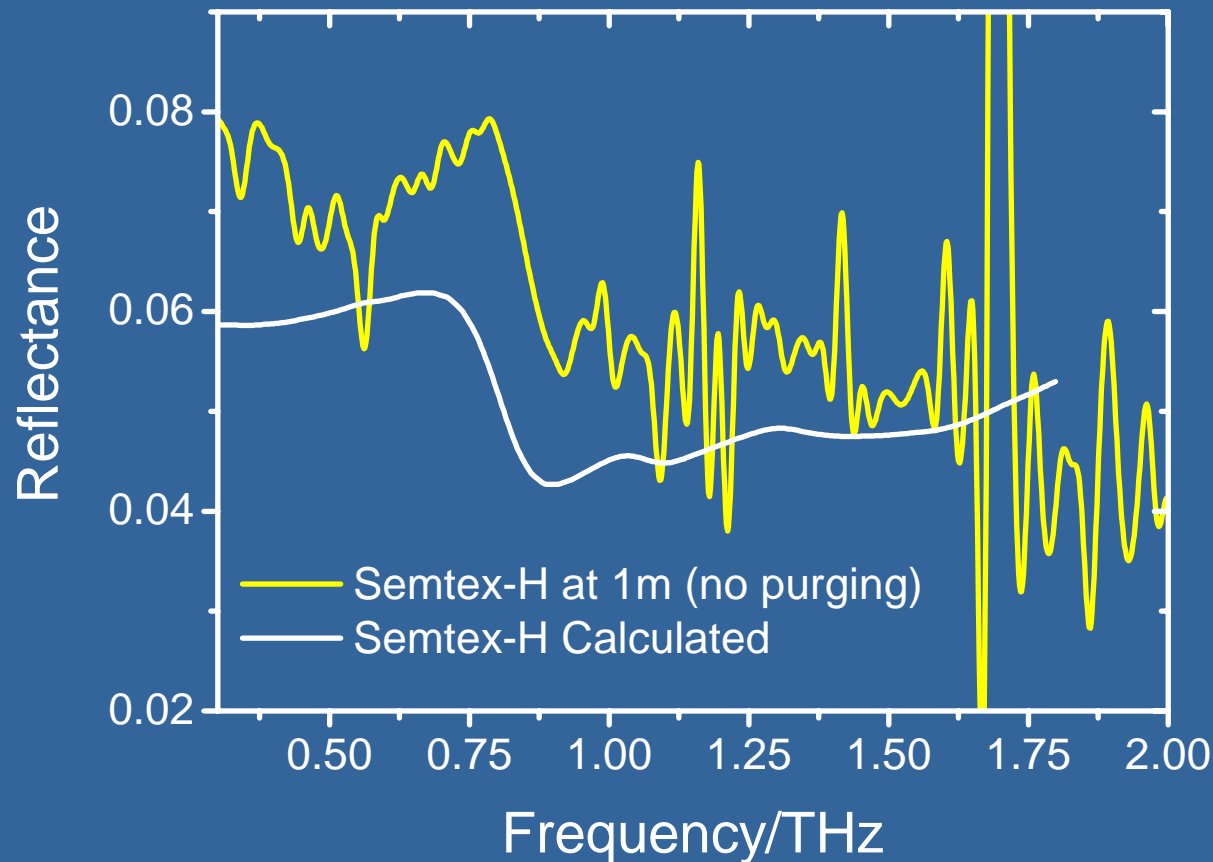
# Semtex-H Stand-off spectrum at 1 metre

- THz spectrum of Semtex-H (composed of RDX and PETN) measured data at stand off distance of 1 m
- System purged with nitrogen gas to remove water vapour.
- Data collected in 70 ms, with a spectral range of 0.3 – 2 THz



