

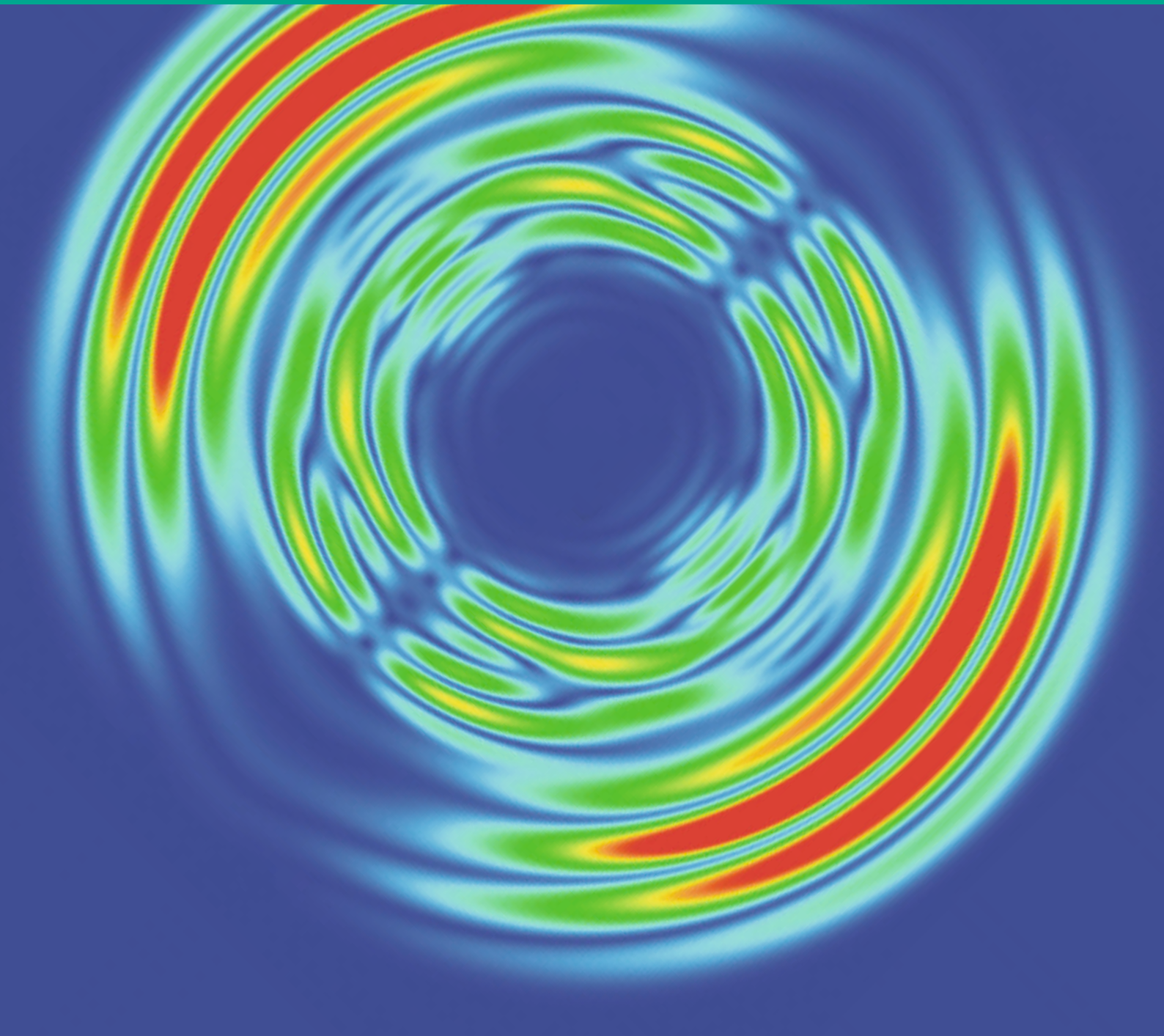


**Fraunhofer**  
IKTS

FRAUNHOFER INSTITUTE FOR CERAMIC TECHNOLOGIES AND SYSTEMS IKTS

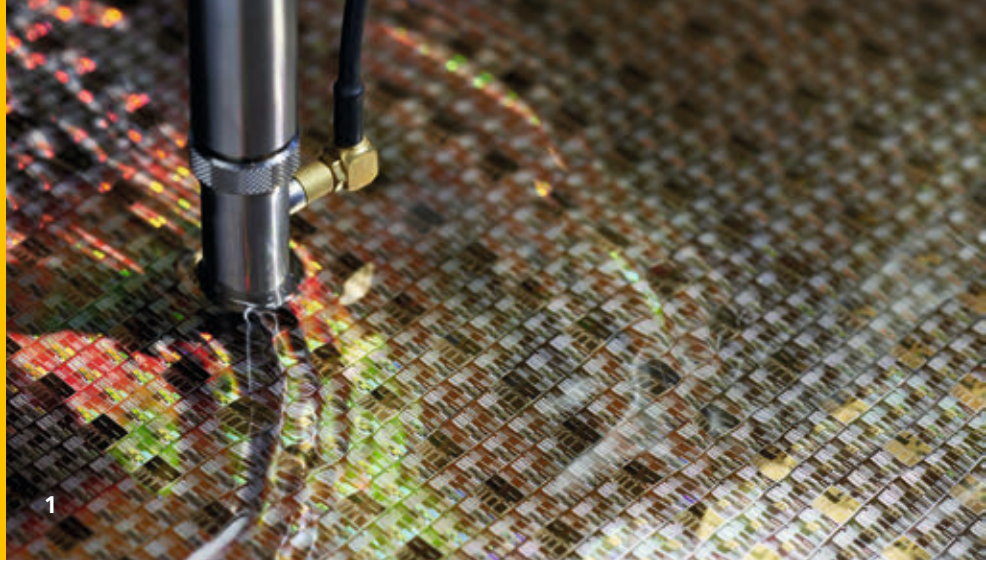
INDUSTRIAL SOLUTIONS

**ULTRASONICS**



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**COVER IMAGE** *Wave field of a PZT fiber transducer.*  
**1** *Ultrasonic probe scanning a waver.*



# “ONE STOP SHOP” FOR ULTRASONIC TECHNOLOGY

Ultrasonic technology represents the most commonly used process in non-destructive testing. The Fraunhofer Institute for Ceramic Technologies and Systems IKTS combines long years of experience in materials testing with unique know-how in the field of ultrasonic technologies. As a developer of customer-specific industrial ultrasonic test systems, Fraunhofer IKTS offers transducers, probes, testing electronics, software, simulation and modeling services, as well as an accredited test lab for the validation and verification of ultrasonic methods.

Fraunhofer IKTS has been researching ultrasonic testing since the 1960s, when it was still part of the Central Institute for Nuclear Research in Dresden-Rossendorf. Today, the largest ceramics research institution in Europe creates smart solutions for non-destructive testing – from piezoelectric ceramics to certified ultrasonic test systems.

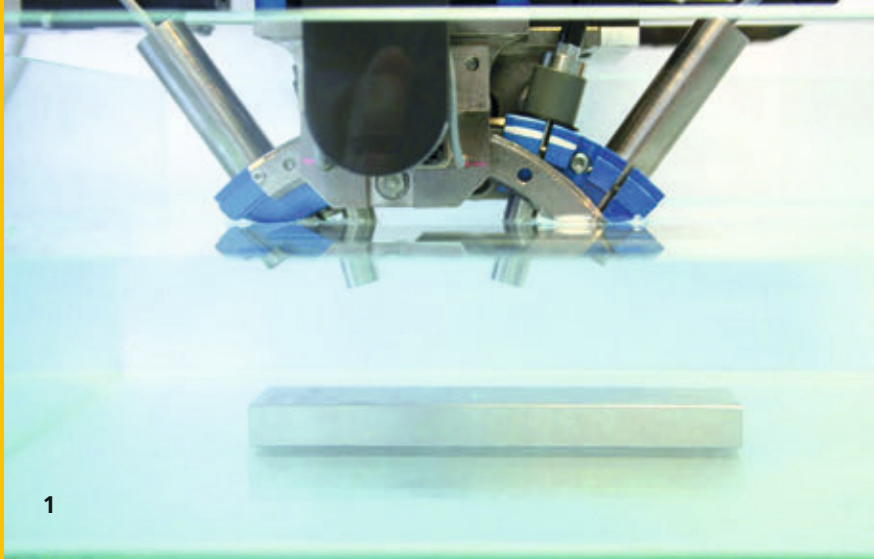
Transducers are at the heart of any test system. Fraunhofer IKTS supplies its own developed transducers designed for special applications. They can be adapted optimally to fit various geometries, materials and other acoustic parameters. Customer-specific test systems are equipped with modular and very powerful electronics (PCUS®*pro* device family) and equally modular and versatile software (PCUS®*pro* Lab).

Fraunhofer IKTS strives constantly to optimize and develop further all test systems and test procedures. This is done with simulation technologies, which are also used to seek out new approaches to measuring. The very own accredited test lab – certified for five classic methods of non-destructive testing in accordance with DIN EN ISO/IEC 17025 – is able to validate ultrasonic testing methods developed by Fraunhofer IKTS thanks to its versatile accreditation, and apply them in the same way as standardized procedures.

