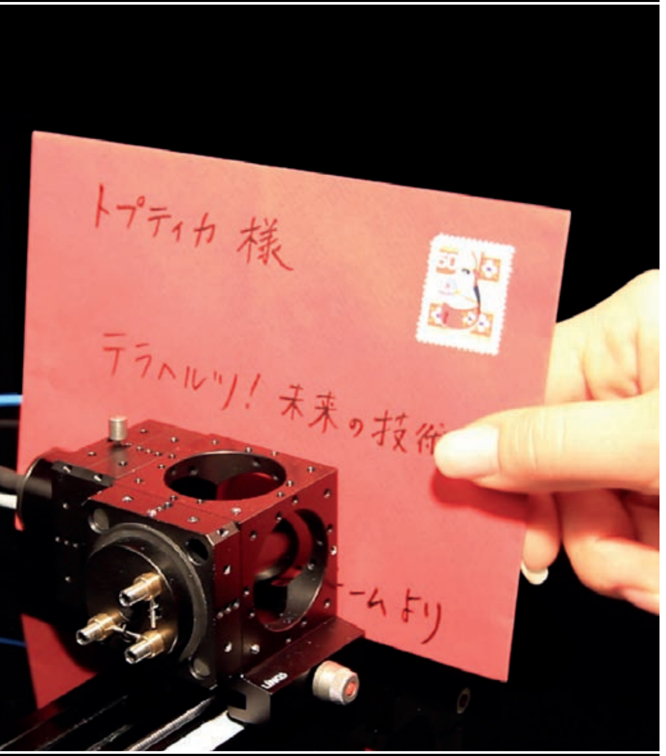
Terahertz Technologies
Systems and Accessories

Plastic Inspection
Paint and Coating Layers
Industrial Quality Control
Non-Destructive Testing
Material Research
Gas Sensing
Metamaterials and Micro-Optics
Fundamental Physics

TOPTICA PHOTONICS



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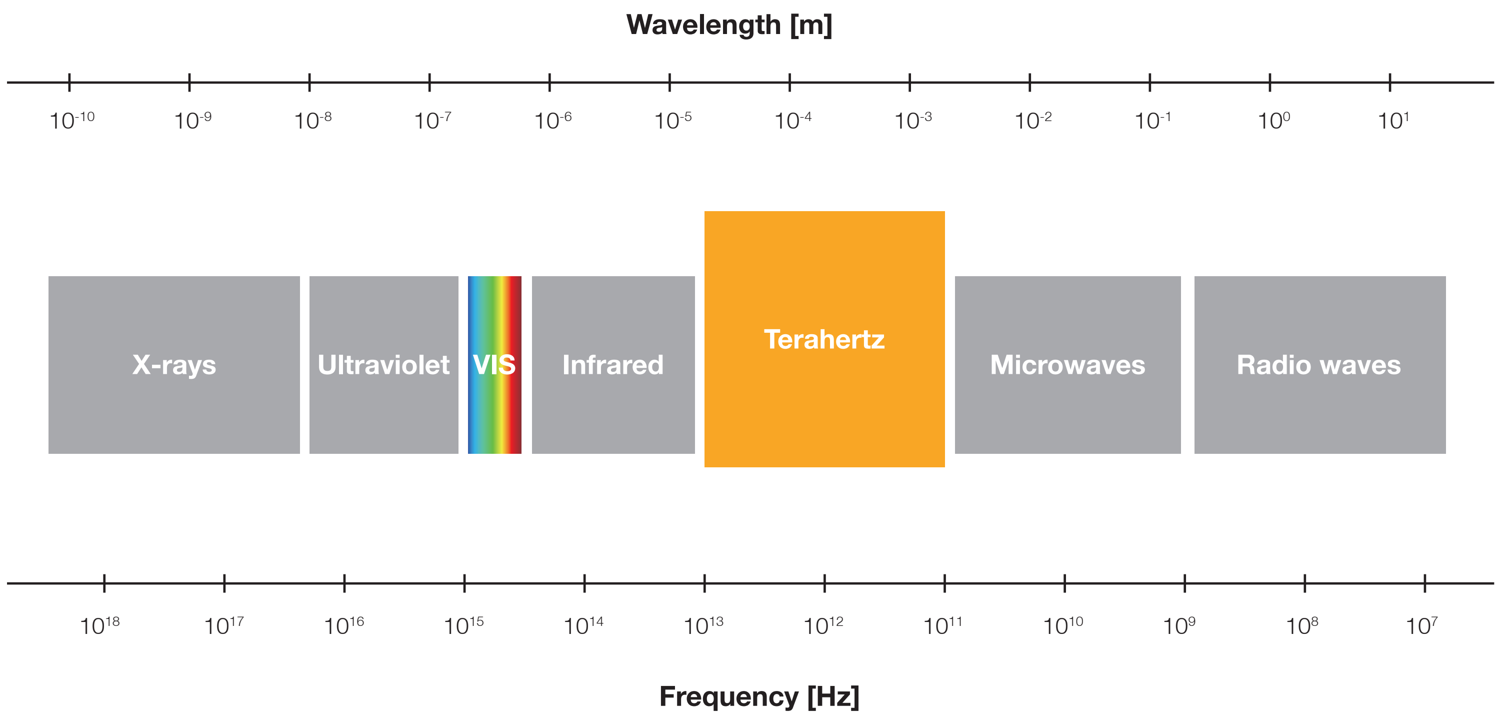


Terahertz Waves
The Final Frontier of the Electromagnetic Spectrum

Between Microwaves & Infrared

The terahertz range refers to electromagnetic waves with frequencies between 100 GHz and 10 THz, or wavelengths between 3 mm and 30 µm. Light between microwaves and infrared has some unique properties. Terahertz waves can “look inside” plastics and textiles, paper and cardboard. Many biomolecules, proteins, explosives and narcotics also feature characteristic absorption lines – so-called spectral “fingerprints” – at terahertz frequencies. Unlike X-rays, terahertz waves do not have any ionizing effect and are generally considered biologically innocuous.

Closing the Terahertz Gap

For a long time, it has been difficult to generate intensive, directional terahertz radiation, and the terahertz range was considered the final frontier of the electromagnetic spectrum. Now, frequencies between 0.5 and 10 THz have become the domain of laser-based techniques. Optoelectronic approaches use either femtosecond lasers or tunable diode lasers. Photomixers, photoconductive switches or nonlinear crystals convert the near-infrared laser light into terahertz waves, either broadband or spectrally resolved. The terahertz gap is bridged at last.

The Complete Portfolio

With more than 150 complete systems and 500 lasers for terahertz generation in the field, TOPTICA has become one of the most successful suppliers of terahertz instrumentation world-wide. Our ultrafast fiber lasers form the basis of the time-domain systems TeraFlash pro, TeraFlash smart and TeraSpeed, and precisely tunable diode lasers lie at the heart of the frequency-domain platform TeraScan. In more than 30 countries around the globe, TOPTICA’s terahertz customers engage in fields as diverse as trace-gas sensing and low-temperature physics, the development of metamaterials and micro-optics, material inspection, layer thickness measurements and terahertz communication.

Applications

- Plastic Inspection
- Paint and Coating Layers
- Industrial Quality Control
- Non-Destructive Testing
- Material Research
- Gas Sensing
- Hydration Monitoring
- Ultrafast Dynamics
- Communication
- Metamaterials and Micro-Optics
- Fundamental Physics

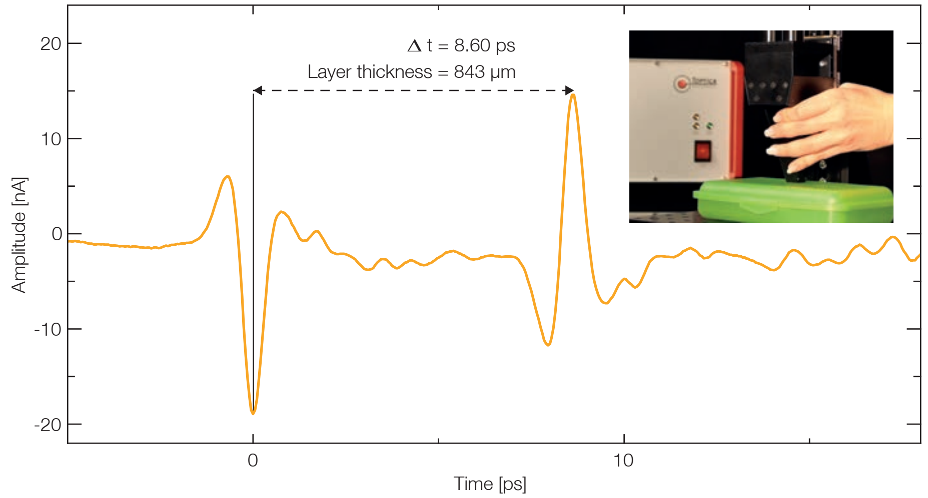
TERAHERTZ APPLICATIONS

Plastic Inspection

Accurate thickness measurements play an increasingly important role in the production of extruded polymers: Plastic pipes and bottles require a minimum wall thickness for mechanical stability, yet material costs increase drastically once the layers become too thick. A variety of conventional techniques exist, including ultrasonic testing, x-ray CT, magnetic gauges and eddy-current measurements. However, they all face challenges: either in terms of radiation hazards, or contact media required, or they are limited with respect to depth resolution and measurement speed.

Many polymer materials, though optically opaque, exhibit a pronounced low absorption at terahertz frequencies. Pulsed terahertz radiation can thus provide information of an object's thickness, even in multi-layered samples, via time-of-flight techniques: Each layer interface reflects a part of the incident pulse, and the time elapsed between the arrivals of pulse "echoes" from either side is directly proportional to the optical thickness of that layer.

Applications of terahertz radiation in thickness profilometry are not limited to extruded polymers though: In chip production, polymer coatings shield the semiconductor from moisture, dust and mechanical stress. In jet engines, ceramic thermal-barrier coatings protect turbine components from high temperatures and wear. The majority of coating materials are sufficiently transparent for terahertz light to enable contact-free thickness measurements.



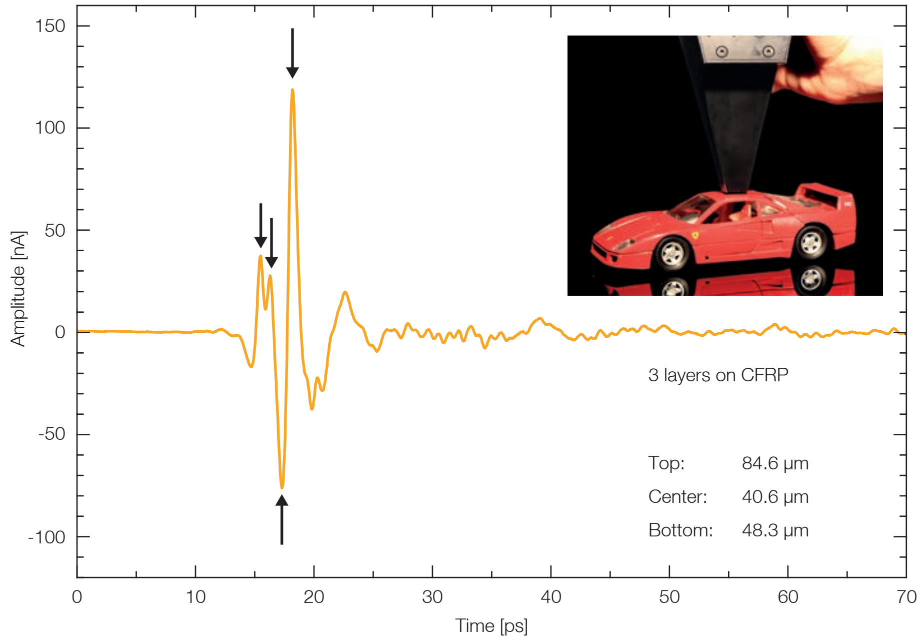
Pulse trace obtained with TOPTICA's TeraFlash pro and a piece of high-density polyethylene. The pulse spacing of 8.60 ps corresponds to a wall thickness of 843 µm.

Paint Layers

Measuring the thickness of paint layers forms an important step in automotive manufacturing. The layers not only give a vehicle its color, but also provide protection against scratches, corrosion and chemicals. Therefore, color pigments, smoothing "primers" and protective coatings all cover a substrate made of steel or carbon-fiber composites, with each layer having a thickness of a few ten microns only.

Most of the traditional thickness gauges require physical contact to the layer under test, and fail in case of non-metallic substrates. Terahertz pulses, by contrast, resolve the thickness of each individual layer, as long as adjacent coatings differ in their refractive index.

Layer thickness analysis combines time-of-flight measurements of terahertz pulse echoes with elaborate data post-processing, which involves time-trace simulations and advanced fitting routines. This method has proven successful: TOPTICA's customers have achieved thickness measurements down to 5-10 µm, with accuracies on the single-micron level.



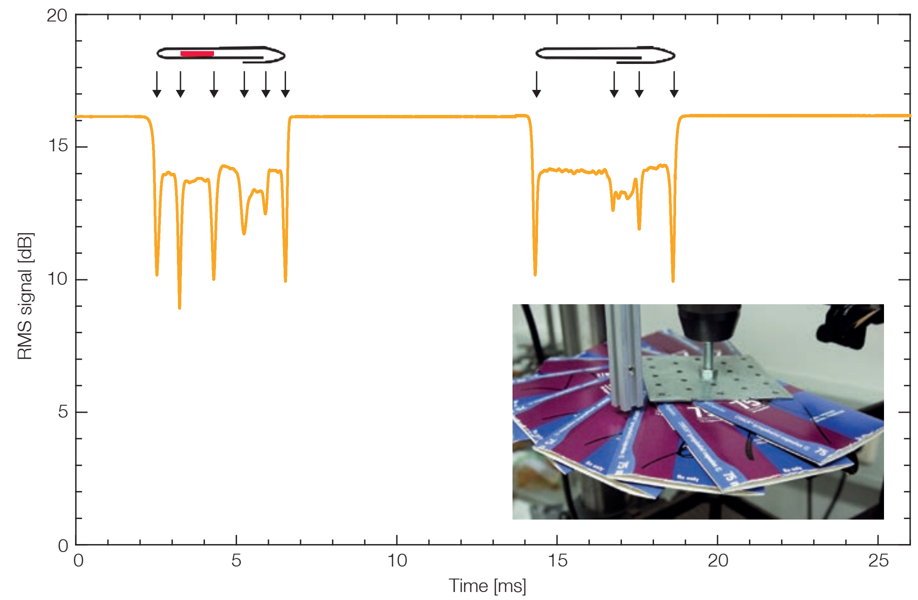
Pulse echoes of a carbon-fiber-reinforced polymer substrate with three different coating layers. The arrows indicate the reflections at the respective interfaces.

Industrial Quality Control

Applications in quality and process control take advantage of terahertz systems that are inherently safe, work in a contact-free manner and achieve a very high measurement speed. The latter aspect becomes particularly relevant if the task involves rapidly moving samples, e.g., if items on fast conveyor belts need to be screened with single-millimeter resolution.

One emerging application is quality control of folded cardboard boxes used for packaging pharmaceuticals. European legislation dictates that pharmaceuticals may only be sold with patient information leaflets enclosed. While this requirement necessitates "100 % inspection", present-day techniques still rely on weighing large batches of boxes, a method that provides integral values only.

