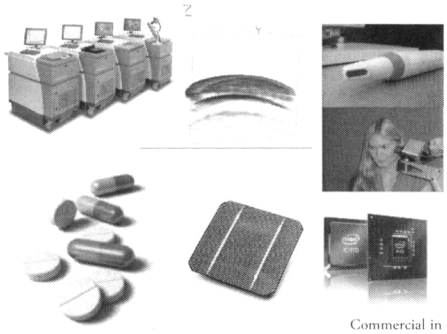
TeraView



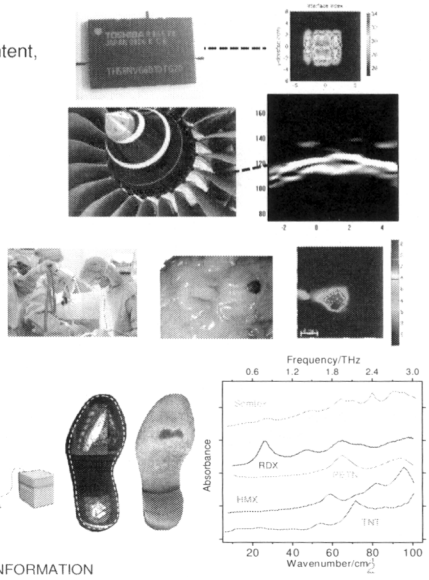
Terahertz imaging & spectroscopy: technology and applications

Dr DD Arnone, CEO/Co-Founder

Commercial in confidence

Terahertz Applications – across a range of industries

- Semicon inspection
  - •Packaging/wafers – intereconnect FA/QA, moisture content, doping/mobility mapping, interconnect integrity
  - •Semicon wafers – cracking, delamination, defects
  - •High frequency/high speed materials characterisation
- •Non destructive testing – devices & materials
  - •Moisture content and contamination in food stuffs
  - •Delamination/defects in composites for aerospace
  - •General materials FA & characterisation
- •Solid state materials characterisation
  - •Crystallographic orientation
  - •Dielectric characterisation and nanomaterials
- •Medical
  - •Early stage cancer detection
  - •Intra-operative probe for breast cancer surgery
- •Homeland Security & Defense
  - •Airborne toxic agent detection
  - •Explosives detection

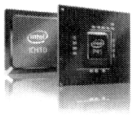


TERAVIEW CONFIDENTIAL INFORMATION

Company History and Background

- Spin-out of Toshiba and University of Cambridge (UK), with over 20 years experience working in the Terahertz.
- Terahertz: 3D imaging with unique spectroscopic signatures not found at other wavelengths – complementary to existing imaging and spectroscopy
- Team of 20 PhD chemists, physicists & engineers to support products and customer applications – emphasis on collaborative support
- Global company with sales & support in US, EU & Asia Pac
- Range of publications (100+) and patents (60) covering core technology & applications in different areas