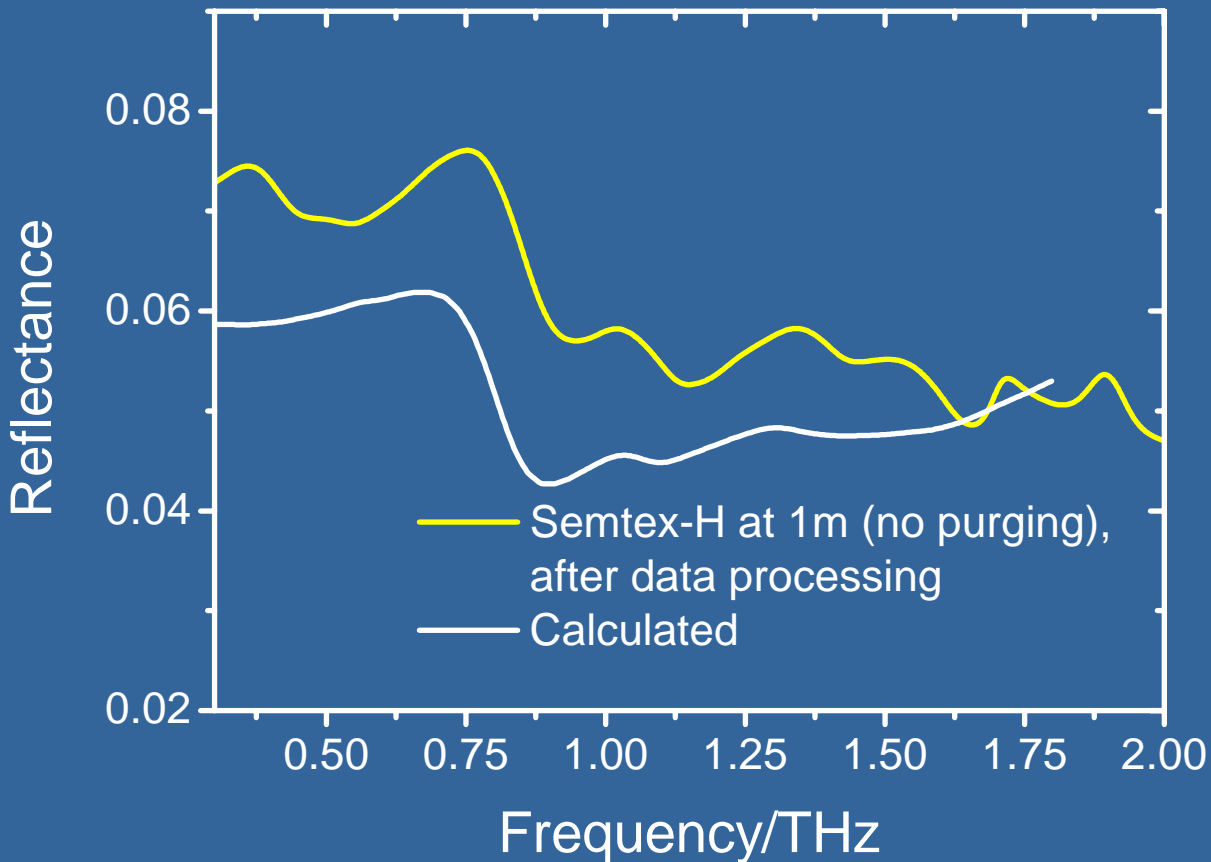
# Semtex-H spectrum with water vapour

- THz spectrum of Semtex-H measured data at stand off distance of 1m in atmospheric air
- Note effect of water vapour absorption lines