In proof-of-principle measurements, TOPTICA's researchers showed that fast terahertz screening detected the presence or absence of a package insert unambiguously. The method succeeded even for samples moving at more than 20 meters per second, and for boxes that overlapped in a tile-like manner.



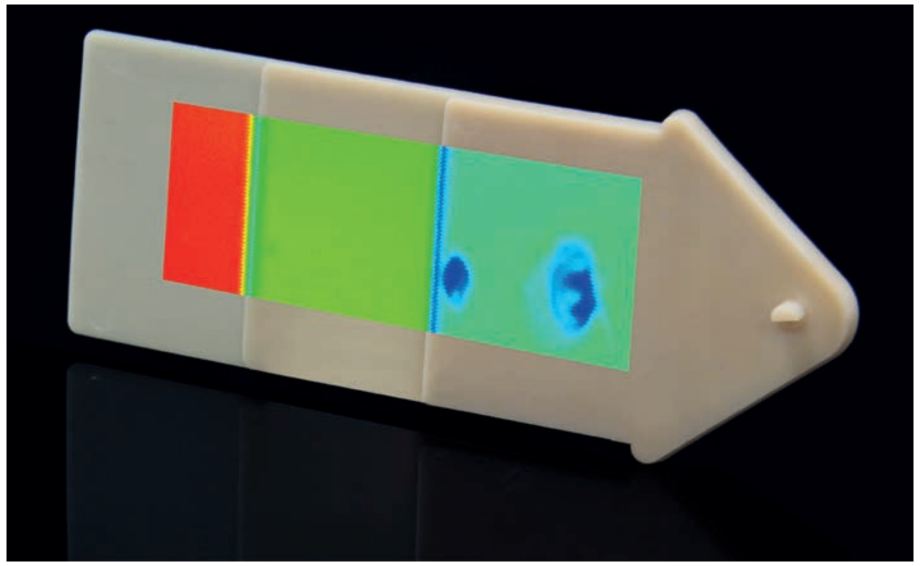
1D-scan of folded cardboard boxes with and without a package slip. The graph shows the transmitted terahertz intensity while the boxes moved at a velocity of 21 m/s. In the example, the TeraSpeed recorded more than 150,000 intensity values per second.

Non-Destructive Testing

Terahertz systems offer a unique combination of imaging and spectroscopic methods. Terahertz waves penetrate materials like plastics, paper and – to some extent – textiles. They can thus reveal the presence of concealed objects, e.g., in mail envelopes, and identify the material in question using spectroscopic techniques.

Pulsed terahertz radiation not only measures an object's reflectance, transmittance or chemical composition, but also probes its depth profile. Scanning a sample with the help of a terahertz beam then generates a three-dimensional image that pinpoints sub-surface cracks, voids and delaminations.

The liquid state of water generally provides a stark contrast in terahertz imaging – a property exploited in humidity measurements in paper production lines. Water contrast terahertz imaging can help to avoid drought stress and optimize irrigation strategy by monitoring plant leaves. This is a topic of relevance for agricultural crops in arid regions where desertification and water shortages present serious threats.

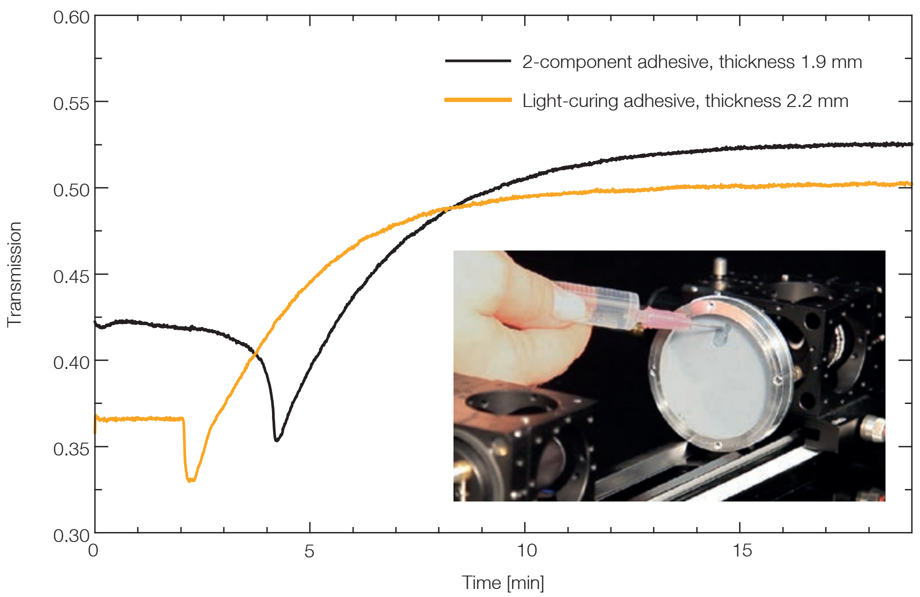


Photograph and overlay terahertz image of a plastic step-wedge with two sub-surface voids.

Material Research

Terahertz spectroscopy helps uncover the properties of a variety of substances. Refractive-index measurements complement the information gained from amplitude data: In polymers, the variation of the refractive index with temperature reveals minute structural changes. For fiber-reinforced plastics, the refractive index yields information on the orientation of the fiber strands. For ceramics, the optical properties change with the transition from the green body to the sintered material. Other applications rely on terahertz intensity measurements rather than spectroscopy: The transmission properties of adhesives change during the curing process, and terahertz screening can aid in optimizing the material composition or the curing conditions.

An active field of research involves metamaterials, microscopic structures that exhibit remarkable transmission characteristics, often with narrow signatures. Depending on the design, the resonance frequency changes when the sample is loaded, e.g., with biological probes. The excellent frequency resolution that cw-terahertz systems deliver provides an extra benefit for these studies.

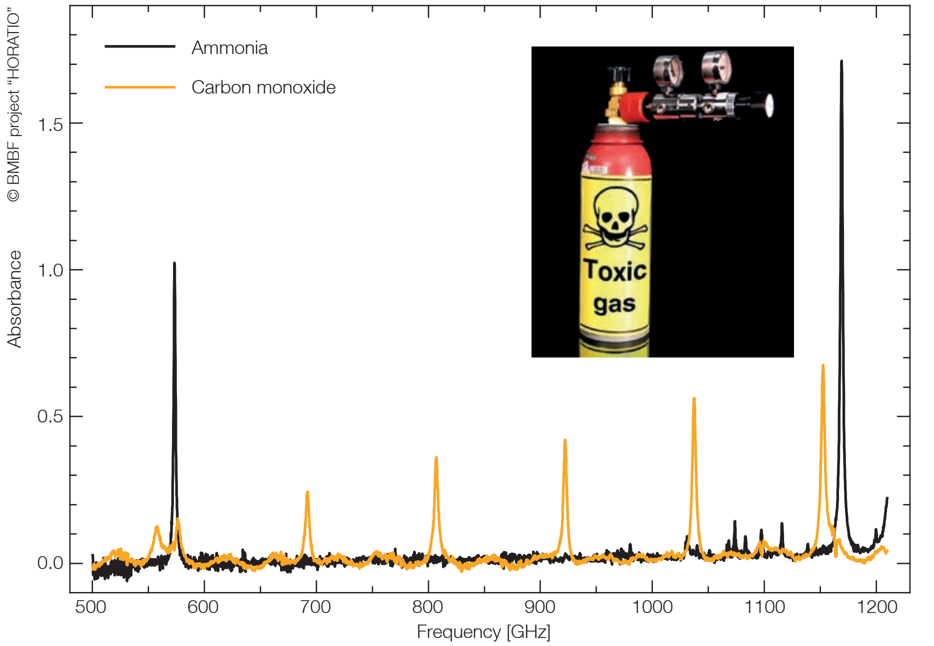


Transmitted terahertz signal during the curing process of a two-component adhesive (black curve) and a light-curing epoxy adhesive (yellow).

Gas Sensing

Many polar gas molecules possess distinct transitions in the terahertz frequency range. At standard pressure, their linewidths appear pressure-broadened to a few GHz, but at low pressures these absorption lines narrow to single-MHz widths. This opens the possibility to identify individual gases by their terahertz "fingerprint". Whilst gas sensing works in the near-infrared part of the spectrum, too, available lasers offer a limited tuning range, and each gas species may require an individual laser setup. Unique benefits of cw-terahertz spectroscopy include chemical specificity (a single system detects a large number of gases), high bandwidth, MHz-level resolution, and the ability to monitor "inaccessible" settings, such as flames and black smoke. Carefully designed instruments have achieved detection limits on the parts-per-million level.

Two application scenarios are industrial process control, and threat detection in public institutions. Demands are high: A monitoring system in a subway station must unambiguously identify hazardous substances in a cluttered background of cleaning agents, glues, engine fumes and paint.

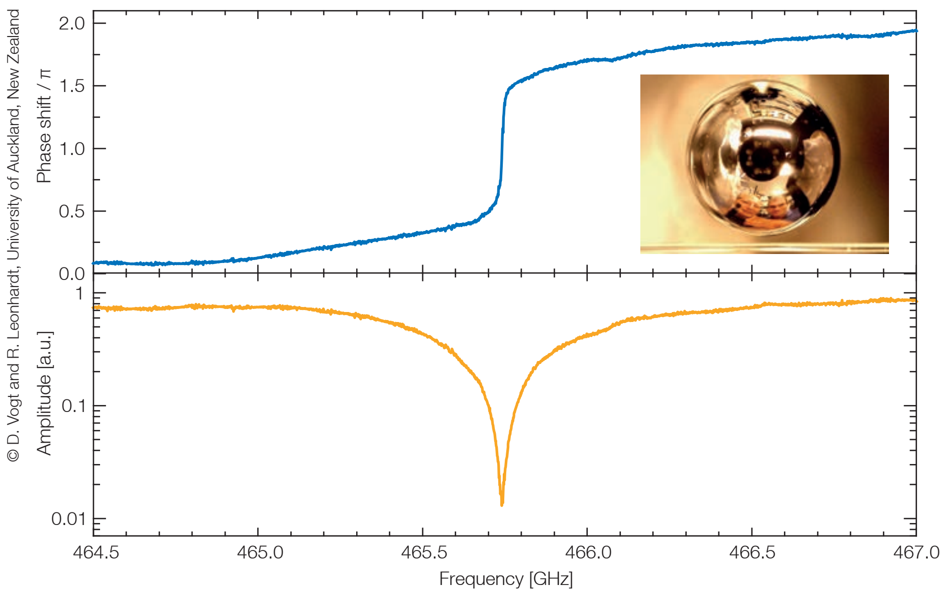


Absorption spectra of ammonia and carbon monoxide, recorded with a TeraScan 1550 system.

Fundamental Physics

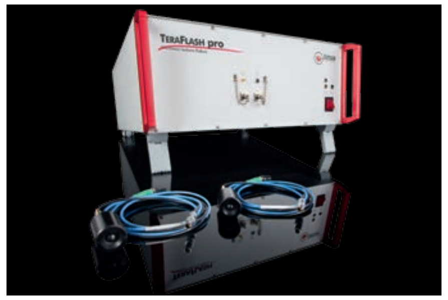
Spectroscopy, polarimetry, pump-probe studies or near-field sensing: The potential of terahertz radiation in fundamental research appears almost unlimited. Phase-sensitive time-domain or frequency-domain measurements unveil the complex dielectric constant of gases or organic solids, and probe essential semiconductor parameters such as conductivity or carrier density. In carefully designed experiments, TOPTICA's customers relied on terahertz technologies to measure narrow resonances in whispering-gallery-mode spheres, characterize graphene-based spatial light modulators, examine trapped, cold ions, or gain insights into the molecular dynamics of liquid crystals. Scientists have even equipped TOPTICA's instruments with near-field sensors and screened the physical properties of samples on micrometer scales, a technique that finds use in the quest for next-generation solar cell materials.

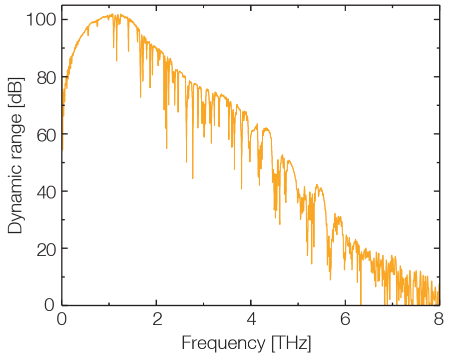
So far, every year has brought stunning new discoveries, and TOPTICA takes pride in supporting researchers at the forefront of terahertz science.



Relative phase shift (top) and amplitude spectrum (bottom) across a narrow resonance of a whispering-gallery-mode bubble-resonator made of silica glass. In the experiment, the frequency step size of a TeraScan 1550 was set to 1 MHz. The photo insert shows a sphere made of high-resistivity silicon, another material used for studying high-Q resonators.

Time-Domain Terahertz Generation





Time-domain terahertz spectrum (dynamic range of terahertz power), measured with TOPTICA's TeraFlash pro. All of the dips are absorption lines of water vapor.

Direct and Indirect Sources

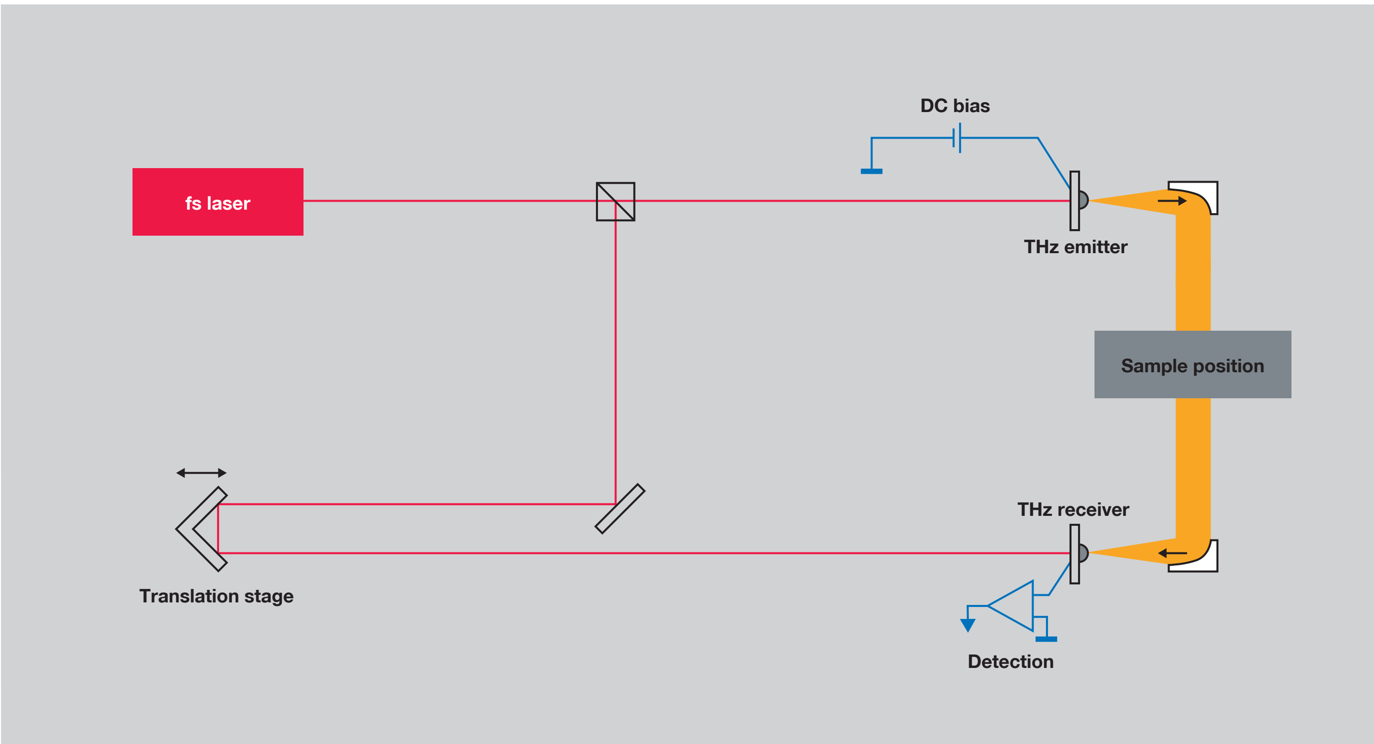
The spectroscopically relevant frequencies from 0.5 - 6 THz prove difficult to access. Electronic sources, such as voltage-controlled oscillators with frequency multipliers, offer power levels in the mW range. However, they become inefficient at terahertz frequencies and provide rather limited frequency tuning. Direct optical sources, like quantum cascade lasers, must operate at cryogenic temperatures and suffer from poor beam profiles and low spectral purity.

