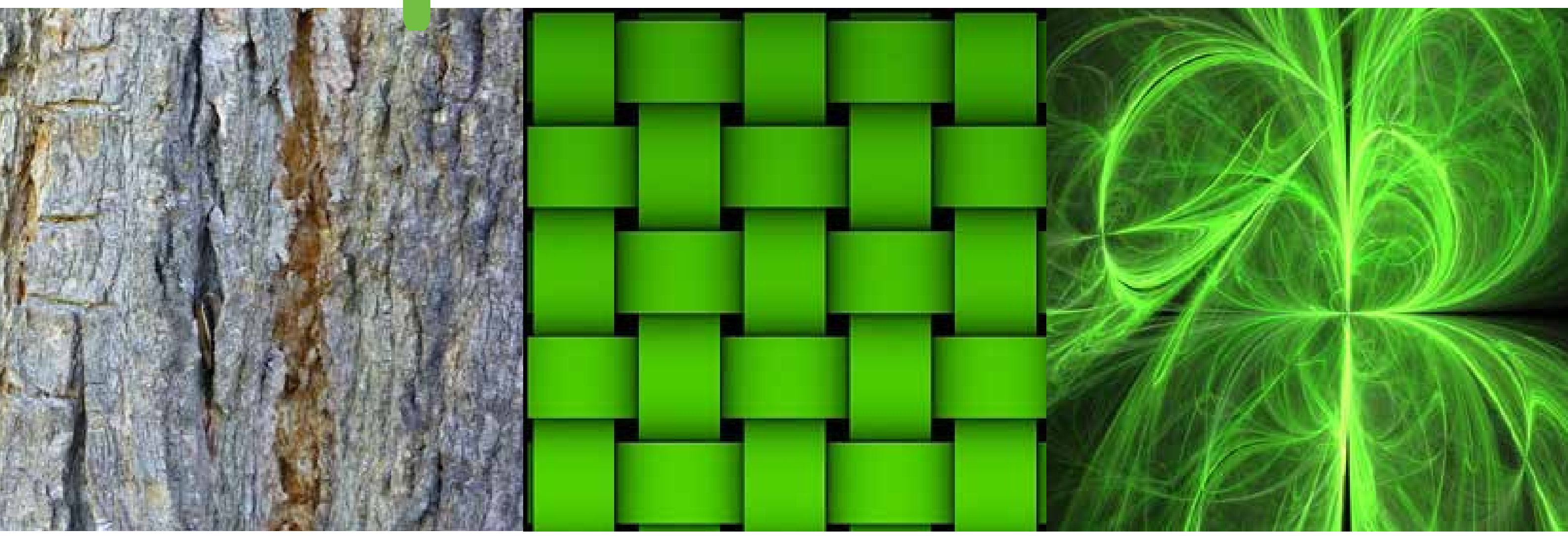
MenloSystems

Discover the World of THz



Originating from our experience in manufacturing high-performance femtosecond fiber lasers and stabilization electronics, Menlo Systems has been an expert for THz technology since 2007. We supply complete and easy to use solutions for THz time-domain spectroscopy and imaging applications to our customers worldwide. Our systems are designed to address the various needs ranging from a demanding scientific laboratory setup to the harsh conditions at an industrial production site.

Our THz technology benefits from strong collaboration with research institutes in the field, ensuring latest standard of our THz components. We integrate our own ultra-stable femtosecond lasers and bring products for highest technological requirements to the market. The development of our systems is motivated by applications such as novel standards for safety and quality control, and our THz products are embedded in various projects in paper and polymer industry.

Contents

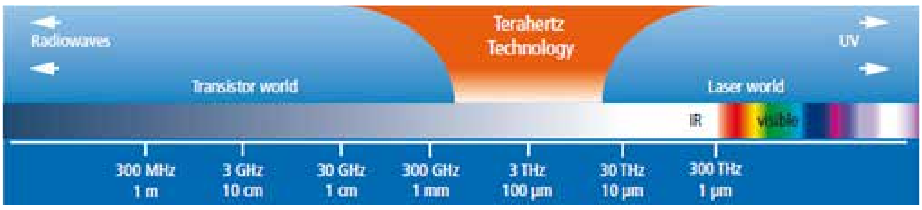
Why THz Technology?

Optics meets electronics

Over the past few years reliable THz sources have become commercially well-established, making the frequency range between the microwave and the far IR end of the visible spectrum available for exploration. Bridging several orders of magnitude in frequency, optoelectronic devices are merging the worlds of high-frequency electronics and photonics, and gave new impulses to THz research and applications. Affordable lasers of unprecedented stability, in combination with highly engineered and efficient electrooptical materials, are driving the fast progress of THz instrumentation into various fields of science and industry, offering complementary or even alternative methods of material characterization.

Find out about our THz solutions

Whatever the task, Menlo Systems offers complete systems for THz time-domain spectroscopy (THz-TDS) and THz imaging applications. Since the requirements for high-end laboratory experiments are substantially different from those of reliable characterization of serial products, the architecture of our THz instrumentation is optimized to serve the needs accordingly. Our open platform model offers highest flexibility, while our compact fiber coupled models are ideally suited for integration. In all cases, they are stand-alone solutions ready to use, leaving space for an individually tailored design. We integrate our home-built femtosecond fiber lasers and latest model photoconductive antennas developed by our collaboration partners.



1 THz ~ 1 ps ~ 300 µm ~33 cm-1 ~ 4.1 meV ~ 47.6 K

What makes THz waves unique?

THz waves

- penetrate a wide variety of non-conducting materials such as polymers, paper, textiles, ceramics, composite materials, chemical powders
- are being reflected by metals
- are sensitive to charge carriers in semiconductor materials
- identify numerous organic molecules through selective absorption and dispersion due to rotational and vibrational transitions
- exhibit low photon energies (4 meV @ 1 THz), unlike UV light or X-rays are non-ionizing and safe in operation
- do not require a coupling medium, unlike ultrasound waves

Where is THz useful?

THz spectroscopy is a rapidly evolving field in research, industry, and security applications. Fingerprinting of spectroscopic lines in the THz region not only helps identifying chemical or biochemical molecules, but also remote signals from astronomic systems. Imaging with THz waves can be used for pharmaceutical, security, or scientific identification of substances such as drugs, explosives or weapons. Furthermore, THz imaging is implemented into quality control and optimization of industrial manufacturing processes. For example, one can look for tiny variations or defects of polymer and plastic materials within an object or characterize the quality of paper products.

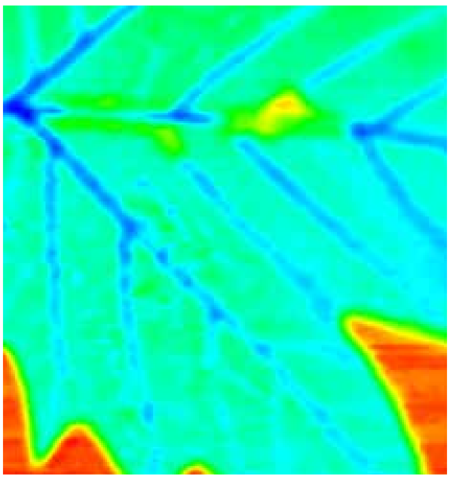
Explore the various fields of THz applications:

- material science
- non-destructive testing
- paper industry
- plastics industry
- pharmaceutical industry
- food industry
- homeland security
- atmospheric research

Principle of THz-TDS

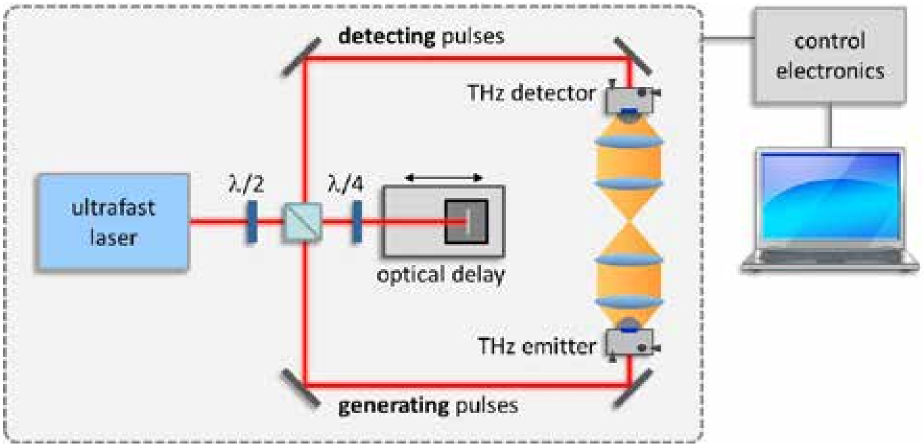
THz-broadband spectroscopy

Unlike single frequency spectroscopy, experiments with pulsed THz radiation probe the response of a sample over a wide spectral THz range at once. The information contained in a single reference measurement reveals versatile information on the type, the composition, or the quality of the investigated material. The typical spectrum obtained from photoconductive antennas (PCAs) ranges from about 100 GHz to more than 4 THz. Vibrational or rotational transitions of molecules in gas phase matching the radiation frequency lead to sharp characteristic absorption lines. Like a fingerprint they can be used for chemical identification. The absorption intensity is proportional to the concentration of the substance. Because THz time-domain spectroscopy is a coherent detection scheme, it is phase sensitive and allows measuring the refractive index or the thickness of a sample. In THz imaging, the amplitude and phase of a THz pulse reveal the local internal properties of a sample.