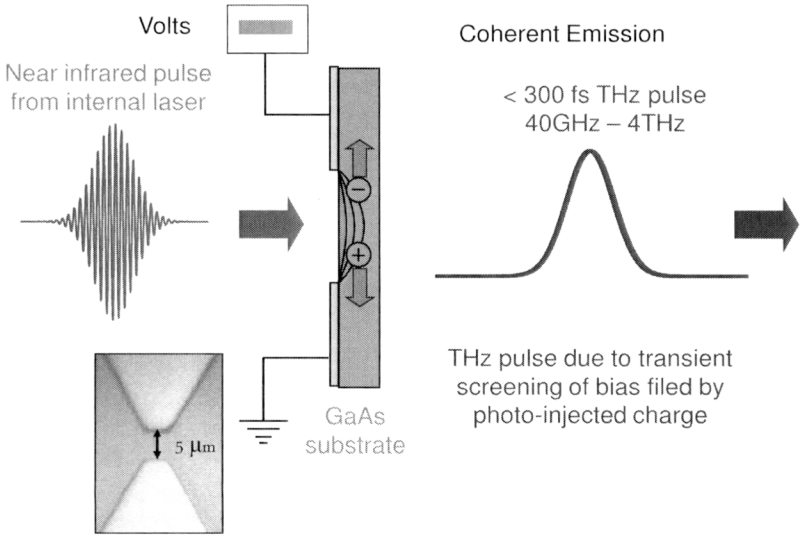




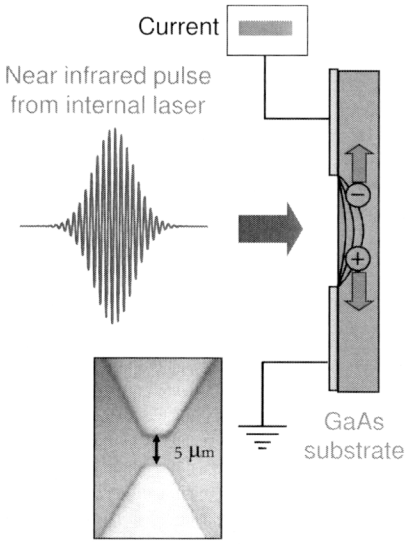




Core Technology – how it works, photoconductive generation of THz

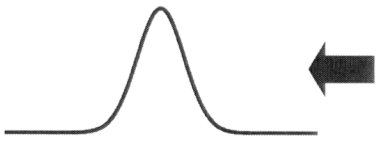


Core Technology – how it works, photoconductive detection of THz



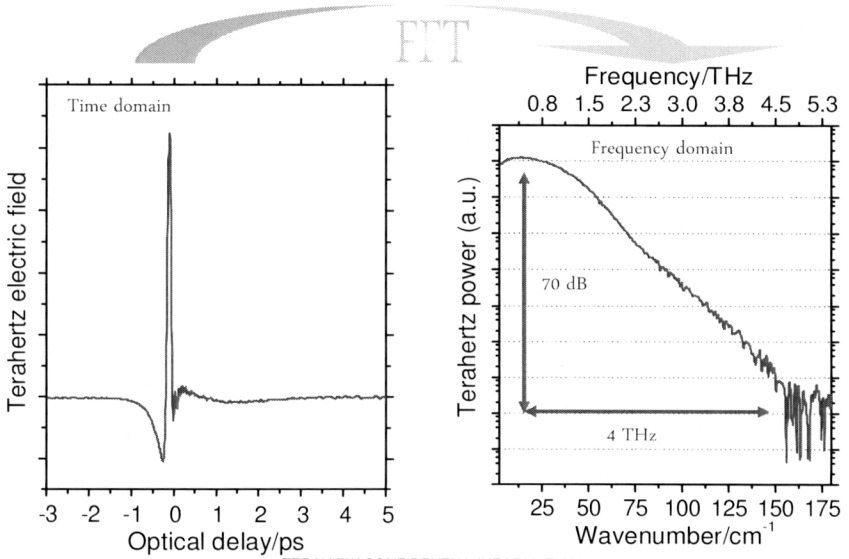
Coherent Detection

< 300 fs THz pulse
40GHz – 4THz



- THz pulse induces current by rectifying photogenerated (near Infrared) carriers, measure resulting current with ammeter – proportional amplitude & phase of THz wave
- Very low noise due to coherent, time gated detection

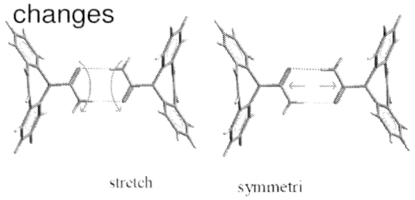
Technology Overview – imaging (pulse) and analytical (spectroscopy) capabilities



