

Single shot pulsed terahertz imaging for in-line production control and automated inspection

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The challenge of controlling innovative products

Key markets



2 major industrial trends:

- Growing use of **technical materials**: coatings, composites, assemblies...
- Industry 4.0 for the reduction of the **cost of poor quality** (~5% of revenues – source: AFNOR)

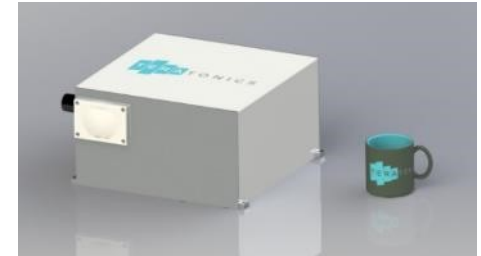
➔ Increased need for **innovative Non-Destructive Testing** systems for **in-line** deployment

- Penetrating ➔ no machine vision, no visual inspection
- Contact less ➔ no ultrasounds (typical)
- Harmless ➔ no X rays
- Rapid ➔ no tomography

How can we satisfy these needs?

Our game changing Non-Destructive Testing (NDT) solution

- Teratonics uses ultrashort **Terahertz pulses** to reveal the invisible **inside composites, plastics, assemblies, and coatings**



THz Sensor head

- Our solution can do **dimensional control** and **detect defects**

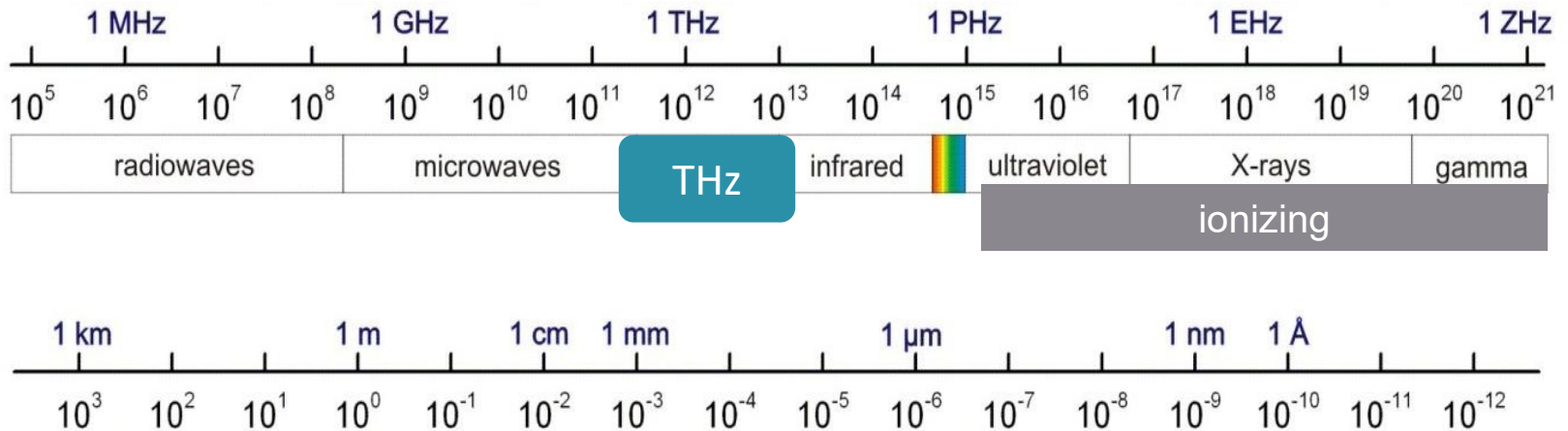
- Our solution is **contactless** and **harmless**

- Our solution can be **directly integrated in a production line** because it is **fast and fully automated** (including the scan of **complex 3D shapes**)



First product line
mobile rack system solution

Terahertz radiation: a “new” frequency for NDT



Properties of Terahertz "light":

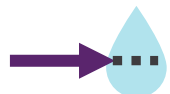


High penetration of **dielectric materials: testing of volumes**
(Ceramics, cardboard, glass, fabric, foam, plastic, semicond. etc.)



