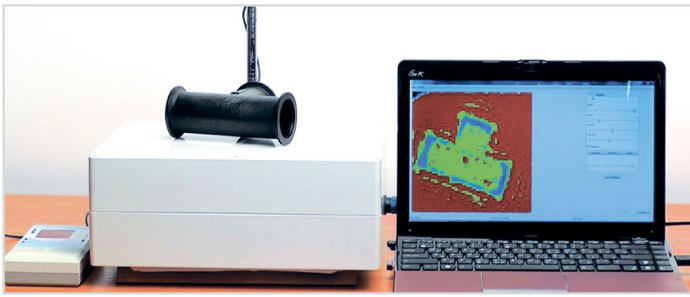# TeraSense
Terahertz imaging systems

The World's First
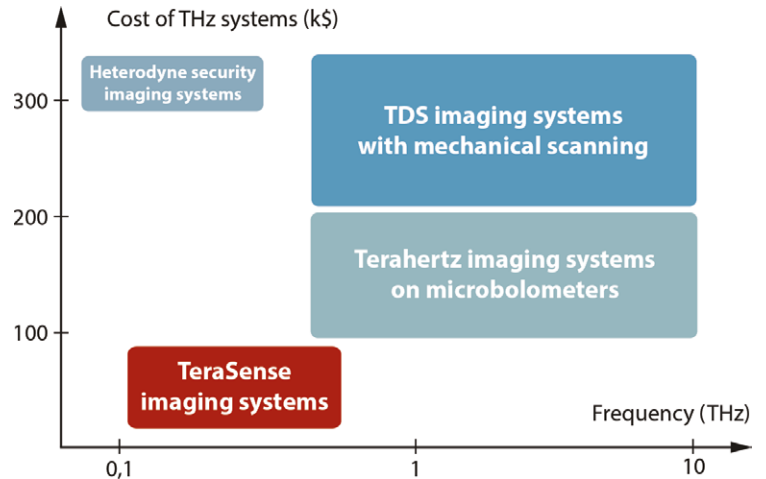
HIGH SPEED TERAHERTZ
IMAGING SYSTEMS

TeraSense has developed an original patent-protected technology for making a new generation of semiconductor detector arrays for terahertz imaging. The detectors developed by TeraSense have good sensitivity compared to other available detectors working in THz range (0.05 – 0.7 THz). TeraSense detectors have an advantage with their low cost and ease of fabrication in large quantities in the form of 2D arrays, thanks to compatibility of the TeraSense technology with mass-production lines of semiconductor industry. The detector arrays are scalable in the number of pixels.

With the use of TeraSense imaging chips, an extremely compact and sensitive THz camera can be produced. It is essential that spatial resolution of such a camera is around 1 mm and registration time is less than 1 second. That makes it possible to effectively use TeraSense imaging chips for medical diagnostics, nondestructive testing and many other terahertz applications.

For the terahertz generation purposes Terasense uses reliable IMPATT technology which makes it possible to produce low-cost and compact 100 – 300 GHz wave sources with output power up to 400 mW.

Existing terahertz imaging systems

Cost of THz systems (k$)

- Heterodyne security imaging systems
- TDS imaging systems with mechanical scanning
- Terahertz imaging systems on microbolometers
- TeraSense imaging systems

Frequency (THz)

0,1   1   10

Terasense products

Terahertz imaging cameras

- Wide spectral range 50 GHz – 0.7 THz
- Noise Equivalent Power 1 nW/√Hz
- High speed image acquisition rate up to 5000 frames per second
- 1.5 mm pixel pitch
- Customized solutions and compact size
- Low cost

Ultrafast line camera for conveyor applications

TeraSense has developed Terahertz camera optimized for high-speed conveyor industrial applications.
The camera features 5 kHz (5000 frames per second) speed, custom pixel number and special software to stitch shots.