Optoelectronic terahertz generation, an expression for indirect methods, involves infrared laser light generating free charge carriers in a semiconductor or organic crystal. The charge carriers are accelerated by internal or external electric fields and the resulting photocurrent becomes the source of the terahertz wave.

The Ultrafast Approach

Pulsed terahertz radiation is generated with femtosecond lasers. In a typical time-domain setup, the laser pulse is split in two; one part travels to the terahertz emitter, the other part to the detector.

The ultrashort laser pulses produce a current transient in the emitter and as a result, electromagnetic wave packets with a broad spectrum in the terahertz range. The terahertz pulses interact with the sample and reach the receiver, which works in a "pump-and probe" fashion: The incident terahertz pulse changes the properties of the material (e.g. conductivity or birefringence) and the laser pulse probes this effect. A variable delay stage scans the terahertz wave packet with the much shorter "probe" pulse. A Fourier transform of the terahertz amplitude then reproduces the spectrum.



Frequency-Domain Terahertz Generation

Give me a Beat!

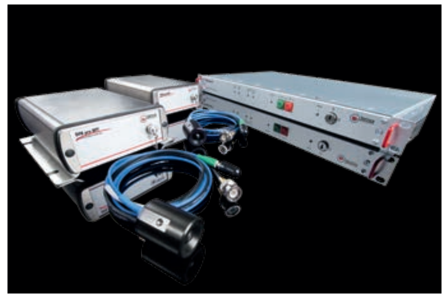
Continuous-wave (cw) terahertz radiation is obtained by optical heterodyning in high-bandwidth photoconductors: The output of two cw lasers is converted into terahertz radiation, exactly at the difference frequency of the lasers.

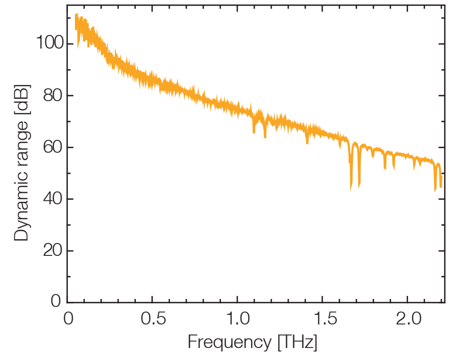
The core component is the "photomixer," a microscopic metal-semiconductor-metal structure. Near-infrared laser light irradiates this structure at two adjacent frequencies. Applying a bias voltage to the metal electrodes then generates a photocurrent that oscillates at the beat frequency. An antenna structure surrounding the photomixer translates the oscillating photocurrent into the terahertz wave. State-of-the-art photomixers are based on either GaAs or InGaAs/InP and require laser wavelengths below the semiconductor bandgap (i.e., around 0.8 µm or 1.5 µm, respectively).

Coherent Signal Detection

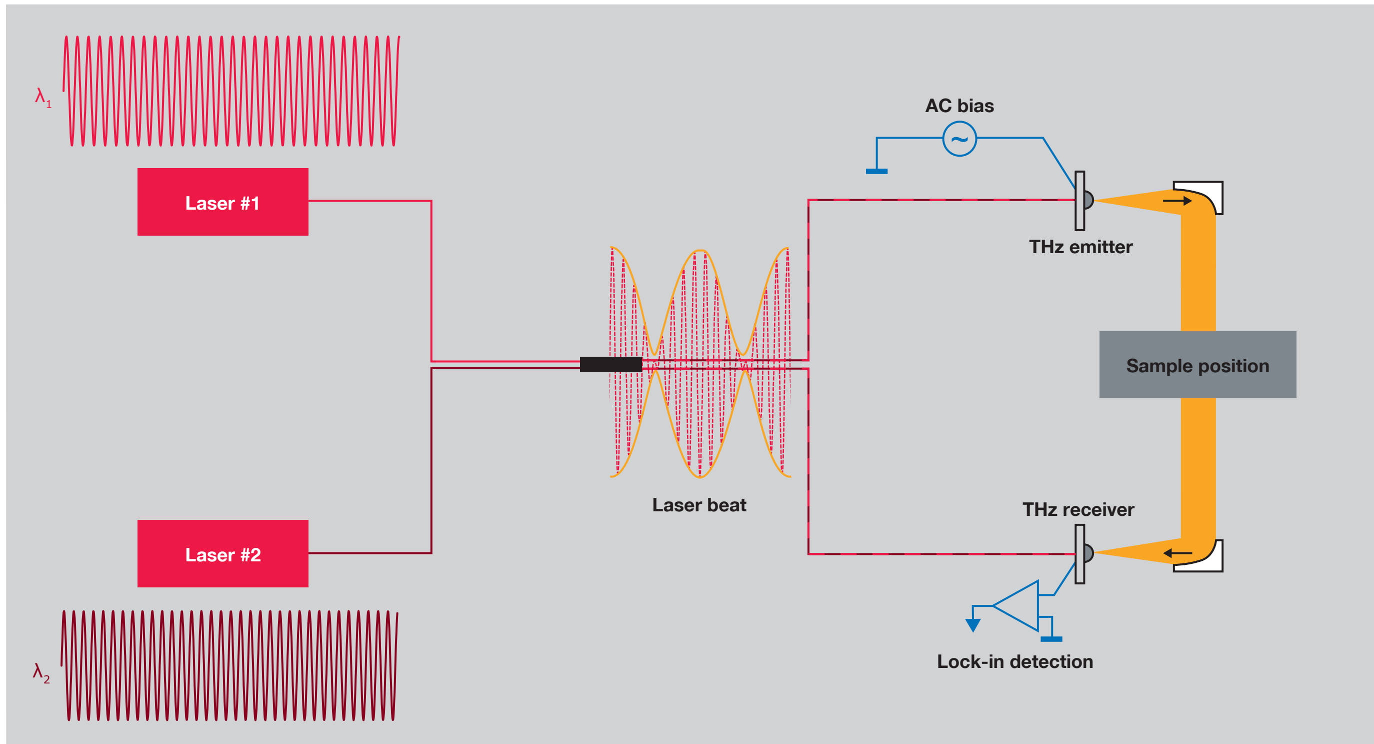
In a coherent detection scheme, a second photomixer serves as terahertz receiver. Similar to the pulsed scenario, both the terahertz wave and the original laser beat illuminate the receiver. The incoming terahertz wave generates a voltage in the antenna while the laser beat modulates the conductivity of the photomixer. The resulting photocurrent, typically in the nanoampère range, is proportional to the amplitude of the incident terahertz electric field. It further depends on the phase difference between the terahertz wave and the optical beat. Spectroscopic measurements commonly take advantage of both amplitude and phase data.

Coherent detection methods offer the advantage of a very high efficiency, and can attain dynamic ranges in excess of 100 dB.





Frequency-domain terahertz spectrum (dynamic range of terahertz power), measured with TOPTICA's TeraScan 1550 (+ Tuning Range Extension 2.0).



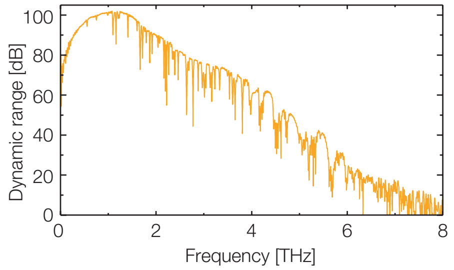
TIME-DOMAIN VS. FREQUENCY-DOMAIN

Highest Bandwidth:
Time-Domain Systems

Time-domain spectroscopy offers the advantage of a broad bandwidth and high measurement speed. The TeraFlash pro generates spectra up to 6 THz. The TeraFlash smart, on the other hand, produces a single pulse trace in only 625 µs, and the collection of 1000 averages, an efficient method to increase the dynamic range, is completed in less than a second.

Time-domain systems lend themselves to thickness gauging via time-of-flight measurements: The broad spectrum translates into micrometer-level thickness resolution.

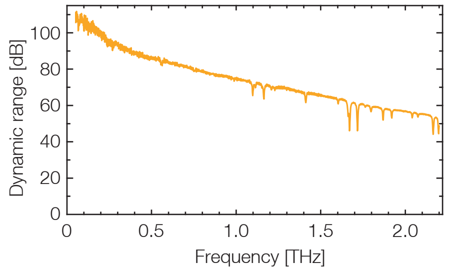
TD-Terahertz: More than 6 THz bandwidth.



Highest Resolution:
Frequency-Domain Systems

Frequency-domain spectroscopy is the preferred choice for applications requiring highest spectral resolution. While a pulsed terahertz spectrometer offers a resolution on the 10 GHz level, cw systems allow frequency steps with single-megahertz precision. Trace gas sensing, specifically at low pressure, benefits from the precise frequency control of TOPTICA's TeraScan platforms. In terms of system complexity, frequency-domain systems do not require a delay stage, therefore the price is lower than that of their time-domain counterparts.

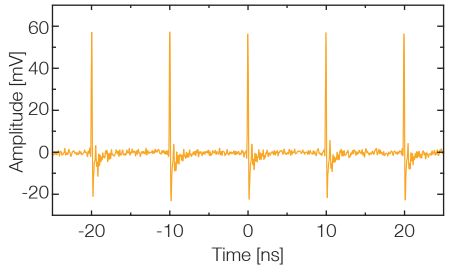
FD-Terahertz: Single-megahertz resolution.



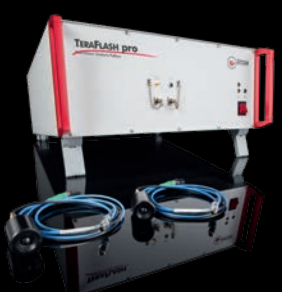
Highest Speed:
Terahertz Screening Systems

Numerous applications in industrial process control require neither spectral data nor thickness information, but call for intensity measurements at maximum speed. The novel concept of the TeraSpeed – the combination of a powerful photoconductive switch and a sensitive Schottky receiver – necessitates neither any delay stage, nor pulse-picking or lock-in detection. The result is not only a very robust system, but one that outperforms conventional time-domain terahertz instruments in terms of speed by four to seven orders of magnitude.

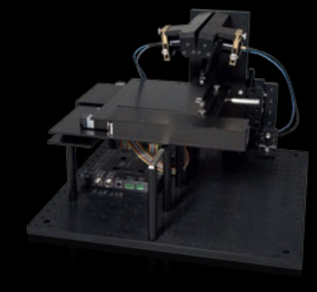
Terahertz screening: 100 MHz pulse train.



Time-Domain Instrumentation



TeraFlash pro
Time-domain system, > 6 THz bandwidth, 95 dB peak dynamic range

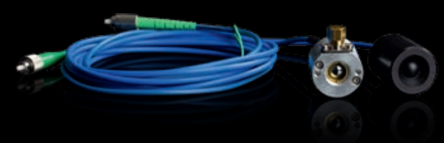


Imaging Extension
Imaging in transmission and reflection, > 30 pixel/s

TeraFlash smart
ECOPS-based terahertz platform, up to 1600 pulse traces/s

Frequency-Domain and Terahertz Screening Instrumentation

TeraScan 780/1550
Frequency-domain platform, < 10 MHz step size, 90 dB dynamic range



Photomixers
GaAs and InGaAs photomixers with fiber pigtail, for frequency-domain terahertz

TeraSpeed
Fast terahertz screening platform, digital output up to 500 kS/s

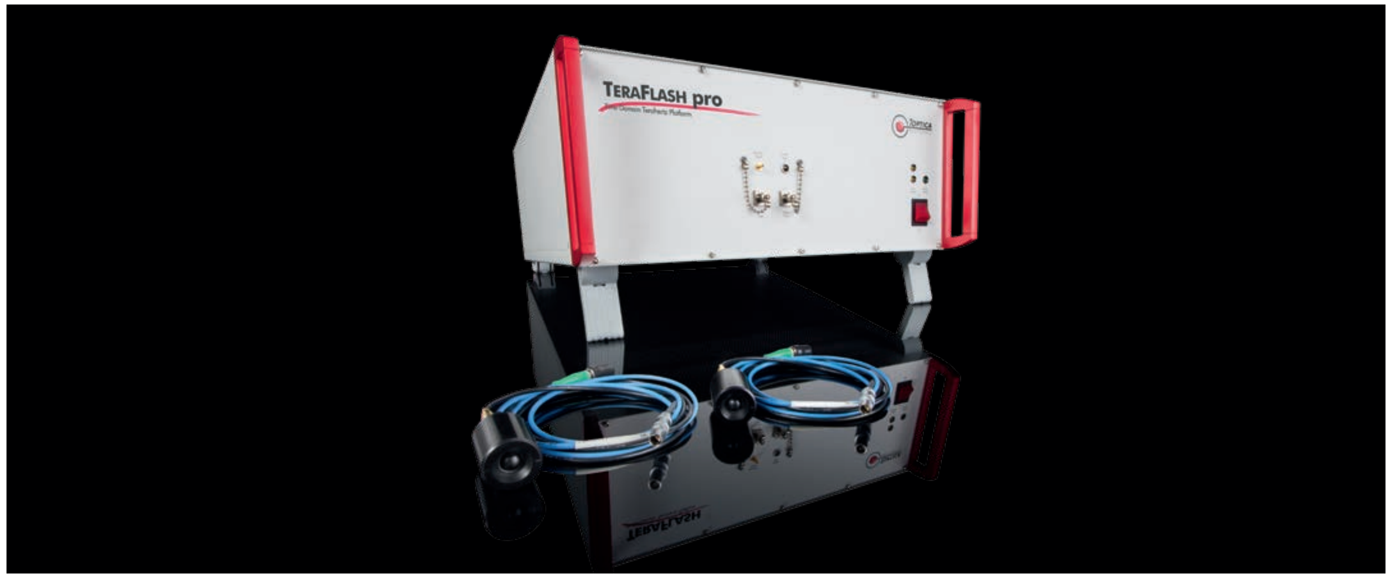
	TeraFlash pro	TeraFlash smart	TeraScan	TeraSpeed
Bandwidth	0.1 – 6 THz	0.1 – 4.5 THz	0.05 – 2.7 THz	N.A.
Peak dynamic range	95 dB	60 dB	90 dB	40 dB
Highest frequency resolution	5 GHz	1.5 GHz	1 MHz	N.A.
Spectral selectivity	No	No	Yes	No
Acquisition time (spectrum)	6 ms .. 1 min (depending on scan range and number of averages)	625 µs .. 5 s (depending on scan range and number of averages)	30 s .. 3 hrs (complete spectrum, depending on resolution and lock-in time)	Analog: 10 ns Digital: 2 µs (no frequency information)
Applications				
Plastic inspection	+	++	+	+
Paint and coating layers	++	+	0	-
Industrial quality control	+	++	+	++
Non-destructive testing	+	++	+	++
Material research	++	+	++	+
Gas sensing	0	0	++	-
Hydration monitoring	+	++	+	++
Ultrafast dynamics	0	+	-	++
Communication	-	-	++	-
Metamaterials and micro-optics	+	+	++	-
Fundamental physics	++	++	++	+

Suitability: ++ Excellent + Good 0 Limited - Not suitable

TeraFlash pro

Versatile Time-Domain Terahertz Platform

Class 1 Laser Product EN 60825-1:2014.
Invisible laser radiation. Avoid direct exposure to beam.



