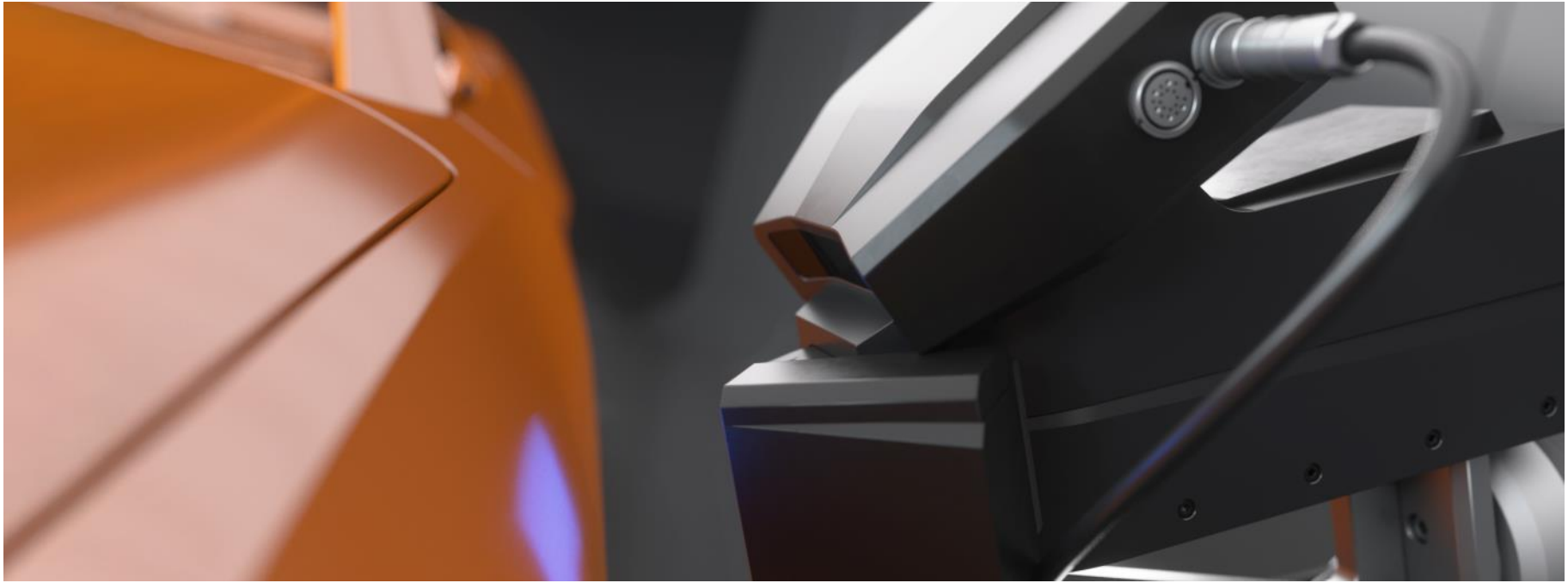
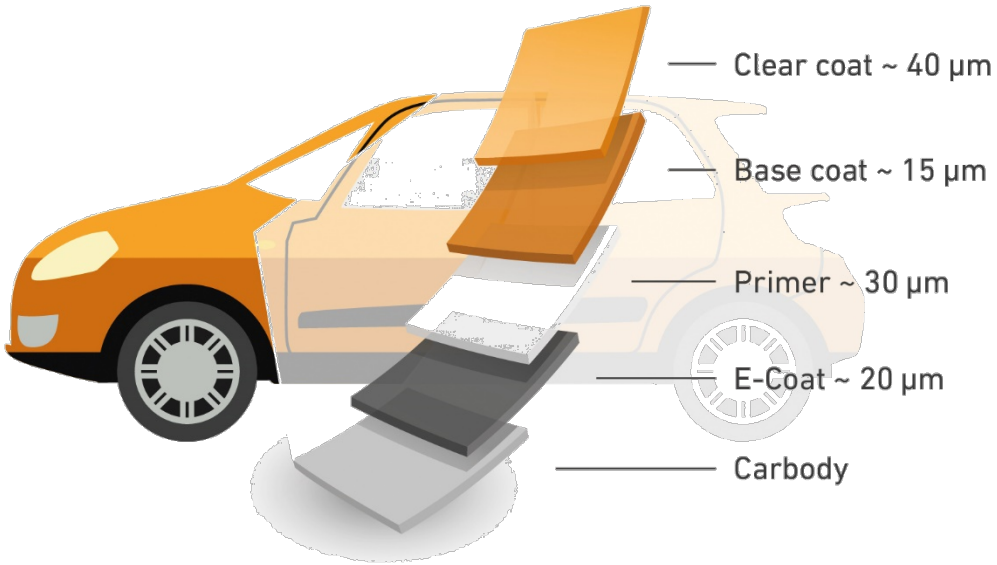


The Fischer TERASCOPE® - Terahertz Systems for Thickness Measurement

Dr. Rüdiger Mästle, Programm Manager THz | Dr. Lars Anklamm, Abteilungsleiter Algorithmik

Motivation

- Determine individual layer thicknesses of multilayer systems:
  - within a single measurement
  - in non-contact operation
  - non-destructive
  - fully automated



