LINSEIS

pushing boundaries

PLH

thermal conductivity of µm films, foils and membranes

Periodic **Laser Heating**

Since 1957 LINSEIS Corporation has been delivering outstanding service, know how and leading innovative products in the field of thermal analysis and thermo-physical properties.

Customer satisfaction, innovation, flexibility, and high quality are what LINSEIS represents. Thanks to these fundamentals, our company enjoys an exceptional reputation among the leading scientific and industrial organizations. LINSEIS has been offering highly innovative benchmark products for many years.

The LINSEIS business unit of thermal analysis is involved in the complete range of thermo analytical equipment for R&D as well as quality control. We support applications in sectors such as polymers, chemical industry, inorganic building materials, and environmental analytics. In addition, thermophysical properties of solids, liquids, and melts can be analyzed.

Rooted in a strong family tradition, LINSEIS is proudly steered into its third generation, maintaining its core values and commitment to excellence, which have been passed down through the family leadership. This generational continuity strengthens our dedication to innovation and quality, embodying the essence of a true family-run business.
LINSEIS provides technological leadership. We develop and manufacture thermoanalytic and thermophysical testing equipment to the highest standards and precision. Due to our innovative drive and precision, we are a leading manufacturer of thermal Analysis equipment.
The development of thermoanalytical testing machines requires significant research and a high degree of precision. LINSEIS Corp. invests in this research to the benefit of our customers.

CLAUS LINSEIS

CEO DIPL. PHYS.

The strive for the best due diligence and accountability is part of our DNA. Our history is affected by German engineering and strict quality control.

We want to deliver the latest and best technology for our customers. LINSEIS continues to innovate and enhance our existing thermal analyzers. Our goal is constantly develop new technologies to enable continued discovery in Science.

Enginering & InnovaTion

Periodic
Laser Heating

The characterization of micrometer materials is a critical issue today due to ongoing R&D for new technologies, such as battery and hydrogen applications, as well as miniaturization efforts.

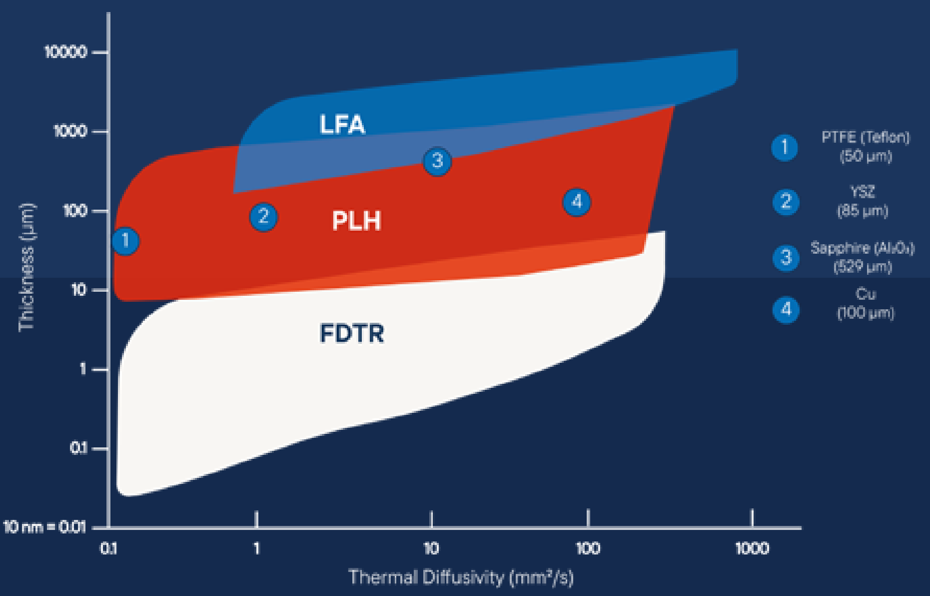
Due to the large surface to volume ratio, these types of materials need to be studied separately from bulk materials, but sample preparation and measurements can be very challenging.

In addition to our well-established laser flash technique, the PLH setup allows us to extend the measurement range of our non-destructive optical instruments in terms of thickness and thermal transport properties.

The PLH has been developed and optimized to characterize samples with high accuracy over a measurement range of sample thickness from 10 µm to 500 µm and a thermal diffusivity range of 0.01 - 2000 mm²/s.

The system can handle a wide range of materials. It is possible to measure samples with semiconducting behavior as well as metals, ceramics or polymers. Typical applications include freestanding films and membranes for the battery and hydrogen industries.