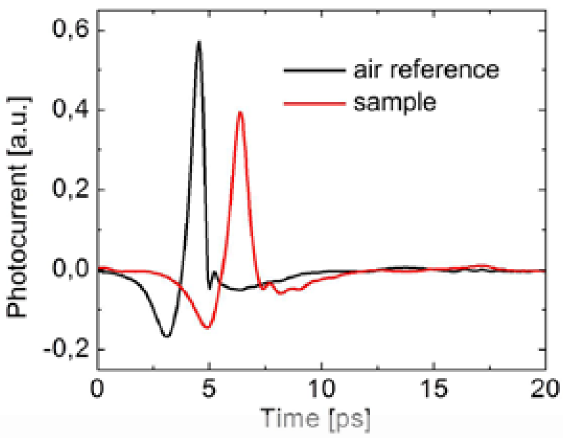
THz-TDS – our technology

Schematics of a conventional THz-TDS system:



Our broadband THz spectrometer is simple, reliable, and easy to use. For optimal performance and long term stable operation we integrate our latest technology femtosecond lasers based on erbium-doped optical fibers and telecom fiber components at 1560 nm wavelength. Efficient frequency doubling gets you to the wavelength of a Ti:Sapphire laser, yet at a much smaller footprint and cost factor.

For broadband spectroscopy, operation in pulsed mode is efficient and technologically well established. It can be understood thinking of a movie that is constructed of snapshots with a fast camera shutter. In the THz spectrometer we split the output of the laser and send the ‘generating’ and the ‘detecting’ pulses onto two different optical paths to the emitter and the detector antenna, respectively. One path is variable in length, controlling the delay of the pulses arriving at the corresponding antenna. For a detailed description of THz pulse generation and detection, please see the next page. After a THz pulse has been generated in the emitter antenna, the detecting pulse allows the detector antenna to measure its electrical field. By changing the optical delay, the THz field is measured at different points in time. Finally, the recorded time trace is transferred into frequency domain by Fourier transformation for spectroscopic evaluation.
When a sample is placed into the THz path it will respond to the THz field and influence the detected signal. To obtain information on the sample material properties, the THz signals with and without the sample are compared in a reference measurement:

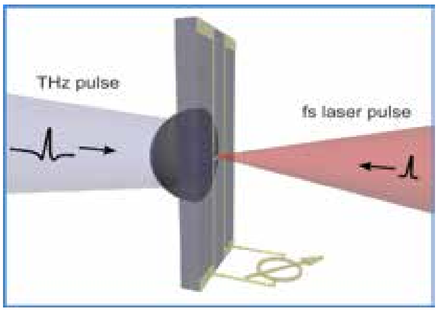


THz-Generation and Detection

Optical THz generation

Broadband THz radiation can be efficiently generated and detected using femtosecond lasers and photoconductive antennas based on semiconductor materials. This indirect approach is reliable, cost efficient, and user friendly. The technology benefits from the rapidly evolving market for femtosecond fiber lasers and low cost THz antennas. Moreover, fiber coupled components allow for compact design and easy operation.

THz antenna with Si-lens in detection scheme:



THz generation:

- a femtosecond pulse creates electron-hole pairs
- charge carriers are accelerated by the antenna bias field
- a transient photocurrent is induced
- a THz field is generated proportional to the time-derivative of the photocurrent

Photoconductive antenna operation

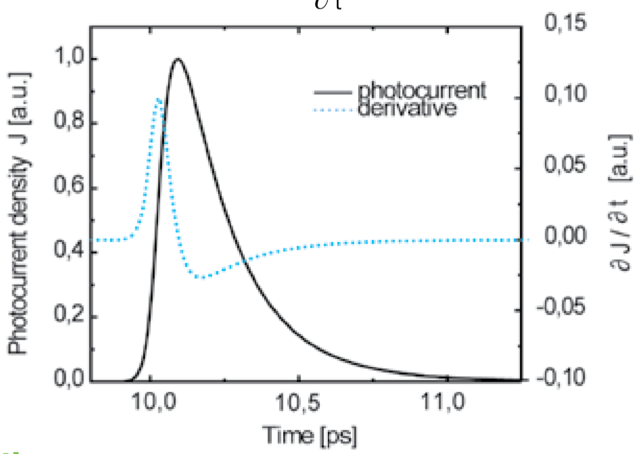
Our THz antennas are photoconductive switches based on optimized semiconductor materials with a metal electrode structure on their surface. The output of a femtosecond laser at a suitable wavelength is focused onto the gap between the antenna electrodes and the light is absorbed by the substrate. The interaction of the laser pulses with the semiconductor material results in the generation of electron-hole pairs. Upon the availability of charge carriers, the antenna is switched into a conductive state for the duration of the carrier life time.

THz emission and detection are analog processes where the charge carriers sense the presence of an electric field. A bias voltage applied to the antenna leads to a photocurrent across the structure, and the accelerated charge carriers emit a THz electrical field proportional to the time-derivative of the photocurrent. During the detection process, the generated charge carriers are accelerated by the THz field towards the electrodes. This leads to a weak photocurrent which can be amplified and measured. The detected photocurrent is proportional to the amplitude of the THz electric field. The characteristics of the ps-long THz wave are traced in time by the much shorter fs-optical pulses.

The bandwidth of the THz spectrum increases with shorter lifetime of the charge carriers, in accordance with the Fourier relation between the time domain and the frequency domain. A silicon lens ensures efficient coupling of the THz radiation out of and into the antenna substrate.

Relation between the THz field E_{THz} and the derivative of the photo current J:

$$E_{THz} \propto \frac{\partial J}{\partial t}$$

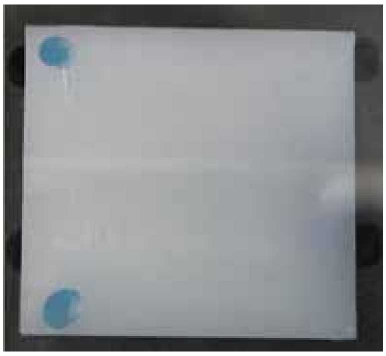


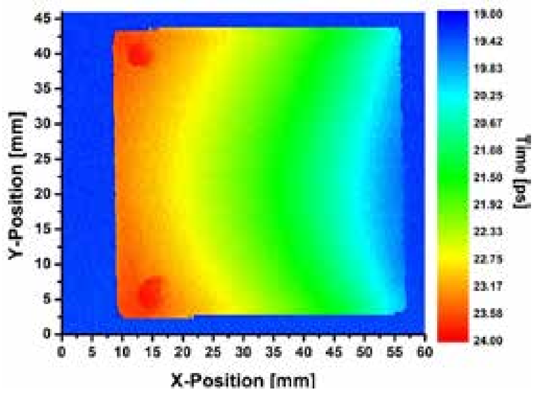
THz detection:

- a fraction of the THz pulse coincides with the femtosecond pulse
- optically generated charge carriers are accelerated by the incident THz field
- a weak photocurrent is measured proportional to the electric THz field amplitude
- the temporal characteristics of the THz field are traced in a time-resolved measurement

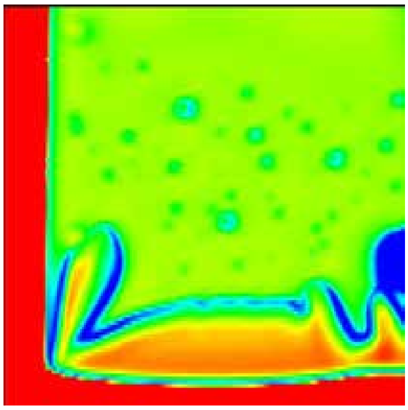
THz Imaging

Photograph and THz image of a plastic wedge, recorded with TERA K15 THz-TDS system and TERA Image extension (size: 30 mm x 35 mm):