Key Features

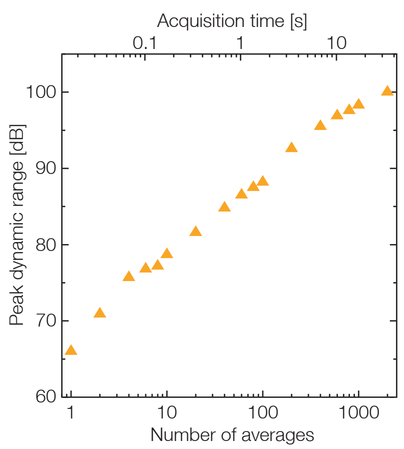
- Fiber-coupled InGaAs photoconductive switches
- > 6 THz bandwidth, 95 dB peak dynamic range in < 20 s
- Variable terahertz path length between 15 cm and 110 cm

TeraFlash pro

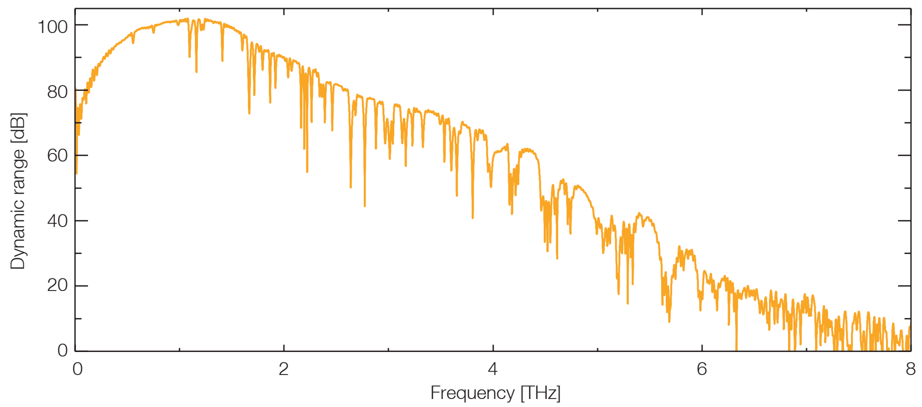
The TeraFlash pro system combines TOPTICA's established femtosecond laser technology and state-of-the-art InGaAs photoconductive switches into a top-grade terahertz platform. Owing to a highly precise voice-coil delay stage with a timing resolution of 1.3 fs, the TeraFlash pro achieves a bandwidth of 6 THz and a peak dynamic range of 95 dB – within a measurement time with less than half a minute!

The control software can flexibly adjust the scan time and the number of averages. A carefully designed fiber delivery (patent US 9,774,161) guides the laser pulses to the terahertz antennas. Users can thus arrange the antennas in transmission or reflection, according to the requirements of the experiment. They can even vary the terahertz beam length between 15 cm and 110 cm, thanks to a unique time-of-flight compensation stage.

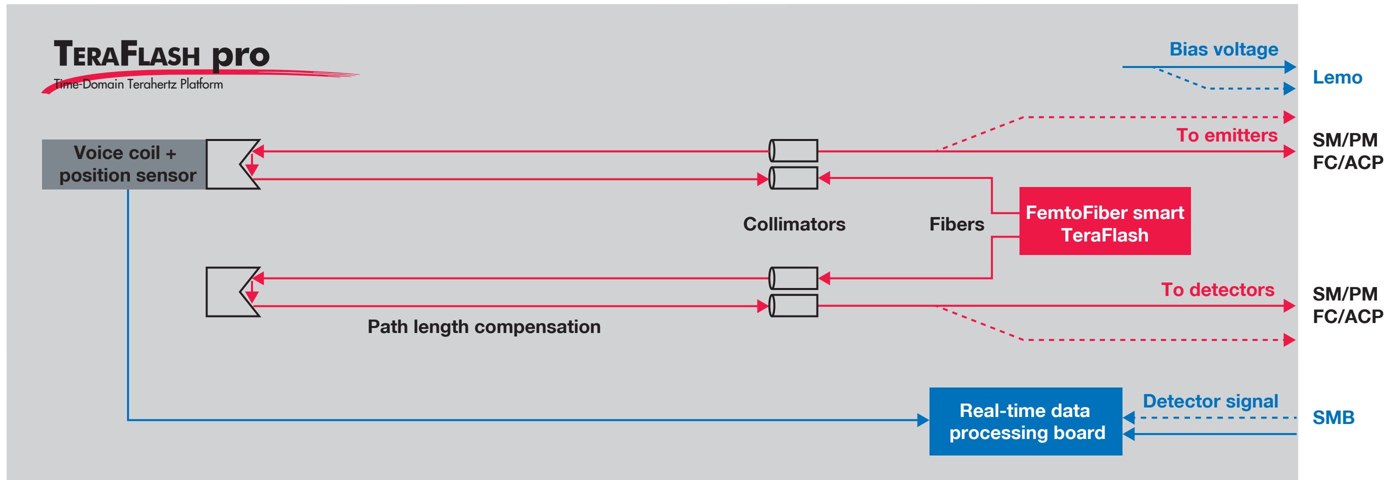
Specifications TeraFlash pro	
Components	One femtosecond laser SM/PM fiber delivery 2 mechanical delay stages (stationary / moving) 2 InGaAs photoconductive switches Electronics for data acquisition
Laser wavelength	1560 nm
Laser pulse width	typ. 80 fs
Laser repetition rate	100 MHz
External fiber length	2.5 m
Terahertz emitter	#EK-000978: InGaAs/InP photoconductive switch with 100 µm strip-line antenna, 2.5 m fiber pigtail
Terahertz receiver	#EK-000980: InGaAs/InP photoconductive switch with 25 µm dipole antenna, 10 µm gap, 2.5 m fiber pigtail
Antenna package	Cylindrical, 25 mm, integrated Si lens and SM/PM fiber pigtail
Scan range	5 .. 200 ps
Scan speed	166 traces/s (5 ps) 95 traces/s (20 ps) 60 traces/s (50 ps) 6 traces/s (200 ps) Intermediate settings possible
Spectral range	0.1 – 6 THz, in < 20 s
Average terahertz power	typ. 30 µW
Time-domain dynamic range	typ. 70 dB in < 40 ms 100 dB in < 20 s
Spectral peak dynamic range	typ. 70 dB in < 40 ms 95 dB in < 20 s
Useable terahertz path length	15 – 110 cm, adjustable via software (stationary delay)
Frequency resolution @ max. scan range	< 5 GHz
Computer interface	Ethernet
Computer software	LabView-based GUI, included
Size (H x W x D)	180 x 450 x 560 mm³
System weight	20 kg
Operating voltage	110 / 220 V AC
Accessories	Transmission optomechanics, Reflection head, Imaging extension



Peak dynamic range versus the number of averaged time traces (lower abscissa) and total acquisition time (upper abscissa).



Terahertz spectrum of air with water vapor lines, measured with the TeraFlash pro. Within a measurement time of less than half a minute, the bandwidth reaches 6 THz and the peak dynamic range exceeds 95 dB – an industry record!



Schematic diagram of the TeraFlash pro. Blue lines depict electric signals, red lines the optical signals.

Further reading:

N. Vieweg et al., *Terahertz-time domain spectrometer with 90 dB peak dynamic range;* J Infrared Milli. Terahz. Waves **35** (2014) 823-832.

Class 1 Laser Product EN 60825-1:2014.
Invisible laser radiation. Avoid direct exposure to beam.

Key Features

· Enables fastest terahertz-based thickness measurements to-date

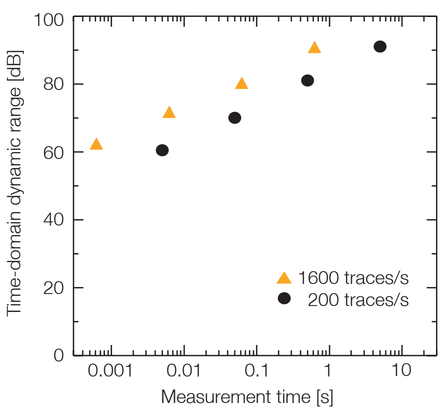
· Proprietary ECOPS technology

· Robust design

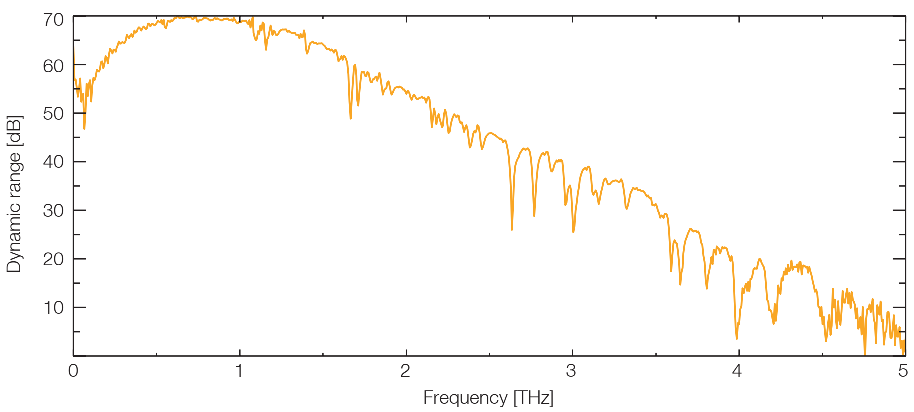
· 1600 pulse traces/s @ 150 ps scan length

TeraFlash smart

TOPTICA's TeraFlash smart utilizes a proprietary laser modulation scheme dubbed ECOPS ("electronically controlled optical sampling"). The approach employs two femto-second lasers rather than one, eliminating the need for a mechanical delay. This results in extremely high measurement speeds: the TeraFlash smart acquires 1600 complete terahertz waveforms per second. In a "single-shot" measurement, the system achieves a time-domain dynamic range of > 50 dB and a spectral bandwidth of 3 THz. Within one second of averaging, the time-domain dynamic range increases to > 80 dB and the bandwidth reaches 4.5 THz. The system enables terahertz-based thickness gauging at unprecedented speed, and lends itself particularly to measurements on rapidly moving samples, e.g. conveyor belts, papermaking machines, or extrusion lines.

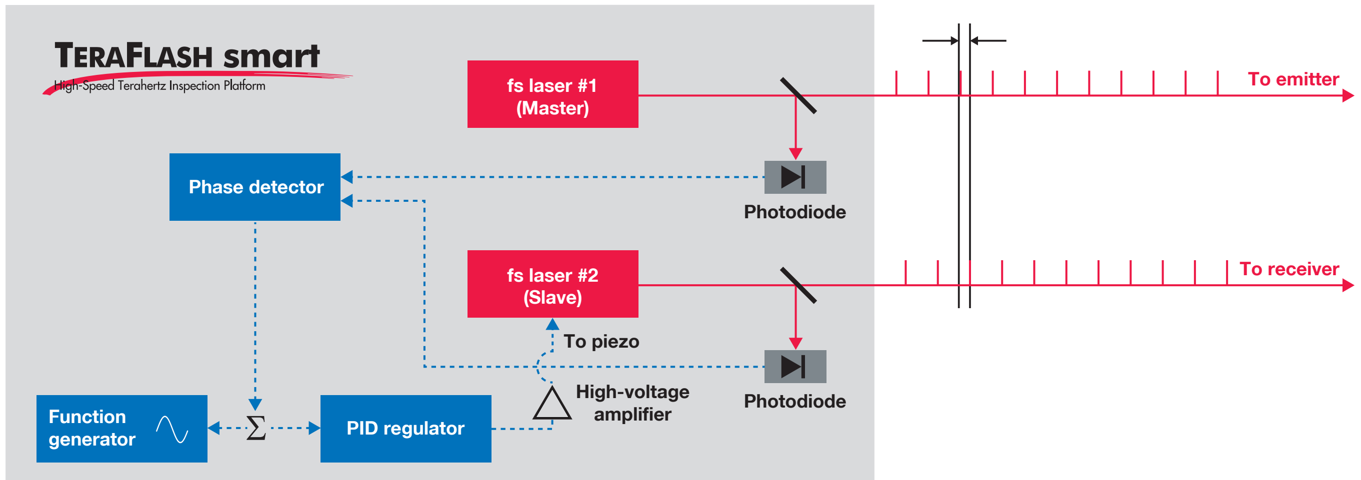


Time-domain dynamic vs. measurement time. Yellow and black symbols denote measurement speeds of 1600 traces/s and 200 traces/s, respectively.



Terahertz spectrum of air with water vapor lines, obtained with the TeraFlash smart. With 1000 averages, the spectrum spans almost 5 THz – within a measurement time as short as 600 milliseconds.

Specifications TeraFlash smart	
Components	2 synchronized femtosecond lasers SM/PM fiber delivery Electronic delay 2 InGaAs photoconductive switches Electronics for data acquisition
Laser wavelength	1560 nm
Laser pulse width	typ. 80 fs
Laser repetition rate	80 MHz
External fiber length	10.8 m
Terahertz emitter	#EK-001123: InGaAs/InP photoconductive switch with 100 µm strip-line antenna, 0.3 m fiber pigtail
Terahertz receiver	#EK-001125: InGaAs/InP photoconductive switch with 25 µm dipole antenna, 10 µm gap, 0.3 m fiber pigtail, integrated preamplifier
Antenna package	Cylindrical, 25 mm, integrated Si lens and SM/PM fiber pigtail
Scan range	150 ps / 400 ps / 700 ps
Scan speed	1600 traces/s (150 ps) 800 traces/s (400 ps) 200 traces/s (700 ps)
Spectral range	0.1 – 4.5 THz, in < 1 s
Average terahertz power	typ. 30 µW
Time-domain dynamic range	typ. > 50 dB in < 1 ms 80 dB in 1 s
Spectral peak dynamic range	typ. 35 dB in < 1 ms > 60 dB in 1 sec
Useable terahertz path length	10 – 180 cm, adjustable via software (electronic phase shift)
Frequency resolution @ max. scan range	< 1.5 GHz
Computer interface	Ethernet and USB, Data streaming via USB
Computer software	LabView-based GUI, included
Size (H x W x D)	200 x 450 x 440 mm³
System weight	20 kg
Operating voltage	24 V DC, power supply included
Accessories	Transmission optomechanics, Reflection head



Schematic diagram of the TeraFlash smart. Blue lines depict electric signals, red lines the optical signals. The black arrows depict the momentary difference in repetition rates.