Scientific consulting in basic aspects of non-destructive testing, and the implementation and supervision of complete R&E projects, complete the IKTS portfolio.

**Ultrasound methods and technologies for NDT, materials diagnostics and materials characterization**

Development of methods	Transducers & sensors	Electronics	Software	Simulation & modeling	Accredited test lab	Ultrasound testing systems



## DEVELOPMENT OF METHODS

New manufacturing processes, ever more complex components and increasing expectations of quality mean that companies are faced with questions that conventional approaches to ultrasonic technology cannot solve.

As a NDT specialist, Fraunhofer IKTS develops new and effective testing methods for industrial ultrasonic applications "out of the box". These applications can be completed with customized measuring and analysis technology as required.

## CHARACTERIZATION OF BOUNDARY LAYERS

In order to improve materials properties, such as vibration resistance, stiffness, resilience and fatigue strength, the boundaries of components under heavy strain, such as camshafts, gears, bending and pressing tools or engine components, are modified with regard to their mechanic and thermal parameters.

This can be achieved by shot blasting metals in order to modify their microstructure (strain hardening) or to introduce surface compression stress. Surface hardening is another option. However, these modifications frequently result in unwanted side effects, such as surface degradation from micro cracks.

In any case, the non-destructive characterization of the material's condition will always be of interest. Rayleigh waves help to obtain the desired information. These ultrasonic waves are brought onto the surface of the component and penetrate it to varying levels of depth, depending on their frequency. The frequency-dependent sonic velocity (dispersion) provides information on the depth gradient of the examined properties. The acoustoelastic effect – the dependency of the velocity of propagation from the elastic stresses – makes it possible to determine an internal stress (depth) gradient. The laser-optical determination of the Rayleigh wave dispersion has become a

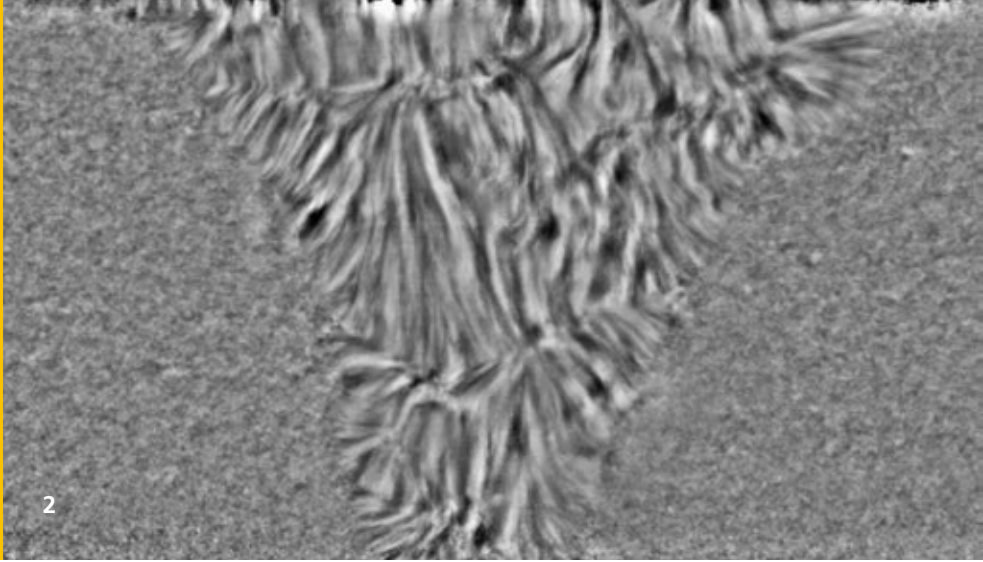
well-established and very accurate method for the non-destructive characterization of boundary layers. However, it is a highly complex and mechanically not very robust process.

Therefore Fraunhofer IKTS was looking for an alternative to characterize internal stress in shot-blasted metals. Using the "High Resolution Ultrasound Goniometer" (HUGO), which was developed at the institute, the spectrum of the signal, reflected through immersion technology, is visualized through the angle, which allows generating a dispersion curve. This approach enabled the researchers of Fraunhofer IKTS, in several projects for customers, to characterize the internal stress condition of hardened and shot-blasted metals quickly and without destroying the materials. Furthermore, the testing device can be used to determine layer thickness and surface degradation.

## REPRESENTATION OF VOLUME IMAGES

High-frequency ultrasonic immersion technology, also called ultrasonic microscopy or scanning acoustic microscopy (SAM), makes it possible to represent volume images. This method is ideal for objects with small defects (scatterers), but rather imprecise when it comes to detecting sloped, planar inhomogeneities, such as cracks.

**1** *HUGO III system by IKTS for the swift and non-destructive characterization of hardened and shot-blasted metals.*



The newly developed measuring technique and analysis software for ultrasonic microscopy by Fraunhofer IKTS solves this problem. SAM tomography does a lot more for objects with an even coupling area than conventional ultrasonic microscopy, since it can correctly detect and represent sloped planar defects as well.

## MEASURING ULTRASONIC WAVE PROPAGATION

Optimizing ultrasonic testing methods requires extensive knowledge about how ultrasonic waves propagate. Numerical simulation, which is used as a tool for this purpose, often falls short if the tasks are more complex, for instance if input parameters are missing or imprecise. In such cases, experimental methods are indispensable in order to get information.

The researchers of Fraunhofer IKTS can look back on long years of experience in measuring ultrasonic wave fields using various methods. The laser vibrometric measurement of ultrasonic wave propagation on surfaces or cross-sections has emerged as a particularly suitable approach for this. This method is completely free from retroactive effects and delivers snapshots and videos of the wave propagation. It is particularly suited to fiber-reinforced materials or materials that are elastically highly anisotropic, such as austenitic weld seams. Furthermore, it is possible to gain relevant insight into ultrasonic wave propagation even for defect-based interactions.

## DETERMINATION OF MICROSTRUCTURES

An ultrasonic wave propagating along a surface does not just carry information on the varying elastic macroscopic properties. It also contains information on the microstructure of the examined object.

The researchers of Fraunhofer IKTS have managed to make the microstructure visible by performing laser vibrometric measurements of grazing ultrasonic waves.

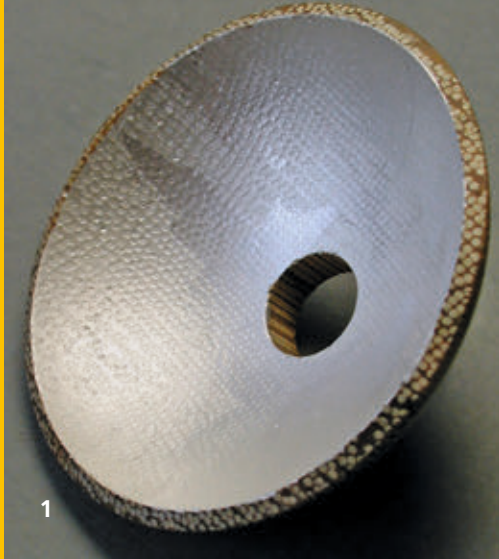
This new type of elastodynamic near-field microscopy, also called "grazing incidence ultrasound microscopy" (GIUM), represents an alternative to metallographic methods for grain structure analyses; it also does without etching. Also, in contrast to electron backscatter diffraction (EBSD), GIUM does without a vacuum and allows for much larger samples.

### Services offered

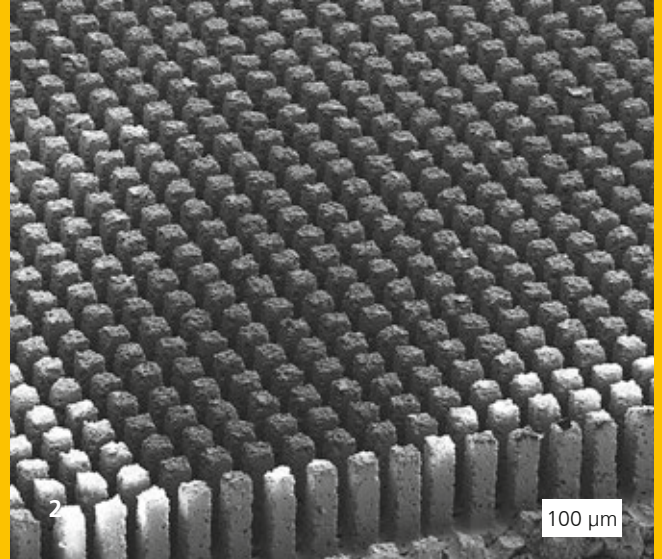
Fraunhofer IKTS provides innovative solutions for industrial tasks using ultrasonic methods. Furthermore, other NDT methods are available; they pass through all or some of the following steps, depending on the problem to be solved:

- Analysis of the problem
- Search for known or established solutions or approaches
- Modeling of the facts and situation
- Experimental investigation
- Demonstration of feasibility
- Development/adaptation of sensors and/or electronics
- Development of software
- Measurements as a service or supply of a test system

**2** *Grain structure of an austenitic weld seam, visualized through GIUM.*



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100 μm

## ULTRASONIC TRANSDUCERS

Ultrasonic transducers are the most important component of ultrasonic probes. Utilizing its material and manufacturing know-how, Fraunhofer IKTS provides unique solutions for specific transducers as well as innovative testing applications.