Number of pixels (scalable): 256 x 1
Min detectable power/pixel:

- 100 nW (at 5000 fps)
- 45 nW   (at 1000 fps)
- 14 nW   (at 100 fps)

Featured Product

Sub-terahertz sources

IMPATT diodes (IMPact ionization Avalanche Transit-Time)

Frequencies	100 GHz	140 GHz	200 GHz	300 GHz
Output power	80/180/400 mW	30/90 mW	10/50 mW	10/25 mW

- High power output
- Protective isolator for enhanced stability
- TTL modulation option with 1µs rise/fall time
- High gain horn antenna or WR- type flange

Terahertz security body scanner

Working distance:	3 - 6 m
Imaging area (at 3 m):	70 x 70 cm (at 3 m)
	120 x 120 cm (at 6 m)
Resolution:	3 cm (at 3 m)
	6 cm (at 6 m)
Operating frequency:	100 GHz
THz sensor array:	3 x 3 mm, 32 x 32 px
Number of sources:	6
Frame rate:	Live Stream
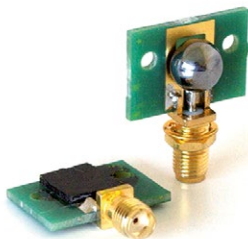
Ultrafast terahertz detectors

	Ultrafast	Fast
Response time	150 ps	1 µs
Spectral range	50 GHz - 0.7 THz	50 GHz - 0.7 THz
Impedance	50 Ω	10 k Ω
Responsivity	0.5 V/W	10 V/W
Noise equivalent power	2 nW/ √Hz	1 nW/√Hz
No power supply	✓	✓

Optics for terahertz

TeraSense offers custom manufacturing of quasi-optical components for THz range: PTFE and TPX lenses, windows, prisms, attenuators, polarizers, beam splitters. Terahertz lenses are done with diameters 1 - 30 cm and focal lengths 50 - 300 mm.

Featured clients

INO ENEA NEC SAMEER Pioneer SMART

KERI SISTEMA ANTERAL TOPTICA PHOTONICS PI THE UNIVERSITY OF UTAH 威视 NUCTECH
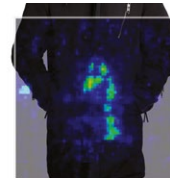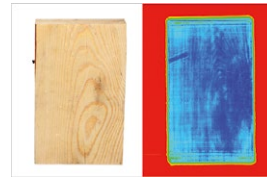
Applications

Terahertz quality control

Non-destructive analysis (NDT) of the internal structure of objects (quality control of products). THz cameras enable to visualize the contents of sealed packages or food products under various enclosures.

Terahertz wireless communication

Building high-frequency wireless telecommunication systems of new generation (up to 100 Gbit/sec). This application holds high promise for high-speed information transmission between electronic devices; building wireless local area networks (WLAN) and wireless personal area networks (WPAN) of new generation, as well as creating entirely secured dedicated channels of wireless communication.

Terahertz imaging security

Security systems for various applications: people screening, luggage scanning, as well as scanning postal parcels and envelopes in terms of prohibited items inside. Here the emphasis is primarily made on one feature that unlike X-ray, THz radiation is not detrimental to human body. THz scanners allow remote detection of metallic, plastic, ceramic and other object concealed under clothes — at a distance of a few meters.

Terahertz imaging in medicine

THz tomography in medicine allows to conduct analysis of the upper layers of a human body — skin, vessels, joints and muscles. There are known successful applications of THz tomography for detecting skin and breast cancers at early stages. Capability of visualizing current conditions of wounds under gypsum/bandage layers also represents high interest.

Terahertz science

Scientific applications of THz radiation include spectroscopy of long-wavelength lattice vibrations of crystals, bending vibrations of molecules. Frequencies of soft modes in ferroelectric materials and frequencies matching the energy of apertures in superconductors are also 'residing' within THz range. Terahertz frequency range is convenient for creation and study of meta-materials and plasmonic effects.