Further reading:
M. Yahyapour et al., *Fastest thickness measurements with a terahertz time-domain system based on electronically controlled optical sampling;* Appl. Sci. **9** (2019) 1283.

TeraSpeed
Superfast Terahertz Screening Platform

Class 1 Laser Product EN 60825-1:2014.
Invisible laser radiation. Avoid direct exposure to beam.

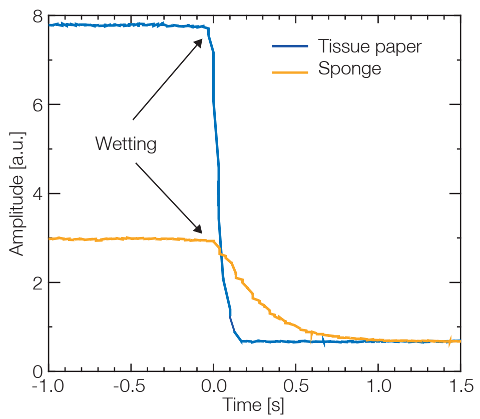
Key Features

- Extremely fast measurements of terahertz pulse intensities
- Digital output: Data rates up to 500 kS/s, analog output up to 100 MHz
- Robust setup, no mechanically sensitive components

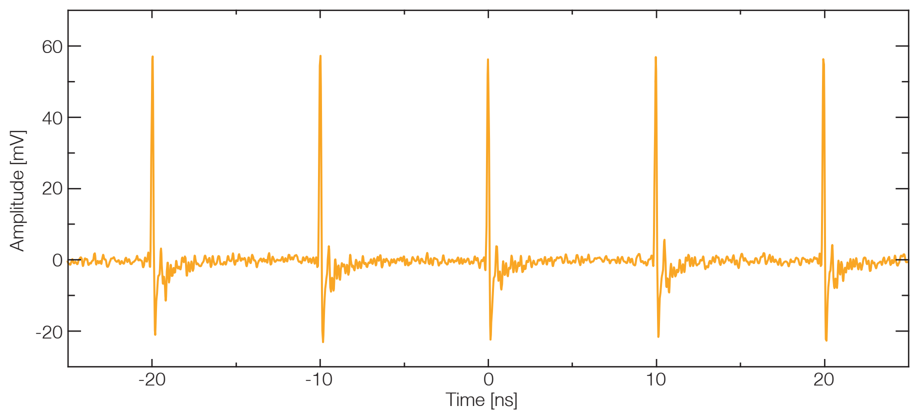
TeraSpeed

The TeraSpeed serves applications in quality control and process monitoring that require no spectral information, but call for terahertz intensity measurements at “extreme” speeds: The system is capable of detecting individual terahertz pulses at repetition rates as high as 100 MHz. An integrated data-processing unit converts the pulses to RMS values, enabling data streams at sampling rates up to 500 kHz – orders of magnitude faster than conventional terahertz systems.

Bringing together several cutting-edge technologies, the TeraSpeed takes advantage of mature fiber laser technology, powerful photoconductive emitters and fast yet sensitive Schottky receivers.

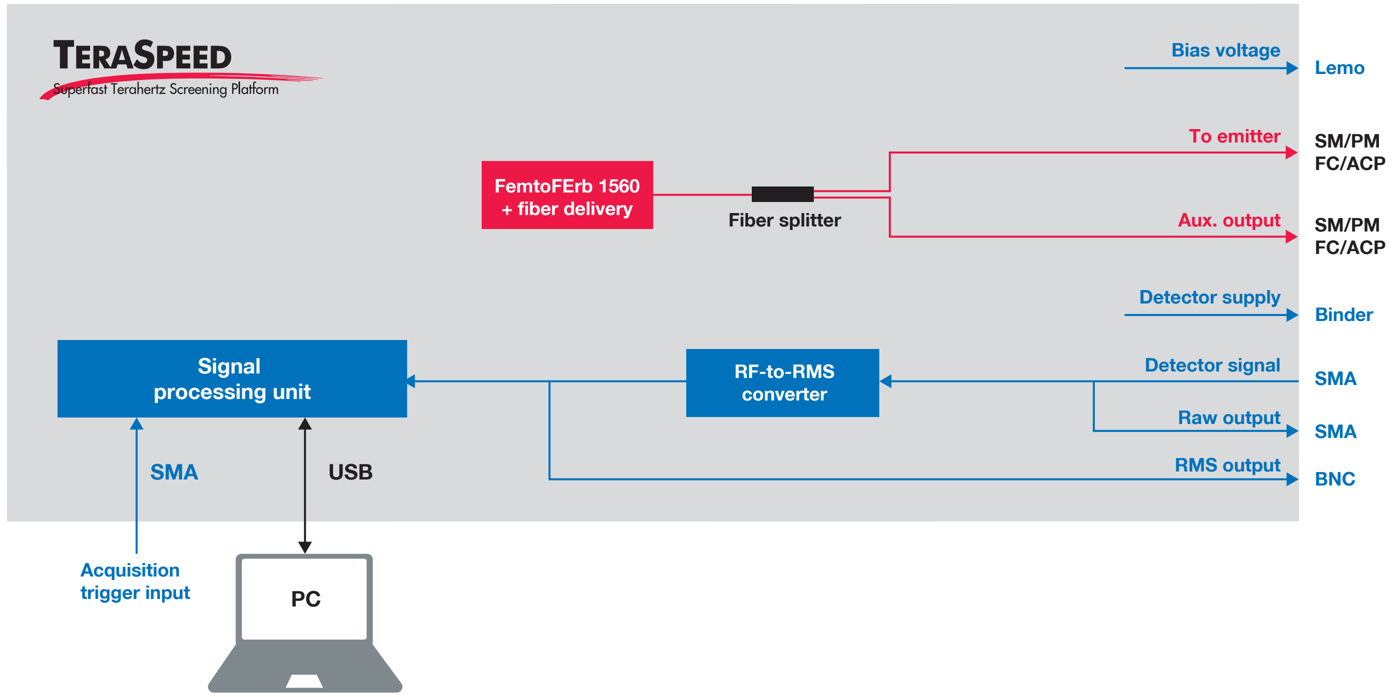


Absorption dynamics of a sheet of tissue paper and a sponge, wetted with water.



Terahertz pulse train at 100 MHz repetition rate, as measured with the TeraSpeed.

Specifications TeraSpeed	
Components	Femtosecond laser, SM/PM fiber delivery (patent US 9,774,161), TX: InGaAs photoconductive switch (#EK-000978) RX:High-bandwidth Schottky receiver (#EK-000961)
Antenna package	See pages 19 and 26
Analog outputs	“Raw signal out”: Direct signal of Schottky receiver, 100 MHz repetition rate “RMS signal out”: Processed signals of RF-to-RMS converter, 100 kHz bandwidth
Dynamic range @ RMS signal output	typ. 40 dB
Digital output	USB interface
Measurement modes of digital output	“Snapshot”: Single-shot measurement, up to 100000 data points, sampling rate max. 500 kHz “Continuous”: Continuous data streaming, sampling rate 1 kHz .. 500 kHz
Trigger input/output	Input trigger for acquisition start in “snapshot” mode “Laser clock out”: Clock output of femtosecond laser, 100 MHz repetition rate
Control software	Graphical user interface, included
Size (H x W x D)	90 x 450 x 500 mm^3; 110 x 450 x 545 mm^3 with handles and feet



Schematic of the TeraSpeed. Red: optical signals, blue: analog signals, black: digital signals.

Further reading:
F. Rettich et al., *Field intensity detection of individual terahertz pulses at 80 MHz repetition rate*; J Infrared Milli. Terahz. Waves **36:7** (2015) 607-612.
S. Brinkmann et al., *Towards Quality Control in Pharmaceutical Packaging: Screening Folded Boxes for Package Inserts*; J Infrared Milli. Terahz. Waves **38:3** (2017) 339-346.

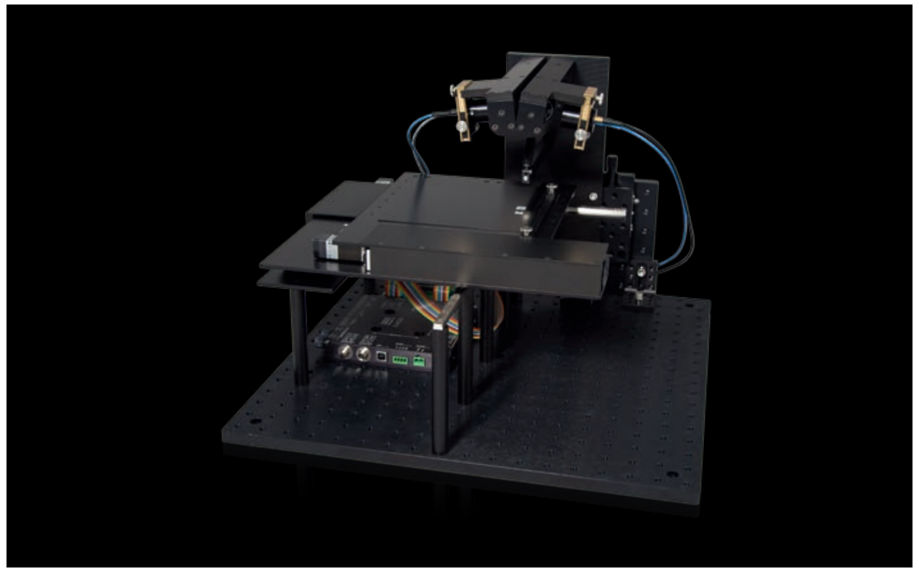
Imaging Extension
Fast and Flexible Imaging Platform

Key Features

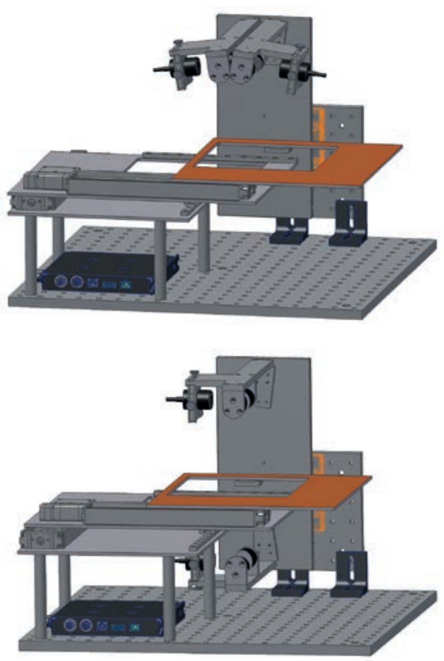
- Fast-scan option: > 30 pixel/s
- Flexible configuration in transmission and reflection mode
- Numerous data post-processing options, including filtering in both time-domain and frequency-domain

An accessory to the TeraFlash pro, the Imaging Extension utilizes two precise linear stages to scan a sample through the focus of the terahertz beam. A novel “fast-scan” option enables a high measurement speed of more than 30 pixel/s.

A “basic” setup is available for researchers who wish to use their own optical components, and a “complete” version includes parabolic mirrors for beam shaping and focusing. The system comes with a powerful postprocessing software for image analysis.



Specifications Imaging Extension		
	Basic Version	**Complete Version**
Linear stages	2 stages + motion controller included, positioning accuracy < 0.2 mm	
Terahertz optics	--	4 mirrors included, easy configuration in transmission and reflection
Mounts for terahertz antennas	--	Included for TX and RX
Beam focus size	--	Approx. 2.5 mm
Measurement speed	> 30 pixel/s (fast scan)	
Positioning accuracy	< 200 µm	
Maximum field of view	15 cm x 15 cm	
Sample weight	Max. 2 kg	
Angle of incidence (reflection)	n.a.	± 8 deg.
Data acquisition	Shaker movement and translation of linear stages are synchronized	
Data filtering	Possible, both in time-domain and frequency-domain	
Contrast parameters	Amplitude, phase, layer thickness, spectral amplitude in a pre-selected range, amplitude and height profile as cross sections	
Interfaces	TTL control lines, Switchbox (optional) or remote control (USB, Ethernet)	TTL control lines, Switchbox (optional) or remote control (USB, Ethernet)
Environment temperature	15 – 35 °C (operating), 0 – 40 °C (storage and transport)	15 – 35 °C (operating), 0 – 40 °C (storage and transport)
Environment humidity	Non-condensing	



Complete version of the Terahertz Imaging Extension, configured in reflection (top) and transmission (bottom).

Photograph and terahertz images of a Japanese pre-paid public-transport card. The terahertz reflectivity image (middle) reproduces the look of the card. Removing the front-side reflection (right) provides an inside view of the underlying electronics.

Photoconductive Switches
InGaAs Antennas for Time-Domain Terahertz Generation & Detection

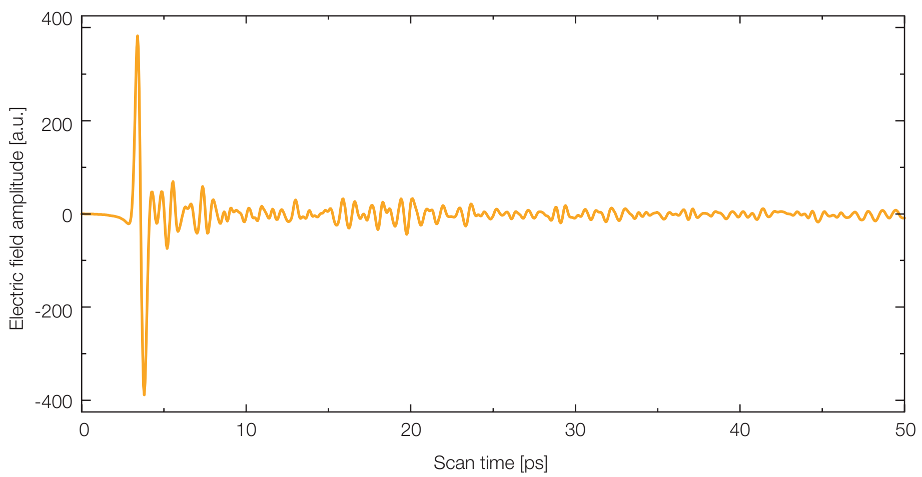
Key Features

- Compact modules with SM/PM fiber pigtail and silicon lens
- High terahertz power: > 30 µW average
- Large bandwidth: 6 THz

Pulsed terahertz generation and detection with leading-edge technology: Fiber-pigtailed InGaAs antennas provide a bandwidth up to 6 THz and an average power of 30 µW. The design, developed by Fraunhofer Heinrich-Hertz Institute (HHI, Berlin/Germany), uses a multi-stack of InGaAs absorber layers and InAlAs trapping layers to reduce the dark conductivity of the semiconductor and maximize the efficiency of the device.