### FIBER COMPOSITES

The combination of piezoceramic elements with polymer offers a wide range of high-performance ultrasonic transducers. In order to manufacture such transducers efficiently, both the piezoceramic components used and the piezoelectric composites derived from them need to be tailored specifically to the individual application.

Fraunhofer IKTS manufactures PZT fibers using spinning process, thus offering powerful technology for the production of high-performance, long piezoceramic elements. They are arranged in composites in random or regular distribution allowing for the manufacture of ultrasonic transducers, which fit specific requirements:

- High frequency/low frequency
- Focused/non-focused
- Single element/segmented

Resonance frequency	40 kHz to 8 MHz
Coupling coefficient	0.60
Acoustic impedance	15 to 25 MRayl
Fiber dimensions	100 to 800 μm
Maximum transducer dimensions	60 x 60 mm

1 Focusing ultrasonic transducer based on piezofiber composite.

### DICE AND FILL COMPOSITES

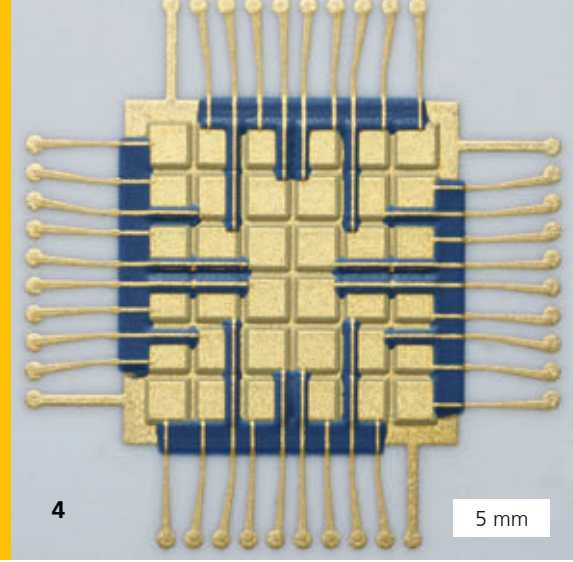
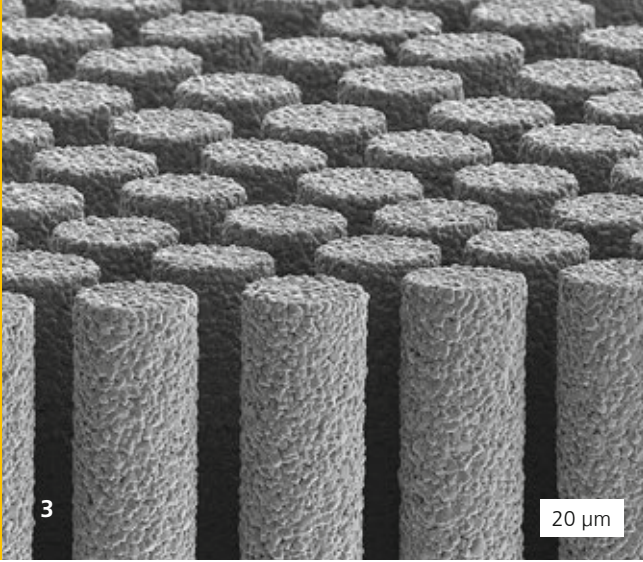
The dice and fill technique is the most common method to manufacture 1-3 piezoceramic composites. For this, a series of parallel cuts is made into a bulk piezoelectric plate in two directions that are perpendicular to one another. Usually, rods with a rectangular cross section are the result. The diced material is backfilled with a polymer and the base ceramic support removed by grinding. The resulting 1-3 piezoceramic composites offer the following advantages over standard bulk piezoceramics:

- Lower acoustic impedance  $Z_a$
- Higher coupling coefficient  $k_t$
- Higher bandwidth B
- Lower mechanical quality factor  $Q_m$

The piezoceramic material will be selected according to application needs. For highly sensitive ultrasonic transducers 1-3 piezocomposites based on single crystal PMN-PT are manufactured.

Resonance frequency	1 to 15 MHz
Coupling coefficient	0.68 (ceramic) 0.75 (single crystal)
Acoustic impedance	18 to 22 MRayl
Minimum element dimension	50 μm
Minimum interspace dimension	35 μm
Maximum transducer dimensions	60 x 60 mm

2 Diced PZT ceramic plate for 1-3 piezocomposite fabrication.



## SOFT MOLD COMPOSITES

For the manufacturing of ultrasonic transducers greater than 10 MHz the dice and fill process is limited due to the width of the dicing blade and brittleness of the piezoceramic plate. Fraunhofer IKTS has been invented the soft mold process which allows for 1-3 piezocomposites with smaller pitch size and free design of the piezoceramic rods.

The idea of the soft mold process is to use master molds, which have been structured by microsystems technology like deep reactive ion etching of silicon wafers. From these, soft polymer templates are taken which are subsequently filled with a ceramic slip. After drying, demolding and sintering fine-scaled piezoceramic arrays are obtained which can be back-filled with a polymer and ground to the desired thickness.

Using the soft mold process Fraunhofer IKTS is able to offer high-frequency ultrasonic transducers in the range of 5 to 40 MHz.

Resonance frequency	5 to 40 MHz
Coupling coefficient	0.60
Acoustic impedance	10 to 20 MRayl
Minimum element dimension	25 μm
Minimum interspace dimension	8 μm
Maximum transducer dimensions	10 x 10 mm

3 Sintered PZT rod array for 1-3 piezocomposite fabrication.

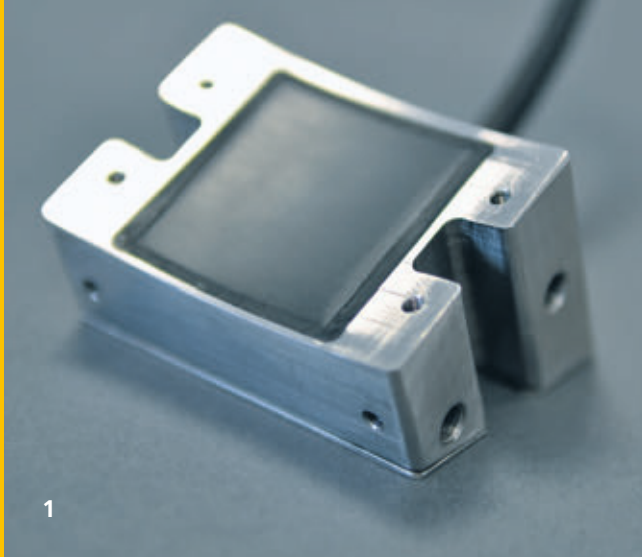
## SCREEN PRINTED ULTRASONIC TRANSDUCERS

Fraunhofer IKTS supplies special ultrasonic transducers manufactured by screen printing technology. Net-shaped PZT thick films with typical thickness of 30 to 150 μm can easily be deposited on standard electronic substrates like Al<sub>2</sub>O<sub>3</sub>, LTCC (Low Temperature Cofired Ceramics), silicon, and selected steel grades. Thereby compact devices with integrated piezoelectric function and electronics can be realized in batch production on wafer-level. They fulfill market requirements towards miniaturization and concentration.

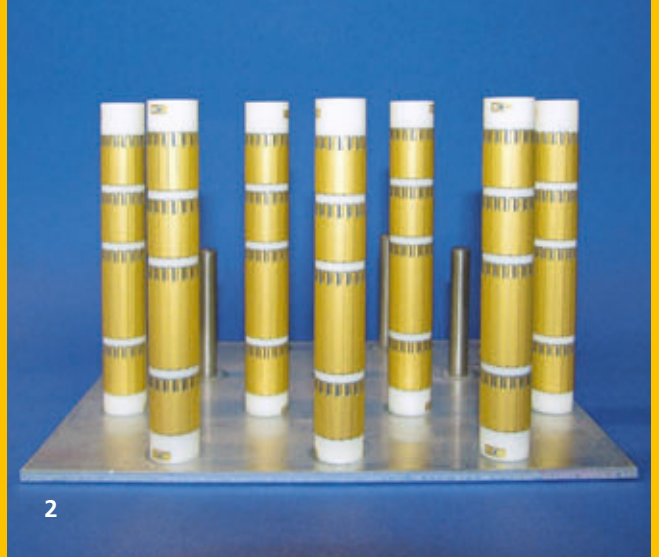
By patterning piezoceramic thick-film and electrode structures ultrasonic transducers can be designed as phased arrays or as line-focused transducers. Moreover, tubular screen printing can be applied onto cylindrical substrates for inspection tasks of hollow shafts and smaller tubes.

Resonance frequency	5 to 30 MHz
Coupling coefficient	-
Acoustic impedance	-
Minimum element dimension	300 μm
Minimum interspace dimension	300 μm
Maximum dimensions	100 x 100 mm

4 2D ultrasonic transducer array on Al<sub>2</sub>O<sub>3</sub>.