About TeraSense

Since 2008
bringing innovations in THz imaging

Over 500 happy clients
in science and industry

50+ distributors
around the world

2 headquarters and
**40 people team**
with half holding Ph.D. degree

Products used at
5 continents in over
50 countries of the world

100+ publications
and **5 patents**

TeraSense
Terahertz imaging systems

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TERAHERTZ IMAGING CAMERAS

- 0.05 - 0.7 THz frequency range
- 256, 1024, 4096 pixels models are available
- Compact and low cost
- 1.5 year warranty
- Video mode (50 Hz)
- **Software:** Terasense Viewer ® and SDK
- Customer-focused solutions
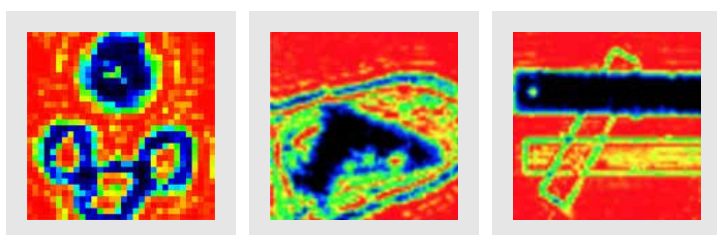
Description

TeraSense has developed an original patent-protected technology for making a new generation of semiconductor detector arrays for terahertz imaging. The detectors operate at room temperature and arrays are scalable in the number of pixels. The company is developing flexible terahertz imaging solutions for science and industry.

The detectors offered by Terasense have good responsivity comparable with other available detectors working in terahertz range (50 GHz - 0.7 THz), but in contrast they are low-cost, has uniform pixel-to-pixel sensitivity (pixel-to-pixel deviation of the responsivity is less than 20%) and they can be easily produced in large quantities in the form of 2D array thanks to compatibility of the TeraSense technology with mass semiconductor producing lines. That makes these detectors suitable for use in our terahertz imaging cameras, which have no moving elements at all.

Specifications

Model name	Tera-256	Tera-1024	Tera-4096
Number of pixels	256 pixels (16 x 16)	1024 pixels (32 x 32)	4096 pixels (64 x 64)
Pixel pitch	1.5 mm	1.5 mm	1.5 mm
Noise Equivalent Power	1 nW/$\sqrt{Hz}$	1 nW/$\sqrt{Hz}$	1 nW/$\sqrt{Hz}$
Device size	10 x 10 x 5.5 cm	10 x 10 x 5.5 cm	16.5 x 16.5 x 4.5 cm

About TeraSense

TeraSense is a manufacturer of low-cost portable sub-terahertz imaging cameras, generators and ultrafast detectors. Our products balance at the cutting edge of scientific and technological breakthroughs. The company is a very strong team of 20 highly skilled scientists and engineers bringing a wealth of experience in the field. TeraSense has a steady growing global outreach supported by a very wide network of authorized distributors avaliable in more than 30 countries of the world.

HIGH SPEED LINEAR TERAHERTZ CAMERA

- ✓ **Image acquisition rate: 5 kHz (5000 fps)**
- ✓ **Scanning speed: up to 15 m/sec**
- ✓ **Optimized at frequency ~100 GHz**
- ✓ **Number of pixels (scalable): 256 x 1**
- ✓ **TeraFast® Viewer software**
- ✓ **Software Developer's Kit (SDK)**

Description

The High-Speed Terahertz Imaging Scanner is our flagship product. It features both, an unprecedented imaging speed of 5000 frames per second and ease of integration into any industrial process. The Terahertz Imaging Scanner fits most conveyors with a belt speed up to 15 m/s. Its ultrafast linear sensor array is built to satisfy the needs in Non-Destructive Testing (NDT) and Quality Control (QC) for many industrial applications.

The Terahertz Imaging Scanner system consists of two parts: a linear terahertz imaging camera and a Terahertz generator at 100 GHz. Both parts are optimized and synchronized to each other. THz radiation power is properly delivered from the generator onto the camera sensor. The camera pixel size determines an image resolution of 1.5 mm, which exceeds the requirements of most industrial applications.

Layout for Linear Terahertz Imaging System installation on conveyor

COMPETITIVE ADVANTAGES:

- ✓ **No ionizing radiation**
- ✓ **Extremely high image acquisition rate (5 kHz)**
- ✓ **Ease of integration into industrial process**
- ✓ **CE Certification of Compliance**
- ✓ **Plug-and-Play design and customized solutions**
- ✓ **LOW COST**
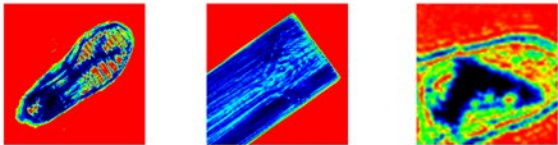
Samples of THz images made by Terasense THz camera

Terasense® technology employs standard semiconductor manufacturing processes for mass-market production, which allows to produce sensor arrays in large quantities, ensure high-performance and claim reasonable price.