Overview of our optical measurement devices



The PLH Insturment

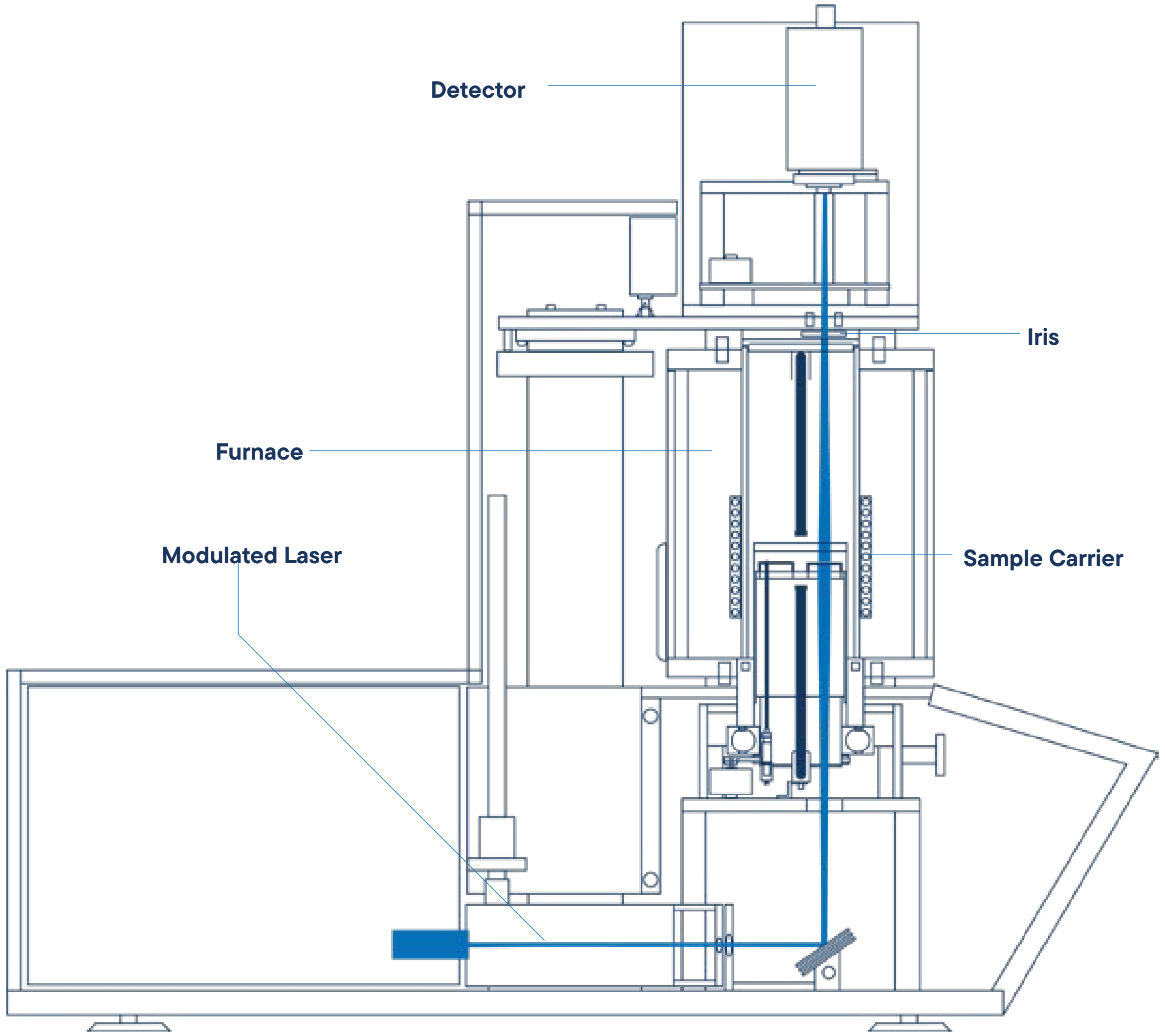
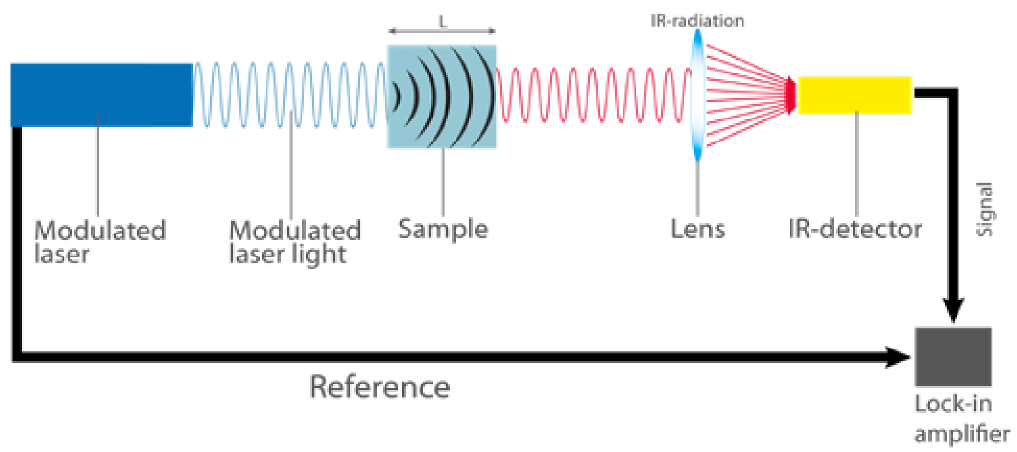