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## ULTRASONIC PROBES AND SENSORS

Ultrasonic probes are used in many branches of industry for non-destructive testing (NDT) of materials. With various frequencies, configurations, connector styles, and cable types ultrasonic probes of IKTS detect the precise location of objects for a safe and reliable assessment of defects.

### FOCUSED ULTRASONIC PHASED-ARRAY PROBES

Fraunhofer IKTS supplies special probes for ultrasonic applications at curved construction components, pipes and holes. The focused/curved ultrasonic phased-array probe focuses the sound field geometrically, improving the sound transmission into the test object.

### SINGLE-ELEMENT SENSORS

The measurement with a single element sensor, combined with the analysis of the travel time between two successive wall echoes, enables great precision without systematic errors. Fraunhofer IKTS supplies single-element sensors for immersion technology, for instance with a water tightness of up to 2 m water column and up to 9 m cable length.

### HIGHLY SENSITIVE PHASED-ARRAY SENSORS

Fraunhofer IKTS supplies highly sensitive sensors for ultrasound test applications of spot welding seams, in strongly anisotropic materials, especially in the automotive industry.

The sensitivity is more than 10 dB higher than in sensors based on piezo-ceramic polymer composites. Moreover the relative bandwidth increases by 20 percent.

### CYLINDER-TYPE TRANSDUCERS

Fraunhofer IKTS supplies special transducers manufactured by the tubular printing of thick-film piezoceramic pastes onto cylindrical substrates for inspection tasks in ducts of heat exchangers, hollow shafts and smaller tubes.

These can be designed as phased arrays or as line-focused transducer. This opens up new potential for the ultrasonic testing of small inner diameters within the sample (10 to 30 mm).

Probes	Focused ultrasonic phased-array probes	Single-element sensors
Number of elements	16 to 64	1
Sensor material	Composite	Composite
Connection	Hypertronics or Olympus	LEMO or as per customer's request
Cable	Coaxial cable	Coaxial cable
Operating frequency	2 to 15 MHz	2 to 15 MHz
Element diameter	Line arrays as per customer's request	3 to 50 mm
Max. temperature	40 °C	40 °C
Housing	Stainless steel	Stainless steel
Membrane	-	-
Adaption medium	As per customer's request	As per customer's request

1 Mechanically focused ultrasonic phased-array probe.

2 Cylinder-type transducers for special inspection tasks.





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## HIGH-FREQUENCY SENSORS

Fraunhofer IKTS manufactures sensors based on an aluminum-nitride thin-film transducer with a frequency range of 100 to 250 MHz. These high-frequency sensors are used for ultrasonic microscopy as a focusing or non-focusing version.

## ACOUSTIC EMISSION SENSORS

Acoustic emission sensors are available for the active and passive structural monitoring of steel pipes, vapor pipes and large tank bottoms, depending on customer's request and the required temperature stability in the typical frequency range of 100 to 700 kHz.

## HIGH-TEMPERATURE SENSORS

Fraunhofer IKTS supplies suitable specialist sensors for measuring construction components, liquid media and samples from steel, nonferrous metals, aluminum with alloys, plastics, ceramics and glass.

The sensors can be used for the most varied applications in temperatures of up to 200 °C. They are designed and manufactured for testing in contact method or immersion technique.

Probes	Highly sensitive phased-array sensors	Cylinder-type transducers	High-frequency sensors	Acoustic emission sensors	High-temperature sensors
Number of elements	16	16	1	1	1
Sensor material	Composite (single crystal)	PZT thick film	AlN thin film	PZT ceramics	PZT ceramics
Connection	Hypertronics or as per customer's request	Hypertronics or as per customer's request	UHF, Microdot	LEMO	LEMO
Cable	Coaxial cable	Coaxial cable	-	Teflon coaxial cable	Teflon coaxial cable
Operating frequency	2 to 10 MHz	10 MHz	100 to 250 MHz	100 to 600 kHz	1 to 10 MHz
Element diameter	Line arrays as per customer's request	Line arrays	2 to 5 mm	3 mm	3 to 12 mm
Max. temperature	40 °C	60 °C	60 °C	150 °C	200 °C
Housing	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel
Membrane	-	-	-	Steel membrane	Ceramic tip
Adaption medium	As per customer's request	As per customer's request	Quartz	-	-

3 Acoustic emission sensor.

4 High-temperature sensors.

## ELECTRONICS

Only powerful and modular electronics and software allow to utilize the maximum performance of a transducer. With its PCUS® *pro* device family, Fraunhofer IKTS offers an electronic system that is suited for use in manual ultrasonic testing, as well as automated ultrasonic test systems.

The products of the PCUS® *pro* device family range from the simple manual test system – the PCUS® *pro* Single – to the phased-array system for automated ultrasonic testing – PCUS® *pro* Array.

All PCUS® *pro* devices are compact, energy-efficient and comply with the respective relevant parts of the ultrasonic standard DIN EN 12668. The modular structure allows for an adaptation of the equipment to suit the testing task at hand, all with only little development effort.

The connection of any numbers of PCUS® *pro* devices to desktop, laptop or tablet PC gets easy with USB. The compact design is ideal for sensor-near applications.

### PCUS® *pro* SINGLE

PCUS® *pro* Single is a handy ultrasonic frontend which together with a standard PC makes an ultrasonic testing system. All the components required for signal generation, measurement and processing are included in a small housing.

PCUS® *pro* Single is the ideal solution for manual testing, automated single-channel testing, as well for education and research purposes.



#### Product details

- Method: Manual testing
- Compact electronic unit for manual and mechanized ultrasonic tests with a single channel
- Power supply and data transfer via USB 2.0
- Optional external encoder interface for four axes
- For single and dual element transducers within the frequency range of 500 kHz to 30 MHz
- Low-noise A/D conversion providing 14-bit resolution and sampling rates of up to 100 MS/s

### PCUS® *pro* MINI

PCUS® *pro* Mini is a four-channel ultrasonic frontend with an extremely compact build for ultrasonic testing in constrained spaces, such as in pipelines or tanks. As a special feature, it has an optional integrated USB fiber optics converter for operation with cables up to 500 m long.

#### Product details

- Method: Automated multi-channel testing
- Ultracompact electronic unit for automated ultrasonic testing within constrained spaces offering up to four channels
- Optional: Integrated USB via fiber optics for cables up to 500 m long
- Integrated encoder interface for two axes
- For single and dual element transducers within the frequency range of 500 kHz to 30 MHz
- Low-noise A/D conversion providing 14-bit resolution and sampling rates of up to 80 MS/s

1 Test electronics of the PCUS® *pro* device family.



## PCUS® *pro* MULTI

PCUS® *pro* Multi is a 16-channel ultrasonic frontend for fully automated ultrasonic testing with several transducers. Thanks to the USB 2.0 interface and the ability to compress the measured data, very fast measurements become possible in the industrial context, e.g. in sheet metal testing or hollow shaft testing for rail vehicles. With its modular structure PCUS® *pro* Multi can be adapted to almost any inspection task.

### Product details

- Method: Automated multi-channel testing
- Compact ultrasonic electronic unit for automated testing with up to 16 transducers
- For single and dual element transducers within the frequency range of 500 kHz to 30 MHz
- Low-noise A/D conversion providing 14-bit resolution and sampling rates of up to 80 MS/s
- Up to 400 V transmission voltage
- Integrated encoder interface for four axes

## PCUS® *pro* ARRAY

PCUS® *pro* Array enables fast automated phased-array ultrasonic testing in industrial contexts, e.g. in railway construction or automotive engineering. The test system is ideally suited for weld seams, adhesive joints or other test areas that are difficult to access. Thanks to the large bandwidth and the high scanning rate, CFRP and GFRP structures can be tested as well.

### Product details

- Method: Automated testing with phased array
- Multiple phased-array sensors at one electronic unit possible
- Compact ultrasonic electronic unit for automated testing with phased-array transducers, up to 64 elements (16:64)
- 64 parallel pulsers for flexible beamforming
- For phased-array transducers within the frequency range of 500 kHz to 30 MHz
- Conventional phased array, Full Matrix Capture, Total Focussing Method and SAFT possible
- Integrated encoder interface for four axes

## PCUS® *pro* ARRAY II

PCUS® *pro* Array II is an enhancement of the PCUS® *pro* Array electronic unit for particularly fast phased-array testing with many elements. The fully parallel design and the USB 3.0 SuperSpeed interface enable very high scanning rates. The bipolar transmitter pulse enables a signal-to-noise ratio that is even better.