Technology Overview - spectroscopy

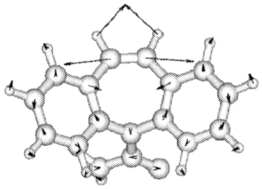
Terahertz Spectral Region

- Intermolecular bond vibrations
- Directly affected by crystal changes

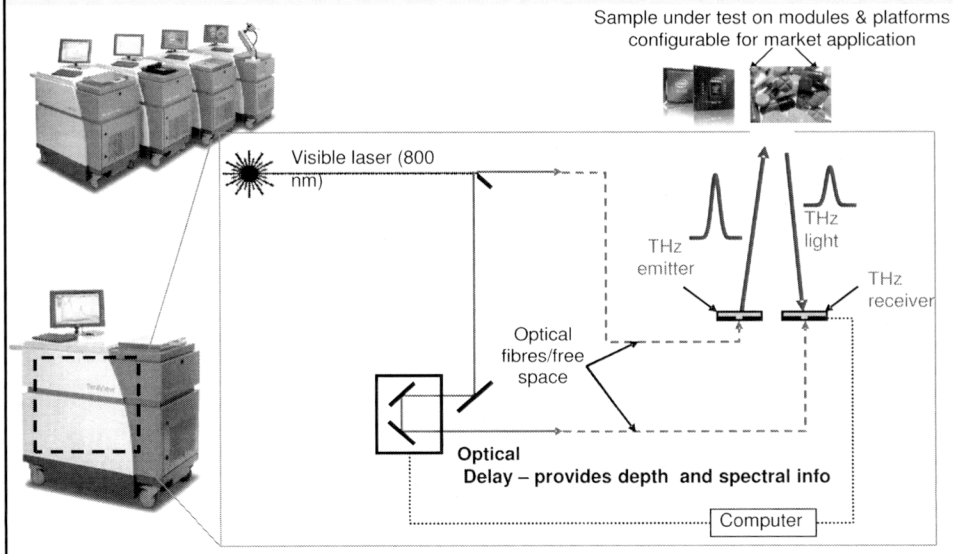


Infrared Spectral Region

- Intramolecular bond vibrations
- Indirectly affected by crystal changes



Terahertz Engine Schematic – core of all Terahertz products



Products to date

Sector-specific Products using core Terahertz engine



Pharma: Tablet imager

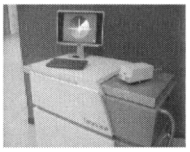




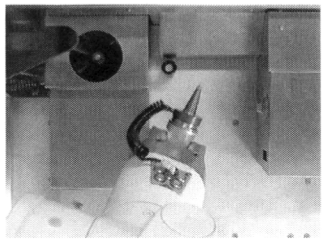
Medical: Breast & skin imaging



Security: explosives detection



Semicon: IC inspection

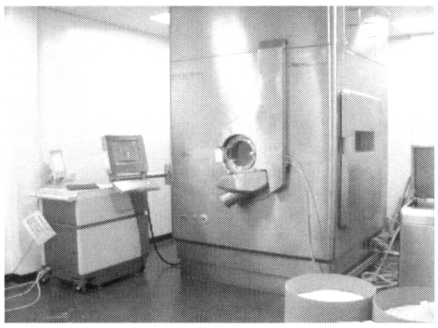


Robotic module to remotely image tablets for pharmaceutical industry

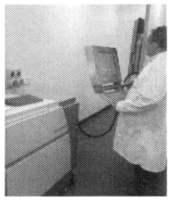


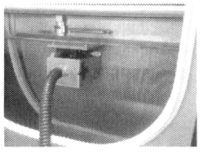
Basic sensor – size of AAA battery

Industrial inspection products – in-line, real time monitoring and control of production processes: coatings for the pharmaceutical industry



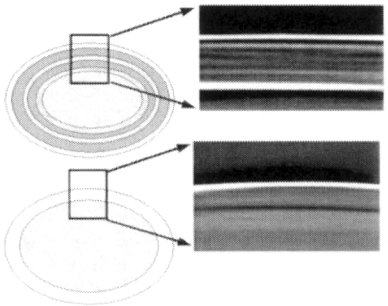
Monitoring coatings on pharma tablets during production





Brand

Generic

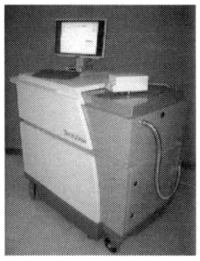


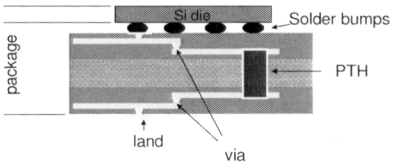
OYSTAR Manesty

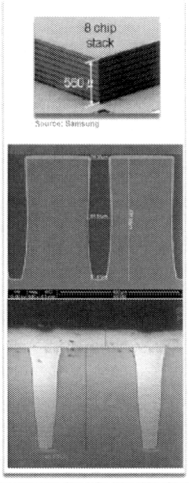
FDA

Advanced 3D packaging FA & Inspection – interconnect integrity FA & inspection

- **Business problem**:
  - Fault detection and QA in the electrical interconnects of ICpackages is limited to ~500 micron resolution using state of the art metrology tools
  - Customer cannot determine where fault is occurring with required accuracy – 10 microns
  - Driven by mobile phone and portable consumer electronics industries - 'more functionality in ICs, requiring smaller more complex packages'
- **Terahertz solution:**
  - Identified by Intel; chose TeraView to supply systems
  - Enabling tool for next generation integrated circuits

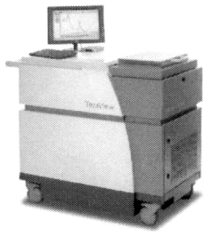




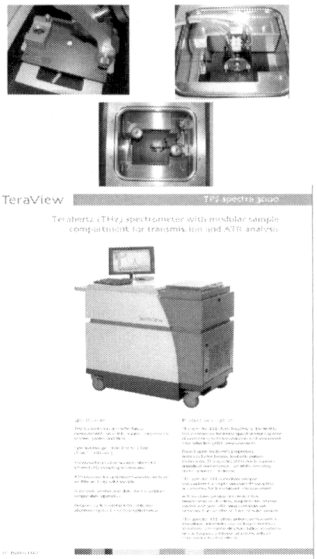


TERAVIEW CONFIDENTIAL INFORMATION

Materials/device characterisation products – spectrometer with plug and play modules for imaging and materials characterisation; TPS