Illustration of a PLH configuration

- temperature range RT up to 300°C
- thickness from 10 µm up to 500 µm
- multi-sample robot
- fully-automatic operation
- measures thermal conductivity as well as thermal diffusivity
- requires a minimum of input parameters
- not knowing any other input parameters

Mode

Cross-Plane Periodic Laser Heating



The system uses a diode laser to periodically heat the backside of a sample with continuous amplitude modulated laser light. This energy is absorbed by the sample on its rear side and induces a thermal wave within the sample. The thermal wave propagates through the sample to its front side, where the initially absorbed thermal energy is emitted as infrared light. The resulting frontside temperature oscillation is recorded using an IR detector, as shown in the figure below.

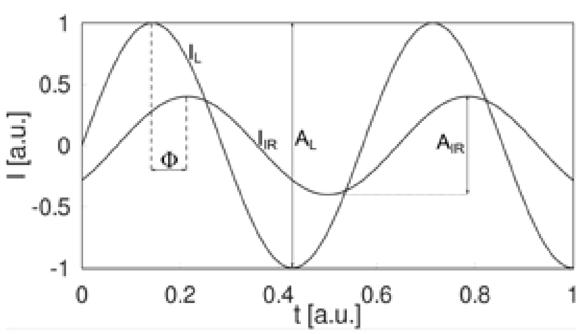
Due to the thermal transport properties of the sample, a characteristic behavior of the phase shift and amplitude of the resulting signal can be observed.

Evaluation of thermal conductivity, thermal diffusivity, and volumetric specific heat capacity performed using our comprehensive Linseis software package. The only input parameter required is the sample thickness.

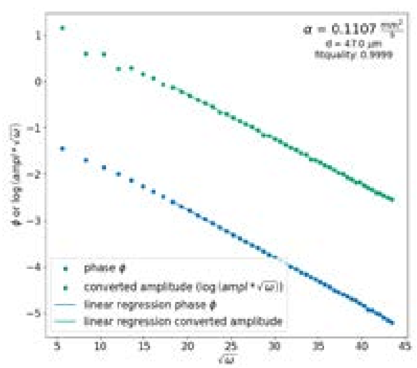
$$\alpha_{\Phi,amp} = \frac{L^2}{2m^2_{\Phi,amp}}$$

$$\alpha = \sqrt{\alpha_{\Phi}\alpha_{amp}}$$

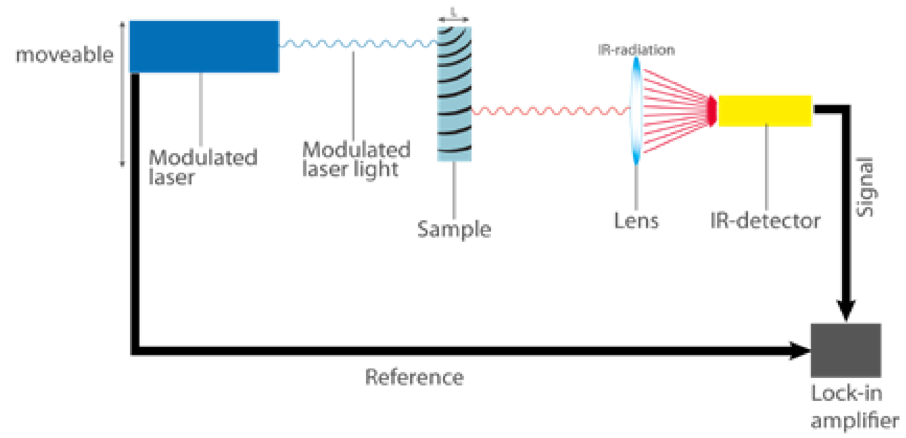
α= Thermal diffusivity [m²/s]
L = Sample height [m]
m = Slope of the linear range [√s]