### Product details

- Compact ultrasonic electronic unit for automated testing with phased-array sensors, up to 128 elements (128:128)
- Multiple phased-array sensors at one electronic unit possible
- For phased-array transducers within the frequency range of 500 kHz to 30 MHz
- Low-noise A/D conversion providing 14-bit resolution and sampling rates of up to 125 MS/s
- Cascadable, e.g. for using matrix arrays
- Bipolar transmitter pulse for the best signal-to-noise ratio
- Conventional phased array, Full Matrix Capture, Total Focussing Method and SAFT possible
- Integrated encoder interface for four axes
- Self-tests and self-diagnosis for highest reliability



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## PERFORMANCE DATA, PCUS® *pro* DEVICE FAMILY

	PCUS® <i>pro</i> Single	PCUS® <i>pro</i> Mini	PCUS® <i>pro</i> Multi	PCUS® <i>pro</i> Array	PCUS® <i>pro</i> Array II
<b>Pulsers</b>					
Number of pulsers	1	4	2...16	64	128
Pulse voltage / step	-50 to -250 V / 1 V	-175 V / fixed	-50 to -300 V / 1V	-20 to -180 V / 1 V	±10...±80 V / 1 V
Pulse delay / step	0 to 40 µs / 5 ns	0 to 51 µs / 6.25 ns	0 to 51 µs / 6.25 ns	0 to 51 µs / 3.125 ns	0 to 131 µs / 2.0 ns
Pulse width / step	0 to 500 ns / 2.5 ns	0 to 500 ns / 3.125 ns	0 to 500 ns / 3.125 ns	0 to 500 ns / 3.125 ns	0 to 500 ns / 2.0 ns
Pulse repetition frequency	Up to 2 kHz	Up to 10 kHz	Up to 2 kHz	Up to 2 kHz	Up to 15 kHz
Integrated damping	50 Ω	50 Ω	50 Ω	50 Ω	50 Ω
<b>Signal path</b>					
ADC sample rate	100 MS/s max.	80 MS/s max.	80 MS/s max.	80 MS/s max.	125 MS/s max.
ADC sample width	14 bit	14 bit	14 bit	14 bit	14 bit
Rectification	Raw / full / positive / negative				
A scan compression	Up to 256:1	Up to 256:1	Up to 256:1	Up to 256:1	Up to 256:1
Gates	One interface gate + four hardware measurement gates				
Digital filter	-	-	-	-	Yes
Recording length	65535 samples	32767 samples	65535 samples	65535 samples	65535 samples
Probe delay / step	0 to 655 µs / 10 ns	0 to 819 µs / 12.5 ns	0 to 819 µs / 12.5 ns	0 to 819 µs / 12.5 ns	0 to 524 µs / 8.0 ns
Receiver delay / step	0 to 655 µs / 10 ns	0 to 819 µs / 12.5 ns	0 to 819 µs / 12.5 ns	0 to 819 µs / 12.5 ns	0 to 524 µs / 8.0 ns
<b>Time gain correction</b>					
Dynamic range / step	80 dB / 0.1 dB	80 dB / 0.1 dB	80 dB / 0.1 dB	80 dB / 0.1 dB	80 dB / 0.1 dB
Slope	40 dB/µs	40 dB/µs	40 dB/µs	40 dB/µs	40 dB/µs
TGC curves	1	16	16	64	128
Points per curve	256	256	256	64	64
<b>Dimensions</b>					
	120 x 100 x 40 mm <sup>3</sup>	95 x 81 x 43 mm <sup>3</sup>	190 x 150 x 65 mm <sup>3</sup>	190 x 190 x 65 mm <sup>3</sup>	272 x 222 x 90 mm <sup>3</sup>

1 PCUS® *pro* Single.

2 PCUS® *pro* Multi.



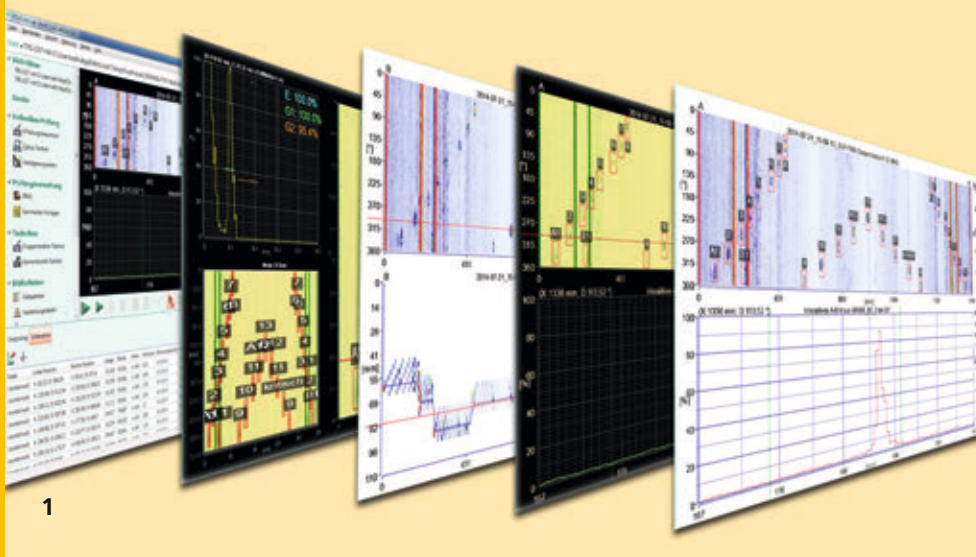
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	PCUS® pro Single	PCUS® pro Mini	PCUS® pro Multi	PCUS® pro Array	PCUS® pro Array II
<b>Receiver</b>					
Number of receivers	1	4	2 to 16	16	128
Input multiplexer	-	-	-	4:1	-
Dual element mode	Yes	Yes	Yes	No	No
Receiver bandwidth	500 kHz to 30 MHz (-3 dB)	500 kHz to 30 MHz (-3 dB)	500 kHz to 30 MHz (-3 dB)	500 kHz to 30 MHz (-3 dB)	500 kHz to 30 MHz (-3 dB)
Analog band filters*	4	2	2	2	4
Maximum input voltage	10 V p-p	10 V p-p	10 V p-p	10 V p-p	2V p-p
Amplification / step	0 to 80 dB / 0.1 dB	0 to 80 dB / 0.1 dB	0 to 80 dB / 0.1 dB	0 to 80 dB / 0.1 dB	0 to 80 dB / 0.1 dB
Preamplifier	40 dB	40 dB	40 dB	40 dB	20 dB
<b>Connectors</b>					
Probe connector	LEMO 00	LEMO 00	LEMO 00	Hypertec	Hypertec / Olympus
PC interface type	USB 2.0 high speed	USB 2.0 high speed	USB 2.0 high speed	USB 2.0 high speed	USB 3.0 super speed
PC interface connector	B type	Micro B type Fiber USB (option)	Bulgin mini B type PX0443	Bulgin mini B type PX0443	USB 3.0 B type
Trigger in	MCX, 5V	-	LEMO 00, 5V	LEMO 00, 5V	DSUB, 5V
Trigger out	MCX, 3.3V	Micro Fit, 3.3V	LEMO 00, 3.3V	LEMO 00, 3.3V	DSUB, 5V
Scanner interface	External (option)	Integrated	Integrated	Integrated	Integrated
Scanner interface axes	4	2	4	4	4
Aux analog input	-	1 channel, 0 to 5V	-	-	2 channels, 0 to 5V
Waveform analog out	-	-	-	-	125 MS/s
Self-test	-	-	-	-	Yes
<b>Power supply</b>					
	USB bus powered	12V DC / 2A	12V DC / 4A Bulgin PX0419	12V DC / 4A Bulgin PX0419	24V DC / 8A

\* Filter frequencies as per customer's request



## SOFTWARE

Software has become an elementary part of the development of test systems in industrial contexts. Users define the features they need and expect an intuitive user interface. Software has to be innovative and available at short notice, for future modifications and extensions.

With the PCUS<sup>®</sup> pro Lab Fraunhofer IKTS has developed a software suite that makes it easy to perform and visualize automated and semi-automated ultrasonic inspections with conventional or phased array transducers suited for the PCUS<sup>®</sup> pro device family.

In this context, the standards of the PCUS<sup>®</sup> pro Lab software suite are always defined by the expectations of its users. At the center of attention are subjects such as modern manufacturing (Industry 4.0) and the ever-growing demands regarding integration, efficiency and cross-linking between components used within the industrial field of ultrasonic testing.

## PCUS<sup>®</sup> pro LAB

PCUS<sup>®</sup> pro Lab is a modular software suite for non-destructive testing. Automated, semi-automated and manual solutions which are adapted to the requirements of the specific testing task are being provided flexibly and quickly.

The software development focuses on usability and user acceptance in order to implement complex testing scenarios in accordance with relevant standards. This goal is supported by clearly defined interfaces and modules to integrate the customer's existing automation concepts. Through the use of these methods PCUS<sup>®</sup> pro Lab guarantees the best possible combination with existing industrial production lines and technologies.

The software assists in the creation of parameterizations for actuator and transducer control, visualization and analysis. The data is organized and managed flexibly within the adaptable revision system.

The methods of agile software development guarantee a transparent development process in close collaboration with the customer. Wishes and requirements are implemented fast and safely, to guarantee the highest degree of quality and safety. The user interfaces and process controls can be adjusted individually to best fit user's demand.