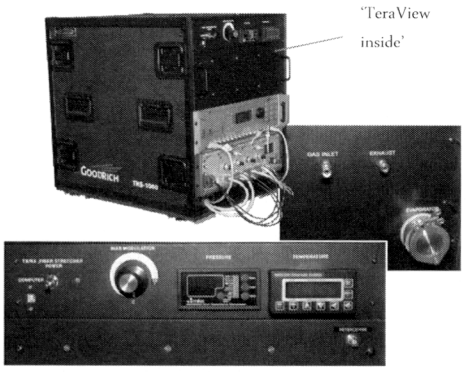


- Terahertz spectroscopy and imaging modules
- transmission or reflection mode modules
- cryogenic/low temperature and heated cell/high T available
- capabilities above provided by a series of plug in modules
- Plug and play, easy to use, no alignment required

- Polymorph detection and quantification
- Hydrates and amorphous material characterisation
- Content uniformity
- Materials characterisation and high frequency studies
- Tissue and biomaterials

TERAVIEW CONFIDENTIAL INFORMATION

Proven product using compact/low cost platform – airborne chemical agent detection to reduce false alarms



The significant system characteristics include the following:

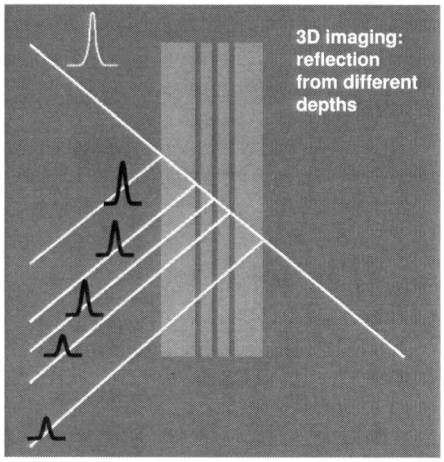
- Range: 0.1 to 1.2 THz
- Resolution and Repeatability: 1.1 MHz
- MDAL: ~1.0 %
- Volume: 25.5"L x 20.5"W x 24.25" H
- Weight: 230 lbs
- Transmission spectra of gases or vapors
- Cell provides 9.6 meters absorption path length in 1.6 liter volume
- Automated sample handling
- Pressure can be reduced to 7 torr
- Heated sample cell and evaporator chamber
- Three methods to introduce gas: direct connection to source, draw from atmosphere, or evaporator cell for liquid vapor measurements
- Provides data analysis graphical output
- USB and network compatibility
- Windows compatible control software

- Current Goodrich product using TeraView THz
- 2ft x 2ft x 2ft; scope to reduce footprint and weight by factor of ~5x, further reductions possible

GOODRICH

Homeland Security

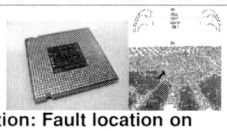
Technology Overview – use of pulses for imaging applications



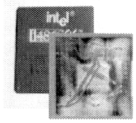
Technology Overview

- Proprietary Terahertz Pulsed Imaging (TPI™) platform and know how lead to ownership of Terahertz spectrum;
- Company produces the Terahertz Engine, the key component used in products across markets;
- Engine generates & detects Terahertz pulses by illuminating patented semiconductors with light from a visible laser;
- Echo pulses of Terahertz are reflected off, or transmitted through an object, and detected to construct 3D images layers, defects, concealed objects – similar in operation to ultrasound or high frequency radar;
- Terahertz spectral fingerprints are also derived from echo pulses to provide identification and diagnostic information;
- 3D image/fingerprints capabilities are optimised for each market application

Multiple applications in semiconductor inspection

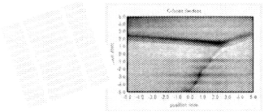


Solution: Fault location on interconnects in packaging
THz time domain reflectometry (TDR) for FA, QA and inspection of advanced 3D packaging (TSV, etc)

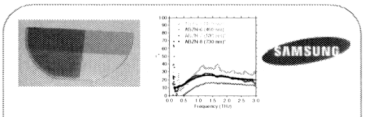


Solution: Packaging inspection
Moisture content



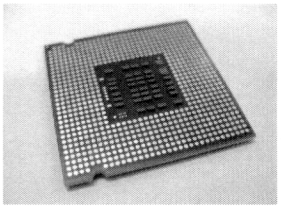


Solution: Cracks in semi wafers

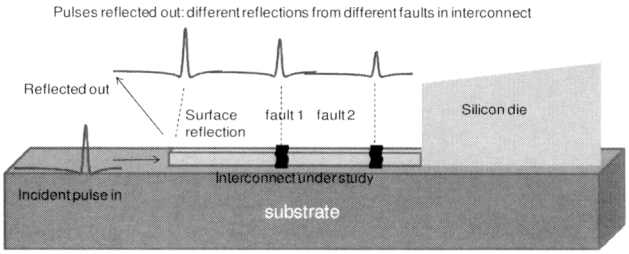


Solution: High frequency test
Dielectric loss

Interconnect integrity in advanced IC packaging: THz time domain reflectometry (TDR)



