

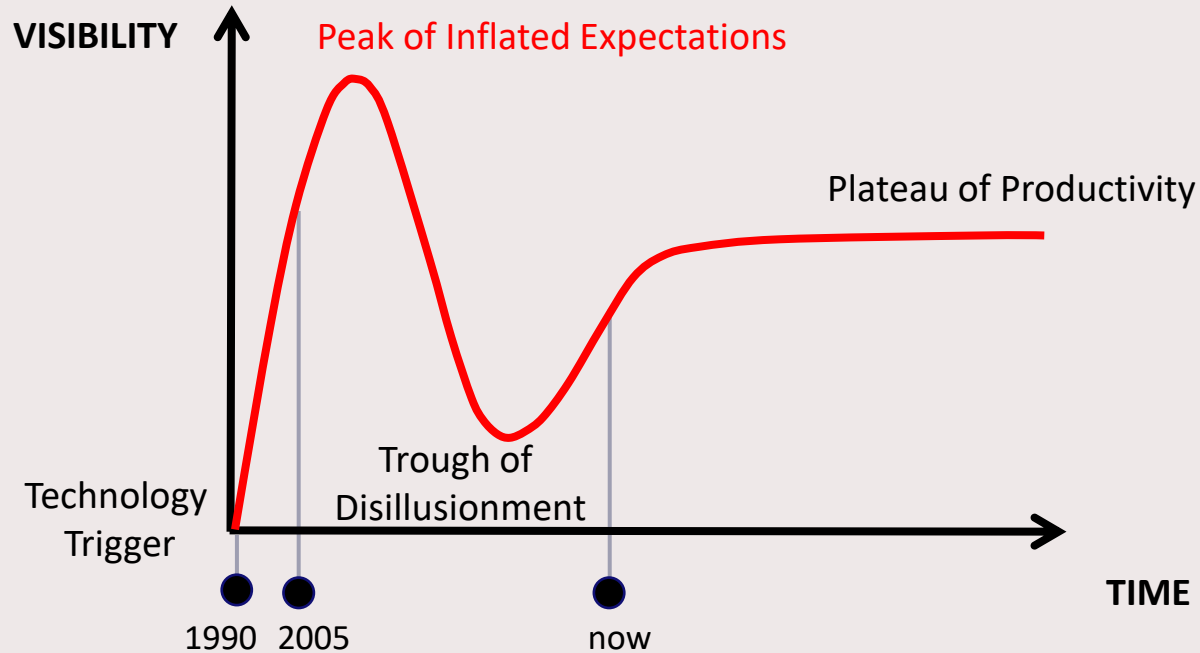


The path of THz technology to the consumer market

DO WE NEED A KILLER APPLICATION?

Dook van Mechelen

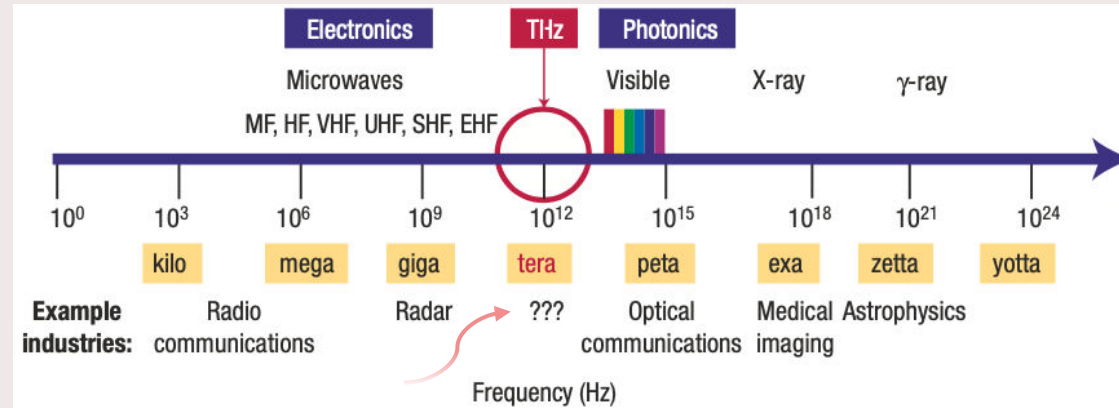
THz technology



Back to 2000



- THz spectroscopy systems: FTIR, THz-TDS
- THz applications: material characterization (chemistry, astronomy, superconductors)
- *Outlook*: biomedical imaging, genetic diagnosis, distant galaxies and quantum interactions