High reflection on **metals: inspection of hidden, coated surfaces**

Sensitive to intermolecular interactions: polymorphism, polymerization



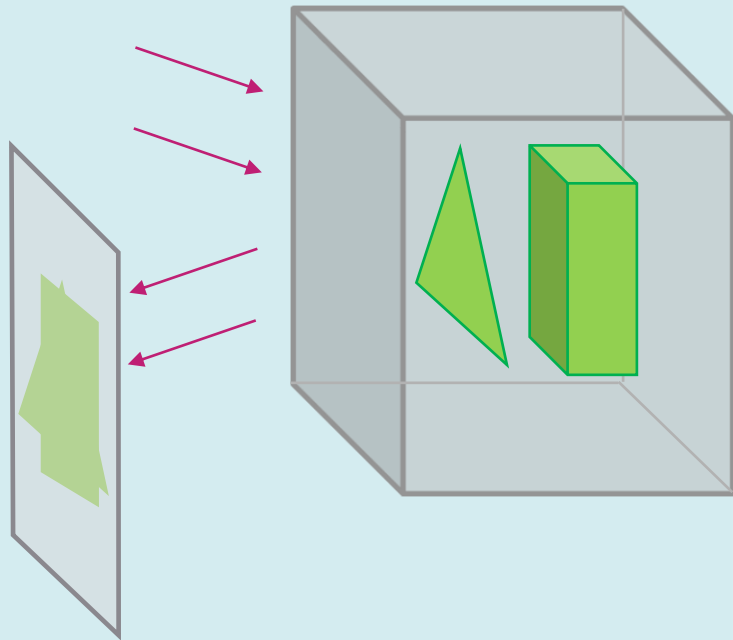
Highly sensitive to polar liquids



Not ionising

Sub-structure imaging with ultrafast THz pulses

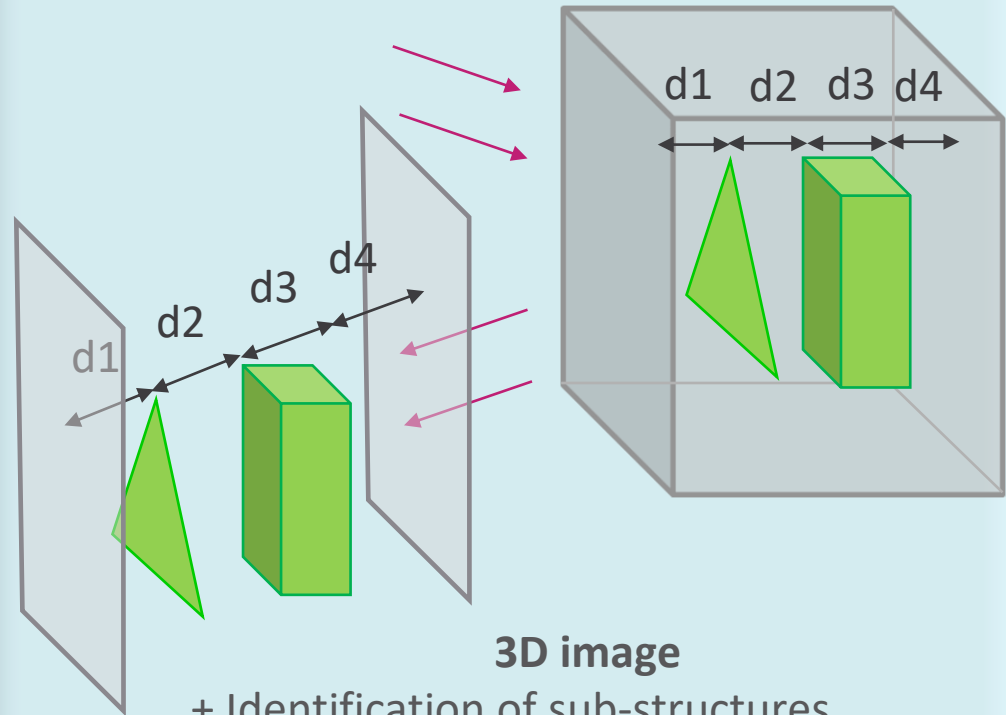
Continuous Wave (cw)



2D Image

- Overlap of structures
- Overlap with diffraction pattern
- Low probability of defect detection

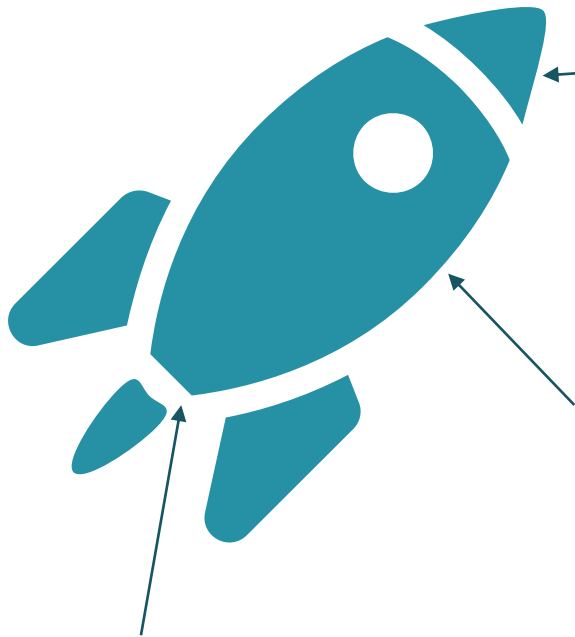
Teratonics Ultrafast Pulses



3D image

- + Identification of sub-structures
- + Dimensional analysis with micrometric depth resolution

In-line sub-structure imaging with ultrafast THz pulses



Teratronics Single-Shot pulsed THz technology

- Same as « THz technology »
- 3D information
- **Rapid: 500cm²/30s typ. !** - Imaging in the cycle time-
 - 1 pixel is acquired with only 1 THz pulse (1ps long)
 - Pixel acquisition time **10.000.000 times faster** than the state of the art
 - International patent