•Interconnects on back of typical IC

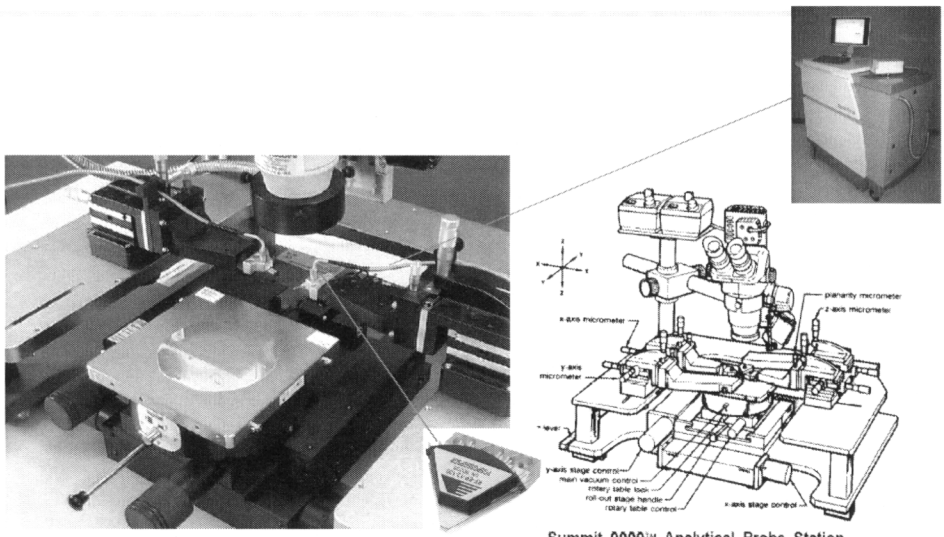


•THz Time domain reflectometry – how it works
• Incident THz pulse in reflects off faults in electrical interconnect between silicon die and IC bond pads
•Reflection locates fault position with high accuracy

• High frequency (~3THz) and narrow (~1ps) pulses lead to high accuracy in determining the position of electrical faults or quality variations – open, shorts impedance variations

• 10 micron accuracy with THz TDR vs. ~500-1000 microns with conventional microwave TDR

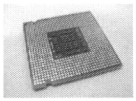
Interconnect integrity in advanced IC packaging

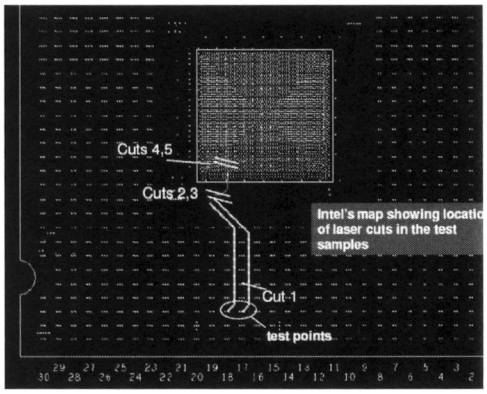


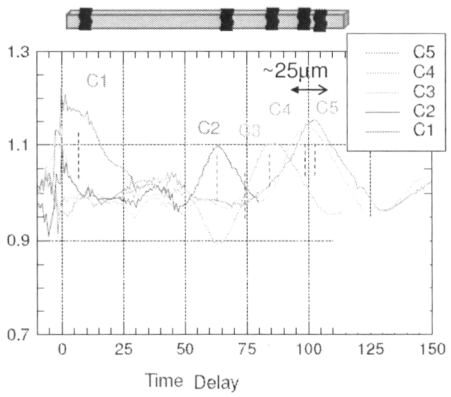
The Summit 9101 Station's unique square chuck with independent vacuum controls holds an ISS, contact substrate, and test wafer simultaneously. The station's rollout stage protects your valuable wafers.

Summit 9000™ Analytical Probe Station.