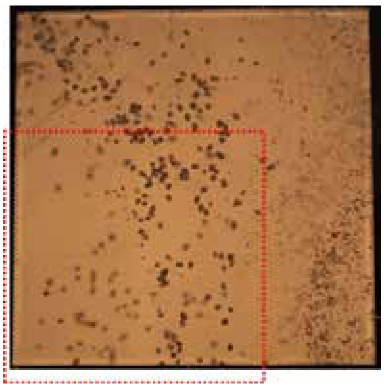


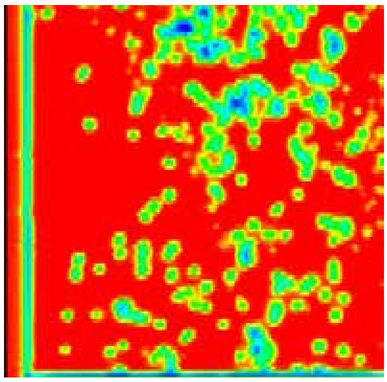


Photograph and THz image of a polymer double layer with internal delamination, air bubbles, and shrink hole defects, recorded with TERA K15 THz-TDS system and TERA Image extension (image cutout: 57 mm x 60 mm):



Photograph and THz image of a plastic slab with enclosed sand grains, image recorded with TERA K8 THz-TDS system and TERA Image extension (image cutout: 47 mm x 50 mm):





Imaging with THz waves

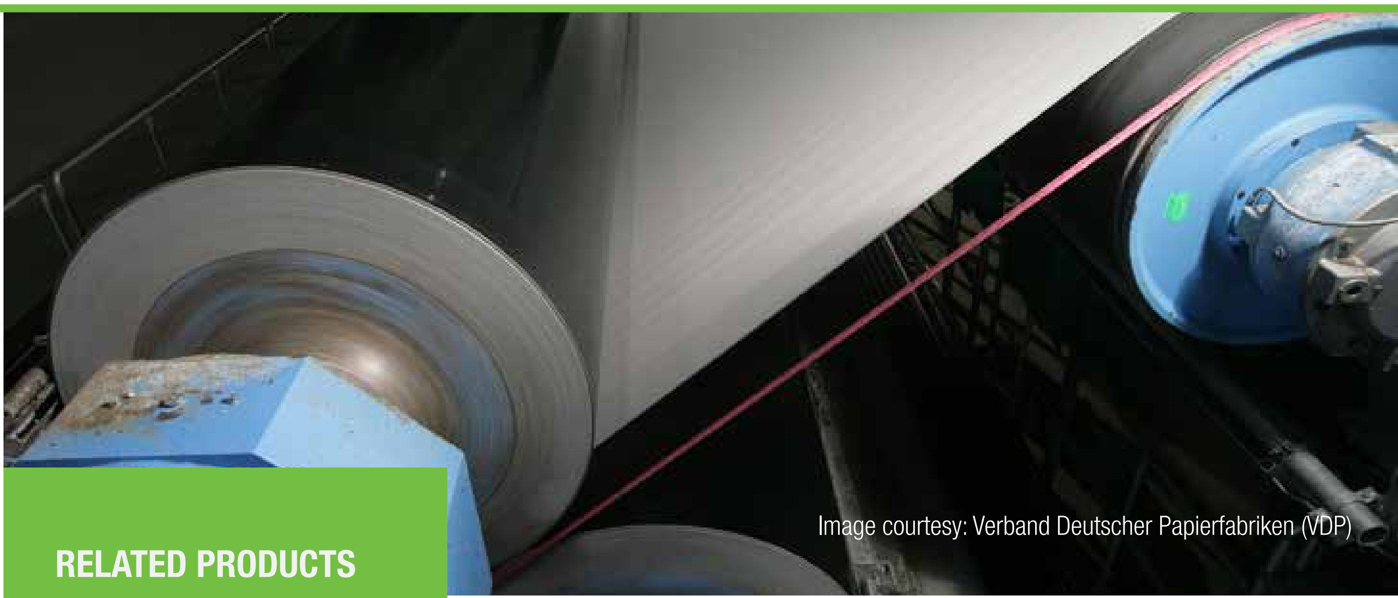
The response of matter to THz radiation, when exploited for imaging applications, reveals the inner composition of opaque materials. By mapping the variation of the material THz properties one can visualize internal defects. Unlike testing with ultrasound waves, THz imaging does not require any coupling medium. THz waves open up new possibilities for quality inspection and non-destructive testing of industrial products, food, or biological tissue.

THz amplitude and phase information

THz waves interacting with an object respond to the material characteristics by changing their intensity and temporal behavior. From the absorption and dispersion of a probing THz pulse one can derive information on the material thickness and density. By measuring the amplitude and the phase of the pulse at well-defined positions, a THz image of an object can be reconstructed. With an additional spectral analysis even different material components can be identified.

We offer an automated TERA Image extension for our THz-TDS systems. It moves a sample in the THz focal plane where a THz spectrum is recorded for each step of the XY-scanning device. From the field amplitude and phase, the software reconstructs a THz image which can subsequently be displayed either in the amplitude or in the phase mode. Inner defects such as delamination, air insets, cracks, or impurities, as small as tiny sand grains, can be resolved.

Application – Mapping the Formation of Paper Products



RELATED PRODUCTS

TERA K15
TERA Image
TERA OSCAT

Paper formation as a quality measure

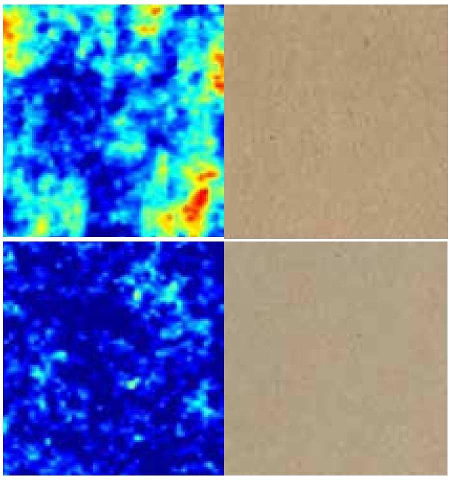
The quality and working properties of paper products are mainly defined by the thickness and uniformity of the mass distribution, technically referred to as formation, in the raw material. Conventional methods of examination suffer limitations, e.g. backlight examination is suitable for thin sheets up to 150 g/m^2 while for thick paperboard complex radiometry methods are applied.

With THz imaging, the Papiertechnische Stiftung (PTS) has introduced a novel technique to test the formation of both thin and thick paper products, integrating Menlo Systems' TERA K15 (p. 16) into their scanning system. With its modular architecture, the TERA K15 is ideal for integration into paper production line.

Figure 1: Backlight image and THz image of a watermark

PTS evaluates THz image data of paper, cardboard, wood, and plastic sheets with grammage between a few g/mm^2 up to 5000 g/m^2, with high sensitivity over the entire range, and resolution of approximately 0.6 mm. The tiny variations within a 70 mm x 24 mm watermark cutout on a 5 Euro bank note demonstrate the sensitivity of the method (Fig.1). The real strength of the measurements, however, lies in the characterization of thick material. Irregular and smooth formation of the 200 µm cardboard in figure 2 (45 mm x 50 mm cutout from a cardboard sheet) cannot be distinguished optically, but the THz image clearly reveals the different formation of the upper and lower cardboard samples.
For quantitative evaluation, the formation and surface mass are displayed in a histogram:

Figure 2: Cardboard with irregular (upper row) and smooth (lower row) formation, THz images and photographs



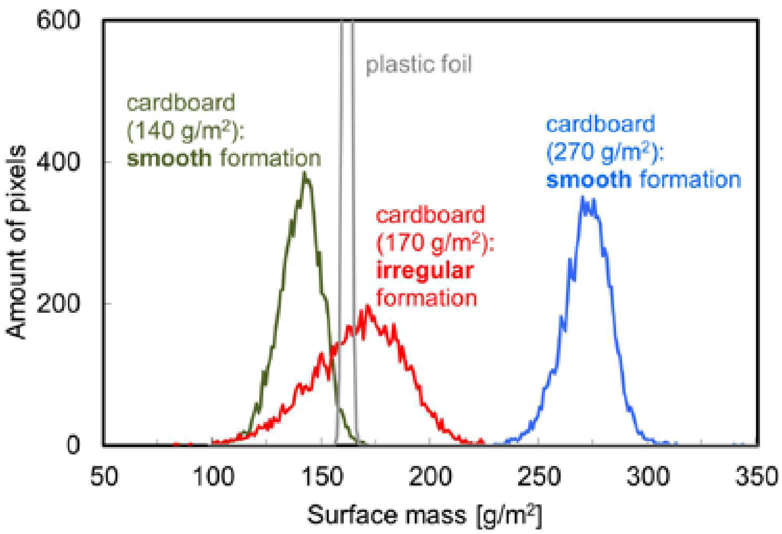
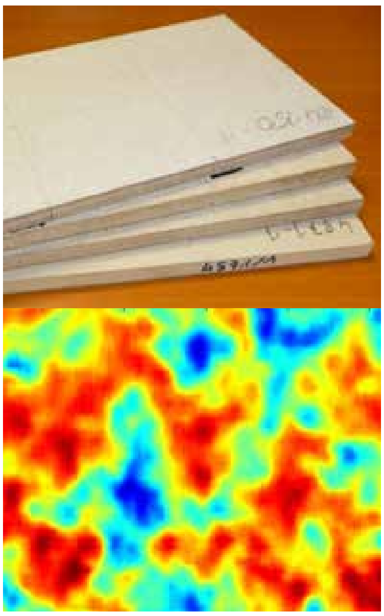