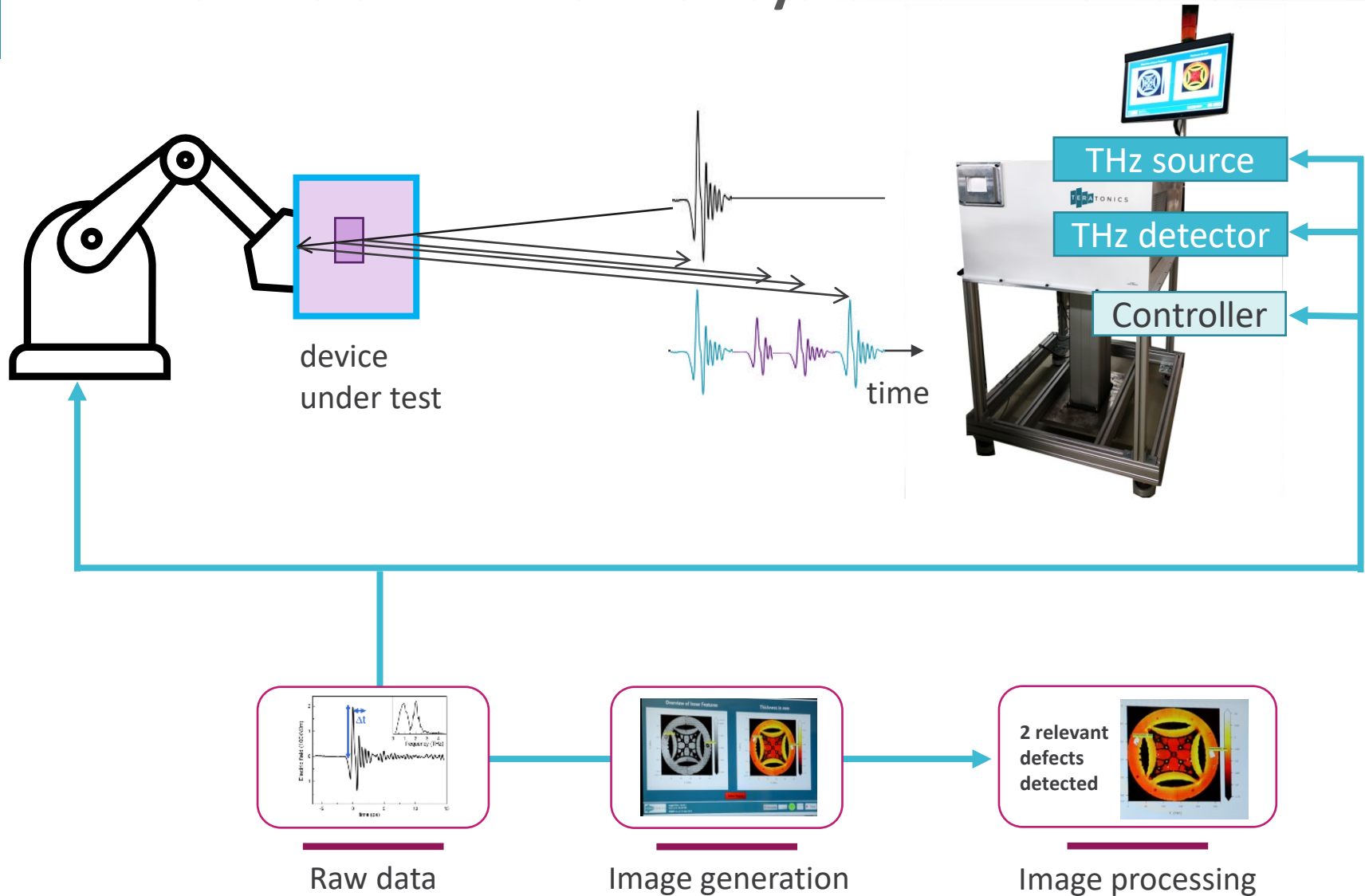
Pulsed THz technology (typical):

- Same as « THz technology »
- Time of Flight Measurement adds **depth / thickness information**
- Problem: 100s of THz pulses necessary for 1 pixel → **slow**, off-line control only

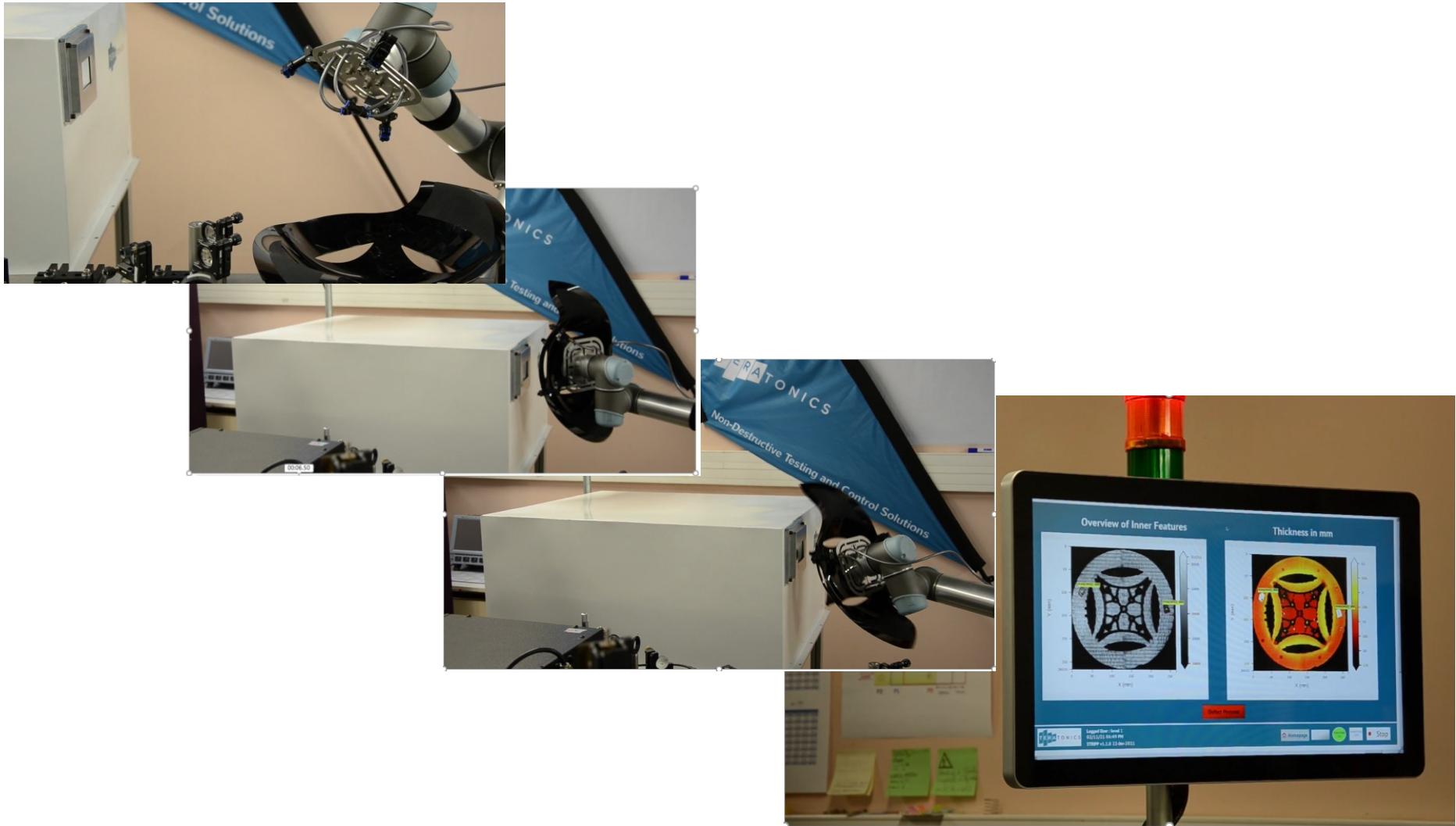
THz technology:

- penetrating in electrically non-conductive materials
- safe (no X-Rays)
- contactless (no ultrasounds)
- ...