Interconnect integrity in advanced IC packaging: customer case study 1

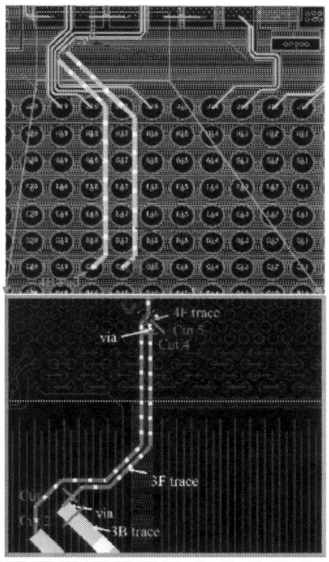






Interconnect integrity in advanced IC packaging: customer case study 2

Locations of cuts in real packages



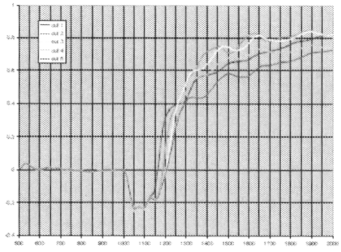
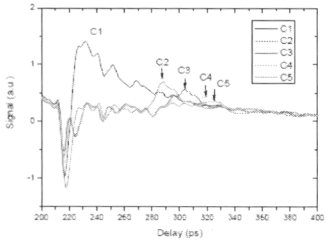


Figure 12. Reflected signals acquired with the conventional TDR

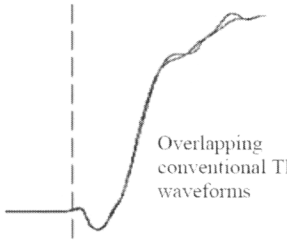
Conventional microwave TDR: peaks overlap, no information on fault location

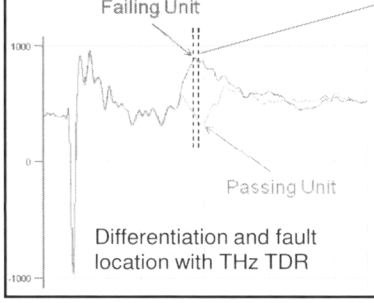


THz TDR: distinguish and locate fault

From Intel paper, ECTC Proc 2010

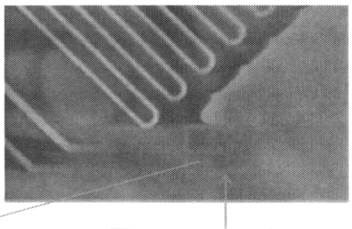
Interconnect integrity in advanced IC packaging: customer case study 3





Differentiation and fault location with THz TDR

THz TDR allows operator to locate and analyse fault in X-Ray CT image

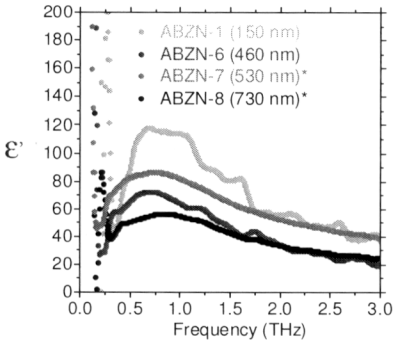


From Intel paper, ECTC Proc 2010

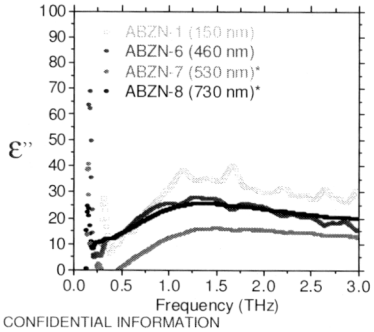
Trace crack

> With such revolutionary concept, innovative design and superior performance, EOTPR will become an essential tool for microelectronic package fault isolation and failure analysis.
>
> By integrating EOTPR and 3D x-ray into to FA flow, FA TPT and success rate can be dramatically improved.
>
> Fully automated systems can be developed for component, board and solder joint quality screening.

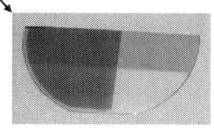
High Frequency Test & Measurement of electronic materials: customer case study



- Requirement to characterise materials at ~10-20x operational frequency dictates use of THz
- Characterise material and device performance at high frequencies (>20GHz through 4THz)
- Useful in R&D and inspection
- Rapid, non destructive measure of material and device integrity and frequency response