1 Measurement screens of the PCUS<sup>®</sup> pro Lab software suite.



## Features

- 64-bit application
- Runs on all popular Windows systems
- Touch-enabled
- Intuitive use thanks to a modern, accessible and easily adaptable user interface
- Industry 4.0 – fully cross-linked integration into existing manufacturing concepts
- Easy transition from lab to industry environment through uniform software for all fields of application
- Combination of any devices and methods in one test for the highest possible efficiency
- Extensively configurable representations of typical volume images (B, C, D, S, L, TD etc.)
- Professional implementation of customer-specific requirements through a modular concept in the area of parameterization, test sequence and analysis (e.g. fully adaptable user interface for testing processes)
- Representation of complex testing requirements using any geometries
- Real-time representation of the volume images during data acquisition
- Assistance during commission through the use of flexible calibrating modes
- Storage of measured data as raw data with optional loss-free compression or as reduced image data
- Integrated logging and archiving of inspections
- Fast integration of external modules for the control of the most varied actuators and sensors
- Acquisition and management of very large quantities of inspection data
- Retroactive adaptation of parameters for all values independent of recording (visualization, gates etc.)
- Individual error logs and reporting as required by the customer
- Numerous options for easy rights management via Windows User Access Control
- Uniform software development kit (SDK) for the whole PCUS<sup>®</sup> *pro* device family for the integration of the PCUS<sup>®</sup> *pro* hardware into the customer's own software

2 *Phased-array test system for wheel-set solid shafts with UT electronics and software from IKTS (source: arxes-tolina GmbH).*



### Modular design

- Free combination of the required functions
- Integration of the customer's own modules into the user interface
- Easy linking of features to user profiles
- Extensive master data base for sensors, materials, test methods, layouts etc.
- Management system for the comfortable management of test results and data

### Parameterization/adjustment

- Modular, library-oriented parameterization for quick, easy extension, modification and subsequent use
- Up to four freely configurable coordinate axes
- Simulation of all axes to co-ordinate the actuators with the test sequence
- Adjustment of all transducer and material parameters
- Unlimited number of focal laws
- Comprehensive standard libraries
- xml export for customer-specific layout
- User-friendly plausibility check of data input for parameterization as well as automatic support via tool tips

### Testing

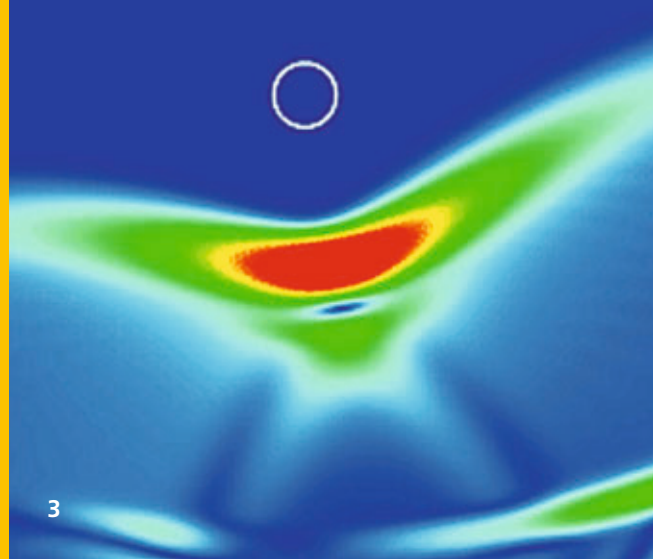
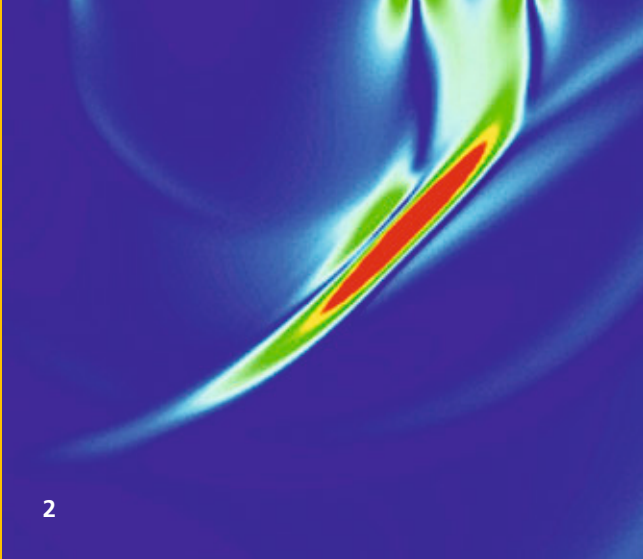
- Quick integration into automated production processes
- Free combination of any number of devices in one inspection
- USB 3.0 with up to 300 MB/s transfer speed
- Tests triggered by coordinates, time or externally
- Live representation of volume images during testing

### Analysis

- Any projection plane of the test specimen can be selected
- Simultaneous display of several inspection groups
- Parallel display of different tests and files
- Automatic or manual detection and application of transfer correction
- Measurement in metric and imperial units
- Zoom function in all planes
- Intelligent algorithms, such as hiding fault indications, searching maximum values, determining surface areas or dynamic cutting of test data along the object geometry
- Individually adaptable layouts and representation of measurements
- Retroactive setting of offline gates
- Versatile reporting and logging
- Export of reports to xml files to suit the customer's own layout
- Numerous measuring tools for all volume images
- Comprehensive and easy-to-adapt color tables
- Freely adaptable offline visualization (B, C, D, S, L, TD etc.)
- Export of raw data into common text-based formats
- Unlimited inspection data volume (limited only by storage space)
- Comfortable use of parametrizations across systems and users

1 Mobile test system for wheel set shafts with longitudinal holes with UT electronics and software from Fraunhofer IKTS (source: arxes-tolina GmbH).





## SIMULATION UND MODELING

Today, simulation tools are essential for optimizing ultrasonic test systems and for developing new methods. They allow to check the method for physical plausibility and determine the best possible measuring and transducer parameters even before the first measurement setup has actually been built. This saves time and money in development and results in test systems with significantly improved performance parameters.

At Fraunhofer IKTS, simulation-supported planning and optimization is carried out with commercially available software as well as with proprietary numerical simulation tools developed at IKTS specifically for ultrasonic applications.

Our own developments are based on the Elastodynamic Finite Integration Technique (EFIT) and allow for a complete and realistic simulation of test systems with regard to wave physics, taking into account diffraction, interference, mode conversions and multiple scattering.

With EFIT isotropic and anisotropic as well as homogeneous and heterogeneous materials can be modelled. Coupled models of solids and fluid media can also be realized.

The simulation results are made available in the form of time-domain signals, B and C images, sector images, wave front snapshots or video animations.

### Fields of application

Simulation-supported methods are suitable for various fields of application. Fraunhofer IKTS has been using simulation-supported tools successfully for many years in numerous ultrasonic and acoustic projects ranging from industrial to research applications:

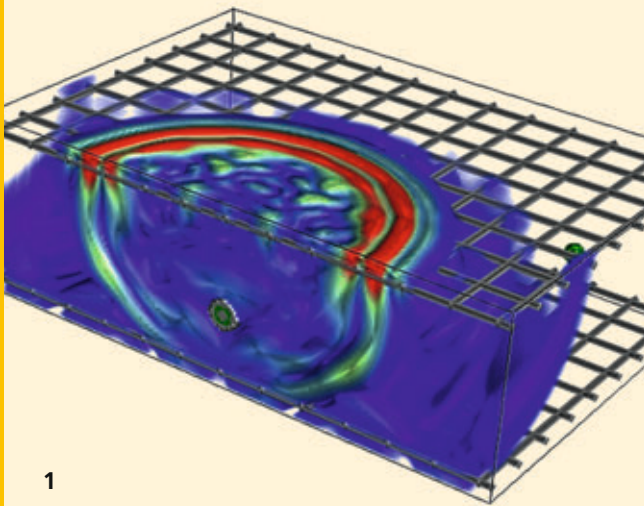
- Simulation-supported optimization of transducer wave fields including phased array
- Optimization of test setups and sensor configurations
- Determination of model-assisted POD (Probability Of Detection) curves for ultrasonic testing
- Guided waves for condition (structural health) monitoring
- Applications based on surface acoustic waves as well as laser and air-coupled ultrasonics
- Acoustic problems (room acoustics, sound emission, noise protection etc.)

### Performance characteristics

- Proprietary numerical ultrasound solvers
- Simulation-based on full wave physics
- Consideration of diffraction, interference, mode conversions, multiple scattering etc.
- Isotropic and anisotropic, homogeneous and heterogeneous materials
- Solids and fluid media
- 2D and 3D models
- Time-domain signals, wave front snapshots, video animations

2 Acoustic field of an ultrasonic angle-beam probe.

3 Focused acoustic field of an ultrasonic phased-array probe.



Over the course of the past 20 years, Fraunhofer IKTS has developed comprehensive know-how on modeling and an extensive and flexible module library for numerous applications in research and development.

When processing new projects, the best-suited existing simulation model from the library is always chosen. In a second step, the model is adapted, optimized and developed further as required by the current application. Consequently the development effort for individual modules and related costs remains relatively moderate and early results are available very fast.