Specifications

Number of pixels:	256 (256 x 1)	**Image acquisition rate:**	5000 fps (5 KHz)
Pixel size:	1.5 x 3 mm^2	**Responsivity:**	8000 V/W
Imaging area:	384 x 3 mm^2	**Min detectable power/pixel:**	100 nW (at 5000 fps) 45 nW (at 1000 fps) 14 nW (at 100 fps)
Dimensions of device:	450 x 160 x 44 mm^3		
Sync out:	TTL (+5 V)	**Included software:**	TeraFast® Viewer
Interface:	mini-USB	**Power supply:**	24 V/ 20 W

TeraSense offers two types of generators, both based on IMPATT technology. Our Type I generator has a horn antenna with a specially designed PTFE refractive optical system. The configuration of the PTFE lenses ensures proper focusing of the THz beam onto the linear window of the camera. The Type II generator is an upgraded version of the THz source. It utilizes our most recent breakthroughs in THz technology which enables the enhanced performance of the THz imaging scanner. The Type II module includes our novel reflective THz optics based on our specially configured high-gain horn antenna in combination with a metallic mirror. The Type II sources are made from exceptional IMPATT diodes that deliver significantly more power than the average diode. The Type II generator considerably improves the THz imaging capabilities of our linear scanner by increasing the amount of power reaching the sensor array.
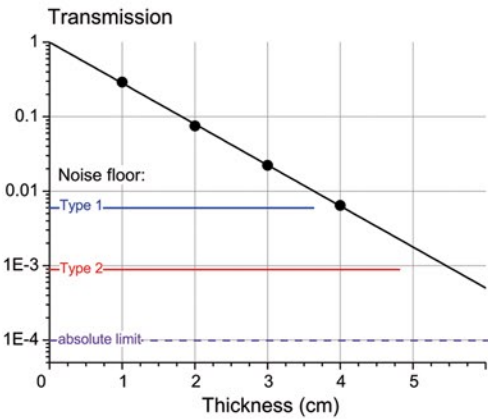
Source Type I

Source Type II

NEW

+ mirror

Comparison of THz generators

	Type I	Type II
Frequency	100 GHz	100 GHz
Power per pixel	20 µW	140 µW
Imaging system dynamic range	24 dB	30 dB
Optical system	PTFE optics	Reflection optics
Technology	IMPATT	Super-Hero IMPATT *

* Selected IMPATT diodes with (30-50)% higher output power

Thz transmission through paper stuck for the generators Type I and Type II

Below are two THz images obtained as a result of comparative imaging test aimed to show the difference in performance between terahertz imaging scanner equipped with Type I and Type II generators. Four flat figures were cut of metallic foil and placed underneath paper stacks of thickness ranging from 1 to 4 cm. Imaging scanner with Type I source can penetrate only paper stacks 1 and 2 and reveal foil figures hidden underneath the paper. The penetration depth of THz imaging setup with Type II source is much deeper. We can discern fairly clear images of the letters hidden under paper stack 3 and even 4.

Type I

Type II

Paper stacks of varying thickness with flat metallic foil figures underneath
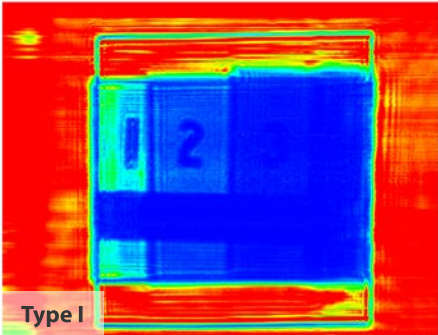
THz images obtained with Type I and Type II generators

TeraSense
Terahertz imaging systems
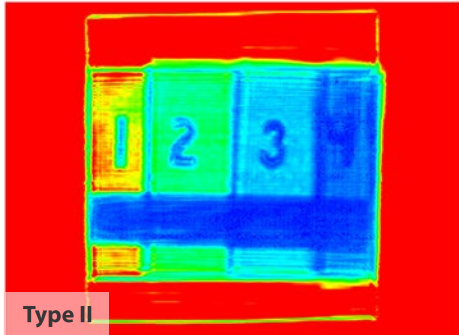
APPLICATIONS

Rapid non-destructive, non-invasive characterization and imaging of objects / defects in uniform materials or under coated surfaces has never been easier and faster than with our high speed camera codenamed TeraFAST. Its record breaking image acquisition rate opens up doors to many industrial applications associated with Non-destructive testing, quality control and process control.