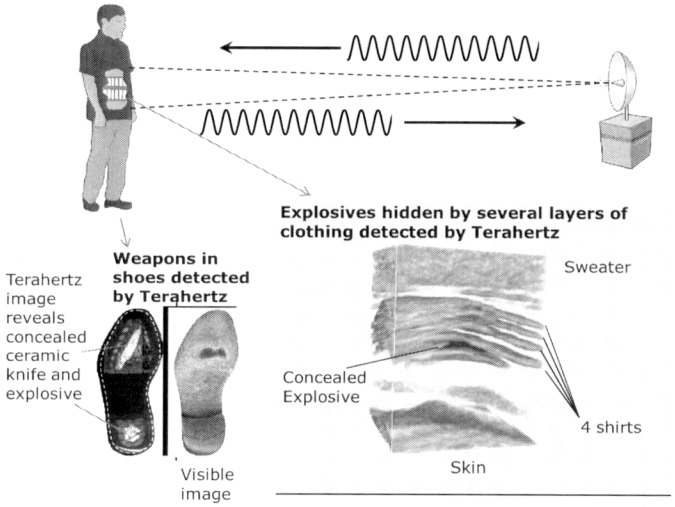


Ceramic epilayer for high speed capacitor in mobile phone



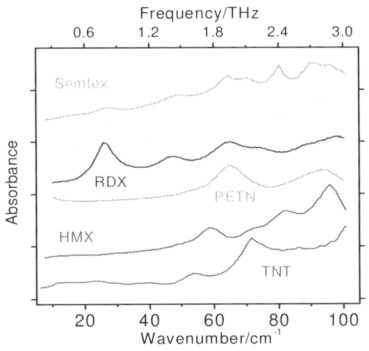


Imaging Benefits – homeland security and defense

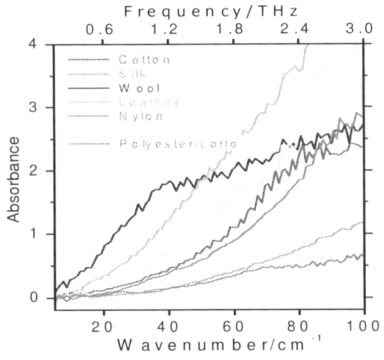


Benefits – explosives detection

'Terahertz fingerprints' of explosives – with sharp absorption features, including PETN used by Detroit bomber



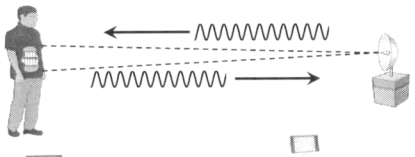
'Terahertz fingerprints' of clothing – lack of sharp features allows for automated detection of explosives



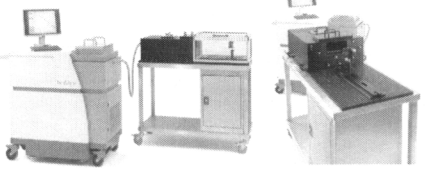
- potential for automation
- operation similar to metal detector, red light/green light or audible alarm

Benefits – explosives detection (SX2): customer case study

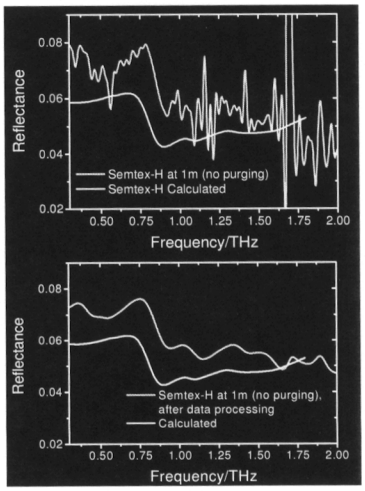
Concept



Evaluation unit: US Navy, US Airforce

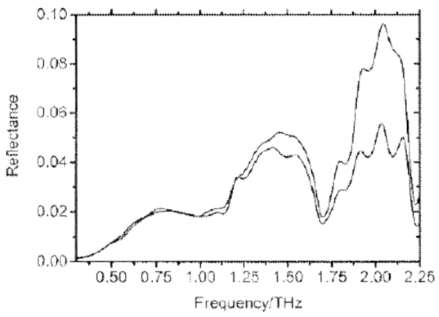


Customer data – SX2 explosives fingerprint



Benefits – explosives detection (PETN): customer case study

- Affect of applying the software method – **measuring PETN through 2m of air**, removing water vapour lines

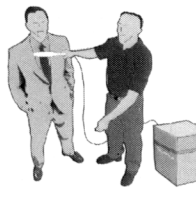


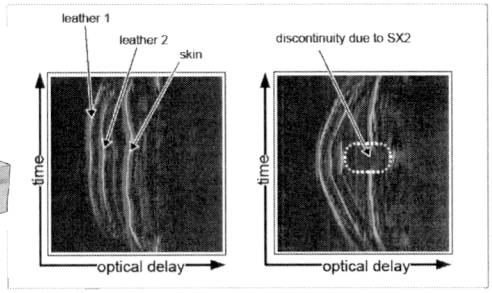
Library spectrum;

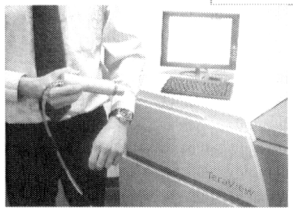
Measured spectrum through 2m air, with sharp water lines removed by algorithm