I_L labels the modulated laser light and IIR is the infrared radiation with the corresponding amplitudes A_L and A_{IR} as well as the phase shift Φ.



In-Plane Periodic Laser Heating



Additionally, the system is capabale of measuring the in-plane thermal diffusivity through the use of a horizontal offset stage, while simultaneously exciting the sample with continous amplitude modulated laser light.

Depending on the in-plane thermal diffusivity of the sample, a characteristic behaviour of the measured phase shift and amplitude with respect to the lateral offset between laser and detector can be observed.

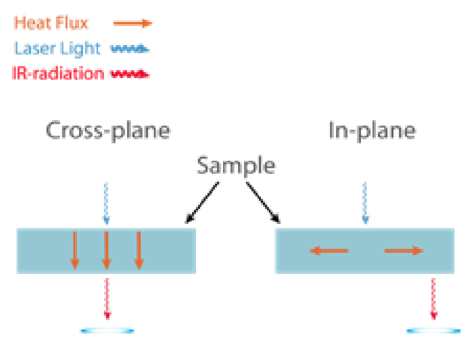
This methodology enables the intricate relationship between thermal conductivity and diffusivity to be elucidated, thereby yielding insights which may have significant implications for the landscape of material science.

Through precise in-plane measurements, thermal bottlenecks can be identified and optimal design solutions can be determined to enhance the performance and efficiency of technologies based on anisotropic materials. The evaluation of the in-plane thermal diffusivity can be performed using the comprehensive Linseis software package **without knowing any other input parameters.**

$$\alpha_{\Phi,amp} = \frac{\omega}{2m^2_{\Phi,amp}}$$

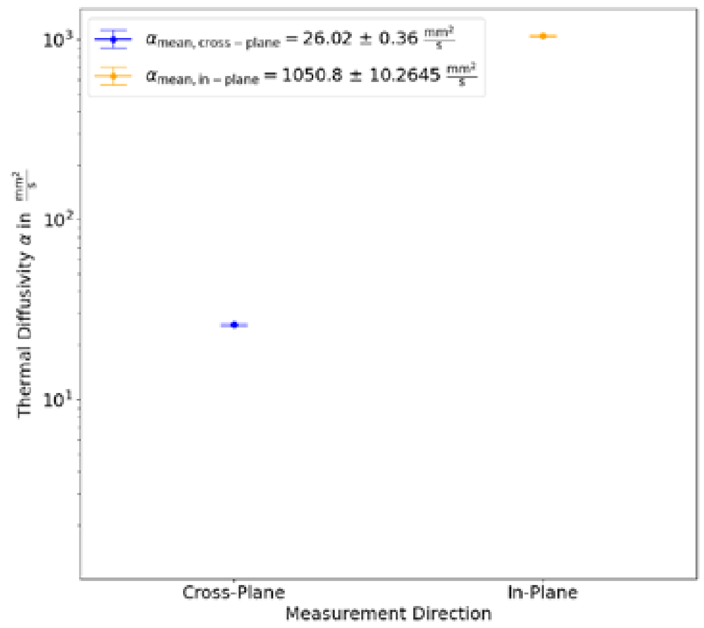
$$\alpha = \sqrt{\alpha_{\Phi}\alpha_{amp}}$$

α =thermal diffusivity [m²/s]
ω = angular frequency (2*π*f) [1/s]
f = modulation frequency [Hz]
$m_{(\Phi, amp)}$ = slope of the two measurement curve once after phase and once after amplitude [1/m]