The close collaboration with the experimental working groups at Fraunhofer IKTS ensures that the simulations are realistic and application-oriented. For instance, the models are validated and optimized regularly through wave field measurements based on immersion techniques or laser vibrometry.

#### Services offered

- Basic research (specifically for new testing approaches)
- Feasibility studies
- Test planning and supervision
- Interpretation of results
- System optimization (including sensors and sensor configuration)
- Visualization and imaging

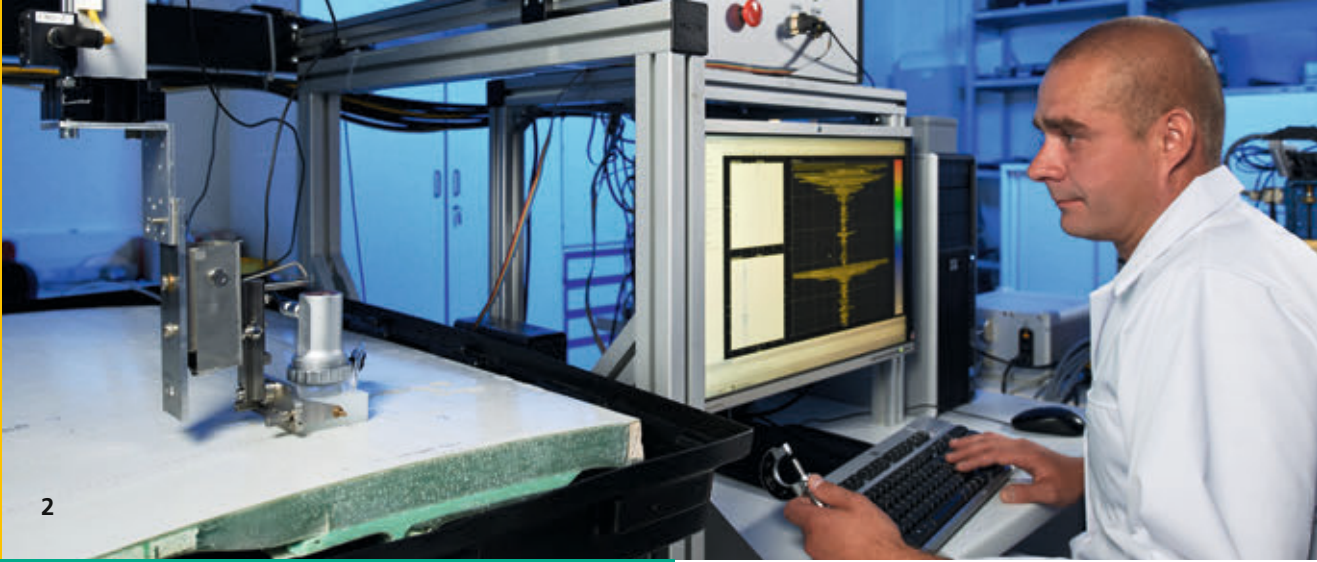
- Demonstration and training (among others, didactic introduction to ultrasonic physics and ultrasonic non-destructive testing using wave front images and animations)
- Simulation services (realization of simulation studies and their interpretation based on the tasks specified by the customer)
- Development of application-specific simulation tools for customers interested in performing their own simulations
- Combinable with commercial solver(s) (such as CIVA, ANSYS, Comsol etc.)

#### Mission

As a provider of new ideas and driver of innovation, Fraunhofer IKTS has a strategic interest in the further development of simulation tools.

To realize these ventures, we seek for collaboration with other research institutions and companies in the context of publicly funded national and international projects.

**1** *Elastic waves in a reinforced concrete specimen caused by a mechanical impact.*



## ACCREDITED NDT TEST LAB

The correct and reproducible performance of non-destructive tests, in particular of complex structures, requires know-how and experience. The proceedings are determined by a number of international standards, which may vary greatly depending on the respective industry. The development of new procedures and systems in particular requires compliance with current regulations and the establishment of new standards or device systems. With its flexible accreditation according to DIN EN ISO/IEC 17025, the test lab has been certified by an objective institution (Deutsche Akkreditierungsstelle GmbH – DAkkS) to perform all the steps required to validate and verify procedures and systems.

The accredited test lab at Fraunhofer IKTS performs conventional and special non-destructive tests of all kinds of metal, non-metal, ceramic and composite materials. All relevant standardized as well as non-standardized procedures, can be applied in this regard. Furthermore, Fraunhofer IKTS provides support solving unusual and highly special questions in measuring and testing.

Germany's national accreditation body Deutsche Akkreditierungsstelle has granted the IKTS test lab accreditation with flexible scope in five methods (ultrasonic testing, eddy-current testing, magnetic particle testing, penetration testing and visual testing) in accordance with DIN EN ISO/IEC 17025. This status allows to validate ultrasonic and eddy-current methods as developed by IKTS and apply them as if they were standardized methods. This means that new testing technologies can be used much earlier than it would be possible relying on standardization procedures.

The range of services offered by the accredited test lab includes the testing of individual components or large quantities of units, even in multiple shifts, as well as the construction of individual semi-automated test facilities for special tasks. The test lab examines components of the most varied materials, geometries and component sizes for defects, however complex or safety-relevant they may be, using a large number of methods.

### Testing expertise

- **Material** (steel, austenite, titan alloys, non-ferrous metals, polymers, ceramic composites, polymer composites, rocks, concrete, natural fibers)
- **Material joints** (welding, sandwich/layers, semi-finished products, rivet, bolt, adhesive and soldering joints)
- **Geometry** (voluminous bodies, complex geometries, flat plates etc.)
- **Component size** (few millimeters up to several meters according to the task)
- **Defects** (cracks, pores, delaminations, geometric defects, inclusions etc.)
- **Test methods** (ultrasonic testing, eddy-current testing, magnetic particle testing, penetration testing and visual testing, hardness measurements, thermography, x-ray computed tomography and x-ray laminography)

2 *Ultrasonic testing for defects in a GFRP sample.*



1



2

## TEST SYSTEMS

Fraunhofer IKTS develops customer-specific ultrasonic test systems for the lab as well as for industrial applications, carrying out their installation and commissioning, including staff training, as required by customers.

### TEST SYSTEMS FOR LAB APPLICATIONS

Fraunhofer IKTS develops highly specialized ultrasonic test systems used in fields not fully served by the current product portfolios of test device manufacturers.

The development of a test system always starts with the assessment of the customer's individual requirements with regard to maximum scan area, required precision, electronics and analysis software. Based on this assessment, ultrasonic test systems for lab applications that comply with the requirements can be developed within collaborative or bilateral projects, e.g. for sample quality testing of materials or products.

One focus of IKTS is the supply and implementation of systems for measuring sound fields and other transducer parameters, such as center frequency and bandwidth, for the manufacturers of ultrasonic transducers. IKTS also implements upgrades of systems for newly developed measurement methods that have already been tested for fixed transducer positions and are now to be extended by a scanning option.

1 *Lab system of the VARIUS ultrasonic scanner for detecting hollow spaces or cracks in weld seams and glued joints and other faults in composite materials.*

#### Services offered

- Building of customized multi-axis scanners according to customer requirements
- Integration of ultrasonic electronics from the PCUS® pro series of Fraunhofer IKTS or from second source providers
- Control of single probes and/or phased array probes
- Signal analysis options and dynamic depth focusing
- Adaptation of alternative sensors is possible (e.g. laser vibrometer, electrodynamic probes, hydrophones, small manipulator systems, such as HUGO III)

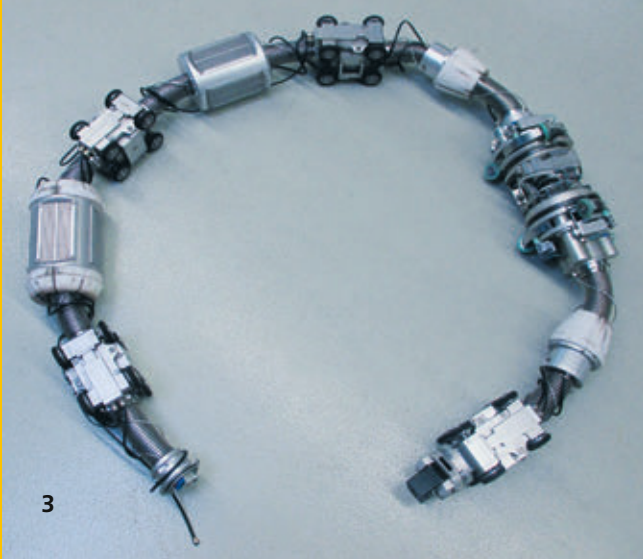
### TEST SYSTEMS FOR INDUSTRIAL APPLICATIONS

Industrial test systems are used for interval-based inspection and maintenance as well as for integrated quality assurance within a production line. The requirements for this with regard to robust hardware and intuitive software vary depending on the actual use case. Beside providing installations from the institute's own development efforts, IKTS also builds customer-specific test systems for manufacturing processes from commercially available industrial robots.

#### ULTRASONIC TEST SYSTEMS FOR RAILWAY VEHICLES

The test systems devised by Fraunhofer IKTS have often been used in the field of railway vehicles, where safety is key. The focus of development was on systems for testing components which experience high levels of stress, such as axles and wheels. These systems were developed in cooperation with partners from industry and are successfully marketed around the world.