Figure 3:
Timber boards with THz image



The focus of the presented study lies on paper, but THz technology can be as well applied to other materials like plastic foils, textiles and wood products which can be significantly thicker, as e.g. the 5 mm thick timber boards in figure 3 (THz image: 45 x 45 mm cutout). With roughly 50 % transmission the material is well suited for THz inspection, making use of the high dynamic range of the measurement method.
Because THz radiation is strongly absorbed in water, it is ideal for determining the humidity content in paper. Another benefit is obtained when making use of the THz response to layer interfaces. Feasibility studies are ongoing for the characterization of paper coatings. On the long term, it is expected that common monitoring systems using x-ray or radioactive radiation will be replaced by THz systems.

Application – Detection of Hazardous Fluids

RELATED PRODUCTS

TERA K15
TERA K8
TeraLyzer

Figure 1: Handheld THz-TDS system

Project funded by the Bundesministerium für Bildung und Forschung (BMBF)

Classification of liquid bottle contents by THz spectroscopy

Liquid explosives cannot be distinguished from harmless substances optically or by routine security checks. THz radiation is increasingly exploited for material inspection, but polar liquids strongly absorb THz waves and are therefore not well suited for measuring in transmission geometry.

In collaboration with the Philipps University of Marburg, the TU Braunschweig Institut für Hochfrequenztechnik (IHF), the Bundesanstalt für Materialforschung und -prüfung (BAM), the Fraunhofer HHI, and TEM Messtechnik we have developed a portable THz system which can classify bottled liquids as hazardous or non-hazardous in an online reflection measurement. It is the first of its kind fiber coupled THz TDS system where the measurement head is held in one hand and the unopened container in the other (Fig. 1). The system is easy to use and eye-safe, and it operates quickly and precisely.

The interior of the handheld demonstrator is a fully fiber coupled THz-TDS system using a Menlo Systems T-Light femtosecond fiber laser at 1560 nm emission wavelength and includes dispersion compensation for ~30 m optical fiber. Temporal scanning is achieved with fiber stretchers and a calibrating reference laser. Constructed in a compact enclosure on wheels the spectrometer can be easily transported to the dedicated site of operation (Fig. 2).

THz spectroscopy in reflection geometry

The fundamental principle of operation is based on spectroscopic evaluation of a THz pulse reflected off the interface between the plastic bottle and the liquid (Fig. 3). Most container materials such as plastics or polymers are transparent for THz radiation. An incoming THz pulse is partially reflected off the outer bottle surface (first reflection) and after passing the bottle layer is reflected off the inner bottle surface forming the interface with the liquid (second reflection). Evaluation of the second reflected pulse is giving information on the dielectric properties of the bottle content.

For proof of principle, a set of liquid explosives, e.g. ethanol, nitrobenzene, toluene, glycerol, or their aqueous dilutions were characterized in a lab spectrometer. With the measured THz spectra and a classification algorithm it was possible to distinguish harmless from potentially dangerous liquids:

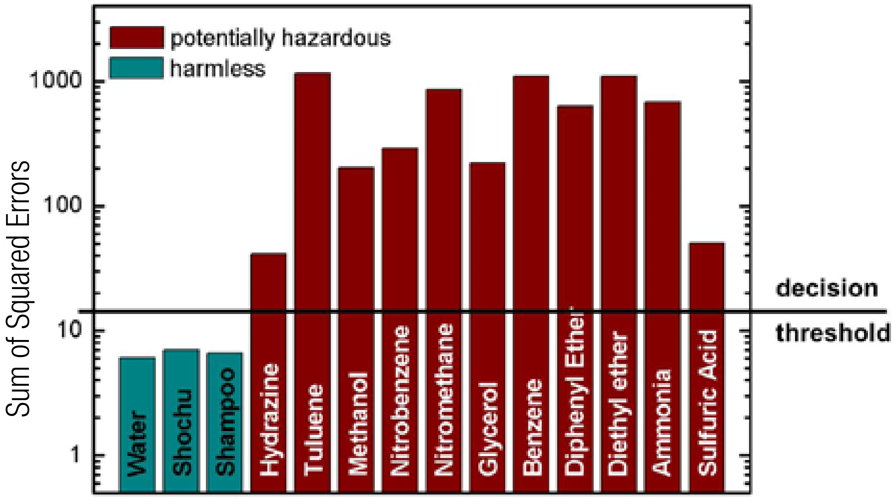
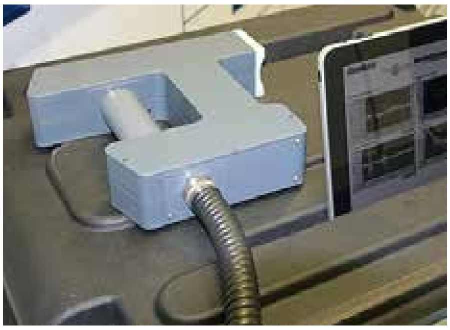


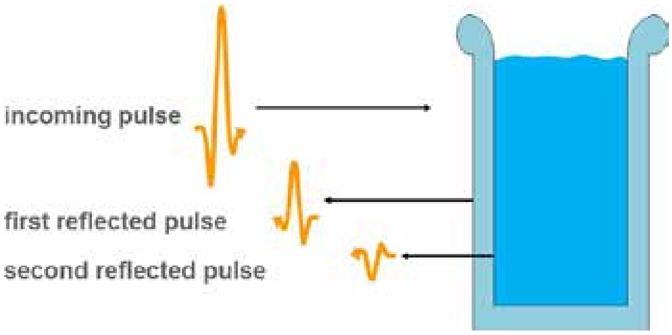
Figure 2: Portable THz spectrometer
a) Housing with femtosecond laser source, system electronics and control panel

a) Fiber coupled measurement head for measurement in reflection geometry



The handheld demonstrator operates in an even simpler way. The decision 'hazardous – non-hazardous' is based on the appearance of the temporal pulse trace reflected from the bottle/liquid interface (second reflected pulse in the graphics above). Its shape is compared to an internal database. From pushing a button on the measurement head the entire measurement process takes just a few seconds. Security applications could profit from the technology of the system.

Figure 3: An incoming THz pulse with first and second reflection from the two interfaces of the container wall



Application – Quality Inspection of Plastic Compounds

RELATED PRODUCTS

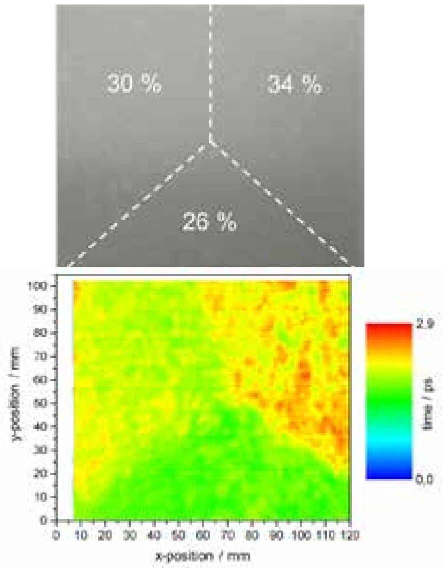
TERA K15
TERA Image
TERA OSCAT

Das Kunststoff-Zentrum

Non-destructive testing (NDT) of plastic compound materials

Quality inspection of polymeric and plastic compound materials with THz radiation is non-destructive, contact-free and eye safe. It is suitable for a large variety of materials and has become a convenient testing method for process optimization and quality assurance. A THz image reveals the inner structure of a product sample. One can distinguish between different types of polymers, map the content of filler media in compound materials, or identify internal defects or contamination.
The Süddeutsches Kunststoff-Zentrum (SKZ), Germany's expert in the plastics industry, is using our TERA K15 with the TERA Image extension to obtain THz images of polymer products and plastic compounds with a resolution of about 500 µm. The presented results demonstrate the high potential of industrial quality testing with THz imaging. Menlo's TERA K15 is compact and flexible, and with its fiber coupled architecture can easily be integrated into a production chain.