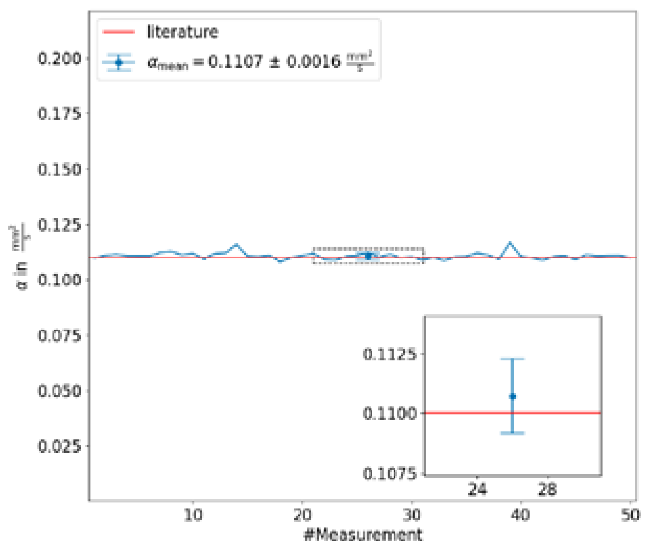
Anisothropy & Inhomogenity Analysis

Anisothropy



The thermal conductivity of the material can be direction-dependent. In-plane and cross-plane are terms used to describe two specifictransport directions within a material, while in-plane actually means within the sample perpendicular to the direction of excitation, the term cross-plane refers to the thermal conductivity of the sample in the excitation direction. The cross-plane and inplane thermal conductivities can significantly differ from each other and can easily exceed several orders of magnitude. Use cases are versatile and its knowledge can be crucial in various applications such as electronic devices, where thermal management is a omnipresent challenge.

Inhomogenity



Depending on the sample, the composition may vary slightly across the sample. This is normally the case for gels, pastes and polymers and so this change will also be seen in the thermal conductivity. Typically, standard LFA instruments ignore this fact and consider the whole sample at once as it is heated up by the light pulse. When interested in this differences our PLH techniques comes in handy. In contrast to the laser flash technique the sample is locally heated and you are able to check the sample for inhomogeneities. Fluctuations in thermal conductivity can lead to hot spots that affect the performance and service life of electronic devices. Ensuring homogeneous thermal conductivity distribution is crucial for effective thermal management and preventing overheating.

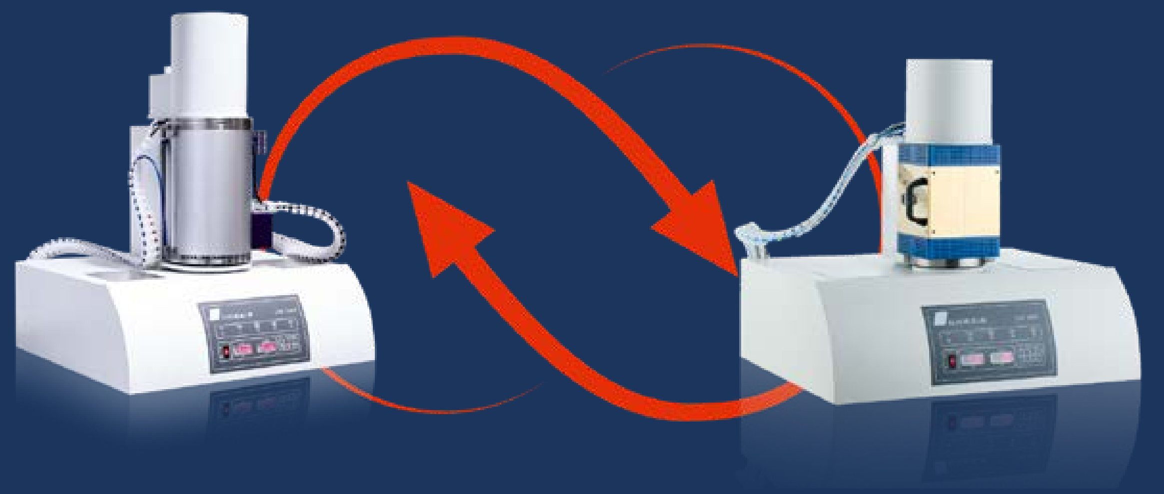
Technical Specifications

Temperature range	RT up to 300°C
Heating Range	0.01 up to 20°C/min
Samples dimensions	Ø 3,6,10,12,7 or 25,4 mm squares 5x5, 10x10 or 20x20mm²
Sample thickness	10 - 500 µm
Sample robot	caousel with 3 or 6 samples
Laser source	cw diode laser up to 5 W wavelength: 450nm
Thermal Diffusivity	0.01 to 2000 mm²/s (thickness depended)
Accuracy	±5%
Repeatability	±5%
Footprint	550x600x680 mm³ 21,6x23,6x26,7 inch³


pushing
boundaries

COMBINED SOLUTION

Ulitimate Thermal Characterization Fusion



LFA PLH

Combining the Laser Flash Method and the Periodic Laser Heating Method offers a range of powerful benefits that can significantly enhance your material characterization endeavors:

Experience the Power of Synergy

Combine the precision of the well-established Laser Flash Method with the dynamic prowess of the Periodic Laser Heating Method. Witness a thermal analysis revolution like never before!