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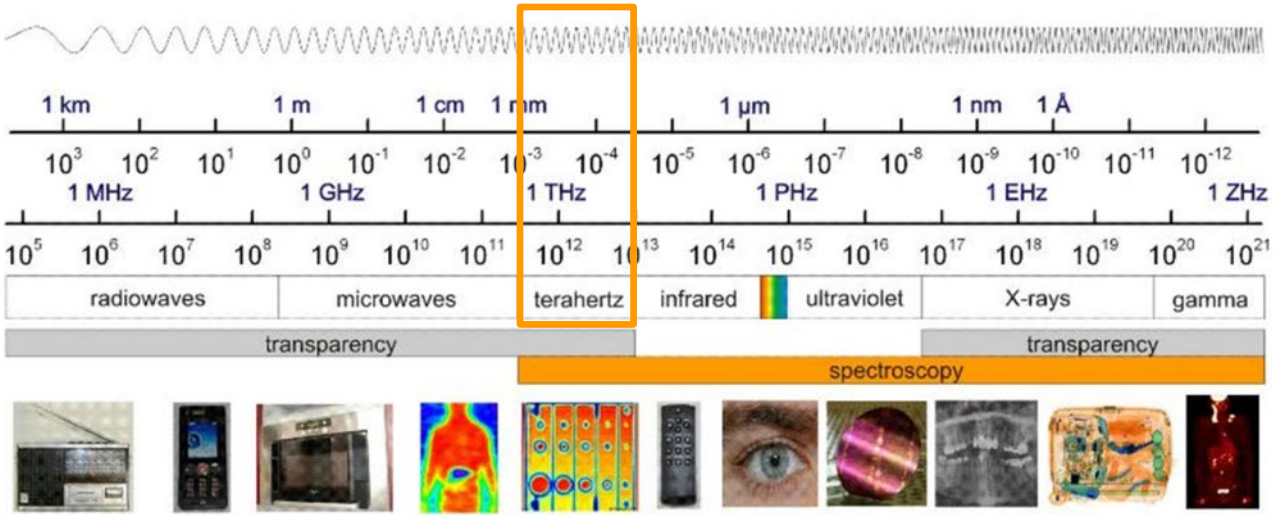
Properties of Terahertz Waves

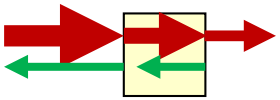
- Electromagnetic waves between infrared and microwave
- 0.1 THz to 10 THz ↔ 3 mm to 30 µm



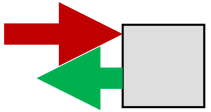
References: Fraunhofer IPM (9), Smiths Detection (1), Forschungszentrum Rossendorf (1)

Properties of Terahertz Waves

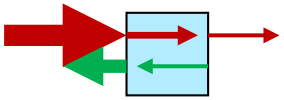
Most materials like plastic, ceramic, paper or semiconductor are transparent.
- Detection of internal structures or inclusions
- Inspection of packed products



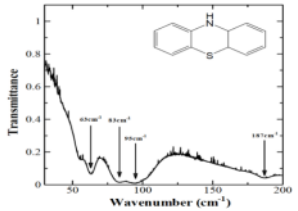
Metals and other electrically conductive materials are reflective.
- No penetration, inspection of surfaces and coatings only



Strong absorption by water.
- Quantitative determination of water content



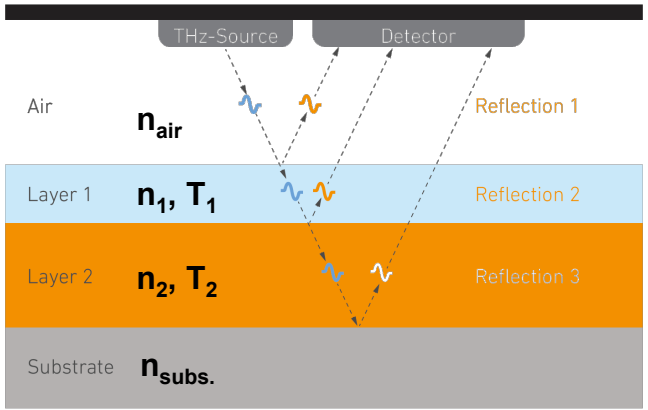
Identification of almost all polar molecules are feasible.
- Identifying substances e.g. drugs, explosives
- Sensitive to structure changes like polymorphism

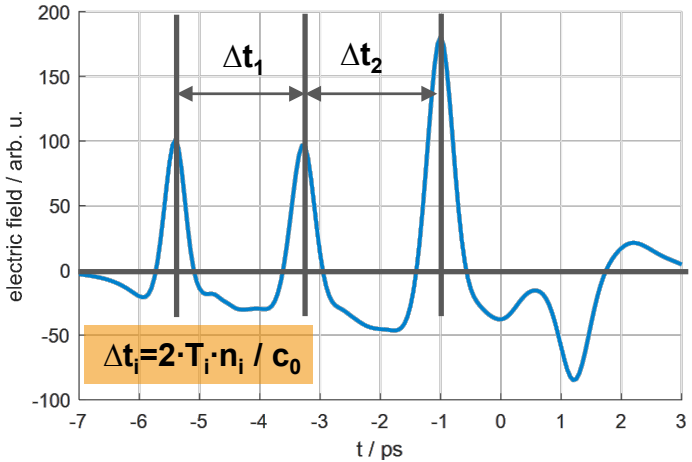


Terahertz waves are safe and harmless.
- No radiation protection necessary

Thickness: Measuring Principle

Measurement Principle: Time of flight measurement; reflection at layer boundaries





THz measurements are based on reflections of layer boundaries (“optical interference effects”).

Time difference between the pulses is related to coating thickness and material properties.