The emitter and detector modules feature a strip-line and a dipole antenna, respectively, and are packaged with a Silicon lens and SM/PM fiber. Customers can choose between three different fiber lengths of 0.3 m, 1.0 m and 2.5 m.

Specifications Photoconductive Switches	
Terahertz emitter	InGaAs/InP photoconductive switch with 100 µm strip-line antenna #EK-000979: fiber length = 0.3 m #EK-000781: fiber length = 1.0 m #EK-000978: fiber length = 2.5 m
Terahertz receiver	InGaAs/InP photoconductive switch with 25 µm dipole antenna, 10 µm gap #EK-000981: fiber length = 0.3 m #EK-000782: fiber length = 1.0 m #EK-000980: fiber length = 2.5 m
Semiconductor material	Multi-layer structure of InGaAs and InAlAs on InP
Excitation wavelength	1.5 µm
Emitter / receiver bandwidth	6 THz
Average terahertz power	typ. 30 µW @ 20 mW laser power
Package	Cylindrical, Ø 25 mm Integrated Si lens and SM/PM fiber pigtail
Recommended operating conditions	Average laser power 20 mW Max. bias +100 V (unipolar, emitter), ± 3 V (receiver, only for testing)
Bias modulation	Possible, up to 100 kHz



Pulse trace of an InGaAs photoconductive switch.

TeraScan 780 / 1550

TOPSellers for Frequency-Domain Spectroscopy

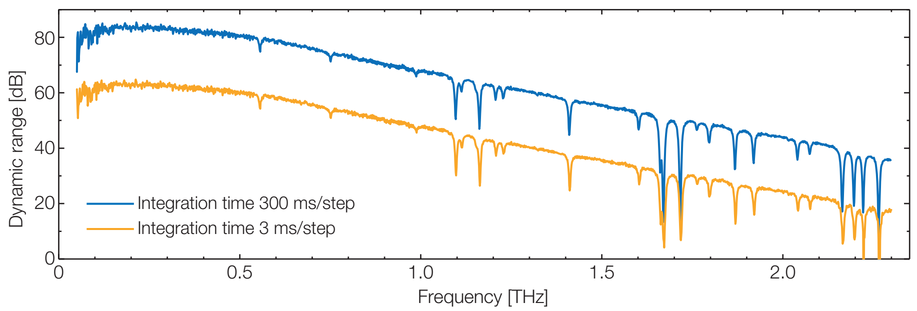
Class 1 Laser Product EN 60825-1:2014.
Invisible laser radiation. Avoid direct exposure to beam.

Key Features

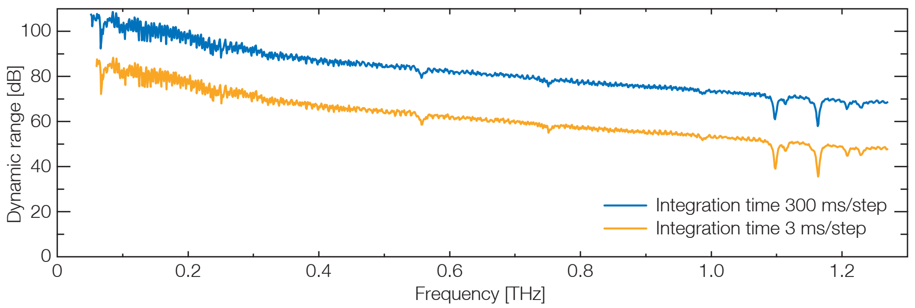
- Complete systems with high-end GaAs or InGaAs photomixers
- Highest bandwidth: TeraScan 780
- Highest dynamic range: TeraScan 1550

TeraScan 780 / 1550

TOPTICA's TeraScan platforms are "TOPSeller" configurations for frequency-domain terahertz spectroscopy. The systems combine mature DFB diode lasers with state-of-the-art GaAs or InGaAs photomixer technology. The TeraScan 780 offers an outstanding bandwidth, owing to the wide tuning range of carefully selected near-infrared DFB diodes. The TeraScan 1550, in turn, sets new benchmarks in terms of terahertz power and dynamic range. Both systems feature TOPTICA's proprietary "DLC smart" control electronics, and an intuitive software interface. The TeraScan systems lend themselves both as a versatile setup for cw-terahertz research, and as a base unit for system integrators.

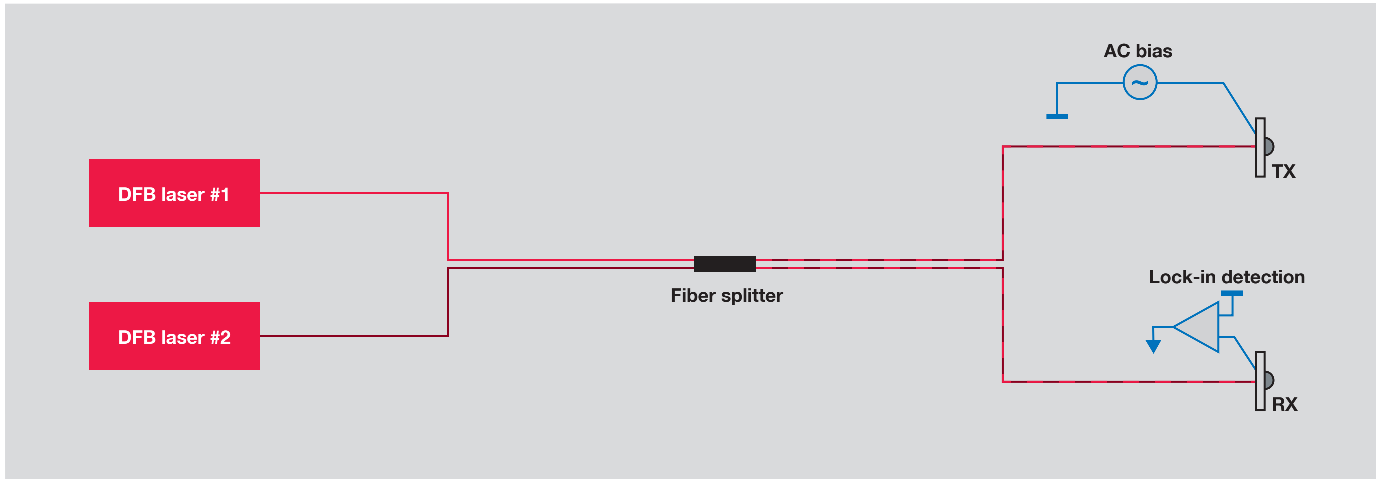


Dynamic-range spectrum of a TeraScan 780. The dips are absorption lines of water vapor.



Spectrum of a TeraScan 1550.

Specifications TeraScan 780 / 1550		
System	**TeraScan 780**	**TeraScan 1550**
Difference frequency tuning	1.8 THz (typ. 2.0 THz)	1.2 THz (up to 2.7 THz with Tuning Range Extension)
Tuning speed	Up to 0.1 THz/s	
Frequency accuracy	< 2 GHz	
Minimum frequency step size	< 10 MHz	
Terahertz emitter	#EK-000831, GaAs photomixer	#EK-000724, InGaAs photodiode
Terahertz receiver	#EK-000832, GaAs photomixer	#EK-000725, InGaAs photomixer
Antenna type	Log-spiral	Bow-tie
Terahertz polarization	Circular	Linear
Emitter and receiver package	Cylindrical, ø 1" Integrated Si lens and SM/PM fiber pigtail	Cylindrical, ø 25 mm Integrated Si lens and SM/PM fiber pigtail
Terahertz power (typ.)	2 µW @ 100 GHz, 0.3 µW @ 500 GHz	100 µW @ 100 GHz, 10 µW @ 500 GHz
Terahertz dynamic range (300 ms integration time)	80 dB @ 100 GHz 70 dB @ 500 GHz	90 dB @ 100 GHz 70 dB @ 500 GHz
Laser size (H x W x D) and weight	Two DFB pro L laser heads, each with dimensions 90 x 90 x 244 mm³ (H x W x D), weight 2.8 kg	Two DFB pro BFY laser heads, each with dimensions 60 x 120 x 165 mm³ (H x W x D), weight 1 kg
Control unit	DLC smart	
Controller size (H x W x D) and weight	50 x 480 x 290 mm³, 4 kg	
Computer interface	Ethernet	
Software	Control software with GUI + Remote command interface	
Key advantages	High bandwidth with one set of lasers	High terahertz power, compact laser units



Schematic of TeraScan systems.

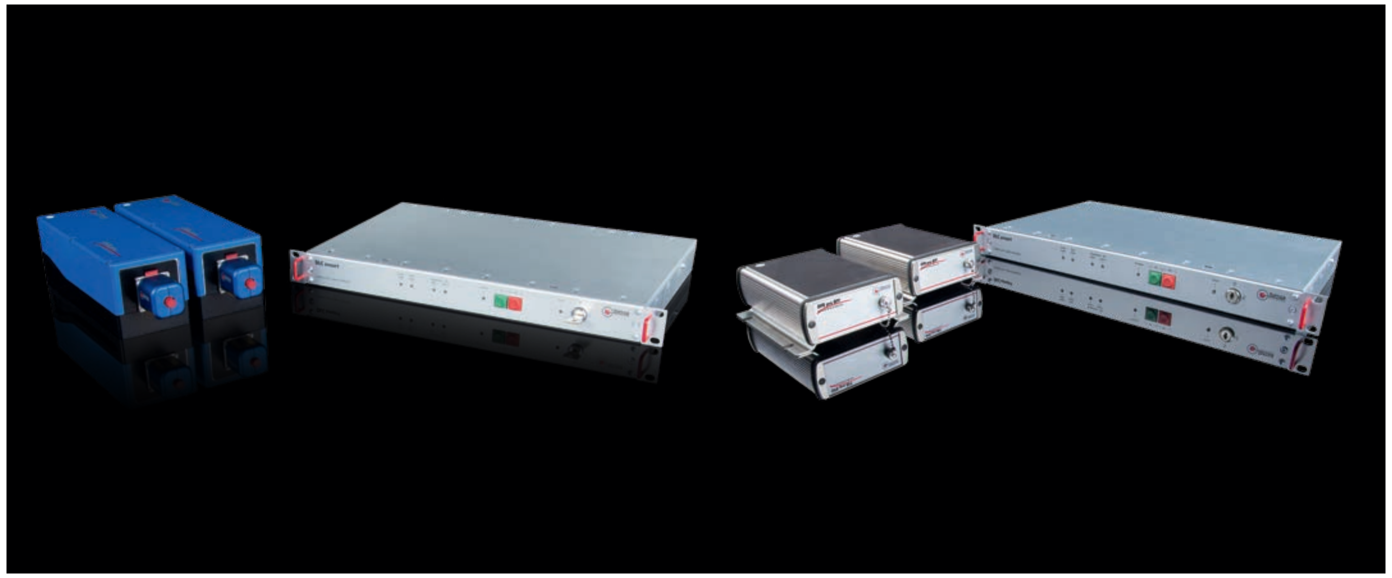
Further reading:

A. Roggenbuck et al., *Coherent broadband continuous-wave terahertz spectroscopy on solid-state samples;* New J. Phys. **12** (2010) 43017-43029.
A.J. Deninger et al., *2.75 THz tuning with a triple-DFB laser system at 1550 nm and InGaAs photomixers;* J Infrared Milli. Terahz. Waves **36** (2015) 269-277.

TeraBeam 780 / 1550

DFB Lasers for cw Terahertz Generation

Class 1 Laser Product EN 60825-1:2014.
Invisible laser radiation. Avoid direct exposure to beam.



Key Features

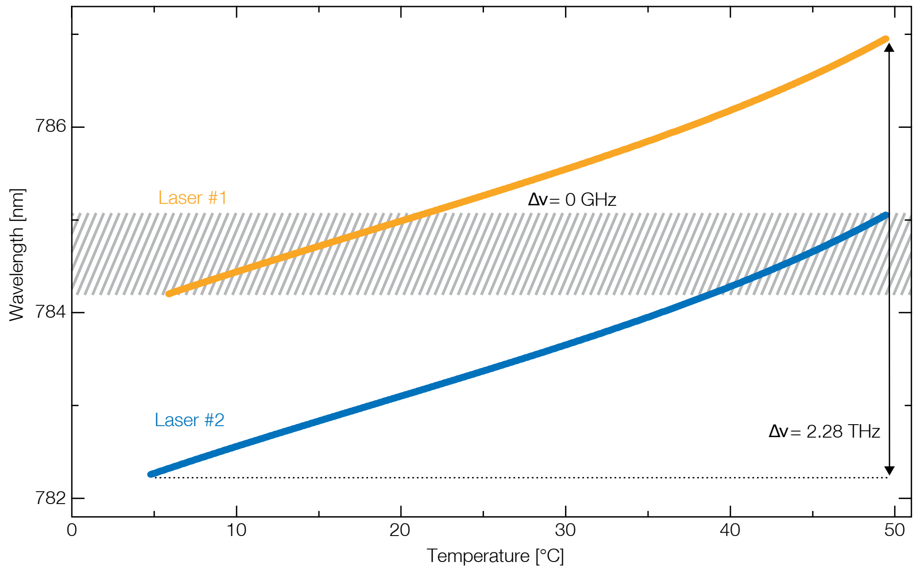
· Two DFB lasers with micro-processor-based frequency control

· Available wavelengths: 780 nm and 1.5 µm

· Frequency accuracy < 2 GHz, minimum step size < 10 MHz

TeraBeam 780 / 1550

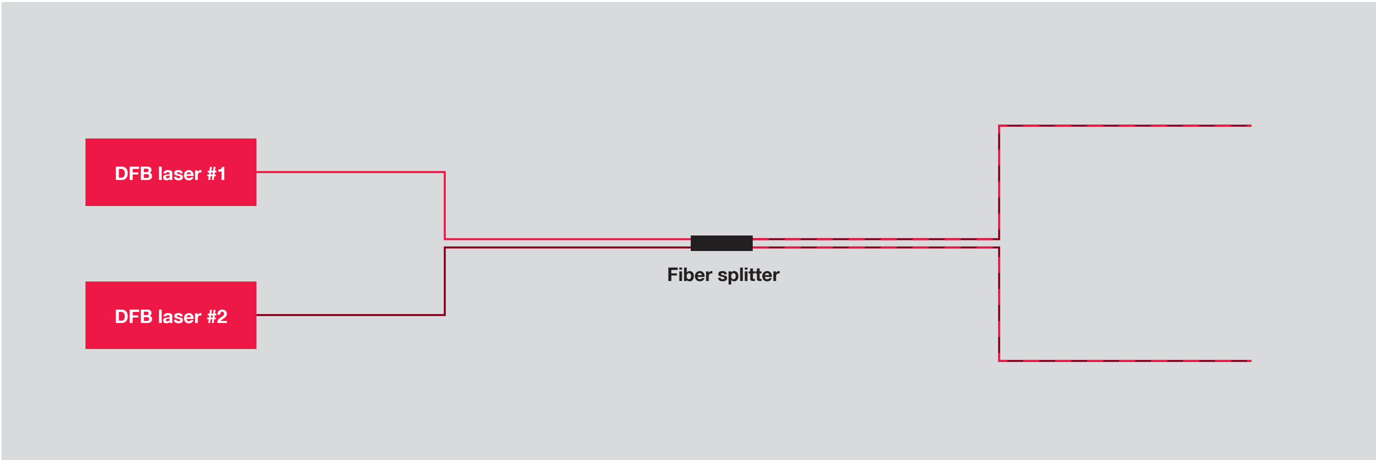
Each TeraBeam system comprises two distributed feedback (DFB) lasers with built-in optical isolators and fiber-optic beam combination. Available at 780 nm and 1.5 µm, the TeraBeam matches the excitation wavelengths of GaAs and InGaAs terahertz emitters, respectively. TOPTICA carefully selects the laser diodes, paying close attention to their mode-hop-free tuning range, and records precise tuning curves (wavelength vs. temperature) for frequency calibration. The DLC smart then addresses the thermoelectric coolers of both DFB diodes in order to tune to a desired terahertz frequency. The minimum step size is on the 1 MHz level, which corresponds to a temperature change of only 40 µK per laser.