Comprehensive Thermal Profiling

Dive deeper into your materials' thermal behavior. Gain a holistic understanding of thermal conductivity and diffusivity, providing a 360-degree view of performance.

Accelerate Innovation

Turbocharge your material development game! Seamlessly optimize thermal management systems, revolutionize energy storage technologies, and engineer cutting-edge electronic components with unrivaled accuracy of the Periodic Laser Heating Method. Witness a thermalanalysis revolution like never before!

Faster Results, Quicker Decisions

Maximize efficiency with streamlined research processes. Rapid data acquisition and analysis mean you'll be making informed decisions faster than ever, saving you time and resources.

Versatile Applications

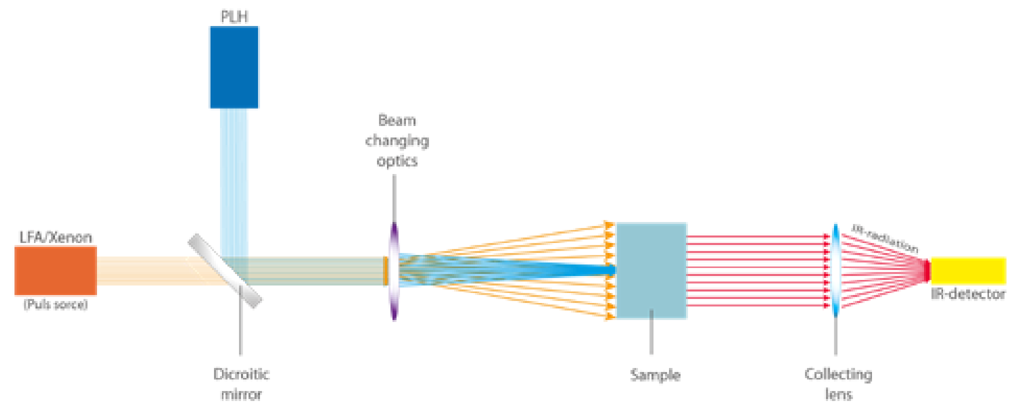
From academia to industrial R&D, this combo is your key to success. Conquer challenges in advanced materials, energy systems, and beyond, all while redefining the boundaries of what's possible.

See the Unseen

Don't settle for half the picture. Unleash the true potential of your materials with a combined approach that uncovers the intricate dance between thermal properties.

Unlock unprecedented insights with the LFA and PLH method combo

- Two measurement techniques combined in a single hardware
- 2 in 1 measurement system to analyze anisotropic materials
- Worldwide unique system (Patent pending)
- Same outside dimensions
- Wide measurement range from µm to mm
- Upgrade from standalone to combined version



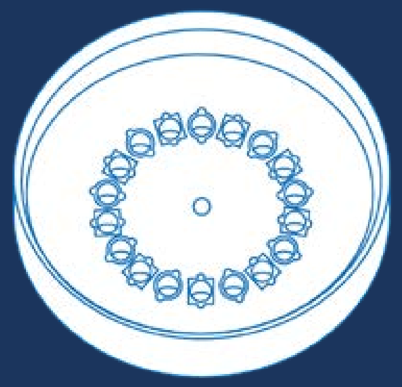
schema of the instrument design

Temperature range	RT up to 300 °C, 500 °C, 1000 °C, 1250 °C, 1600 °C
Sample dimensions	Ø 3, 6, 10, 12.7 or 25.4 mm square 5x5, 10x10 or 20x20 mm
Sample robot	carousel of 3 or 6 samples
Sample thickness	10 to 6000 µm
Thermal diffusivity	from 0.01 up to 2000 mm2/s (thickness depended)
Accuracy	±5%
Repetability	±5%

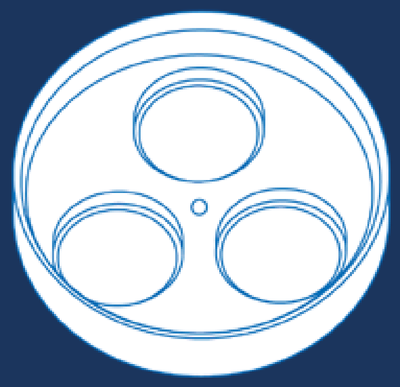
Unmatched sample throughput

Highest throughput in the market. The combination of sample robot and integrated furnace allows unbeaten measurement turnaround times and fully automized measurements for up to 3 or 6 samples. Depending on the sample requirements various sample holder geometries and materials are available.