Pulse amplitude depends on material properties of the layers → For evaluation of thickness material characterization of the layers is required

Adjacent layers need to have a contrast in material properties

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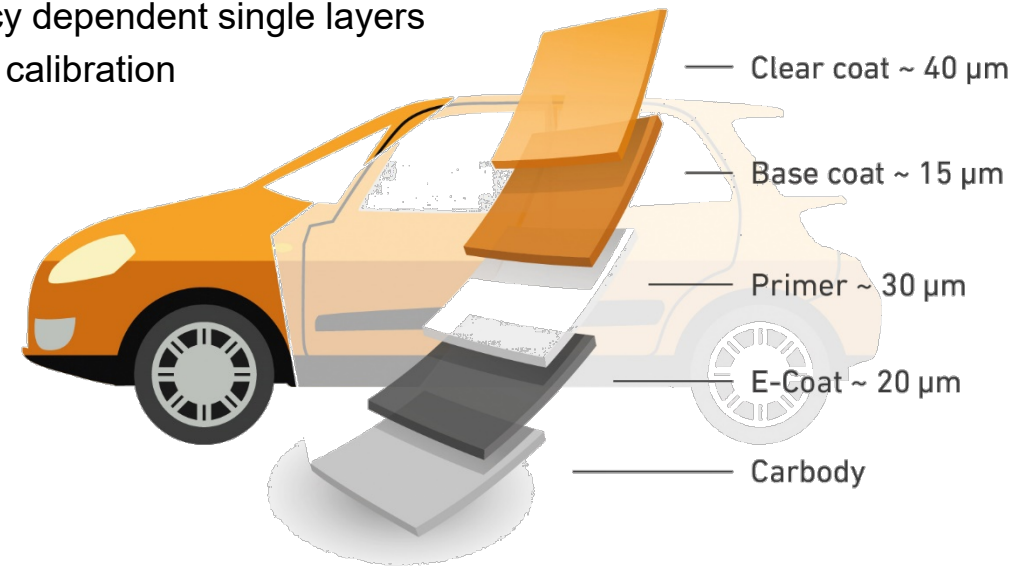
Automotive Application - Advantages of THz Technology

- Perfect application:
  Single multilayer measurement → access to individual layer thicknesses
- Workflow for multilayer measurements
  1. Color Teaching on frequency dependent single layers
  2. frequency dependent stack calibration
  3. multilayer measurements



1. Color Teaching on frequency dependent single layers

Integrated thickness references in THz Lab System

THz Head

- THz System: Autocal & THz measurements

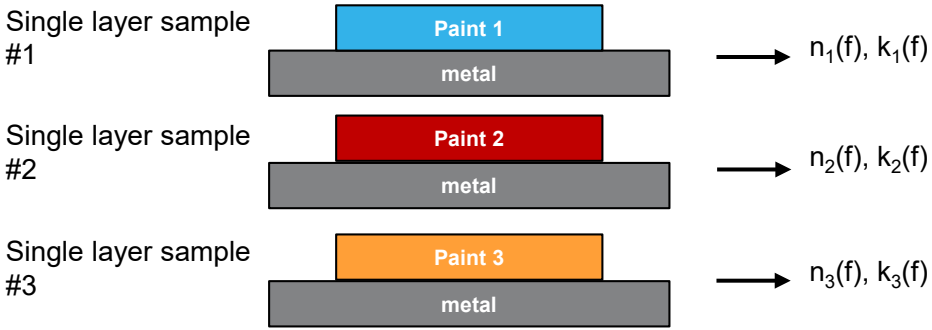
Confocal optical microscope

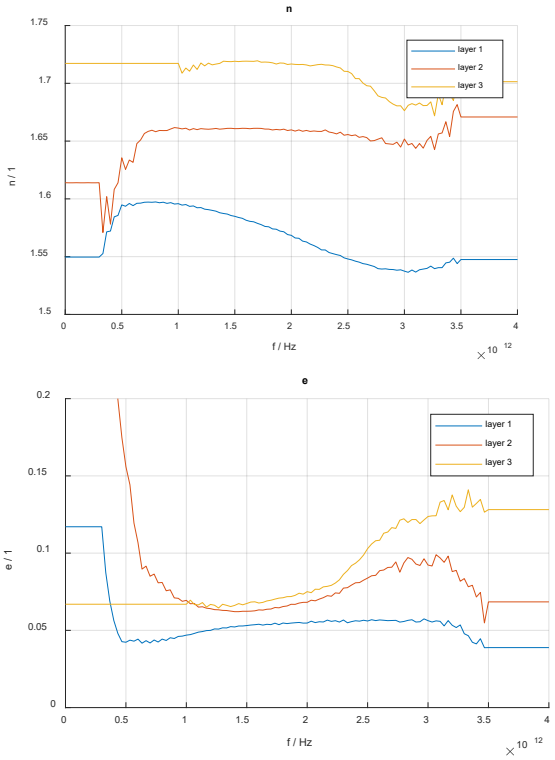
- Global z-axis reference
- Clear coat thickness

Non-contact Eddy/Magna

- Thickness reference values without intendation impact (error)