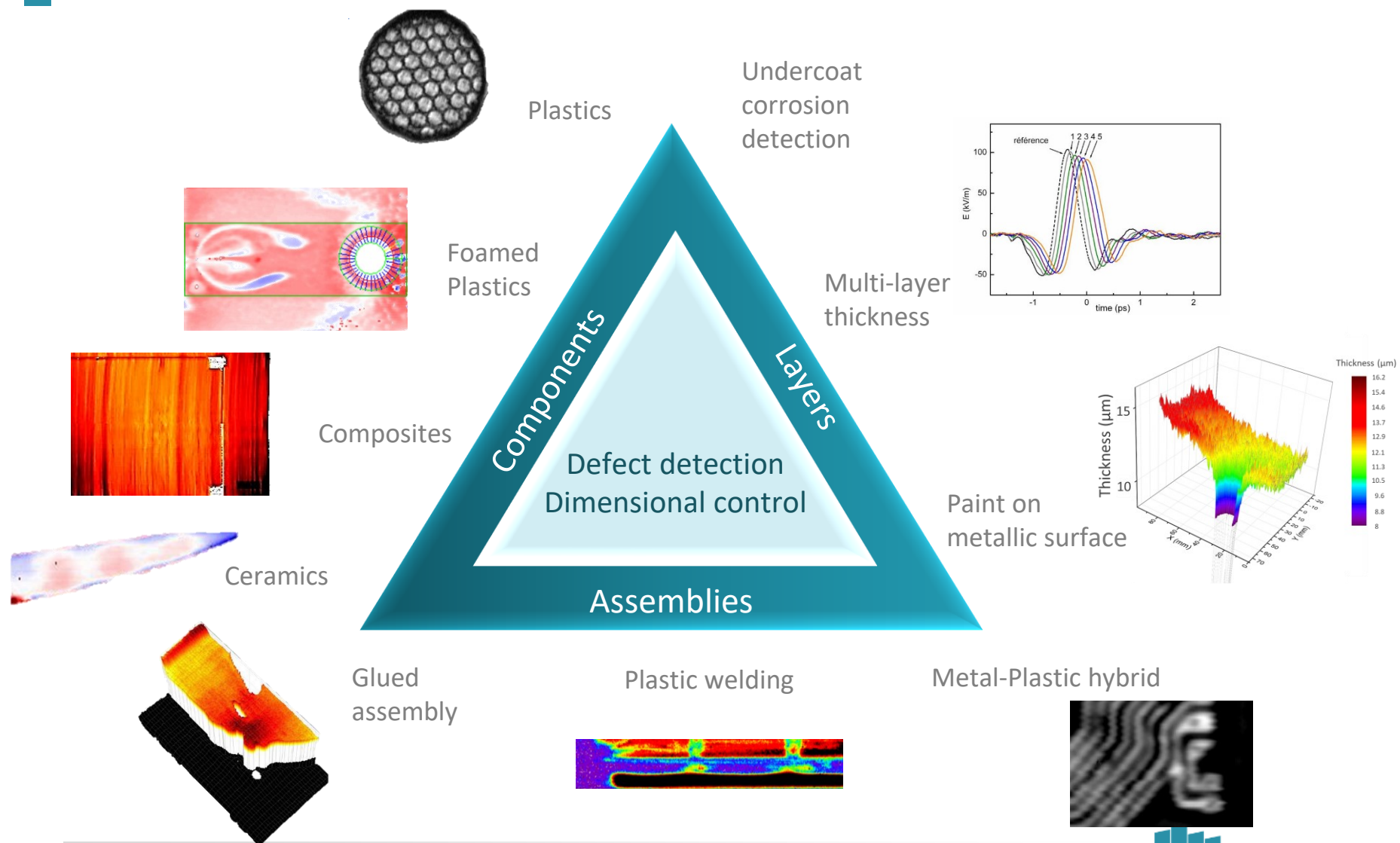
TERATONICS STRIPP Control: system architecture



Robotised scan of complex 3D shapes and automated defect detection

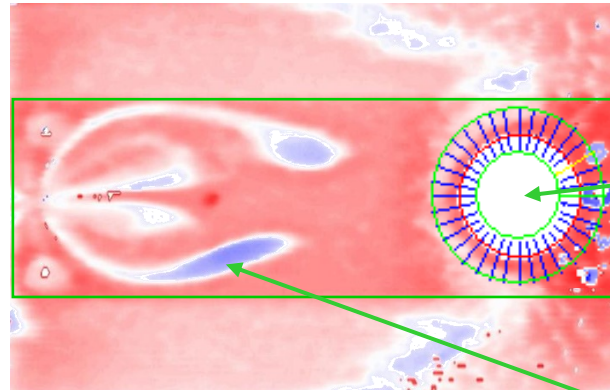


Teratonics's main results for product control / inspection



Automated and robotized scan: foamed plastic example

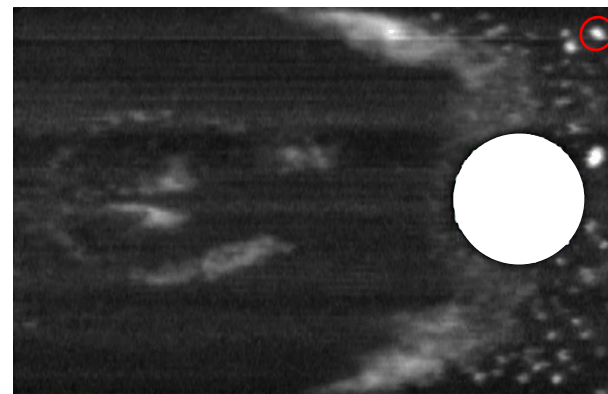
Scan in less than ten seconds << production cycle time (45s)



30 μ m wall thickness jump

Measured diameter: 17.98mm

Density variation:
92 μ m less plastic



Void:

- XY size 1.8*1.6 mm
- depth 975 μ m
- thickness 565 μ m



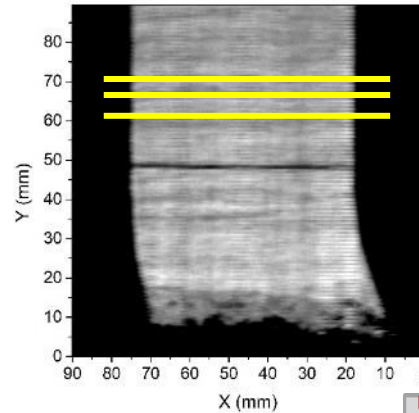
<https://www.youtube.com/watch?v=pt5xzOTGJNM&feature=youtu.be>

Rapid imaging of Glass fiber reinforced PA part based on several patches

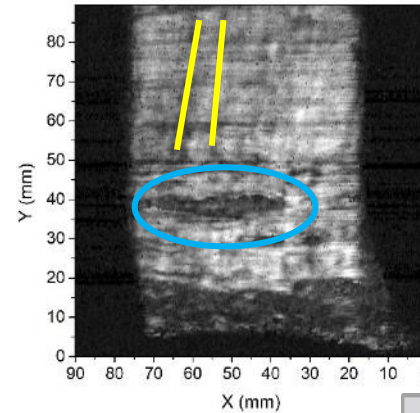
Photo



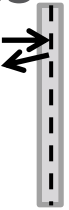
Surface



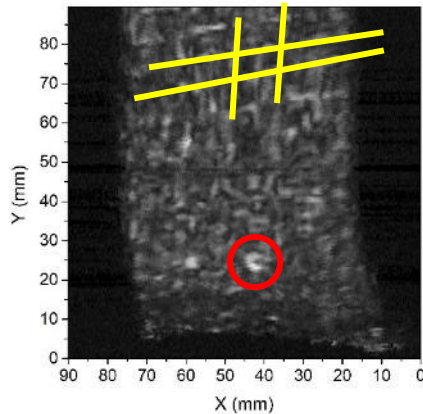
Depth 1



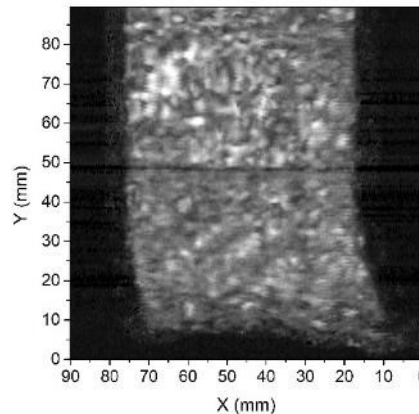
Reflexion measurement



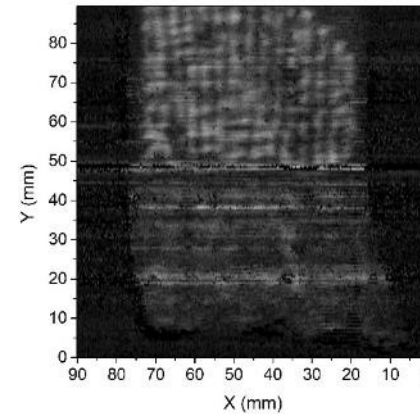
Depth 2



Depth 3



Depth 4



- Identification of the layers and their orientation
- Defects identification, such as:
 - Air gap
 - Fibre cluster
- Can be applied to a variety of processes, like: RTM, pultrusion, Tape Placement ...

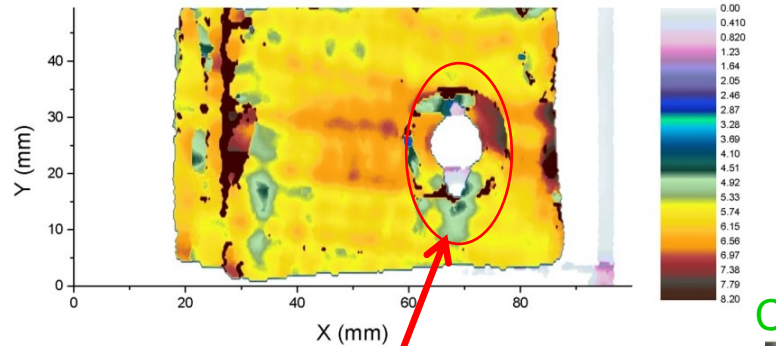
Quilted Stratum Process automated and high-volume production to fabricate within 40 to 90 seconds

GFRP composite control - I

Punched hole

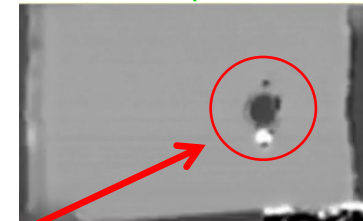


Image - time of flight



Localisation + characterisation of hidden defects

C-Scans (fixed time)



- (partial) destruction of the composite network, also beyond the direct impact

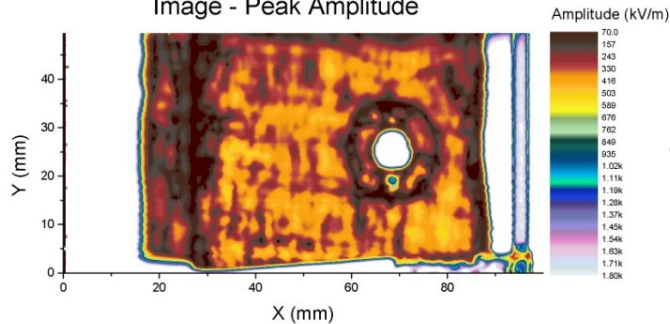


- 2 cavities, remaining material ~360 and 250 μm thick



- Laminar loss of material density, corresponding ~1 sheet

Image - Peak Amplitude



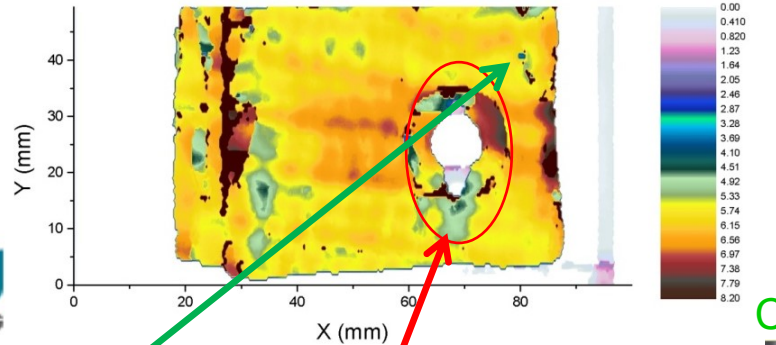
GFRP composite control - II

In 2014: acquisition time
~40 seconds ($5 * 10 \text{ cm}^2$)

