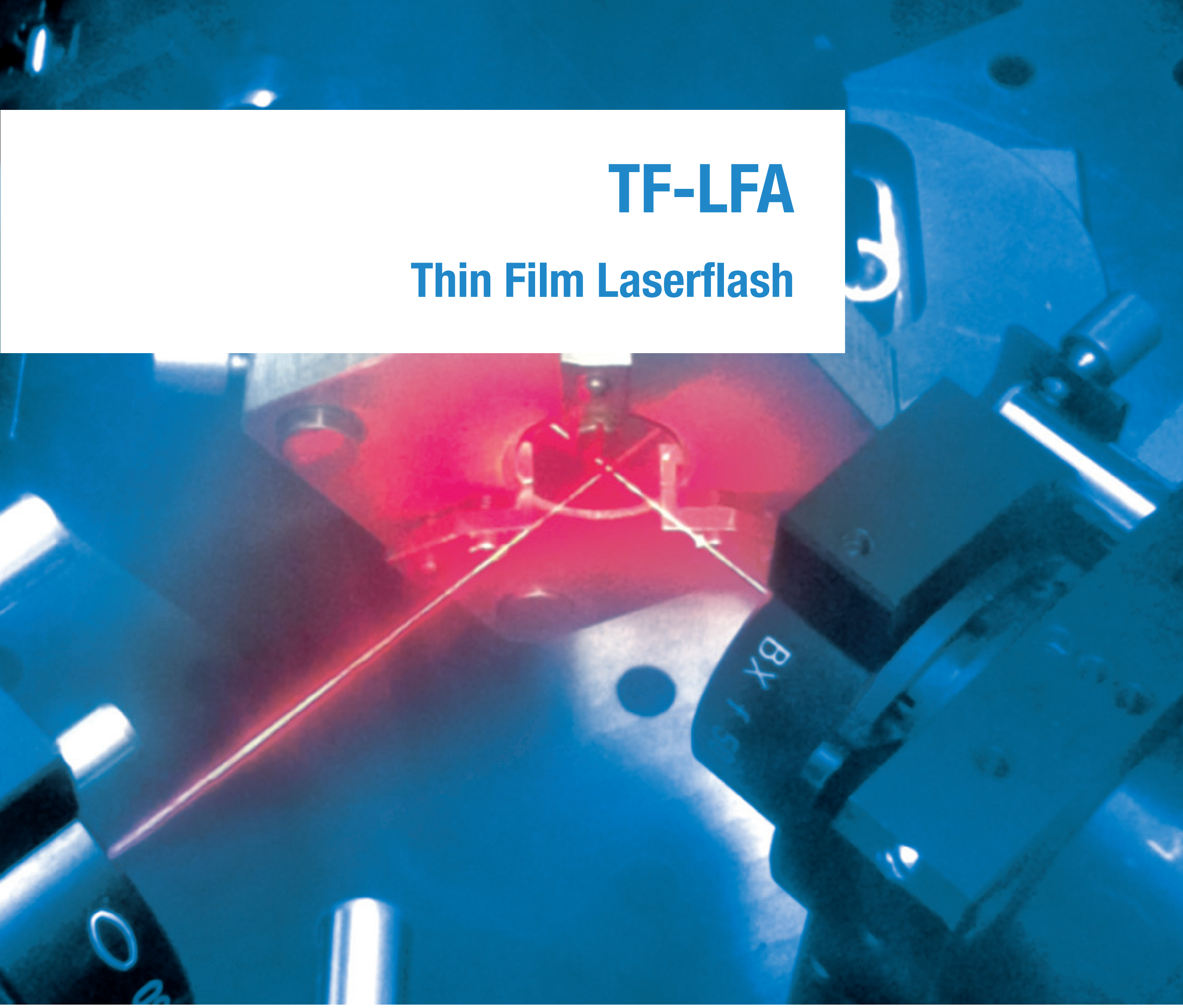
# TF-LFA

## Thin Film Laserflash



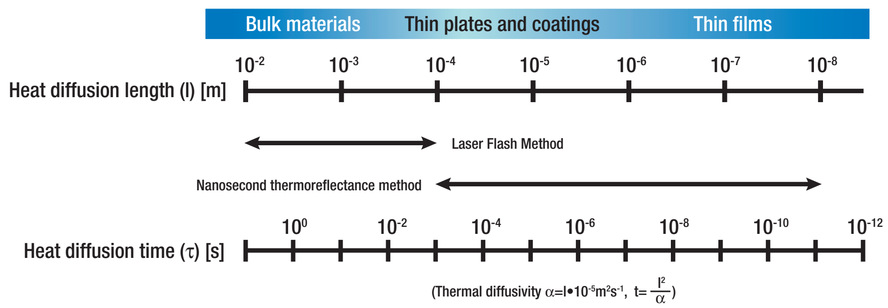
LINSEIS

# General

Information of the thermo physical properties of materials and heat transfer optimization of final products is becoming more and more vital for industrial applications.
Over the past few decades, the flash method has developed into the most commonly used technique for the measurement of the thermal diffusivity and thermal conductivity of various kinds of solids, powders and liquids.