Sample carriers

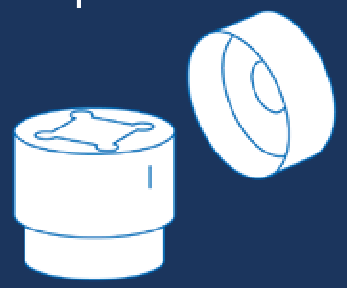


6 samples round or square
3mm, 6mm, 10mm or 12.7mm

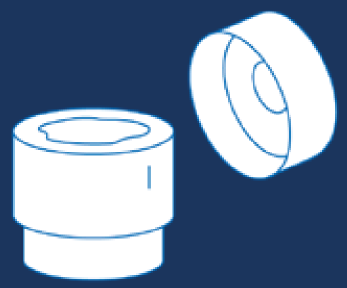


3 samples round
25.4mm or square 20mm

Sample holder



Sample holder square
samples 3x3mm / 10x10mm / 20x20mm



Sample holder round
samples 3mm / 6mm / 10mm / 12.7mm /25.4mm

Software

General

- Brand new design including impro ved user experience
- Responsive and customizable software
- Direct link to online support
- Periodic online software updates
- Live evaluation as well as post-processing / evaluation
- Advanced storage concepts
- Data export and import in ASCII
- Multi-method measurements (LFA, PLH)
- Customized report generation
- Device Plug & Play
- Easy firmware updates
- Intelligent error handling
- Device connection via USB or LAN
- Plausibility checks before measurement

Measurement Software

Easy and user-friendly data input for temperature

- Fully automated measurement procedurefor multi sample measurements
- Specific heat and thermal conductivitymeasurement routine (requires reference)

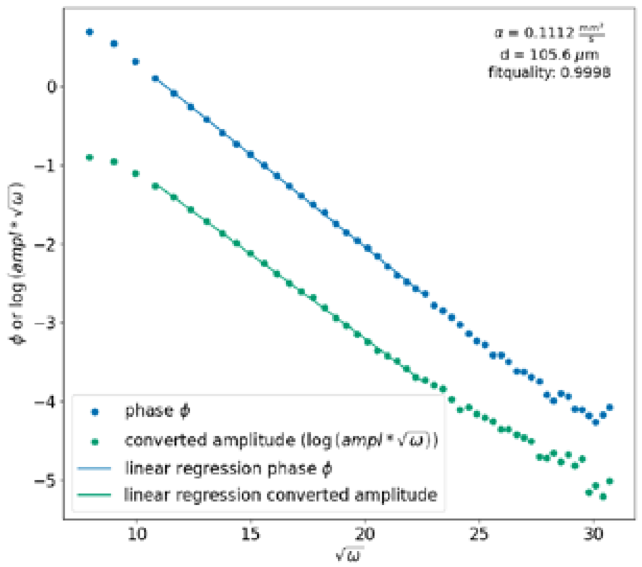
Evaluation Software

- Design update
- Improved user experience and flexibility
- Python-Interface for custom plug-ins
- Combining curves from different sources /measurement devices

PLH Overview

Applications

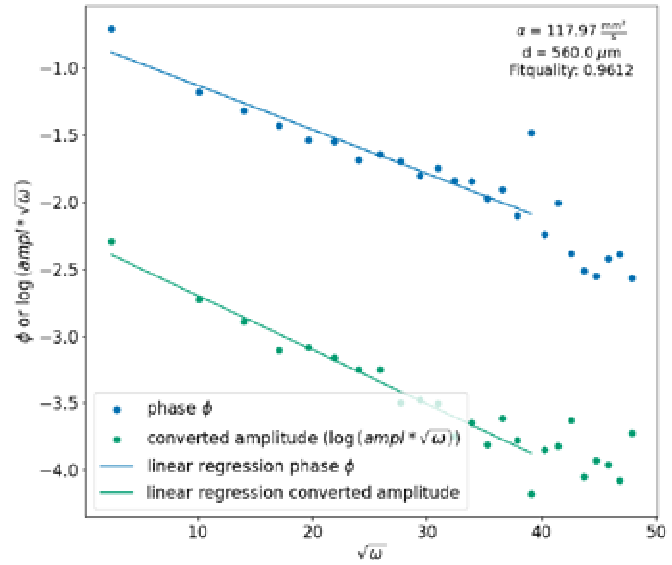
Measurement Polytetrafluoroethylene (PTFE) 100 µm