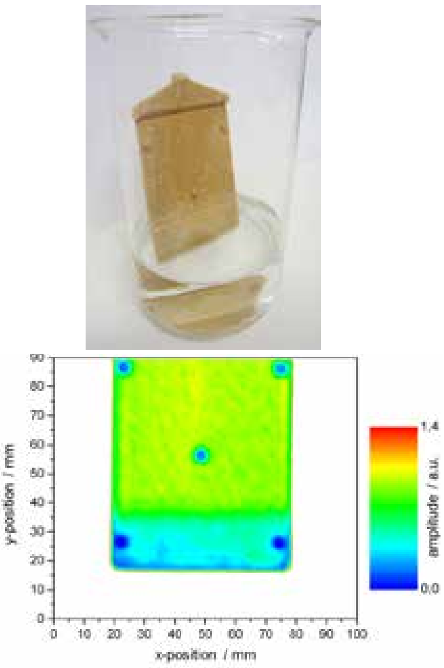
Areas of different fiber content in polymer, photograph and THz image



Glass fiber reinforced plastics (GRP)

Adding glass fiber to plastics is an effective way to improve the mechanical properties of low-cost commodities. Such compounds can replace expensive materials for the production of highly stable and durable parts, e.g. in car industry. However, particularly part production with complex geometry needs careful surveillance of the concentration, homogeneity, and alignment of the fiber within the GRP.
A THz image of a polypropylene specimen with areas of different fiber filling content visualizes the variations by mapping the travel time of a THz pulse through the material (picture). The measurement method exploits the effect of specific refractive index of the different material components. In the picture, red color indicates highest fiber concentration.

Humidity content in a WPC plate, photograph and image

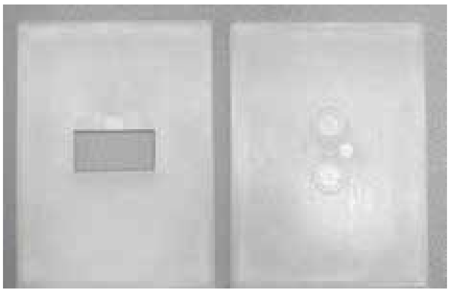


Wood polymer composites (WPC)

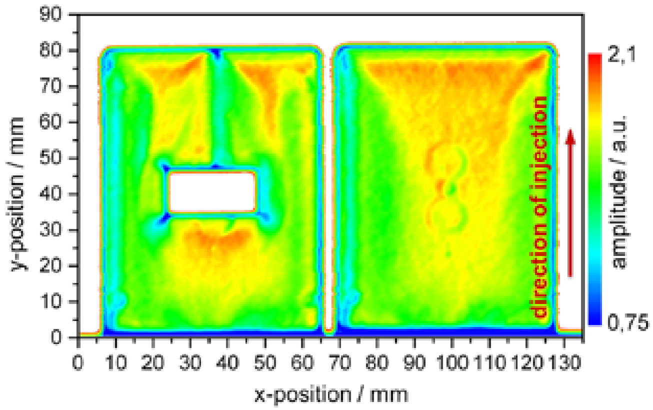
WPC, a mixture of wood powder and thermoplastic, is a true alternative to solid wood. The material is durable, easy to process, and offers novel manufacturing possibilities such as molding or continuous extrusion of wood products, e.g. furniture or pencils. However, the end product is sensitive to water drawn by the material which might lead to deformation and biological decomposition.
THz spectroscopy can be used to monitor the increase in water content within the material by measuring the decreasing THz transmission. In a WPC specimen with 70 % wood fiber, the areas which have been previously wetted are less transparent for THz radiation than the dry parts and appear blue in the picture.

GRP molded into different shapes

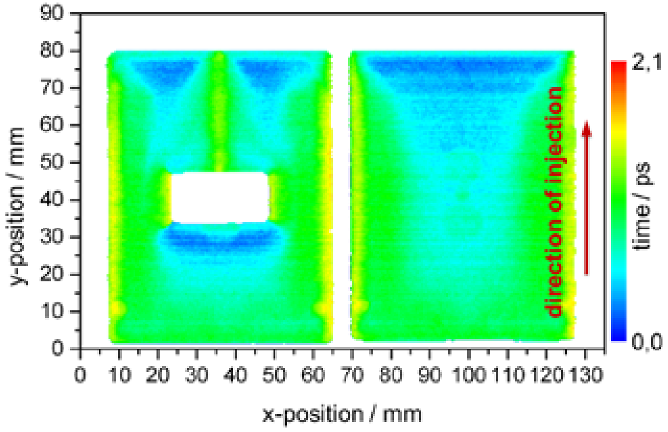
a) Photograph of fiber reinforced plastic parts moulded in different cavities, with and without flow barrier



b) THz amplitude picture



c) THz phase picture



Molding of functional components

Molding allows manufacturing nearly any arbitrary shape, however, the molding process, tools or the geometry need to be optimized in order to prevent defects. Shrink marks, flow or weld lines within molded polymer parts occurring during production often give rise to weak points or even failure of the component. When GRP is injected into a cavity, a flow barrier will cause inhomogeneity (pictures left).

In a THz picture of a sample with 30 % glass fiber content variations of thickness, compactness, or filler concentration become visible. While an increased THz absorption in the amplitude picture (b) indicates compression or thickening, the phase picture (c) allows for precise thickness measurement.

More THz Applications

THz-combs: Optical frequency combs can be transferred into the THz spectral region with photomixer devices or photoconductive antennas [IEEE Trans. THz Sci. Technol. 3, 322; 2013]. The resulting THz spectra with comb-like structure can be used e.g. to calibrate THz radiation sources, or for very accurate phase locking of THz pulses for novel high-precision tools. THz combs open up new possibilities for high-resolution THz spectroscopy, e.g. in gas phase, investigation of ultrafast switching in semiconductors, and high temperature superconductors.

THz-ASOPS: With two fiber lasers synchronized in an asynchronous optical sampling (ASOPS) scheme one can build a rapid scanning THz-spectrometer [Opt. Lett. 35, 3799 (2010)]. By avoiding the use of a mechanical delay line for temporal scanning, the system enables high-speed and high-resolution data acquisition.

Measuring the thickness of coatings: Apart from metals, most materials are transparent or partially transparent for THz radiation, especially if dealt with thin layers like in foils or coatings. Similar to multiple reflections in window glass, the interfaces between thin coating layers induce THz reflections. Separating them with suitable mathematical algorithms such as in the Teralyzer software, allows precise determination of the thickness of such thin layers, a demanding task in paper, air space, or car industry.

Historical art conservation: Fragile art historical objects benefit from the non-destructive investigation method with THz radiation. Hidden layers, their thickness and composition can be identified without any effect on the piece under investigation.

Chemical fingerprinting: Pharmaceutical industry is using THz spectroscopy and imaging for testing of the content, concentration, and homogeneity of medical drug substances in their products.

Communication: Similarly to other regions of the electromagnetical spectrum, the THz band offers novel possibilities for wireless broadband data transfer at highest rates to assure flawless information delivery. With our THz-TDS solution you can already develop and characterize your passive and active components for upcoming communication over THz waves.

THz remote sensing: Within the atmospheric THz window and in relatively dry conditions like in a desert, the observed THz radiation of extraterrestrial objects provides insight into the birth of remote planets. With a suitable emitter, remote detection of explosives provides a more down-to-earth remote sensing application.

THz-TDS with optical excitation: Charge carriers respond to the electromagnetic field of THz radiation. In semiconductor materials, optically excited electron-hole pairs are investigated with THz radiation to learn about their mobility, lifetime, and other characteristics in the quest for novel high-end devices.