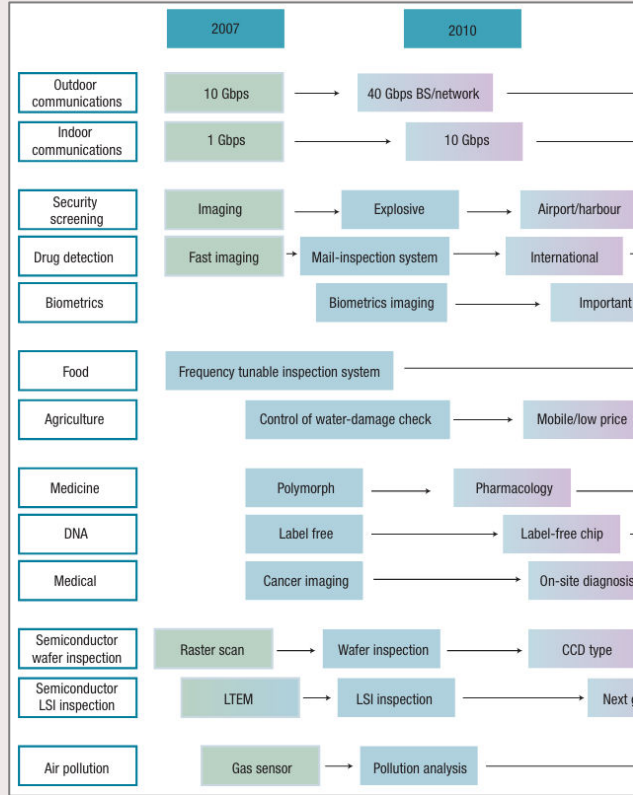
2000

- Little technology
- No signal processing
- No idea of applications

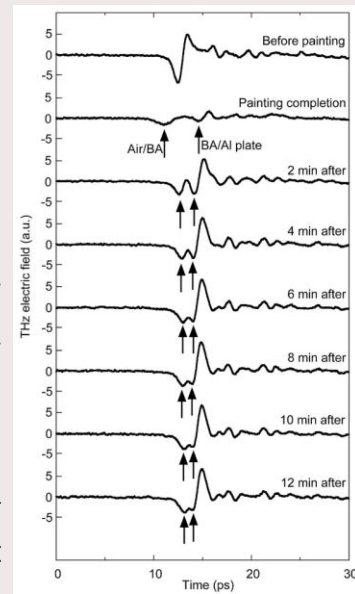
Nature mat. 1, 26 (2002)

In 2010 “Endless applications”

Nature phot. 4, 140 (2010)



- THz systems: first THz cameras, QCLs, ECOPS
- THz appl.: inspection of materials, security, astronomy
- Outlook: low-cost THz system; biomedical; high power sources, sensitive detectors; database in THz range

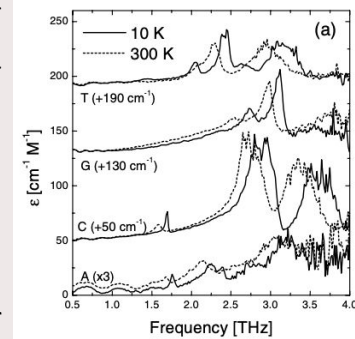


Appl Optics 32, 6849 (2005)

2010

- Application fields
- Technology gets less academic
- No signal processing

Phys. Med. Biol. 47 3807 (2002)



In 2020 “An Industrial THz Killer Application?”

Opt. Phot. News 26, 16 (2015)

A dormant hope

- THz technology,

“should have a novel, innovative use with a business case strong enough to bring it into the industrial mainstream”

How to bring THz mainstream

- Combine state-of-the-art sensors & be cheaper
- Outperform the state-of-the-art
- Novel application with an innovative use



In 2020

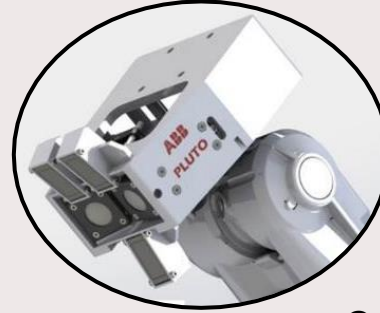
“An Industrial THz Killer Application?”

Opt. Phot. News 26, 16 (2015)



Agri-food

potential
**THz applications
related to materials**



Quality control



Medical



Security

THz quality control: sensing paint layers



Why THz?