Confirmation of the THz results with
CT X-Ray by Novitom
(ESRF Grenoble,
~15 minutes acquisition time)

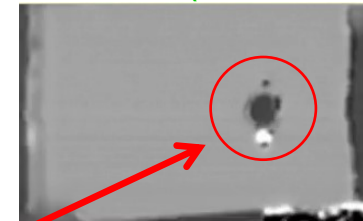


Image - time of flight



Localisation +
characterisation
of hidden defects

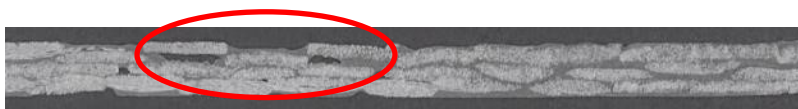
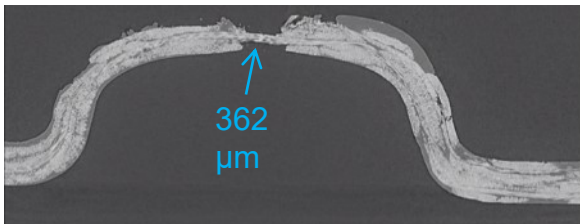
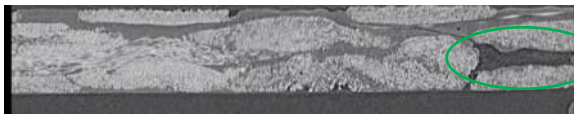
C-Scans (fixed time)



(partial) destruction of
the composite network,
also beyond the direct impact

2 cavities, remaining material
~360 and 250 μm thick

Laminar loss of material
density, corresponding ~1 sheet



Carbon fiber UD tape control Spide TP process (1/2)

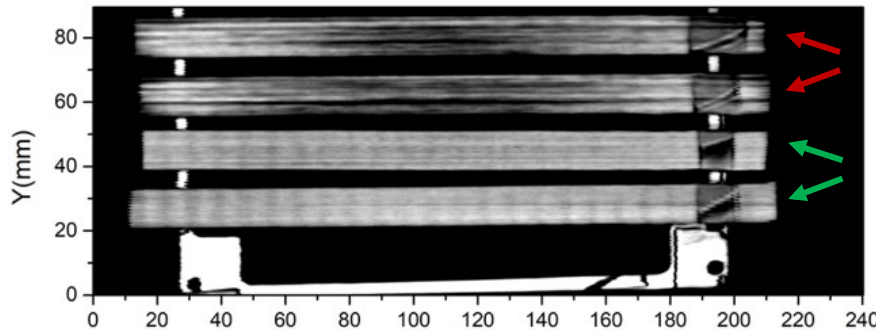
PEEK resin
Nominal thickness: 150 μm



Supplier B : bad impregnation quality, high rugosity...

Supplier A : good impregnation quality

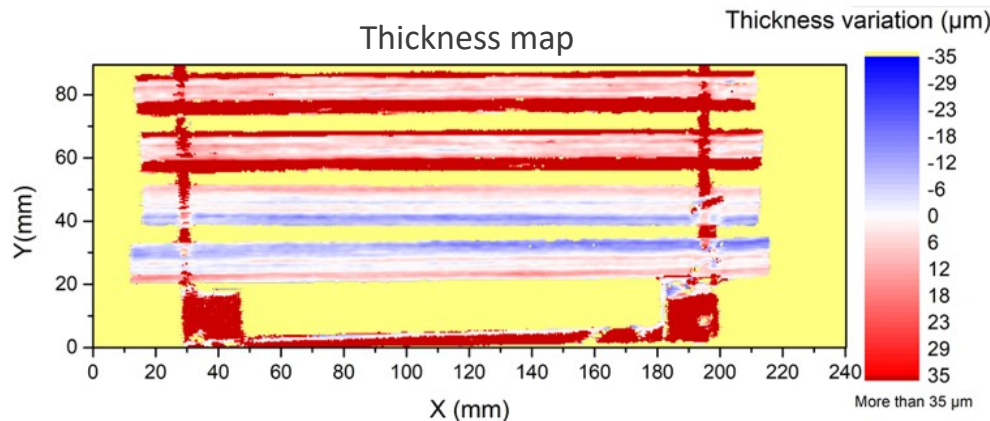
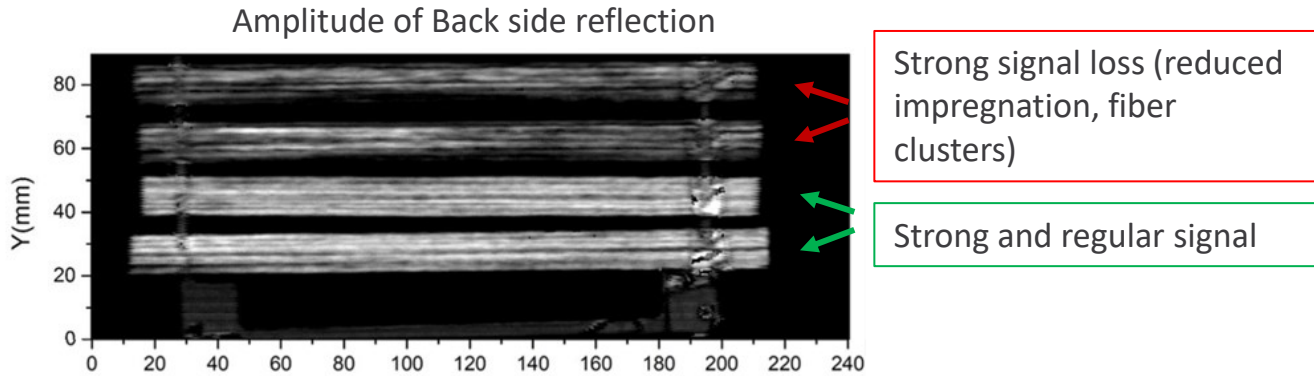
THz Surface Reflection