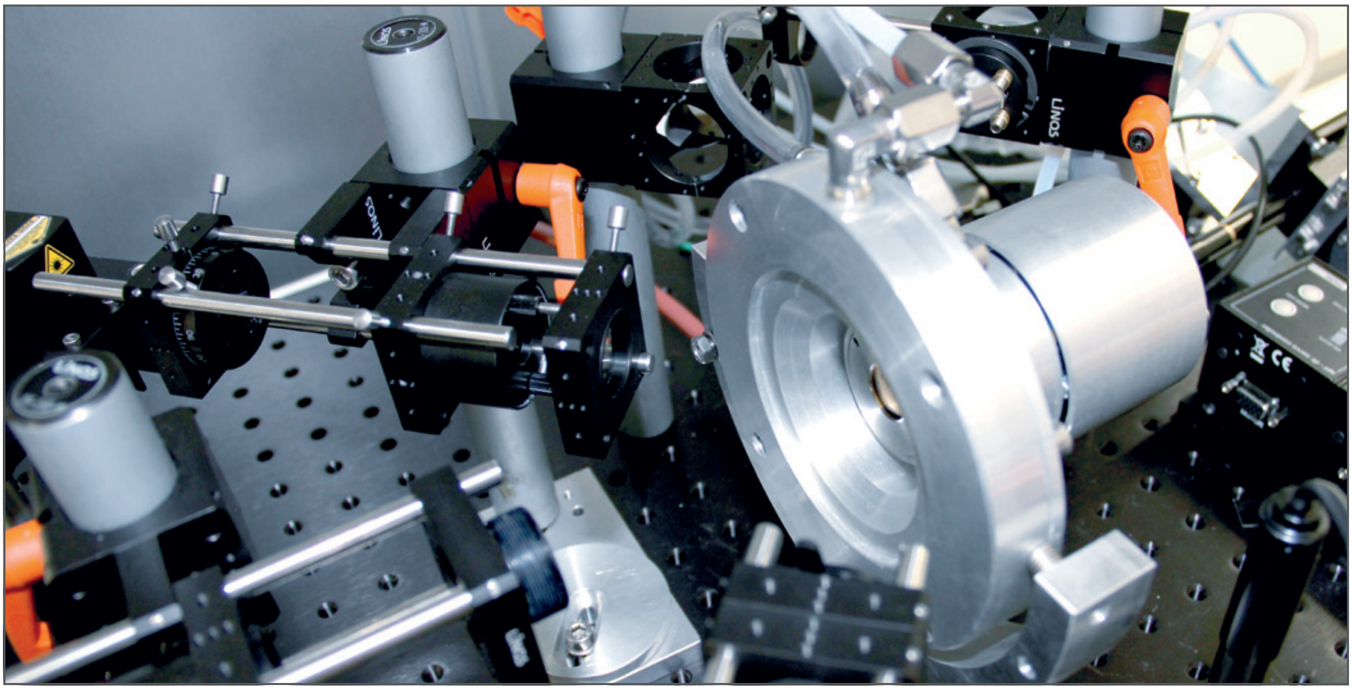
Thermophysical properties from thin-films are becoming more and more important in industries such as, phase-change optical disk media, thermo-electric materials, light emitting diodes (LEDs), phase change memories, flat panel displays, and the semiconductor industry. All these industries deposit a film on a substrate in order to give a device a particular function. Since the physical properties of these films differ from bulk material, these data are required for accurate thermal management predictions.

Based on the well established Laser Flash technique, the LINSEIS "Thin-Film-Laserflash" now offers a whole range of new possibilities to analyze thermophysical properties of thin films from 80nm up to 20µm thickness.