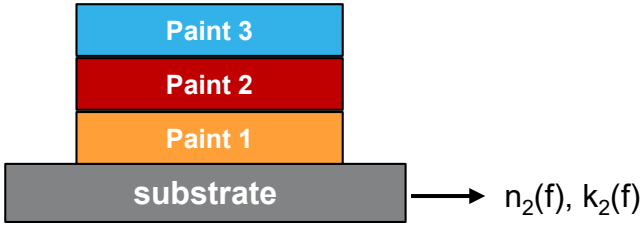
Single layers





2. Frequency dependent stack calibration

Stack calibration

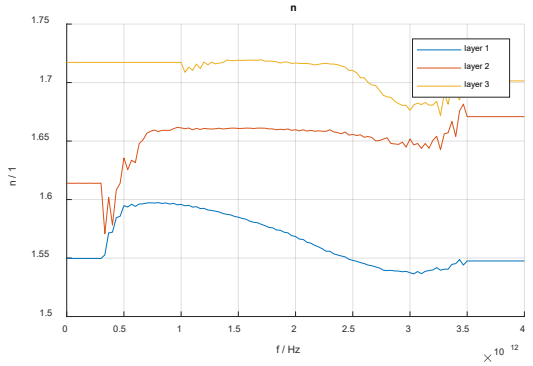


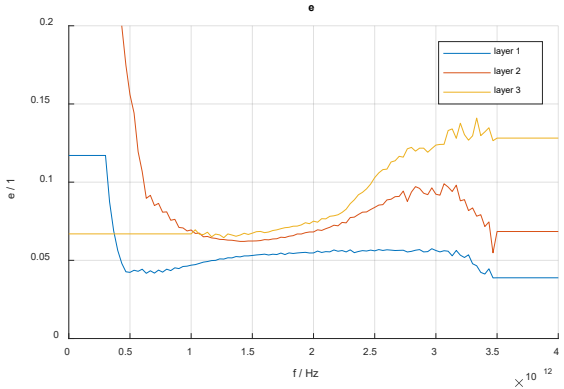
Stack calibration improves accuracy in certain cases

- diffusion zones between stacks
- bad contrast between individual layers

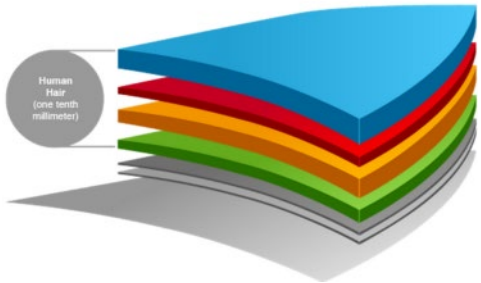
Verification against

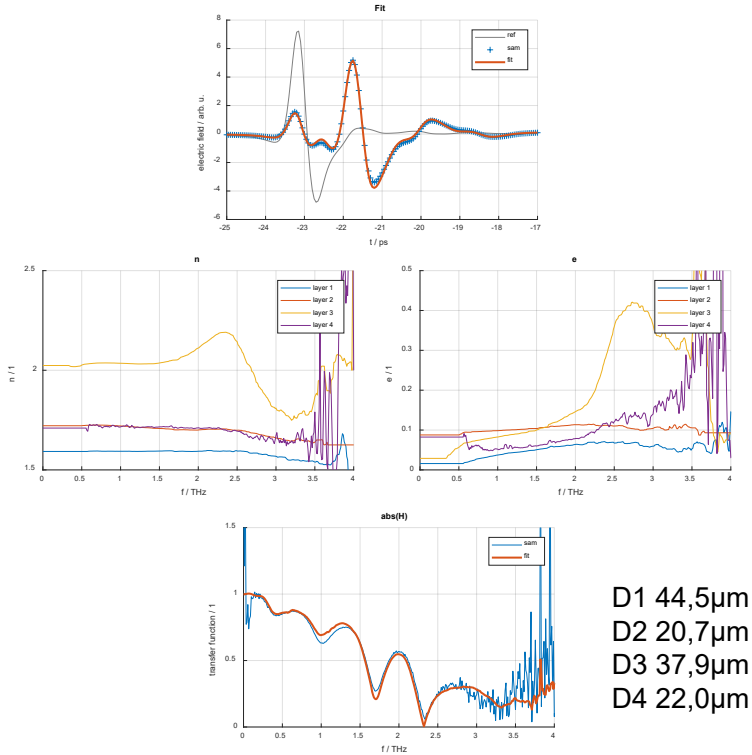
- cross section for individual layers
- Eddy/Magna for total thickness
- Confocal microscope for clear coat thickness
- X-ray thickness measurements





3. Multilayer measurements





D1 44,5µm
D2 20,7µm
D3 37,9µm
D4 22,0µm

Time Domain
THz measurements

⇩

Modelling based
on stack calibration

⇩

Fitting

⇩

Thickness values

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FISCHER THz System for Color-Teaching and Process Testing

- Optical profile and non-contact magnetic inductive reference measurements for total paint thickness
- Vacuum table for planar sample geometry
- Dedicated sample substrate and paint pattern for automated low-cost color-teaching
- Purge air conditions for highest color-teaching accuracy

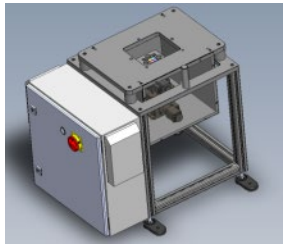
FISCHER THz System For Automation Application

Ideally suited for multilayer film thickness measurements in industrial applications

Key Features for automation:

- Optical surface detection (curvature, direction) for alignment of the THz Head
- Active vibration compensation for harsh environments
- High reliability, 24/7 operation
- Fieldbus interface for external control

THz System for Automation: Overview



Head

Optical sensors:

- object detection

- vibration detection

THz-sub assembly

Ref. & Cal. Station

Fibers (up to 15m distance

TCP/IP

TCP/IP

THz Rack 19“

fs Laser

Delay

shaker

data acq

THz System control IPC 19“

Cabinet

TCP/IP

Material database

Ext. control Robot cell

Profinet Profibus

Gateway

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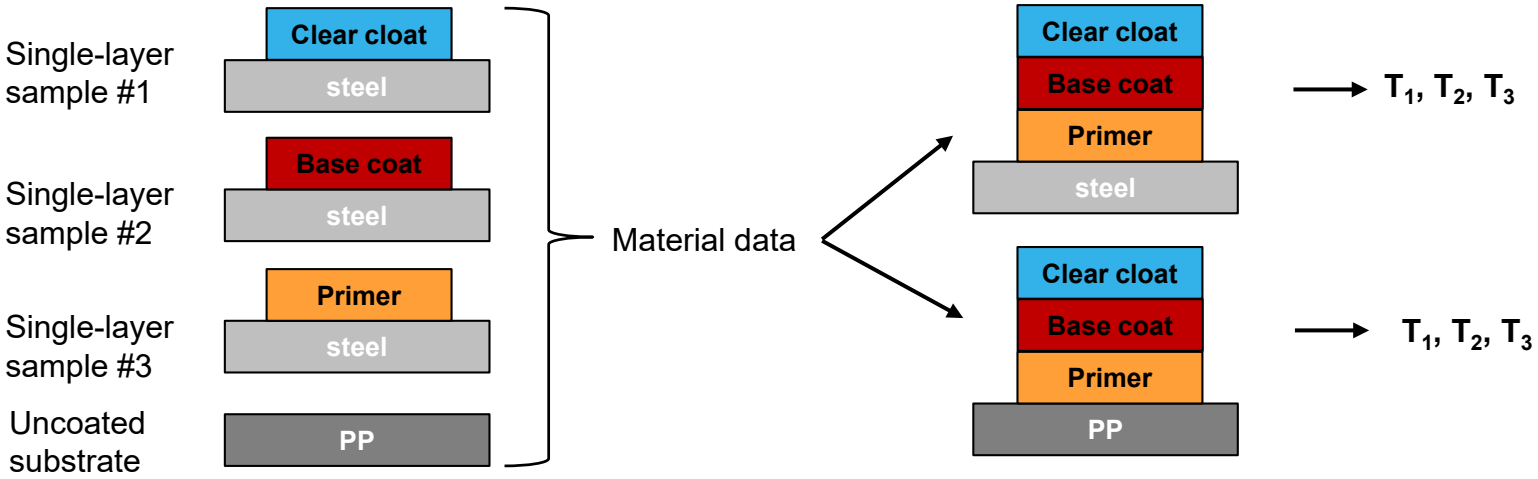
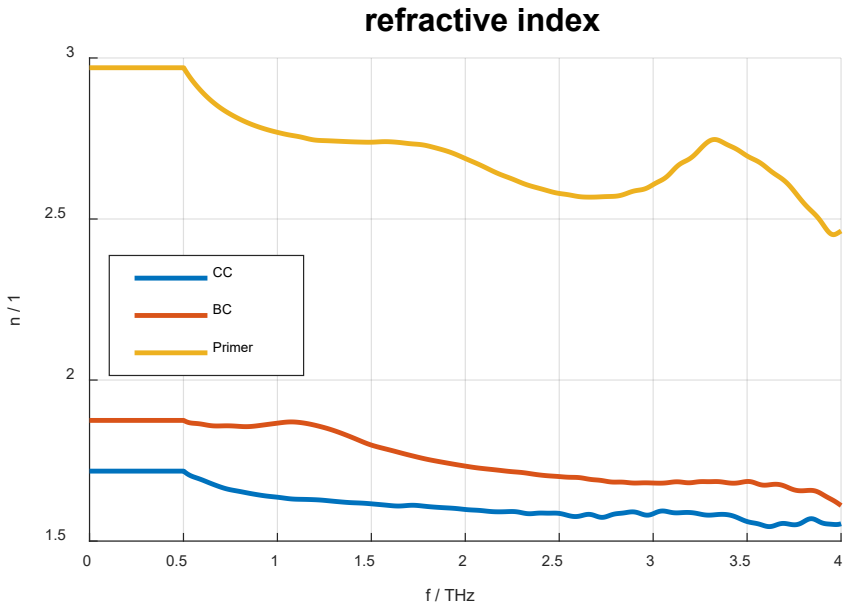
Application Example: Multilayer Stack on various Substrates

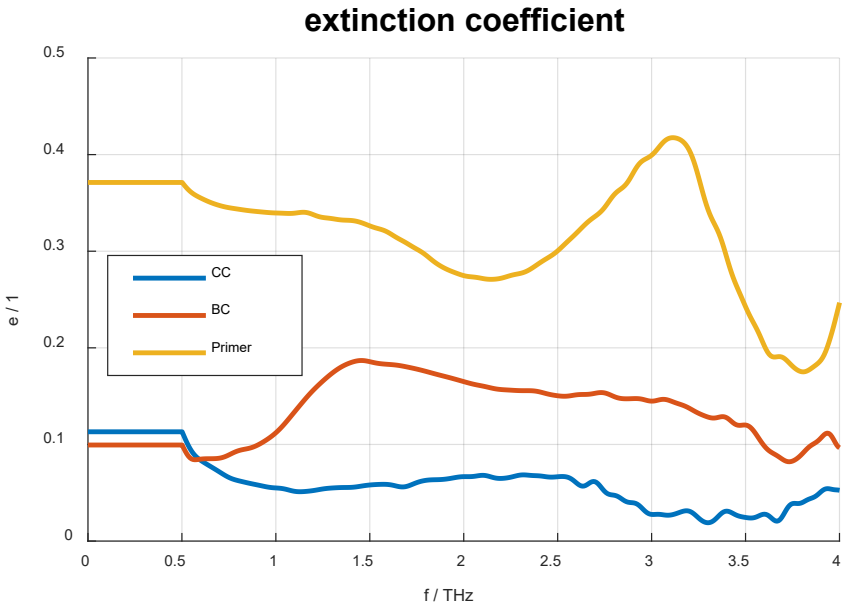
- Three layer stack consisting of clear coat, base coat and primer
- Stack was applied on metal and PP
- Each paint was also provided as single-layer on steel for color-teaching purposes