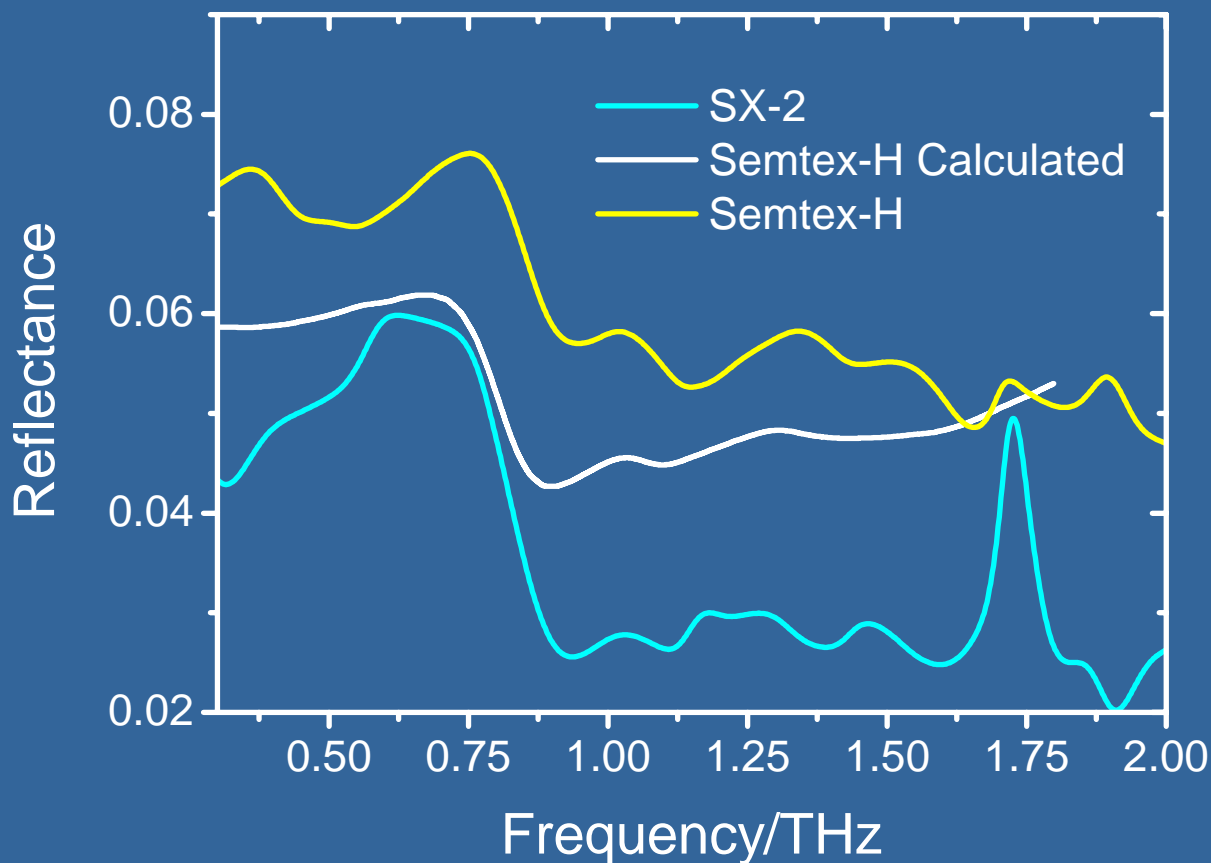
# Semtex-H spectrum corrected for water vapour effects

- Reflection spectrum at stand off distance of 1m, data collected in 70ms
- Water vapour absorption lines removed by data processing algorithm.



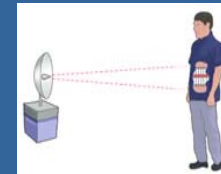
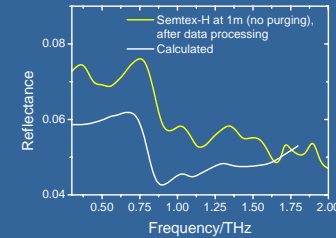
# Semtex and SX-2 spectra

- Spectra of two different RDX based explosives showing same distinctive features
- Data collected at 1m stand-off through normal atmosphere with 70ms integration time – water vapour lines removed



# Conclusion

- Terahertz is very promising technology for many applications
- Proof-of-principle confirmed with measurements and data
- Technology now moving forward to commercialisation



# Acknowledgements

- Dr Bill Tribe
- Dr Tom Lo
- Dr Mike Kemp
- Dr Philip Taday
- Michael Withers
- Michael Evans
- Dr Bryan Cole
- Dr Ian Bradley
- Dr Simon Chandler