Pharmaceutical and Cosmetics Industries

Non-destructive testing (NDT) of drugs, medical products and baby's diapers (nappies) at industrial production lines.

Wood Processing Industry

Detecting concealed hollows, internal forms, shapes and/or defects saves a lot of time on inspections. Wood analysis: checking wood for water / moisture inside.

Identification of hidden forms

Food Industry

Non-invasive technique for monitoring availability / number of hazel nuts inside of chocolate candies already wrapped and packaged;
detecting any metal plastic debris, extraneous bodies or inhomogeneous parts (clots) inside ready food products.

FMCG Packaging

Checking for availability of items inside packages as a process control step; detecting foreign objects inside packaging meant to exclude human error or defective items inside the package.

Construction Materials and Building Trades

Using THz imaging camera at manufacturing facilities or at construction sites to identify and locate inhomogeneous elements or moisture in concrete, floor screed, plaster, wall paint etc.

Automotive Industry

Indentifying presence or absence of steel objects (viz. wires) or foreign bodies and elements inside of rubber tires. Inspecting fitted tires on wheels to identify special run-flat nylon inserts attached to alloy wheels inside a tire, thereby avoiding time-consuming tire removal for visual inspection.
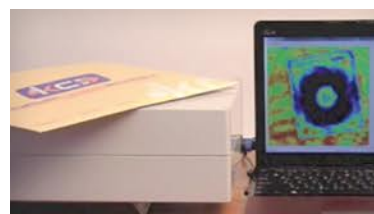
Agriculture and Livestock Farming

Potato selection process running on conveyor belt aimed to separate planting-potatoes from mud clumps and stones.

Measuring the thickness of a wool coat on a live sheep.

Security Screening and Letter Scanning

Homeland security: identification of hidden objects concealed in bags at the airports or check-points.
Checking the contents of envelopes and parcels.

SUB-TERAHERTZ SOURCES

- ✓ **IMPATT technology**
- ✓ **100 GHz, 140 GHz, 200 GHz and 300 GHz available frequencies**
- ✓ **Protective isolator for enhanced stability**
- ✓ **TTL Modulation**
- ✓ **High-frequency modulation option (100 MHz, 1.5 ns rise/fall time)**
- ✓ **Detachable horn antenna**
- ✓ **Low cost and compact size**
- ✓ **1 year warranty**

Conical horn antenna (rigidly attached)   OR   Open flange (UG387)

Description

TeraSense series of terahertz sources (IMPATT diodes) are silicon double drift diodes with a 0.6 um transit region, mounted on copper heat sink. The layers in double-drift diodes are: a heavily doped (p+)-region, a moderately doped pregion, a moderately doped n-region, and a heavily doped (n+)-region. The (p+) — and (n+) — regions allow ohmic electrical contacts to be made to the external circuit. The device relies on negative resistance to generate and sustain an oscillation.

Terasense is now offering its upgraded version of terahertz source. The upgraded IMPATT diode is outfitted with a protective isolator, which significantly improves output power stability. From now on you can order IMPATT diode with either rigidly fixed horn antenna or WR- flange of your choice. Typical output rfpower of THz source with optimized frequency @ 100 GHz can reach up to 100 mW.