Multilayer systems: Material data

Example: stack on metal

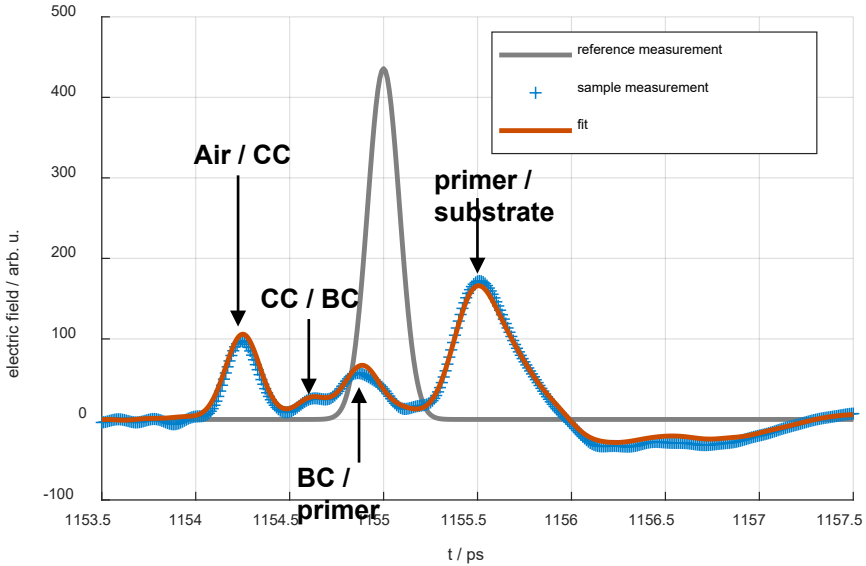




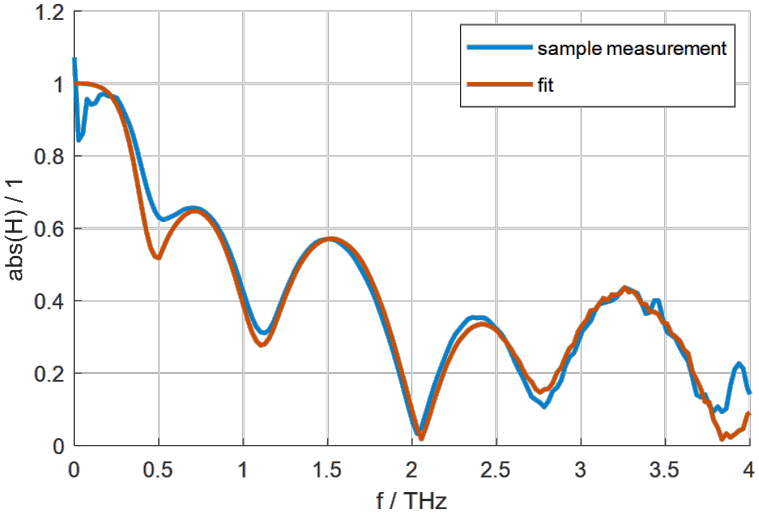
Material data derived from single-layer samples

Multilayer systems: Evaluation

Example: stack on metal



Fit in Time Domain



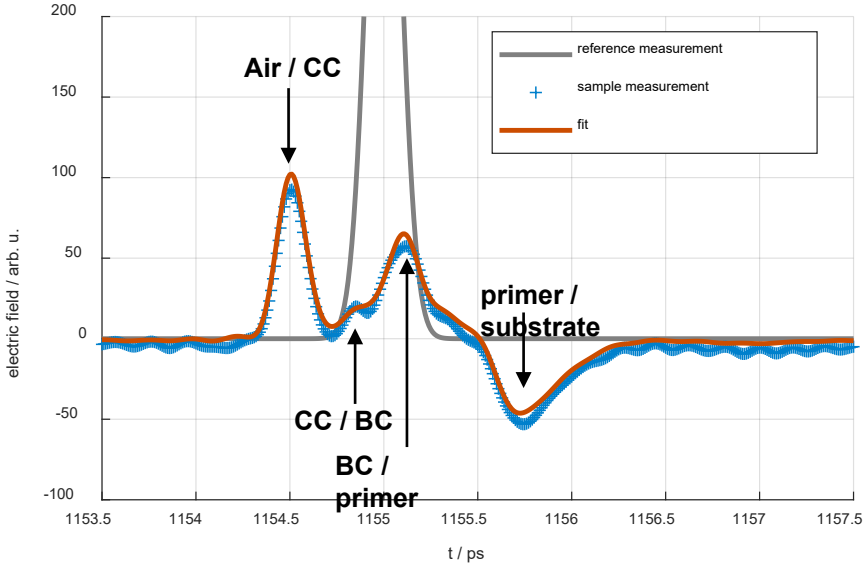
Fit in Frequency Domain

Derived thickness values (in µm):