Frequency calibration of a TeraBeam 780 system. The wavelengths of the two DFB lasers overlap at approx. 784.6 nm (shaded bar).
By heating laser #1 and cooling laser #2, the difference frequency increases up to 2.3 THz.

Specifications TeraBeam 780 / 1550		
System	**TeraBeam 780**	**TeraBeam 1550**
Laser wavelengths	783 nm + 785 nm	1533 nm + 1538 nm
Laser power	35 – 40 mW per two-color fiber output	25 – 30 mW per two-color fiber output
Difference frequency tuning	0 – 1.8 THz (typ. 2.0 THz)	0 – 1.2 THz (up to 2.7 THz with Tuning Range Extension)
Tuning speed	Up to 0.1 THz/s	
Frequency accuracy	< 2 GHz	
Minimum frequency step size	< 10 MHz	
Frequency stability per laser*	typ. 20 MHz RMS, 100 MHz p-p @ 5 hrs	
Laser size (H x W x D) and weight	Two DFB pro L laser heads, each with dimensions 90 x 90 x 244 mm³ (H x W x D), weight 2.8 kg	Two DFB pro BFY laser heads, each with dimensions 60 x 120 x 165 mm³ (H x W x D), weight 1 kg
Control unit	DLC smart	
Controller size (H x W x D) and weight	50 x 480 x 290 mm³, 4 kg	
Laser diode warranty	5000 hrs or 2 years (whatever comes first)	

* At constant environmental conditions



Schematic of TeraBeam systems.

Further reading:
D. Stanze et al., *Compact cw terahertz spectrometer pumped at 1.5 µm wavelength;* J Infrared Milli. Terahz. Waves **32** (2011) 225-232.

Tuning Range Extension
Triple-Laser Systems – Frequencies up to 2.7 THz

Class 1 Laser Product EN 60825-1:2014.
Invisible laser radiation.
Avoid direct exposure to beam.

Key Features

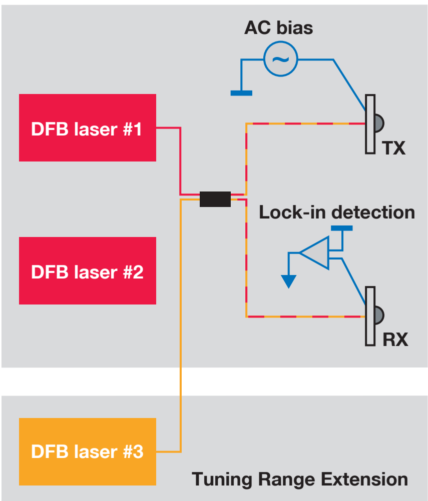
- Third laser head – access to higher frequencies
- Exploits full bandwidth of InGaAs photomixers
- Tuning range up to 2.0 THz or 2.7 THz
- Frequency calibration for each 2-laser subset

Owing to the efficiency of the latest InGaAs photomixers, TOPTICA has been able to push the frequency limits of frequency-domain spectrometers. Whilst one DFB laser at 1.5 µm offers a continuous tuning range of approximately 600 GHz, a combination of three lasers covers the entire frequency range from DC to 2.0 THz, or – using a more elaborate set of combinations – even up to 2.7 THz.

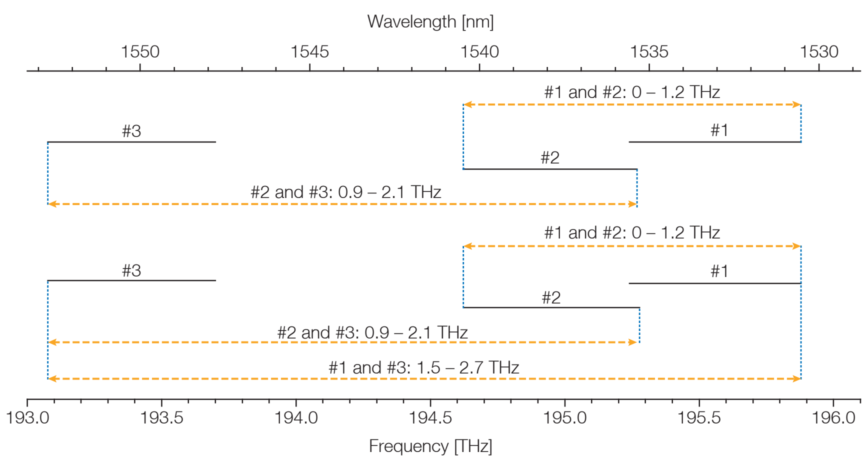
TOPTICA's Tuning Range Extension thus provides access to a frequency range that used to be beyond reach with commercial frequency-domain spectrometers. The frequency accuracy achieved with TOPTICA's DLC smart controller is so high that spectra obtained with different subsets of lasers can easily be "stitched together".

Specifications Tuning Range Extension

	THz Tuning Extension 2.0	THz Tuning Extension 2.7
Base system	TeraBeam 1550 (λ_1 = 1533 nm, λ_2 = 1538 nm)	
3rd laser	λ_3 = 1550 nm	
Difference frequency tuning	**0 – 2.0 THz** · 0 – 1.2 THz with lasers #1 and #2 (TeraBeam) · 0.9 – 2.0 THz with lasers #2 and #3	**0 – 2.7 THz** · 0 – 1.2 THz with lasers #1 and #2 (TeraBeam) · 0.9 – 2.0 THz with lasers #2 and #3 · 1.5 – 2.7 THz with lasers #1 and #3
Laser power	See TeraBeam 1550	
Tuning speed	See TeraBeam 1550	
Frequency accuracy	See TeraBeam 1550	
Laser size (H x W x D) and weight	60 x 120 x 165 mm³, 1 kg	
Controller size (H x W x D) and weight	50 x 480 x 290 mm³, 4 kg	
Laser diode warranty	5000 hrs or 2 years (whatever comes first)	



Schematic of TeraScan (red) with Tuning Range Extension (yellow).



Combinations of lasers used for the Tuning Range Extension to 2.0 THz (top) and 2.7 THz (bottom).

Phase Modulation Extension
Resolution Booster for TeraScan Systems

Specifications Phase Modulation Extension

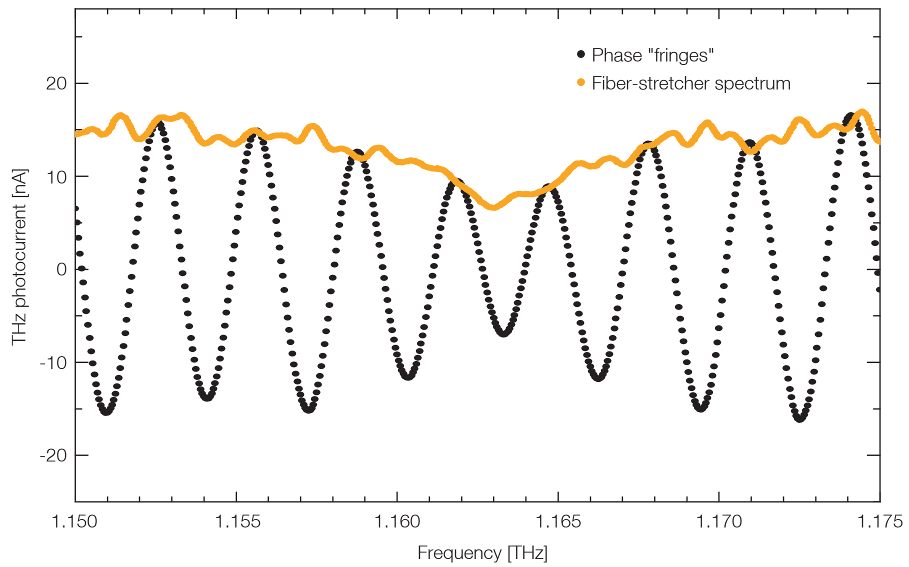
	Phase Modulation Extension NIR	Phase Modulation Extension IR
Concept	Twin fiber stretcher with piezo actuators	
Wavelength	780 nm, as defined by TeraScan 780 / TeraBeam 780	1.5 µm, as defined by TeraScan 1550 / TeraBeam 1550
Difference frequency tuning	See TeraScan / TeraBeam systems	
Difference frequency resolution	See TeraScan / TeraBeam systems. Complete amplitude + phase information available at maximum resolution.	
Fibers	2 x 60 m, SM/PM fibers	
Max. path length modulation	3 mm @ 1 kHz	
HV amplifier	Included	
Software	Included, part of control program	

Key Features

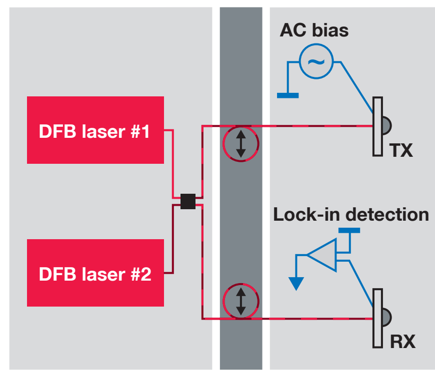
- Fast and accurate modulation of the terahertz phase
- Twin fiber stretcher with piezo actuators and high-voltage driver
- Path length modulation up to 3 mm @ 1 kHz

The Phase Modulation Extension acts as a "resolution booster" for cw-terahertz measurements. Powerful piezo actuators stretch the length of two single-mode fibers (~ 60 m each) - one in the transmitter path, one in the receiver path. This results in a fast and accurate modulation of the THz phase. Users can then retrieve both amplitude and phase information with a spectral resolution on the single-MHz level.

The Phase Modulation Extension is available at 780 nm and 1.5 µm, perfectly fitting the respective TeraScan systems. The twin-fiber concept not only doubles the modulation amplitude, but also increases the thermal stability of the setup.



Terahertz scan across a water-vapor resonance. The black trace depicts the phase "fringes" as measured with a TeraScan 1550 system. The yellow trace shows the envelope spectrum obtained with the Phase Modulation Extension; the high frequency resolution unveils small-scale standing-wave effects in the optical path.



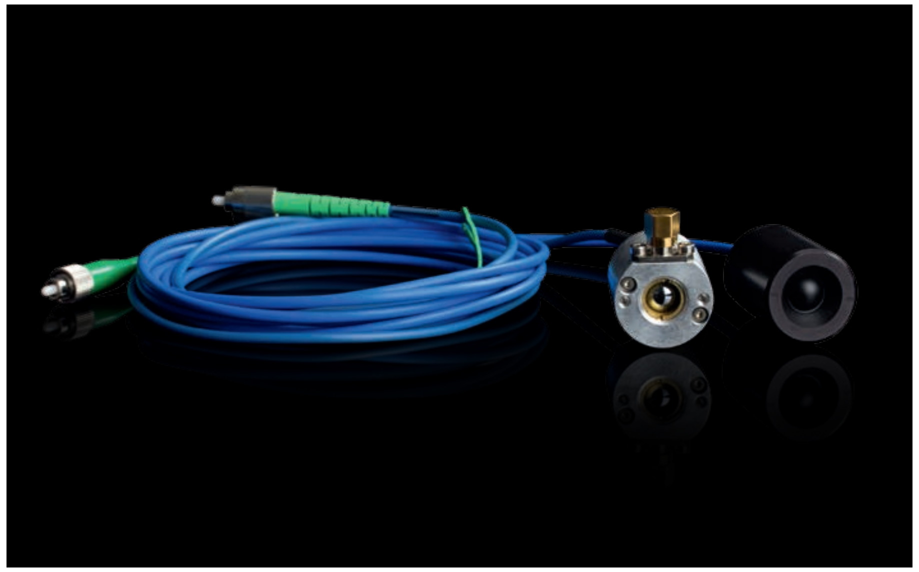
Schematic of TeraScan with Phase Modulation Extension (dark grey).

Key Features

- Cutting-edge GaAs (780 nm) and InGaAs (1.5 μm) photomixers
- Fully-packaged modules with silicon lens and SM/PM fiber pigtail
- Up to 100 μW output power

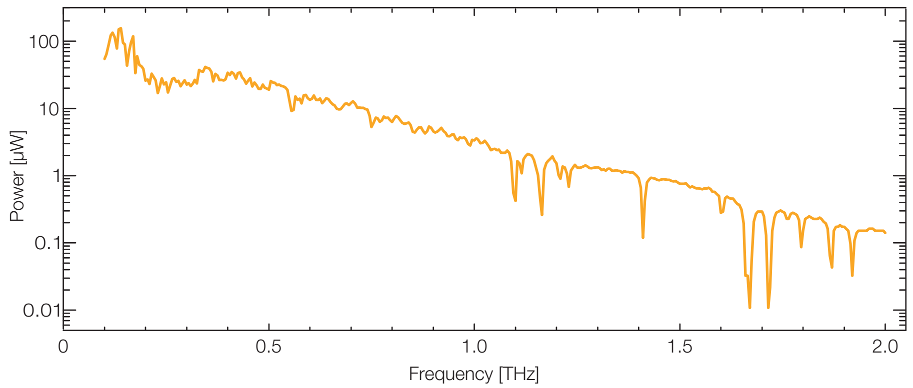
Having teamed up with some of the world's leading terahertz research institutes, TOPTICA is able to offer top-quality GaAs and InGaAs photomixers. Both material systems have their own merits. Systems with GaAs photomixers provide high bandwidths, owing to the wide continuous tuning range of 780 nm lasers. InGaAs emitters, on the other hand, generate power at record levels and take advantage of mature yet inexpensive 1.5 μm telecom technology.

All of TOPTICA's photomixer modules come equipped with a Silicon lens, an electric connector and SM/PM fiber pigtail. The all-fiber design eliminates the need for time-consuming laser beam alignment, and enables an easy and flexible integration into any terahertz assembly.