THz source **100** GHz	THz source **140** GHz	THz source **200** GHz	THz source **300** GHz
~ 80 / 180 / 400 mW output rfpower	~ 30 / 90 mW output rfpower	~ 50 mW output rfpower	290 GHz ~ 10 mW 280 GHz ~ 25 / 50 mW output rfpower
Conical horn antenna / Flange type output	Conical horn antenna / Flange type output	Conical horn antenna / Flange type output	Conical horn antenna / Flange type output
Protective Isolator TTL Modulation	Protective Isolator TTL Modulation	TTL Modulation	TTL Modulation

About TeraSense

TeraSense is a manufacturer of low-cost portable sub-terahertz imaging cameras, generators and ultrafast detectors. Our products balance at the cutting edge of scientific and technological breakthroughs. The company is a very strong team of 20 highly skilled scientists and engineers bringing a wealth of experience in the field. TeraSense has a steady growing global outreach supported by a very wide network of authorized distributors avaliable in more than 30 countries of the world.

HIGH SPEED LINEAR 300 GHz SCANNER

- ✓ **300 GHz imaging technology**
- ✓ **Image resolution: up to 1 line/mm**
- ✓ **Image acquisition rate: up to 5 kHz**
- ✓ **Number of pixels (scalable): 256x1 / 512x1**
- ✓ **External frame synchronization (encoder input)**

The 300 GHz linear scanner is TeraSense's next step forward in high-speed terahertz imaging. The scanner features unprecedented spatial resolution and high imaging speed capability. It helps you find invisible problems faster than ever. Using TeraSense scanner, you can inspect for hidden defects or use it for nondestructive testing in various industries. Quality control, security checks or fiding water presence never been faster and safer.

The 300 GHz linear scanner consists of a camera unit, a camera's controller / interface unit that can be customized by OEM developers, a 300 GHz source and a THz optical system. Each of the camera's pixel specs is optimized to ensure the maximum sensitivity at 300 GHz.

The devices are compact and can be easily integrated into any conveyor system. Enhanced construction with a separate control unit and possibility to customize it, gives greater opportunities for OEM developers.

Mirror

300 GHz Terahertz source

300 GHz Linear camera

Control unit
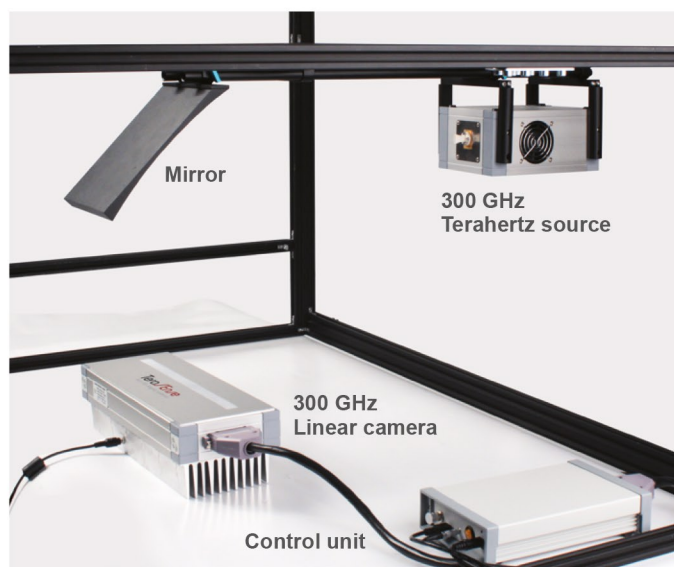
Advantages

- No ionizing radiation
- Extremely high image acquisition rate
- Ease of integration into industrial process
- CE Certification of compliance
- Plug-n-play design and customized solutions
- Affordable solution

The camera has both internal and external synchronization features. The internal synchronization can operate with an externally modulated source to reduce the noise and improve image quality.

A long-awaited external synchronization feature allows the camera to shoot frames at precisely determined time points. A combination with an external encoder, makes it possible to automatically comply with different conveyor belt confiurations.

Innovative TeraSense technology helped to overcome price barrier and now is available for small businesses.

Specifications

Number of pixels:	256 x 1 / 512 x 1
Pixel pitch	0.5 mm
Image acquisition rate	up to 5 kHz (5000 lps)
Imaging area	128 x 0.5 mm / 256 x 0.5 mm
Sync Out, Sync In	TTL (+5V)

Dynamic range	200
Dimensions, camera	189 x 128 x 80 mm / 320 x 130 x 90 mm
Dimensions, control unit	205 x125 x 40 mm
Included software	TeraFAST® Viewer C++ SDK, LabView SDK
Power supply	24 V, 40 W

TeraSense
Terahertz imaging systems