2 *Phased-array test system for solid shafts for wheel sets (source: arxes tolina GmbH).*



3



4

Fraunhofer IKTS has provided these systems with the institute's own power electronics of the PCUS<sup>®</sup> *pro* series, as well as the intuitive PCUS<sup>®</sup> *pro* Lab software, which enable error-safe testing.

### Hollow shaft test system

With the aim of creating an optimized testing process, for instance for detecting transverse cracks in wheel set shafts, Fraunhofer IKTS and partners from the industry have developed a hollow shaft test system for high-speed trains, such as the ICE, TGV, Shinkansen or Bombardier Zefiro. With its high data rates and the parallel FPGA design, the powerful PCUS<sup>®</sup> *pro* electronics ensures fast and customizable parameterization, and thus the safe testing of the axles.

### Performance parameters

- System with seven independent single element probes
- Based on PCUS<sup>®</sup> *pro* Multi and PCUS<sup>®</sup> *pro* Lab software
- Fully automatic operation and analysis mode
- Adapter for connection to different wave types
- Fast testing from only one side

### Solid shaft test system

The solid shaft test system for freight train axles completes the portfolio of ultrasonic test systems for railway vehicles developed by Fraunhofer IKTS. Based on ultrasonic phased array, coated solid shafts for wheel sets can be tested for surface defects in areas that are prone to cracks, such as cross-section transitions.

### Performance parameters

- Testing of coated solid shafts for wheel sets
- Cycle time: less than 4 minutes
- Visualization of test results in real time
- Use of up to 8 phased-array probes (32 elements) simultaneously
- Fully automatic operation and analysis mode
- Three PCUS<sup>®</sup> *pro* Array electronics in parallel operation

### ULTRASONIC INSPECTION ROBOT

Service robots can simplify otherwise very complex inspections. They also increase safety for service staff and reduce costs by saving time. However, the testing manipulators need to be robust and work free of errors.

That is the case for the testing electronics that Fraunhofer IKTS has developed specifically for use in harsh environments, used in so-called crawlers or inspection robots in conjunction with the PCUS<sup>®</sup> *pro* software. These robots work in pipelines that are difficult to access, mostly installed underground, sometimes at great height.

Furthermore, with the ultrasonic scan carriage, IKTS has developed an inspection robot for the inspection and maintenance of rotor blades on wind turbines, which is also equipped with PCUS<sup>®</sup> *pro* electronics. This inspection robot has a range of up to one meter and has adaptable ultrasonic probes. It can drive along and scan high-risk rotor blades fast and automatically.

3 Ultrasonic testing robot for DN 200-300 pipes, equipped with PCUS<sup>®</sup> *pro* (source: INSPECTOR SYSTEMS Rainer Hitzel GmbH).

4 Ultrasonic measurements with scan carriage on the GFRP spar boom area of a rotor blade on a wind turbine.



## COOPERATION MODELS

Innovation and development are the cornerstones of a promising corporate future. In order to create a competitive edge, Fraunhofer offers tailored options for cooperation, so that small and medium-sized companies can work together in the best possible way. This also allows to utilize development skills at short notice and as needed.

### One-off contracts

The classic cooperation model is the one-off contract. A company perceives a need for research or development. A discussion with Fraunhofer IKTS identifies possible solutions and clarifies the form the partnership could take and the estimated cost.

### Large-scale projects

Some challenges are so complex that they require multiple partners to develop a solution. Customers in this situation have access to the full range of Fraunhofer Institutes. It is possible to incorporate external partners and additional companies.

### Strategic partnerships and innovation clusters

Pre-competitive research which starts off without any ties to specific development contracts often results in long-term partnerships with companies on a regional and international level.

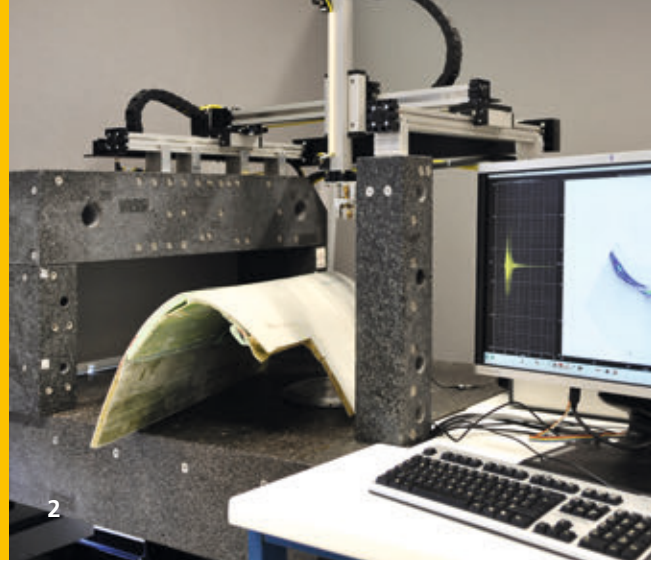
### Spin-offs

Fraunhofer researchers often take the step towards independence by founding their own company. Fraunhofer itself only participates in these kinds of start-ups up to a certain extent. Sometimes the customer who commissioned the new development is interested in taking a stake in the spin-off company.

### Licensing models

Licenses are a way to give third parties permission to use certain industrial property rights under defined terms and conditions. This means that industrial clients can use Fraunhofer innovations for their products and portfolios.

Fraunhofer IKTS offers flexible licensing models for company-wide use, optimizing one's own portfolio, or for marketing one's services to third-party clients. The design of a license agreement depends on the boundary conditions of commercialization for the company in its respective market segment, and on the type of cooperation with Fraunhofer. Therefore, such offers are always negotiated on a case-by-case basis.



## TECHNICAL EQUIPMENT

### Robot measuring cell

- Fast implementation of various measurement methods and measurement systems
- Adaptation of various tools for scanning, scratching, cutting, drilling, welding or bonding
- Accuracy of the robot: 80  $\mu\text{m}$  target point difference
- Accuracy of the camera: 20  $\mu\text{m}$  distortion at 800 mm focal point
- Surface pre-scan (optical): stereo camera and software
- Path planning: with software (parametric with gradient, compensation, caster angle, bearing angle etc.)
- Measuring speed: approx. 500 mm/s at 0.25 mm pitch
- Impedance image: 100 x 100 mm at 0.25 mm pitch: 3 min

### Ultrasonic microscope

- Scan area: up to 310 x 310 mm
- Position accuracy and resolution: < 10  $\mu\text{m}$
- Lateral resolution: < 15  $\mu\text{m}$
- Vertical resolution: < 30 nm (crack thickness)
- Ultrasonic frequency: up to 200 MHz
- Pulse-echo and permeation technology
- Single samples and sample series

### Ultrasonic scan carriage

- Extensive scans over measuring areas of up to 1 m width
- Use of various ultrasonic transducers
- Resolution determined by the frequency range of the sensors
- Automated scanning of surfaces

### Four-axis manipulator for special tests

- Three linear axes, one rotary disk, various (rotatable) plunge basins
- Immersion and contact technology
- Attainable object parameters:
  - Weight: less than 100 kg
  - Geometry: smaller than 500 x 300 x 300 mm<sup>3</sup>
- Various ultrasonic electronic units with numerous parameters
- Free access to raw data (compliant with various analysis algorithms)
- Can be adapted for many sensors and mechanic configurations
- Methods of sound field characterization: beads in water and electrodynamic probes

### Ultrasonic goniometer HUGO III

- Analysis of Rayleigh wave dispersion in layered materials
- Analysis of Lamb waves at thin structures
- Determination of layer thickness
- Experiments with volume waves

### Acoustic Intensity Measurement System – AIMS

- Determination of acoustic fields in water
- Five-axis hydrophone positioning
- Used for characterization and validation of transducer designs

1 Robot measuring cell of Fraunhofer IKTS.

2 Four-axis manipulator.

# FRAUNHOFER IKTS IN PROFILE

The Fraunhofer Institute for Ceramic Technologies and Systems IKTS conducts applied research on high-performance ceramics. The institute's three sites in Dresden and Hermsdorf (Thuringia) represent Europe's largest R&D institution dedicated to ceramics.

As a research and technology service provider, Fraunhofer IKTS develops modern ceramic high-performance materials, customized industrial manufacturing processes and creates prototype components and systems in complete production lines from laboratory to pilot-plant scale. Furthermore, the institute has expertise in diagnostics and testing of materials and processes. Test procedures in the fields of acoustics, electromagnetics, optics and microscopy contribute substantially to the quality assurance of products and plants.

The institute operates in nine market-oriented business divisions to demonstrate and qualify ceramic technologies and components as well as non-destructive test methods for new industries, product concepts and markets beyond the established fields of application. Industries addressed include ceramic materials and processes, mechanical and automotive engineering, electronics and microsystems, energy, environmental and process engineering, bio- and medical technology, non-destructive testing and monitoring, water as well as materials and process analysis.



[www.ikts.fraunhofer.de](http://www.ikts.fraunhofer.de)

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