Specifications Photomixers

	GaAs Modules	InGaAs Modules
Terahertz emitter	#EK-00831, GaAs photomixer	#EK-000724, InGaAs photodiode
Terahertz receiver	#EK-000832, GaAs photomixer	#EK-000725, InGaAs photomixer
Excitation wavelength	0.8 μm	1.5 μm
Antenna type	Log-spiral	Bow-tie
Terahertz polarization	Circular	Linear
Emitter and receiver package	Cylindrical, ⌀ 1" Integrated Si lens and SM/PM fiber pigtail	Cylindrical, ⌀ 25 mm Integrated Si lens and SM/PM fiber pigtail
Emitter and receiver bandwidth	Approx. 3 THz	
Terahertz power (typ.)	2 μW @ 100 GHz 0.3 μW @ 500 GHz	100 μW @ 100 GHz 10 μW @ 500 GHz
Terahertz dynamic range (300 ms integration time)	80 dB @ 100 GHz 70 dB @ 500 GHz	90 dB @ 100 GHz 70 dB @ 500 GHz



Output power spectrum of an InGaAs photodiode emitter.

Further reading:
A. Deninger, *State-of-the-art in terahertz continuous wave photomixer systems;* In: D. Saeedkia (Edt.), Handbook of Terahertz Technology, Woodhead Publishing Series in Electronic and Optical Materials (2013).

T. Göbel et al., *Telecom technology based continuous wave terahertz photomixing system with 105 decibel signal-to-noise ratio and 3.5 terahertz bandwidth;* Opt. Lett. **38** (2013) 4197–4199.

Specifications Accessories - Schottky Receivers

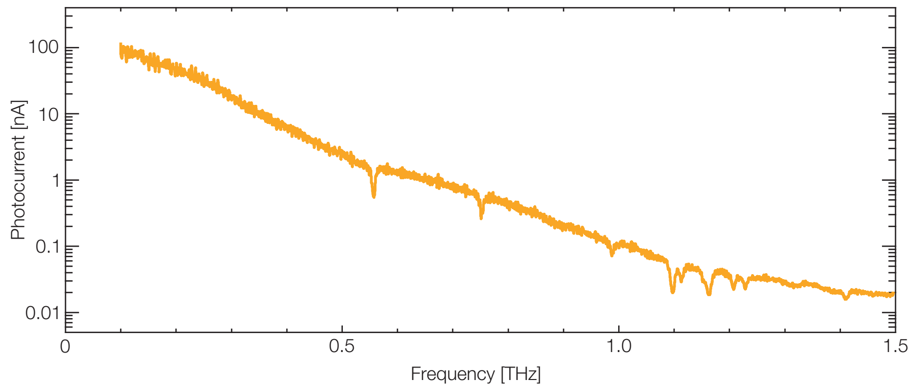
	#EK-000933 ("High Responsivity")	#EK-000961 ("High Bandwidth")
Concept	Zero-bias Schottky diode	
Antenna type	Log-spiral	
Terahertz bandwidth	50 – 1500 GHz	
Noise-equivalent power	7 pW/sqrt(Hz) @ 100 GHz 100 pW/sqrt(Hz) @ 1 THz	70 pW/sqrt(Hz) @ 100 GHz 1000 pW/sqrt(Hz) @ 1 THz
Responsivity	22000 V/W @ 100 GHz, 1100 V/W @ 1 THz	230 V/W @ 100 GHz, 17 V/W @ 1 THz
Amplifier bandwidth	10 Hz – 1 MHz	10 MHz – 4 GHz
Power supply	Included	
Warranty	1 year	

Key Features

- Output signal proportional to incident terahertz power
- Ideally suited for terahertz imaging
- High-bandwidth version measures individual terahertz pulses

Schottky diodes work as incoherent receivers (i.e., power detectors) for both pulsed and cw-terahertz radiation. In contrast to photomixer receivers or photoconductive switches, they are insensitive to the terahertz phase, but accomplish a direct measurement of the field intensity of the incident terahertz wave. This brings significant advantages for terahertz imaging, which benefits from both speed and sensitivity of the Schottky receivers.

A special high-bandwidth version lends itself for terahertz communication, or for the study of ultrafast processes – owing to its capability of resolving the amplitudes of individual terahertz pulses, even at typical repetition rates of femtosecond fiber lasers.



Cw-terahertz spectrum of air with water vapor lines, recorded with a GaAs photomixer-emitter and a Schottky receiver.

Further reading:
F. Rettich et al., *Field intensity detection of individual terahertz pulses at 80 MHz repetition rate;* J Infrared Milli. Terahz. Waves **36** (2015) 607-612.

M. Yahyapour et al., *A flexible, phase-insensitive system for broadband cw-terahertz spectroscopy and imaging;* IEEE Transact. Terahertz Science Technol. **6** (2016) 670-673.

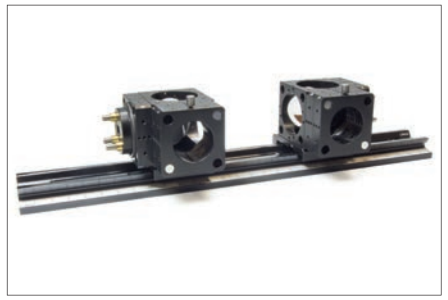
Accessories
Optomechanics

Key Features

- Compact and robust setups for transmission and reflection measurements
- Flexible solutions with and without beam focus
- Parabolic mirrors preserve full system bandwidth

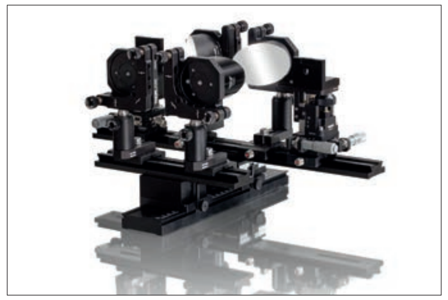
TOPTICA offers four different sets of optomechanics, designed for the most common beam-path configurations. All of the assemblies make use of parabolic mirrors in order to collimate, guide and focus the terahertz beam. Unlike plastic lenses, mirrors do not exhibit any transmission or reflection losses and therefore preserve the full bandwidth of TOPTICA's TeraFlash pro, TeraFlash smart and TeraScan systems.

For transmission-mode experiments, three rail-based assemblies produce a collimated terahertz beam (2-mirror setups), or an additional focus (4-mirror setup). For applications that require a reflection geometry, a compact, pre-aligned module generates a focus at the location of the sample.

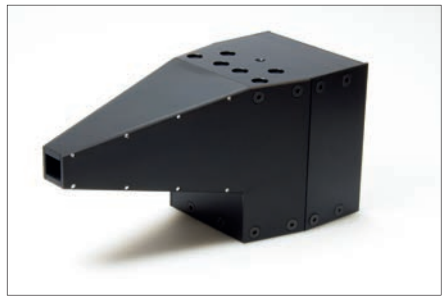


#BG-002653

#BG-001481



#BG-001784



#OE-000888

Specifications Accessories - Optomechanics

	#BG-002653 (Compact 2-mirror setup)	#BG-001481 (2-mirror setup)	#BG-001784 (4-mirror setup)	#OE-000888 (Reflection head)
User mode	Transmission	Transmission	Transmission	Reflection
No. of parabolic mirrors	2	2	4	4
Collimating mirrors	Ø 1", focal length 2"	Ø 2", focal length 3" *	Ø 2", focal length 3" *	Ø 1", focal length 2"
Focussing mirrors	--	--	Ø 2", focal length 2" *	Ø 1", focal length 4"
Focus size	--	--	Approx. 2 mm	Approx. 2.5 mm
2 xyz stages for photomixers	--	Included	Included	--
Manual delay stage	--	Included	Included	--
Motorized delay stage	No, please see Phase Modulation Extension			
Optical rails	Included	Included	Included	--
Compatibility	TeraFlash pro, TeraFlash smart, TeraScan 1550	TeraFlash pro, TeraFlash smart, TeraScan 1550, TeraScan 780, TeraSpeed	TeraFlash pro, TeraFlash smart, TeraScan 1550, TeraScan 780, TeraSpeed	TeraFlash pro, TeraFlash smart, TeraScan 1550

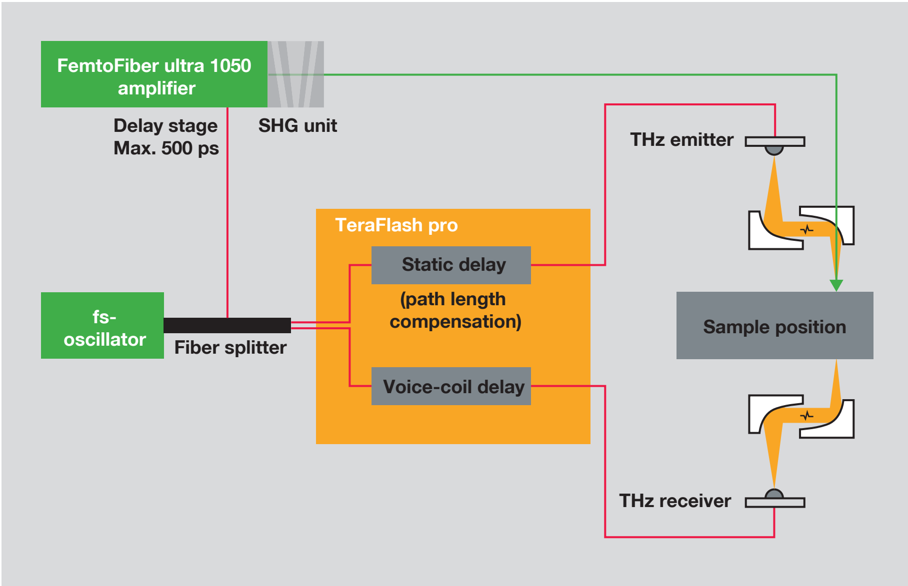
* Other focal lengths on demand

CUSTOMIZED SYSTEMS
Flexible Solutions, Innovative Answers

Solutions from the Specialists

TOPTICA offers a large variety of ultrafast lasers from ultraviolet to mid-infrared wavelengths. All of these systems come as robust, cost-effective light sources with superior specifications. They provide turnkey operation and require neither mechanical alignment nor water-cooling.

TOPTICA can synchronize any laser of the FemtoFiber pro or FemtoFiber ultra family to a TeraFlash pro system, a concept that becomes relevant in optical pump – terahertz probe experiments: An intense laser pulse excites the sample under test, and terahertz spectroscopy analyzes the induced changes in the material. An additional translation stage allows users to vary the time-of-arrival of the pump-laser pulses with respect to the terahertz measurement.



In an alternative scenario, researchers may wish to use a high-power laser to generate pulsed terahertz radiation in the first place, e.g., with the help of large-area emitters or antenna arrays. Vice versa, near-field applications may call for an exchange of the receiver module, whilst the photoconductive emitter remains in place. In both cases, TOPTICA can modify the TeraFlash pro according to customers' requests.

TOPTICA's product specialists have many years of hands-on experience with lasers, electronics and terahertz applications. They look forward to meeting new challenges!

PRODUCT OVERVIEW

TOPTICA provides complete instruments as well as components for both time-domain and frequency-domain terahertz generation.

For time-domain applications, the **TeraFlash pro** has redefined industrial benchmarks in terms of bandwidth and dynamic range. Combining TOPTICA's ultrafast fiber laser technology with state-of-the-art InGaAs antennas, the system achieves a peak dynamic range of 95 dB and a bandwidth of 6 THz – all within a measurement time of less than half a minute. A versatile **Imaging Extension** enables researchers to exploit the full potential that the combination of time-domain imaging and spectroscopy has to offer.

TOPTICA's new time-domain platform **TeraFlash smart** sets a new speed record for terahertz-based test & measurement tasks: the system acquires up to 1600 pulse traces per second. In contrast to conventional time-domain spectrometers, the TeraFlash smart does not use a mechanical delay, but includes two synchronized femtosecond lasers ("electrically controlled optical sampling", ECOPS).

A superb tool for contact-free material characterization, the screening platform **TeraSpeed** achieves unprecedented data rates: A digital output streams terahertz intensity values at sampling rates up to 500 kHz, and an analog signal represents the field amplitudes of individual terahertz pulses at repetition rates as high as 100 MHz.

For frequency-domain terahertz spectroscopy, TOPTICA offers two "Top-Seller" systems – **TeraScan 1550** and **TeraScan 780**. Based on precisely tunable DFB lasers, digital control electronics, and state-of-the-art **InGaAs** and **GaAs photomixer** technology, the TeraScan systems combine ease of use with best-in-class specifications.
A set of modular product packages further extends the cw-terahertz product portfolio: The **Tuning Range Extension** pushes the useable bandwidth out to almost 3 THz, and the **Phase Modulation Extension** acts as a "resolution booster", providing amplitude and phase information with single-megahertz resolution.
Users can combine the packages and upgrade their instruments depending on the requirements of the experiment.

Selected accessories – **Schottky diodes**, **optomechanics** and a compact **reflection head** – are available for both time-domain and frequency-domain systems.

Order Information

Product Name	Order Information	Page
TeraFlash pro	Time-domain terahertz spectroscopy platform	12
THz Imag. / Basic *	Imaging extension, basic version without terahertz optics	18
THz Imag. / Complete *	Imaging extension, complete version including terahertz optics	18
TeraFlash smart	Fast terahertz system based on ECOPS	14
TeraSpeed	Terahertz screening system	16
#EK-000979	InGaAs photoconductive switch for pulsed terahertz generation, fiber length 0.3 m	19
#EK-000781	InGaAs photoconductive switch for pulsed terahertz generation, fiber length 1.0 m	19
#EK-000978	InGaAs photoconductive switch for pulsed terahertz generation, fiber length 2.5 m	19
#EK-000981	InGaAs photoconductive switch for pulsed terahertz detection, fiber length 0.3 m	19
#EK-000782	InGaAs photoconductive switch for pulsed terahertz detection, fiber length 1.0 m	19
#EK-000980	InGaAs photoconductive switch for pulsed terahertz detection, fiber length 2.5 m	19
TeraScan 780	Frequency-domain terahertz platform based on 780 nm lasers and GaAs photomixers	20
TeraScan 1550	Frequency-domain terahertz platform based on 1.5 µm lasers and InGaAs photomixers	20
TeraBeam 780	Two-color DFB laser system at 780 nm, without terahertz antennas	22
TeraBeam 1550	Two-color DFB laser system at 1.5 µm, without terahertz antennas	22
THz Tuning Ext. 2.0 **	3rd laser head for TeraScan 1550, tuning range extension to 2.0 THz	24
THz Tuning Ext. 2.7 **	3rd laser head for TeraScan 1550, tuning range extension to 2.7 THz	24
THz Phase Mod / NIR ***	Twin fiber stretcher for terahertz phase modulation, for 780 nm lasers	25
THz Phase Mod / IR **	Twin fiber stretcher for terahertz phase modulation, for 1.5 µm lasers	25
#EK-000831	GaAs photomixer for cw-terahertz generation	26
#EK-000832	GaAs photomixer for cw-terahertz detection	26
#EK-000724	InGaAs photodiode for cw-terahertz generation	26
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#EK-000933	Schottky receiver, high-responsivity version	27
#EK-000961	Schottky receiver, high-bandwidth version	27
#BG-002653	Compact optics assembly (transmission, collimated beam)	28
#BG-001481	Flexible optics assembly (transmission, collimated beam)	28
#BG-001784	Flexible optics assembly (transmission, collimated + focused beam)	28
#OE-000888	Reflection head	28
*	Requires TeraFlash pro	
**	Requires TeraScan 1550 or TeraBeam 1550	
***	Requires TeraScan 780 or TeraBeam 780	

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