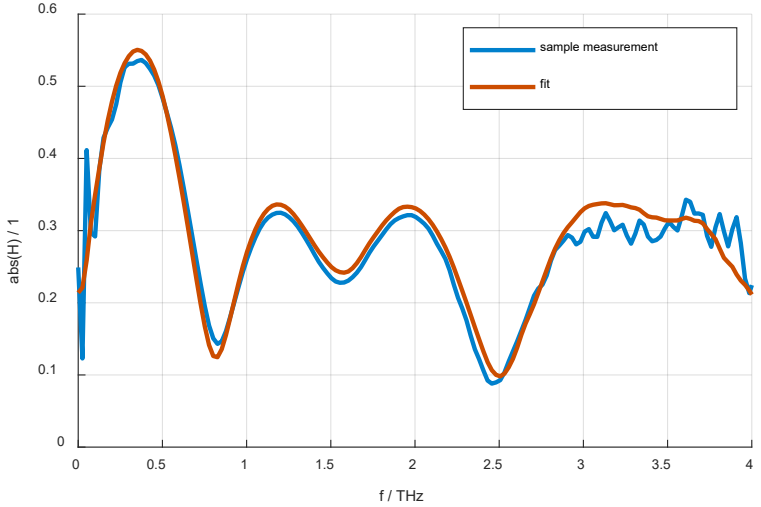
CC:	33.1
BC:	**24**.1
Primer:	**35**.2

Multilayer systems: Evaluation

Example: stack on PP



Fit in Time Domain



Fit in Frequency Domain

Derived thickness values (in µm):

CC:	32.1
BC:	23.3
Primer:	33.1

Multilayer systems: Results

*non-contact magnetic-inductive probe
All values given in µm

Single-layers

Testing point	CC THz	BC THz	Primer THz
1	32.7	23.8	34.0
2	33.5	24.8	35.6
3	32.6	22.8	34.8

Multilayer Metal

Testing point	CC THz	BC THz	Primer THz	∑ THz	∑ Magn. Ind.*
1	33.3	24.1	35.2	92.6	94.2
2	32.4	24.7	34.5	91.6	93.2
3	34.8	24.1	33.9	92.8	94.2

Multilayer PP

Testing point	CC THz	BC THz	Primer THz	∑ THz
1	32.1	23.3	33.1	88.5
2	32.8	24.5	34.2	91.5
3	32.0	24.7	31.6	88.3

Repeatability (standard deviation)

system	CC THz	BC THz	Primer THz	∑ THz
Lab system without repositioning	0.3	0.15	0.15	0.05
Robot mounted system with repositioning	0.4	0.2	0.4	0.09

→ Very good agreement between results on single-layers and different multi-layers

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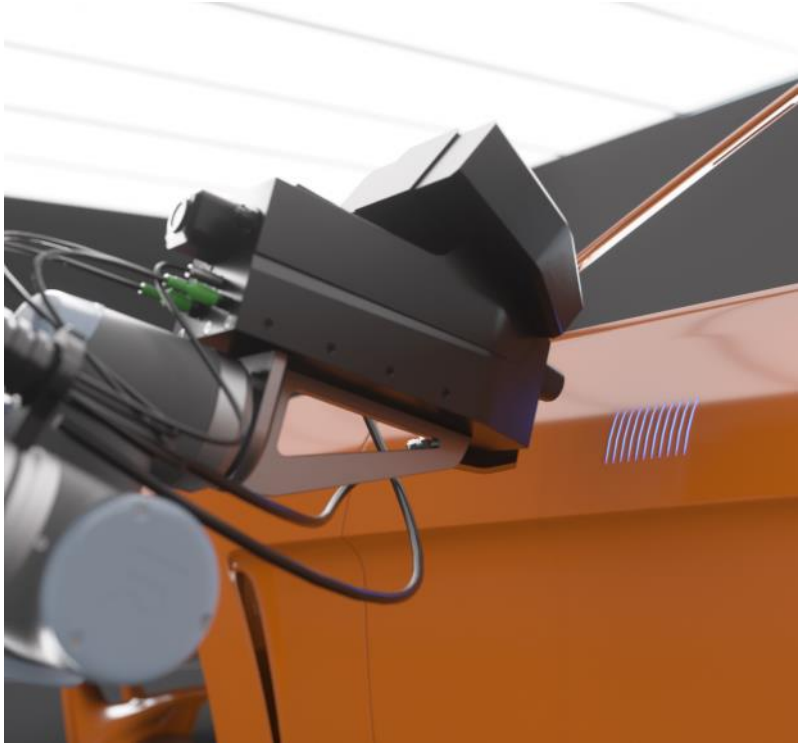
Advantages of THz Technology



Substrate-independent

- Paint systems can be measured on all base materials of interest (Zn coated steel, metals e.g. Al, plastic, ceramics, carbon fiber-reinforced plastics etc.)