For polytetrafluoroethylene (PTFE) - a thin polymer film - better known as Teflon, the reference value of thermal diffusivity for PTFE is 0.11 mm²/s.

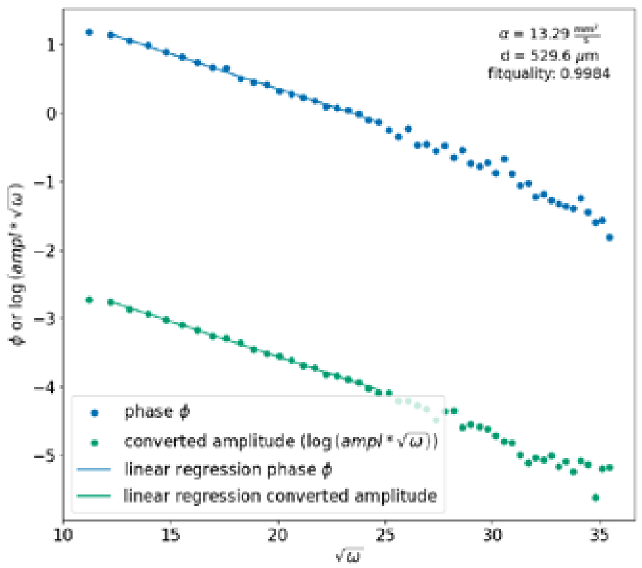
Teflon is used as a coating for pans so that food does not stick to the pan and can be easily cleaned. The thickness of these coatings varies from 30 µm to 150 µm.

Measurement Copper 500 µm



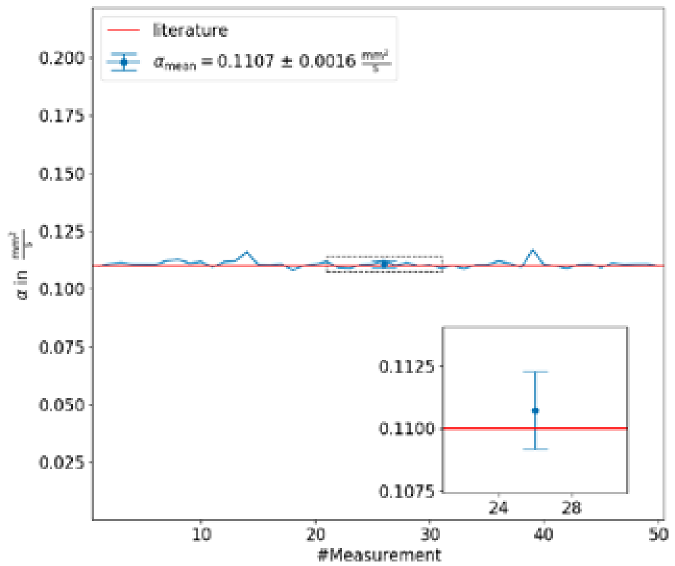
Copper foils, especially those as thin as 560 µm, are widely used as heat spreaders in the electronics industry. They play a crucial role in heat dissipation in electronic components by ensuring efficient distribution of heat, which improves the performance and longevity of devices. Their applications range from everyday devices such as smartphones and laptops to sophisticated aerospace systems. The reference value for this sample is 117 mm²/s.

Measurement Sapphire 500 µm



Sapphire belongs to the category of ceramic materials and has a reference thermal diffusivity value of 13.3 mm²/s. Our measurements confirm this thermal diffusivity value with a high degree of accuracy. As it has excellent thermal and optical properties, it is often used in microelectronics for laser technologies and LEDs.

Repeatability PTFE 100 µm



The repeatability of a polytetrafluoroethylene measurement with a thickness of 105.6 µm is excellent, at just over 1%. This confirms the measurement method and its high performance.

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LINSEIS

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