Surface roughness
→ diffuse reflection

Good impregnation and even distribution of the surface fibers
→ homogeneous reflection

Carbon fiber UD tape control Spide TP process (2/2)



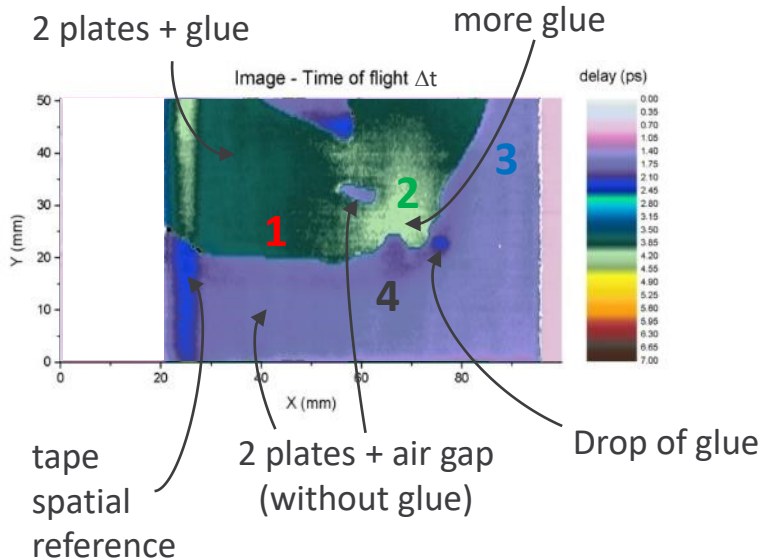
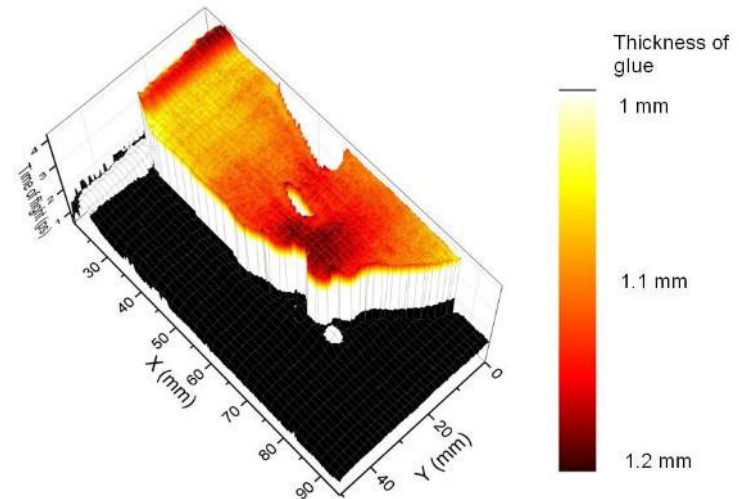
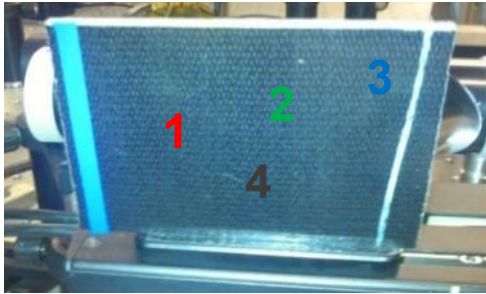
Based on time of flight, with calibrated refractive index

- THz Study gives:**
- Thickness map
 - Fiber clusters
 - Information about roughness, quality of impregnation and fiber orientation

Sealant / Glue bead inspection

Assembly of 2 plates made of glass fiber + PA composites glued by methyl methacrylate

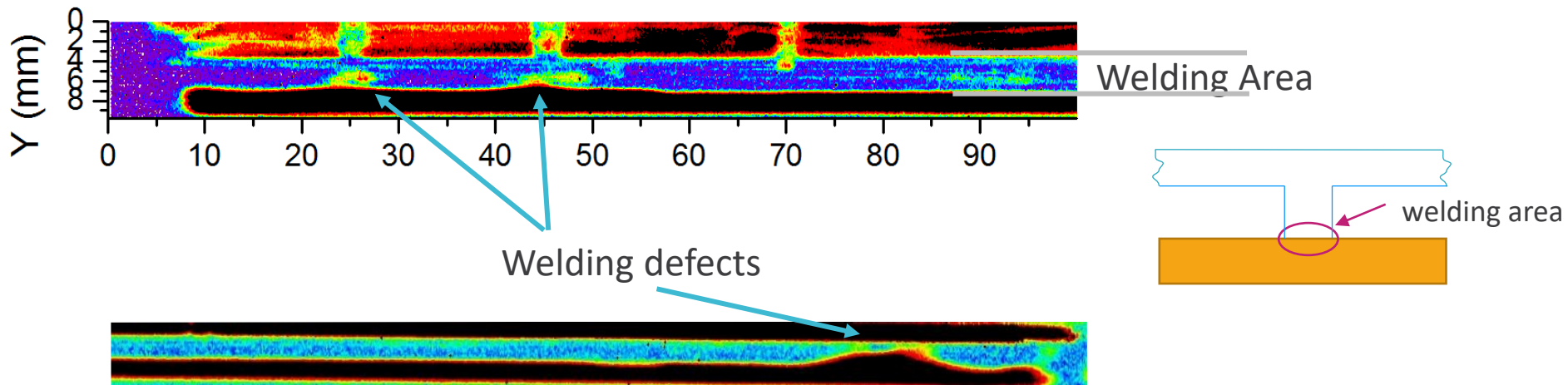
Automotive component



- Glue distribution and thickness (μm precision)
- Localisation of glueless zones and defects