Multilayer Capability

- Thicknesses of all layers in a multilayer system are determined individually

Easy Automation

- Contactless measurement simplifies introduction into automated lines

Advantages of THz Technology

Non-contact Technology

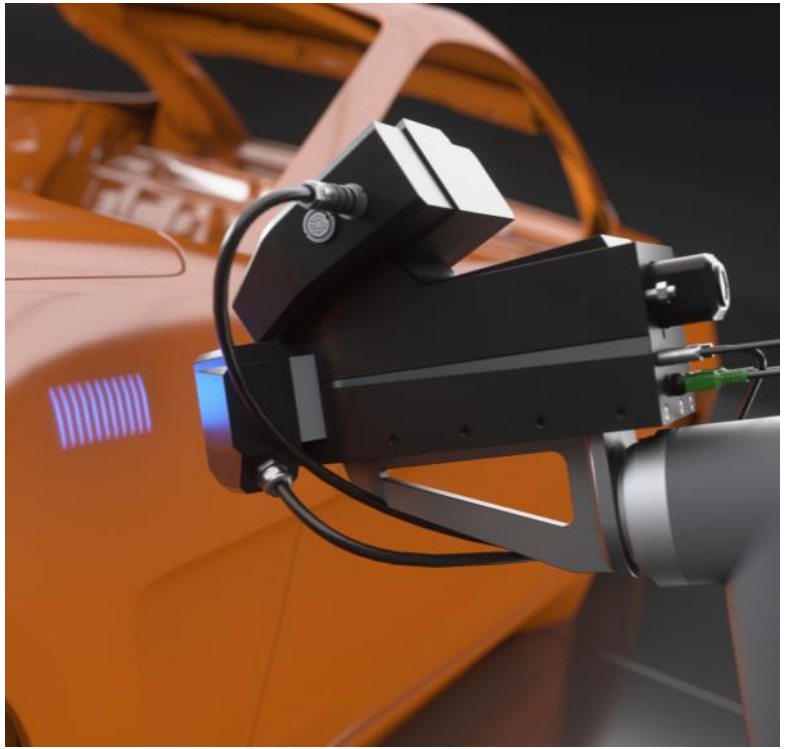
- No couple medium, no contact with sample surface, no contact pressure

Non-destructive Testing

- Tested objects exit the metrology process entirely unchanged

Fast and reliable Measurement

- Highly reliable metrology results in less than 1 sec



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Next steps towards market introduction

Commercial:

- 2017/2018: first on site demos with paint manufacturers
- 2019: offline installations at various car manufacturers and automotive suppliers
- Q1/2020: first inline installation at car manufacturer
- Q2/2020: Market introduction

Technical:

- 2020: Bandwidth expansion to 8 THz, measurement speed improvement to 1.5kHz
  → higher thickness resolution
  → better layer separability

TERASCOPE® TDS 5: Performance & Properties

General:

- Beam Size on Sample: 1mm @ 1 THz
- Bandwidth: 5 THz@100 averages
- Acquisition speed: 5ms to several seconds
- Working distance: 70mm (THz), 35mm (optical sensors)
- Working range: +/-10mm (optical sensors)

Single layer measurement:

- Thickness Range from ~10µm up to several millimeters
- Thickness Accuracy <1µm or <1% of thickness
- Thickness Repeatability typical 0.1µm

Multilayer measurement:

- Maximum 7 Layers
- Thickness Accuracy typical ~1µm or 1% of thickness, dependent on application

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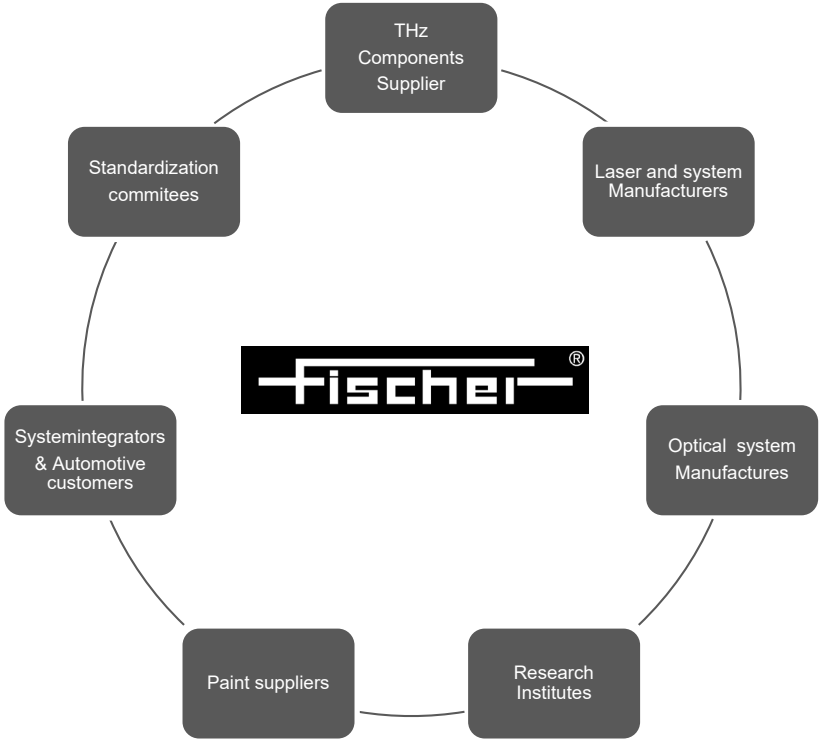
Strategic Cooperations in THz Technology: The Fischer Terahertz Network



FISCHER is YOUR Partner in Terahertz

Strategic partnerships in Terahertz Community and Laser Industry
- Direct access to industry proven components and systems
- Cooperation with THz technology partners and their ongoing developments

Globally active
- 21 subsidiaries and more than 50 contractors
- Available in your area, in your language

Premium customer support
- Reliable and competent
- Short reaction times
- Outstandingly trained staff in customer support

We offer comprehensive Services
- Application laboratory support
- Tailor-made support and life cycle management

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THANK YOU FOR YOUR ATTENTION

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