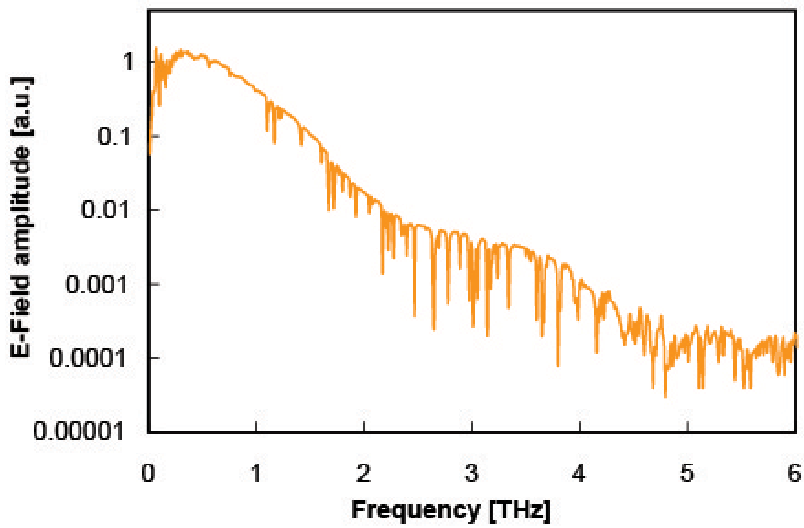
Menlo THz-TDS Systems

TERA K15

TERA K15 / TERA SYNC	THz time-domain spectrometer
operating principle	broadband pulsed operation
configuration	fiber coupled
antenna technology	InGaAs
laser type	1560 nm femtosecond fiber laser

For more information : www.menlosystems.com

Typical TERA K15 / TERA SYNC THz spectrum:



Fiber coupled THz-TDS systems

Our compact THz-TDS system TERA K15 with 1560 nm wavelength femtosecond laser is using fiber coupled THz antennas and TPX polymer lenses and is flexible and easy to operate. The alignment of the THz path can be reconfigured between transmission and reflection geometry within minutes, the THz path can even be arranged outside the housing box. Our novel all-PM figure 9® technology used for mode locking of the Er-doped femtosecond fiber laser makes the TERA K15 a stable solution ready to serve industrial needs.

Our TERA K15 is a complete system ideal for measurements which need flexible arrangement of the setup or where several operators are working with the system. With our extension TERA Image one obtains a versatile THz-imaging system. The Reflection Guide is a useful add-on for quick manual change of the measurement angle of the fiber coupled modules. Our TeraLyzer software is an optional plus to process data of very thin samples.

TERA SYNC uses our C-Fiber scientific laser family for a synchronizable fiber coupled THz-TDS system with additional high-power optical output ports at 1560 nm or 780 nm. The laser can be used simultaneously for other experiments or for optical pumping of the sample. The entire system can be phase locked to an external signal, such as a THz source or another laser.

System features

- flexible fiber coupled solution
- TPX polymer lenses
- high-power THZ antennas
- ultra-stable PM-fiber laser
- transmission / reflection geometry
- imaging applications
- suitable for industry applications
- scientific laser option

Free space THz-TDS system

Scientific laboratory experiments are pushing the limits of the existing technology. Very often they require a THz-TDS system which allows rearrangement of the individual system components to provide a design tailored for a specific application.
Our complete TERA K8 THz-TDS system with 780 nm wavelength femtosecond laser is configured as an open platform giving access to all its optical components. The system is providing all that is necessary for high-performance THz-TDS measurements and can be modified and extended by additional functional components. For example, the TPX lenses in the THz path can be replaced by off-axis parabolic mirrors, since any change in the timing of the femtosecond pulses can be accounted for by adapting the optical path. With our THz-Pump-Probe add-on a fraction of the output from the femtosecond laser can be used for optical excitation of the investigated sample.
For THz-imaging applications, our TERA Image extension can be retrofitted to the system. Material parameter extraction of sub-100 µm samples is an easy task with our advanced TeraLyzer software.

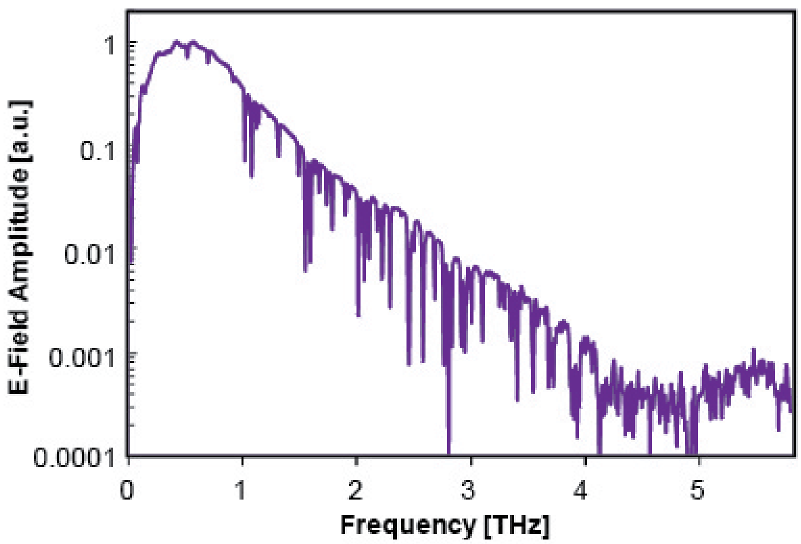
TERA K8	THz time-domain spectrometer
operating principle	broadband pulsed operation
configuration	free space
antenna technology	GaAs
laser type	780 nm femtosecond fiber laser

For more information : www.menlosystems.com

System features

- free space solution
- TPX polymer lenses
- flexible open platform
- imaging applications
- ultra-stable PM-fiber laser
- laboratory applications

Typical TERA K8 THz spectrum:



Direct line to our product expert:
email: p.krok@menlosystems.com
phone: +49 89 189 166 0

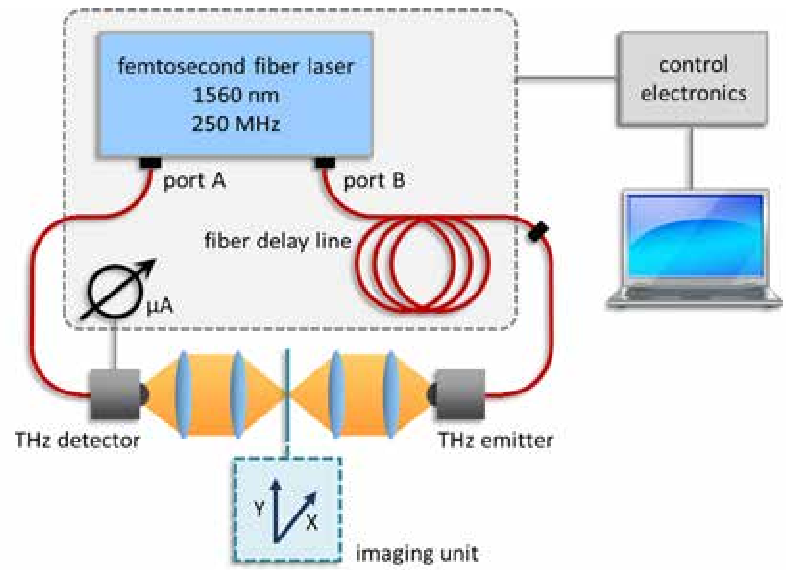
OSCAT Technology

TERA OSCAT

TERA OSCAT	THz time-domain spectrometer
operating principle	broadband pulsed operation with OSCAT technology
configuration	fiber coupled
antenna technology	InGaAs
laser type	1560 nm femtosecond fiber laser

For more information : www.menlosystems.com

The OSCAT technology



At the heart of the novel OSCAT (Optical Sampling by CAvity Tuning) [1,2] technology is a femtosecond fiber laser at 1560 nm wavelength with tunable repetition rate and a passive delay optical fiber as part of one of the two measurement ports. The laser output configuration is equivalent to an unbalanced interferometer. When the laser repetition rate is varied by a small value around the fundamental of 250 MHz the delay between the optical pulses at either fiber end is changed. This results in temporal scanning of the THz pulse trace. The system benefits from our well-established fiber coupled THz antenna technology, ensuring high performance THz spectroscopy and imaging device.

High-speed THz-TDS

Some applications require short measuring time, e.g. THz imaging of larger area objects, or a rapidly changing measurement environment. Menlo's worldwide unique solution is a system capable of high-speed data acquisition. The OSCAT [1] technology needs only one femtosecond laser, and at the same time offers all the advantages of systems based on electrical scanning techniques such as ASOPS and ECOPS.
TERA OSCAT combines efficiency, flexibility and performance to the best in one tabletop setup. Temporal scanning is performed without external moveable delay line, thus eliminating constraints for scanning speed and measurement window. Scanning frequency of more than 200 waveforms per second is achieved with extremely low timing jitter performance. This ensures high signal-to-noise ratio after subsequent data averaging. The scanning window is virtually unlimited [1] which allows investigation of remote objects. The fiber coupled platform of the TERA OSCAT spectrometer allows flexible arrangement of the THz modules.