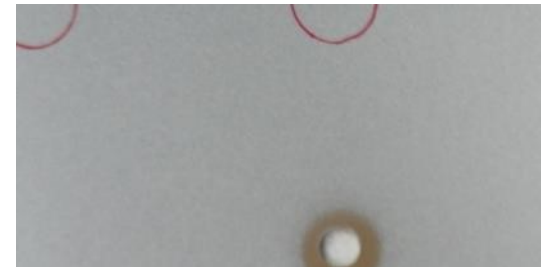
Plastic welding control

- Detection of defects such as voids or areas without welding
- Detection of burrs near the welding area
- Measurement of the materials compenetration
- Compatible with all welding methods (laser, friction, hot plate, HF, US...)

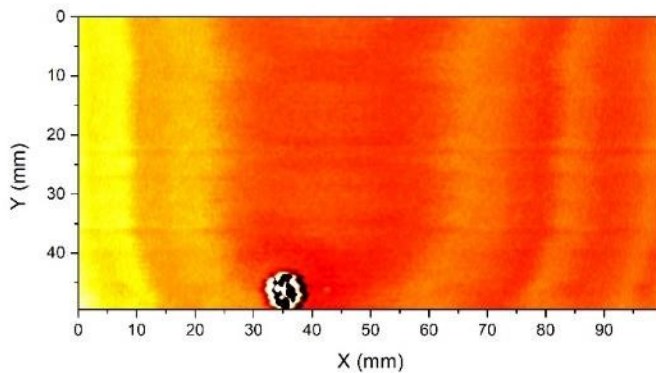


Coating thickness measurement

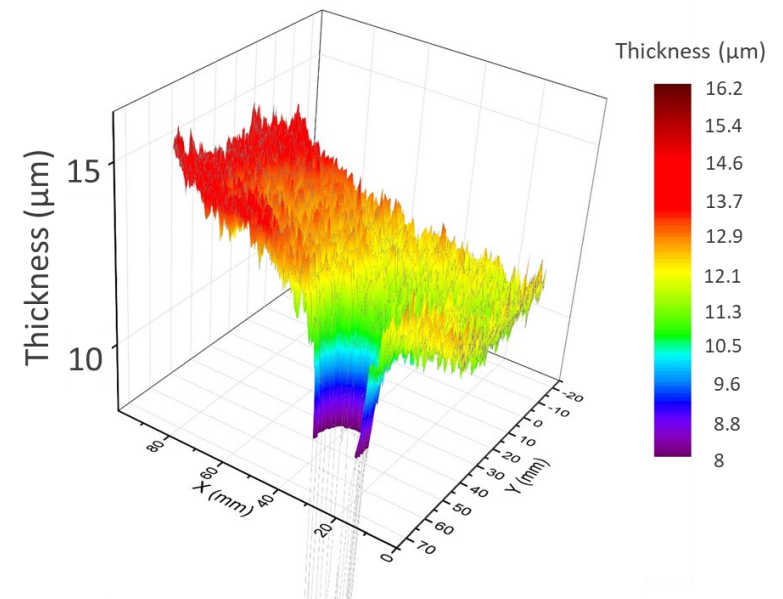
- Full coating thickness map
- Gradient of thickness and “orange peel” revealed
- Also on multi-layers



*single coating of paint on a metallic
cataphoresis layer of a steel plate*



Yellow : thicker varnish
Average thickness: 40 microns



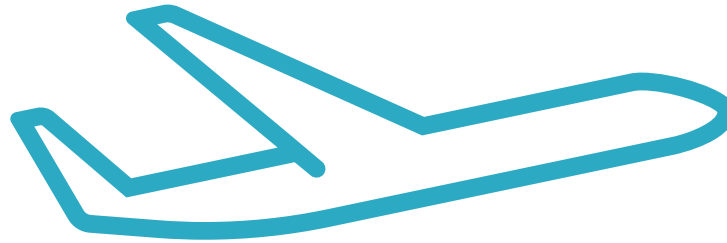
Possible aerospace applications

under coat corrosion detection

thermal barrier coatings

coatings

radomes



composites

sealants

plastic welding / glueing

CFRP UD tapes

ATP / filament winding

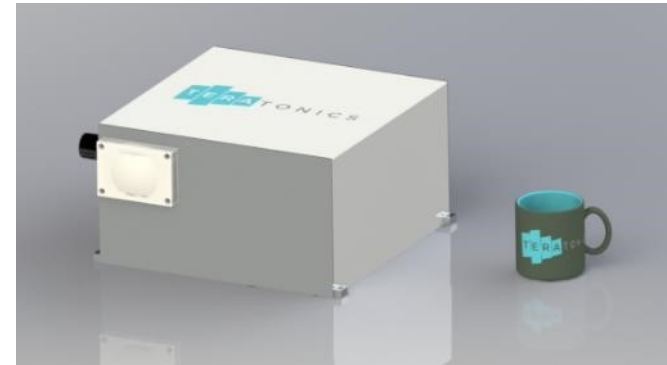
Summary: 100% Inline Quality Control

Non-destructive testing in the production cycle with a pulsed THz single shot sensor:

- Detection of **internal defects**
- **Dimensional control**, in particular the wall thickness
- Detection of **foreign bodies**

Easy to use:

- **contactless**
- **safe** - no x-rays
- Robotised scan of **complex 3D shapes** based on their CAD file
- **10,000,000 times** faster than the state of the art:
 - Insensitive to movement
 - Fast scanning: **> 500 cm² / 30 seconds**





Advanced
Terahertz Photonics
for Enhanced
Productivity and Reliability

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