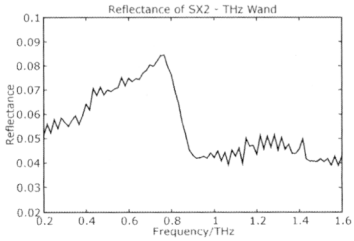
Figure 7.2: Reflectance measurement from PETN

Benefits – explosives detection, imaging and spectroscopy





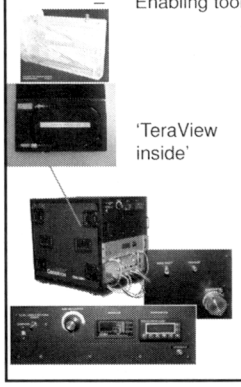




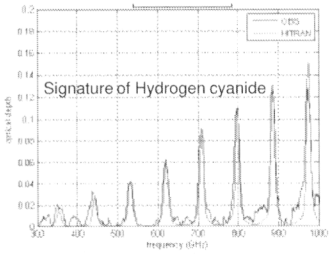
- Hard object detection - metals, ceramics, plastics, explosives
- Reflected pulses show clothing layers and skin as probe is moved over body
- Hard objects detected as discontinuities
- Image shows raw 'B-scan' data
- Algorithms developed for automatic detection and spectral identification

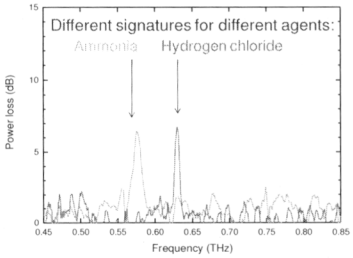
Benefits – airborne chemical agent detection, spectroscopy

- **Business problem**:
  - Need to detect airborne toxic agents that can be used in chemical weapons attack
  - Need to do so with low false alarm rates – limitation on infrared and current technologies
- **Terahertz solution:**
  - Identified by Goodrich and US Dept of Homeland Security; TeraView supplied THz emitters/detectors
  - Enabling tool for early warning of airborne chemical agent attacks



'TeraView inside'



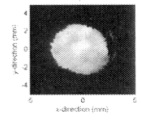


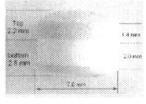
Sensitive to chemical threats **Reduces false alarms**

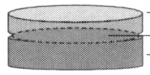
Imaging Benefits – Pharma customer, delamination

- **Business problem**:
  - bi-layer controlled release product removed from market due to delamination at buried interface between two component layers
  - Customer could not predict delamination from shaking (friability) tests
- **Terahertz solution:**
  - image buried interface to distinguish 'good' from 'bad' batches; aid in addressing product issue
  - Enhanced quality, routine inspection of multi-layers in product development

Batch 1 Acceptable

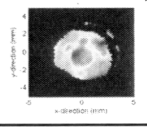






Patent protected

Batch 2 Unacceptable – red regions are delaminating

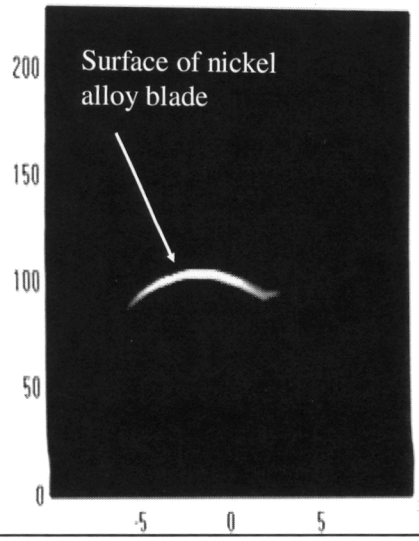


Imaging Benefits – enamel thickness on jet engine turbine blade

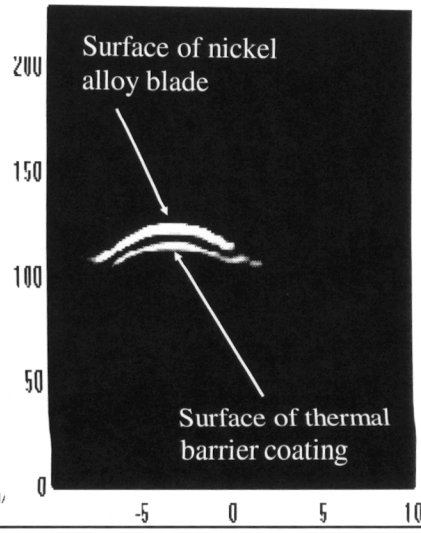


Imaging Benefits – enamel thickness on jet engine turbine blade

Vertical Cross-section THz image of uncoated turbine blade



Vertical Cross-section THz image of coated turbine blade



Imaging Benefits – enamel thickness on jet engine turbine blade