Applications

- high-speed THz imaging
- THz time-domain spectroscopy
- quality inspection
- THz remote sensing

Further reading:

[1] R. Wilk et al.: OSCAT: Novel Technique for Time-Resolved Experiments Without Moveable Optical Delay Lines; J. Infrared Milli. Terahz. Waves 32, 596 (2011)
[2] R. Wilk et al.: Terahertz spectrometer operation by laser repetition frequency tuning; J. Opt. Soc. Am. B 28, 592 (2011)

Ultrastable Femtosecond Lasers for THz Systems

Next generation Er-doped femtosecond fiber lasers

Being an expert in femtosecond fiber laser technology, Menlo Systems offers a wide selection of free space and fiber coupled fs-lasers which are used in THz applications, with models for laboratory or for industrial environment.
The T-Light is a robust and compact turnkey femtosecond fiber laser. It offers exceptional performance for a variety of applications, from ultrafast spectroscopy to THz physics. The laser design is based on polarization maintaining (PM) fiber components, which is the key to stable operation. Our unique figure 9® mode locking technology ensures reproducible and long-term stable femtosecond laser output for 24/7 applications.

Mode locking with unprecedented stability

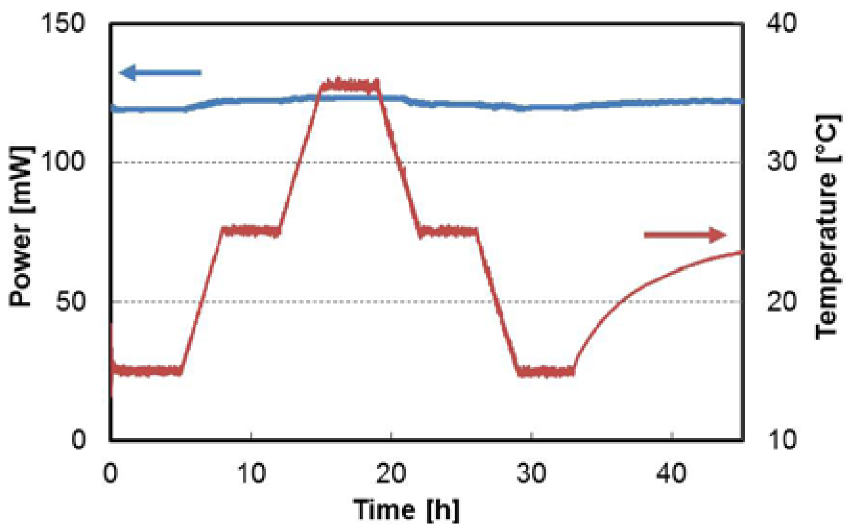
The heart of the novel laser system is an oscillator using polarization maintaining (PM) optical fibers and a nonlinear optical loop mirror (NOLM) for a self-starting mode locking mechanism. Since no moving parts are involved, the laser is mechanically very robust. All optical elements and pump diodes used are reliable standard telecom components.
The miniaturized laser control electronics are integrated into the laser housing together with the oscillator and amplifier in a compact 'one box – one button' solution. The system's minimal energy-to-heat dissipation and the sealed housing make it insensitive to temperature and humidity variations.
The output from the T-Light can be flexibly configured, e.g. with two fiber coupled ports for connecting the patch cords of the THz modules.
Our most compact industrial laser modules from the ELMO family are ideal for THz OEM solutions.

T-Light

T-Light-FC figure 9® femtosecond fiber laser with two fiber coupled output ports

Temperature stability of the output power

<0.2 % per °C peak to peak power noise with temperature cycling from 15 to 35 °C



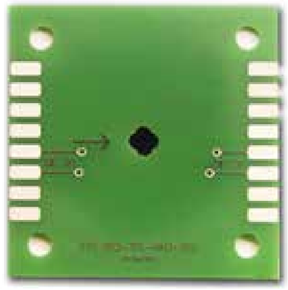
T-Light	femtosecond fiber laser
center wavelength	1560 nm
pulse duration	<90 fs after external PM fiber patch cord (2.5 m or as requested)
repetition rate	100 MHz
output configuration	two fiber coupled output ports, PM fiber (alternatively: one free space output port)

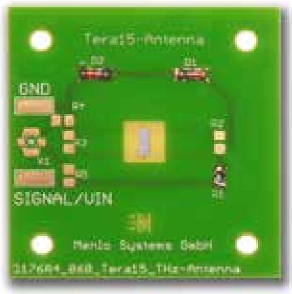
For more information : www.menlosystems.com

Direct line to our product expert:
email: s.kocur@menlosystems.com
phone: +49 89 189 166 0

THz Components and Add-Ons

Upgrade your experiment with our high quality THz antennas and components

TERA8-1 



TERA15

TERA8-1	photoconductive antenna for 800 nm femtosecond laser
antenna material	LT-GaAs with dipole structure
TERA15	photoconductive antenna for 1.5 µm femtosecond laser
antenna material	InGaAs/InAlAs with stripline or dipole structure
configuration	chip mounted on a PCB

TERA15-FC	photoconductive antenna for 1.5 µm femtosecond laser
antenna material	InGaAs/InAlAs with strip line or dipole structure
configuration	fiber coupled module with Si lens

T8-H2 / T15-H2	holder for PCB-mounted antenna chip
configuration	optical and Si lenses with precision positioning

Photoconductive antennas – our bestsellers

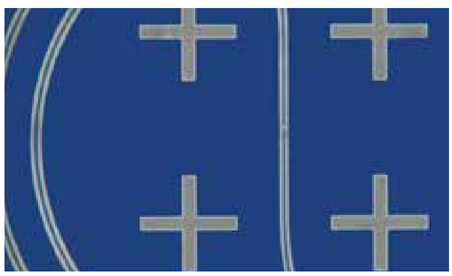
In collaboration with the Fraunhofer Institutes, we bring the latest technology photoconductive antennas to the market for laser wavelengths 800 nm, 1 µm, and 1.5 µm, in free space and fiber coupled configuration.

Further reading:

[1] R.J.B. Dietz et al.: 64 µW pulsed terahertz emission from growth optimized InGaAs/InAlAs heterostructures with separated photoconductive and trapping regions; Appl. Phys. Lett. 103, 061103 (2013)

Antenna holder

Our holders T8-H2 and T15-H2 have been developed for our PCB-mounted antenna package, including laser focusing optics with xyz-micropositioning for precision alignment and an adjustable silicon lens for efficient outcoupling and precollimation of the THz radiation.



Broadband THz polymer lenses

Use our TPX THz lenses with excellent optical properties over a broad spectral range for efficient THz collimation and focusing. The plano-convex lenses TPX50 and TPX100 with two different focal lengths are inexpensive and easy to align. The polymer substrate is very light in weight such that there is no misalignment of the THz path over the time. The lens material is also transparent for infrared laser light and allows using the lens for prealignment of the THz path. A suitable lens mount is included.

TPX50	broadband THz polymer lens with 54 mm effective focal length
TPX100	broadband THz polymer lens with 100 mm effective focal length
TPX200	broadband THz polymer lens with 200 mm effective focal length
configuration	mounted in 1.5“ lens holder

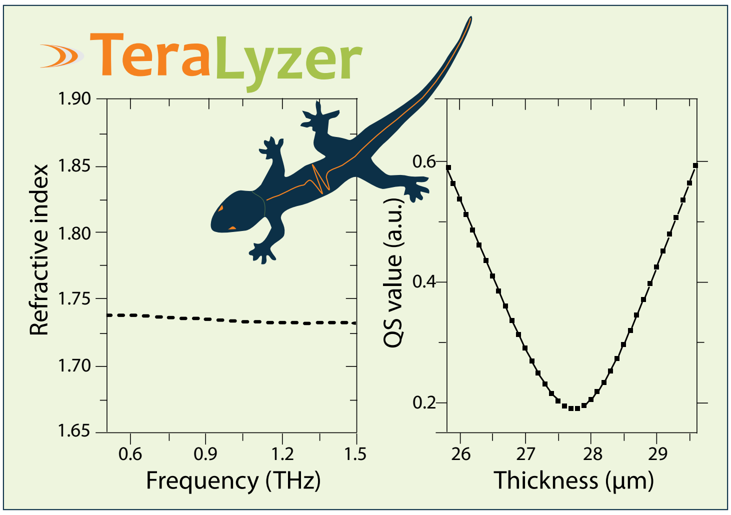
Measuring in reflection geometry

Increase the freedom of measurement geometry by using the Reflection Guide add-on for our fiber coupled THz systems TERA K15 and TERA OSCAT. The THz modules and optics are mounted on a hinged rail indicating the measurement angle on a scale. The angle is manually adjustable down to 38° incidence, while the sample holder is following without loss of signal. When opened completely, the measurement geometry is switched to transmission.