Feature

Low photon energy

Only technology that
can measure wet paint

Sensitive to water

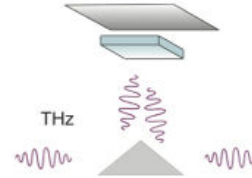
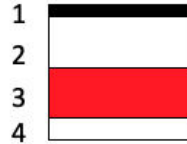
Time-domain acquisition

Form factor and price
are no issue

THz quality control: robust signal processing

Describing the THz light-matter interaction

Measurement
design



- Reflection setup
- In ambient air
- In presence of humidity

Analysis
model

$$E(\omega) = E_0 T_1 T_2 e^{i\left(\frac{n\omega}{c}\right)d} \times \dots \left(1 + R_2^2 e^{2i\left(\frac{n\omega}{c}\right)d} + \dots \right)$$

- Fresnel equations
- For multilayer system
- Include dispersion of $n(\omega)$

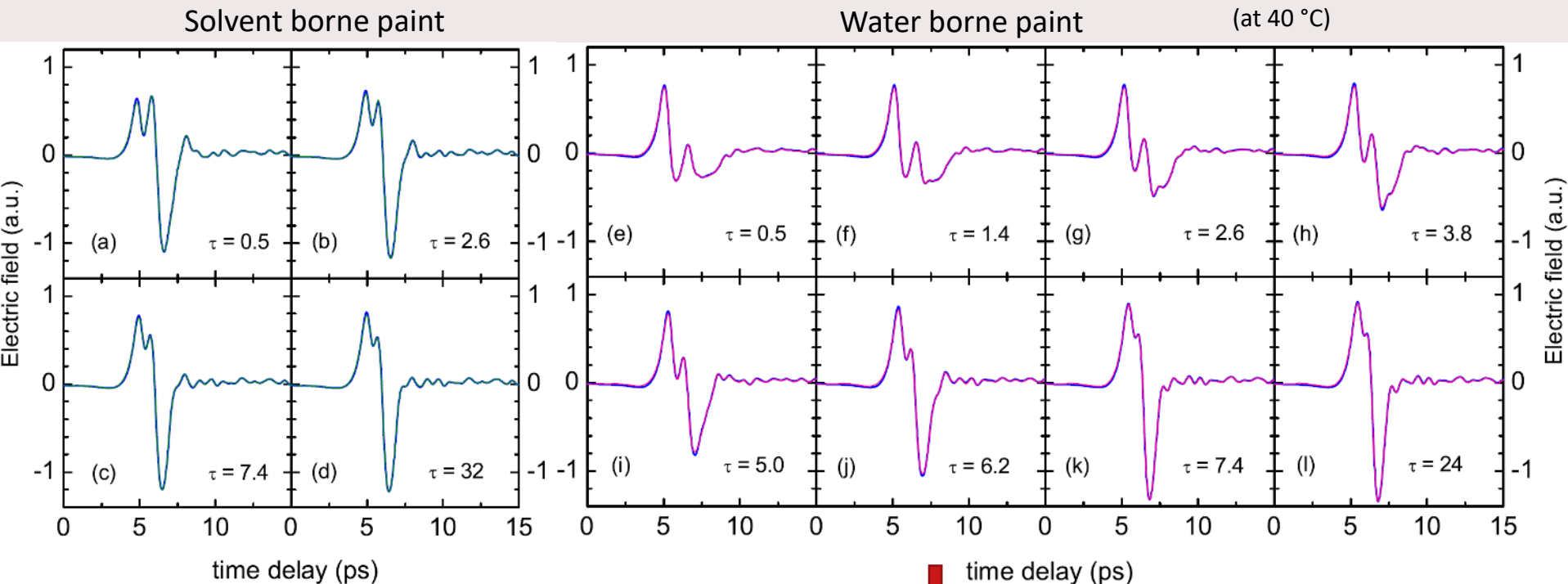
Fitting
procedure

$$E_r^{model}(\omega) \text{ matched to } E_r^{exp}(\omega)$$

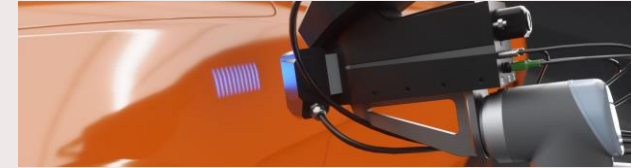
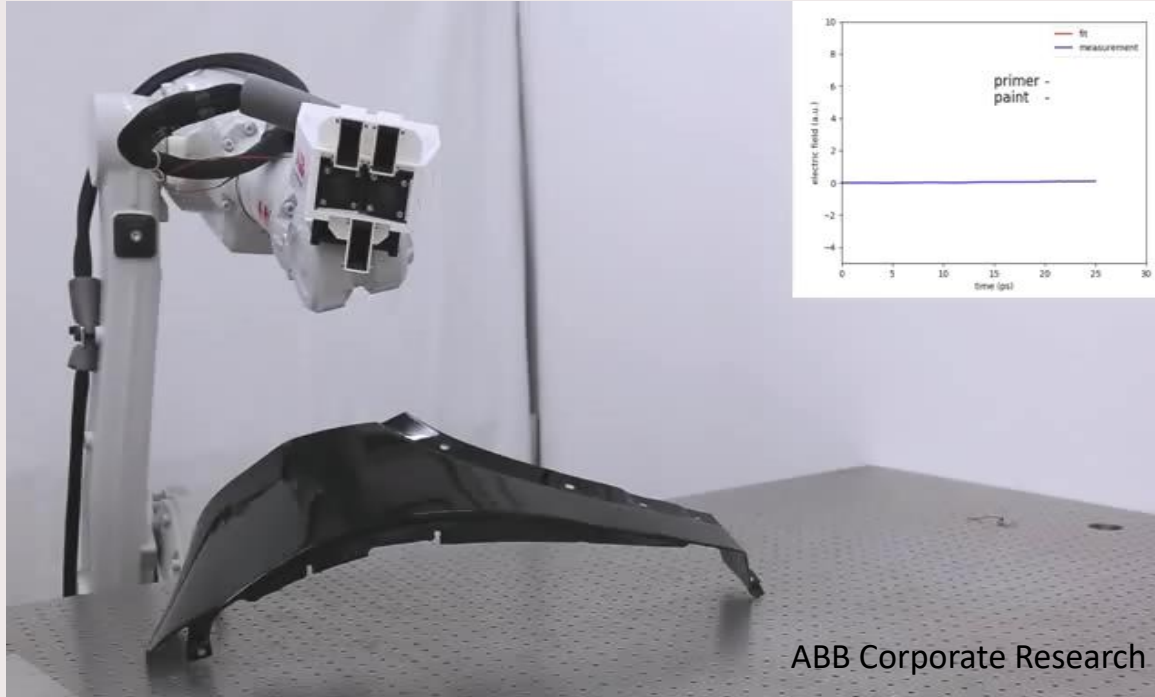
- Least-square algorithm
- Finding global minima
- Obtains unique set of $n(\omega)$ and d

Langmuir 30, 12748 (2014), Optics Letters 39, 3853 (2014)

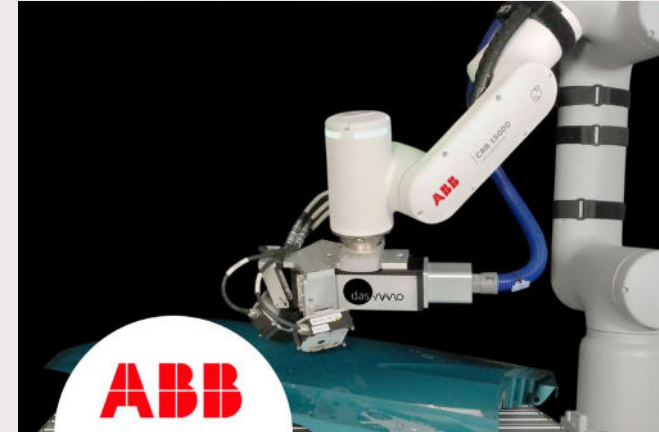
THz radiation probing drying coatings . . . universally for all automotive coatings



Paint sensor for automotive industries



Helmut Fischer GmbH

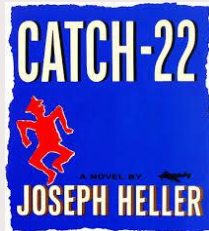


das-Nano

How to bring THz technology to the market?

2022

- + Ideas of application fields
- + Systems suited for niche markets
- + Model-based signal processing
- No idea of a wide-spread application
- No cheap, miniaturized systems
- No large industries that see value



Chips Act



Some thoughts

Industrial killer applications

- Niche markets
- Technology today may be ready
- Why THz?

Consumer killer applications

- Novel application with an innovative use
which (part of) society will consider indispensable
- Technology is not existent
- Semiconductor industry (Intel, Samsung, Qualcomm,...) may take ownership

Some thoughts

Industrial killer applications

- Niche markets
- Technology today may be ready
- Why THz?



Consumer killer applications

- Novel application with an innovative use
~~which (part of) society will consider indispensable~~
- Technology is not existent
- EU may have leadership

Some thoughts

Industrial applications

- Agriculture sensing
(e.g. reactive nitrogen)
- Security
- Layer thickness monitoring
- THz communication
- THz radar

Consumer applications

- Food sensor
- Affective sensing

One way out

- Chip sector investing in future technologies without seeing immediate benefits:

f_{\max} will anyway go up, but market share may go to others

- Supported by the Chips Act 2030
- Research to increase TRL level of application ideas