Reflection Guide	add-on for flexible THz measurement geometry
system compatibility	available for Menlo Systems fiber coupled THz-TDS systems

Direct line to our product expert:
email: p.krok@menlosystems.com
phone: +49 89 189 166 0

THz Components and Add-Ons



Advanced THz evaluation software

Our partner Lytera has developed TeraLyzer, a first-of-its-kind software solution for material parameter extraction from THz time-domain spectroscopy data. It calculates the complex material parameters of a sample (n, α, κ, ε', ε'') with highest precision, including error bars and the estimated sample thickness. TeraLyzer's major strength is that even samples with sub-100 µm thickness can be investigated in a standard experiment without the need for differential measuring setup. Moreover, analysis of multilayer systems promotes a whole new range of experiments.

TeraLyzer	advanced software for material parameter extraction
software compatibility	sub-100 µm layers measured in transmission geometry

Extension for THz imaging

All our THz-TDS systems can easily be upgraded with our TERA Image extension unit for THz imaging applications (see pp. 7 and 14). The add-on contains motion control for sample positioning and software for image acquisition and reconstruction. TERA Image unit can be retrofitted to an existing Menlo Systems THz-TDS system at any time.

TERA Image	extension unit for THz imaging
system compatibility	suitable for all Menlo Systems THz-TDS systems

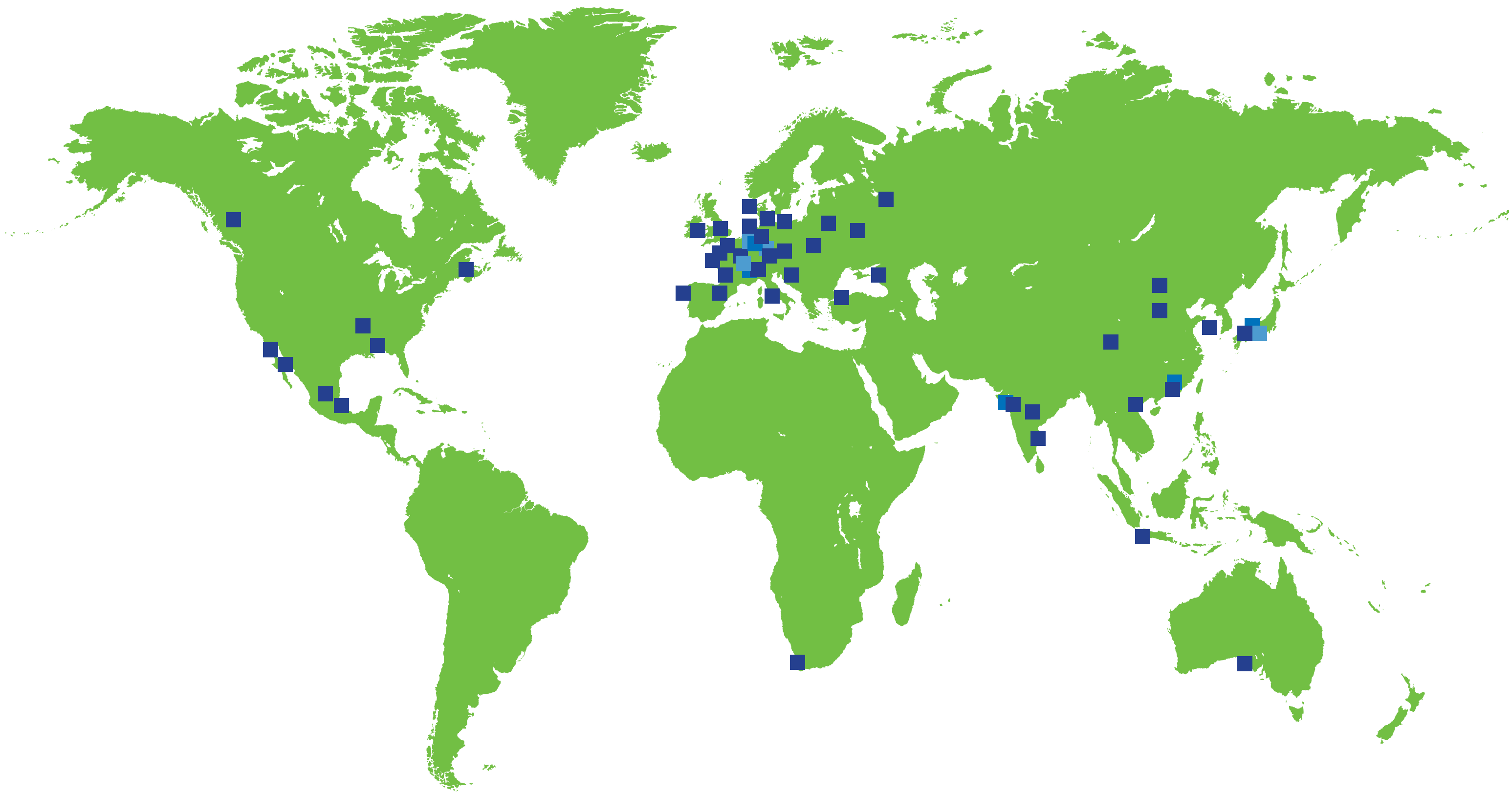
THz-TDS with optical excitation

Our THz-Pump-Probe add-on enables THz-TDS measurements on samples after optical excitation by introducing a temporal delay between the optical pulses and the THz pulses. The add-on can be integrated into our free space THz-TDS systems or can be used in combination with a second synchronized laser. It includes the optical path for the pump laser and a linear translation stage with retro-reflector.

THz-Pump-Probe	add-on for THz-TDS with optical excitation
system compatibility	available for Menlo Systems TERA K8 and TERA SYNC

Our THz Systems Around the Globe

We have more than 50 THz-TDS systems running worldwide.
Would you like to add your pin on to the map?
Please call: +49 89 189 166 0
or send an email : sales@menlosystems.com

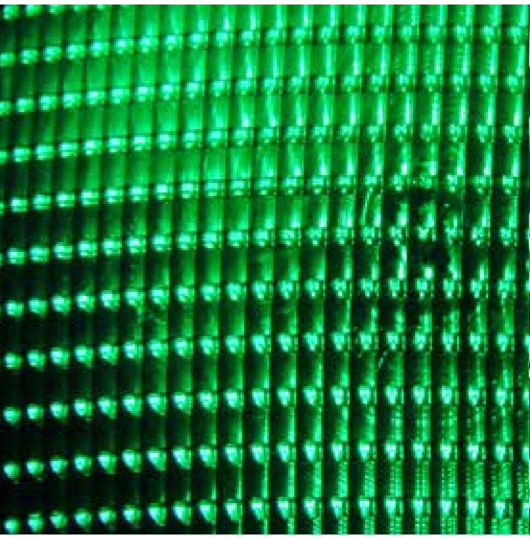


Hamburg
Warsaw
México D.F.
Teddington
Bhopal
Busan
Stralsund
Naples
Adelaide
Zlin
Shanghai
Hong Kong
Mons
Tianjin
Trappes
Moscow
Fribourg
Nijmegen
Heidenau
Geneva
La Jolla
Chiba
Bochum
Hayward
Tokyo
Singapore
Erlangen
Rennes
Beijing
Lausanne
Lubbock
Westerville
Vigo
Barcelona
Stellenbosch
Nizhny Novgorod
Emmerich
Istanbul
Toulouse
Krasnodar
Pecs
Würzburg
Prince George
Kolkatta
León
Storrs
Chennai

Excitement is not measureable. Light is.

Menlo Systems, leading developer and global supplier of instrumentation for high-precision metrology, was founded 2001 as spin-off of the Max-Planck-Institute of Quantum Optics, with the foremost aim to commercialize optical measurement technologies and make it available to newly emerging application fields. Menlo Systems maintains a strong bond to co-founder Theodor W. Hänsch, who pioneered precision laser techniques.

Known for the Nobel Prize-winning optical frequency comb technology, the Munich-based company offers complete solutions based on ultrafast lasers and synchronization electronics. Applications for our products and solutions span from research laboratories to truly industrial tasks. The patented technology is recognized by global laser manufacturers to whom we deliver OEM solutions for integration into cutting-edge products.



MenloSystems

Menlo Systems GmbH
Am Klopferspitz 19a
D-82152 Martinsried
Germany
T+49 89 189 166 0
F+49 89 189 166 111
sales@menlosystems.com

Menlo Systems, Inc.
56 Sparta Avenue
Newton, NJ07860
USA
T+1 973 300 4490
F+1 973 300 3600
ussales@menlosystems.com

Thorlabs, Inc.
56 Sparta Avenue
Newton, NJ07860
USA
T+1 973 579 7227
F+1 973 300 3600
sales@thorlabs.com