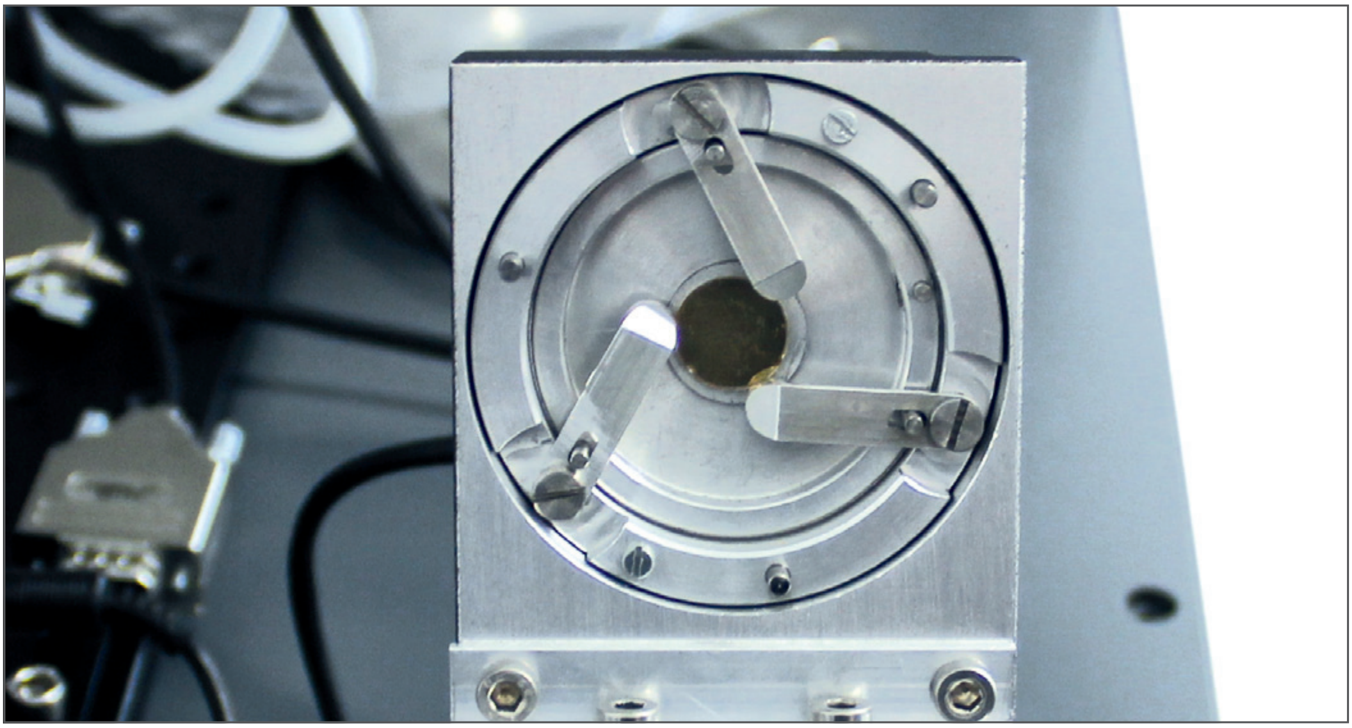
# Components

## Furnace

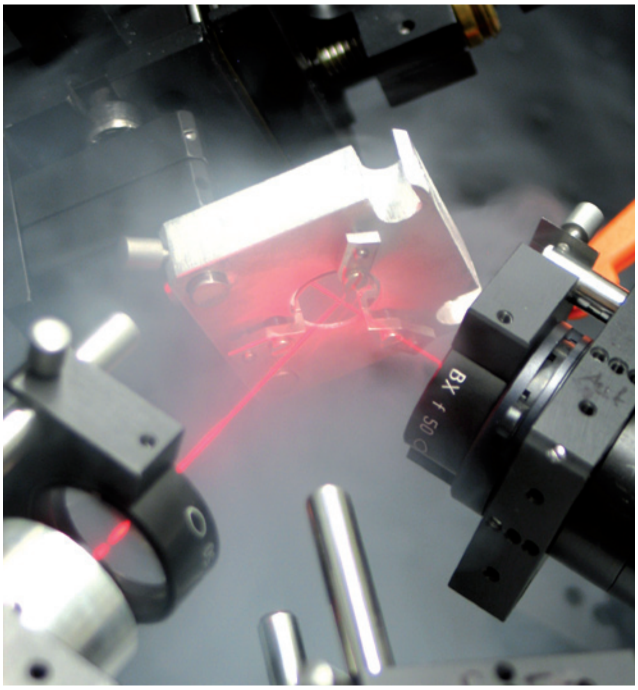


*Furnace RT up to 500°C*
*Cryo Furnace -100 up to 500°C*

## Sample fixture for room temperature



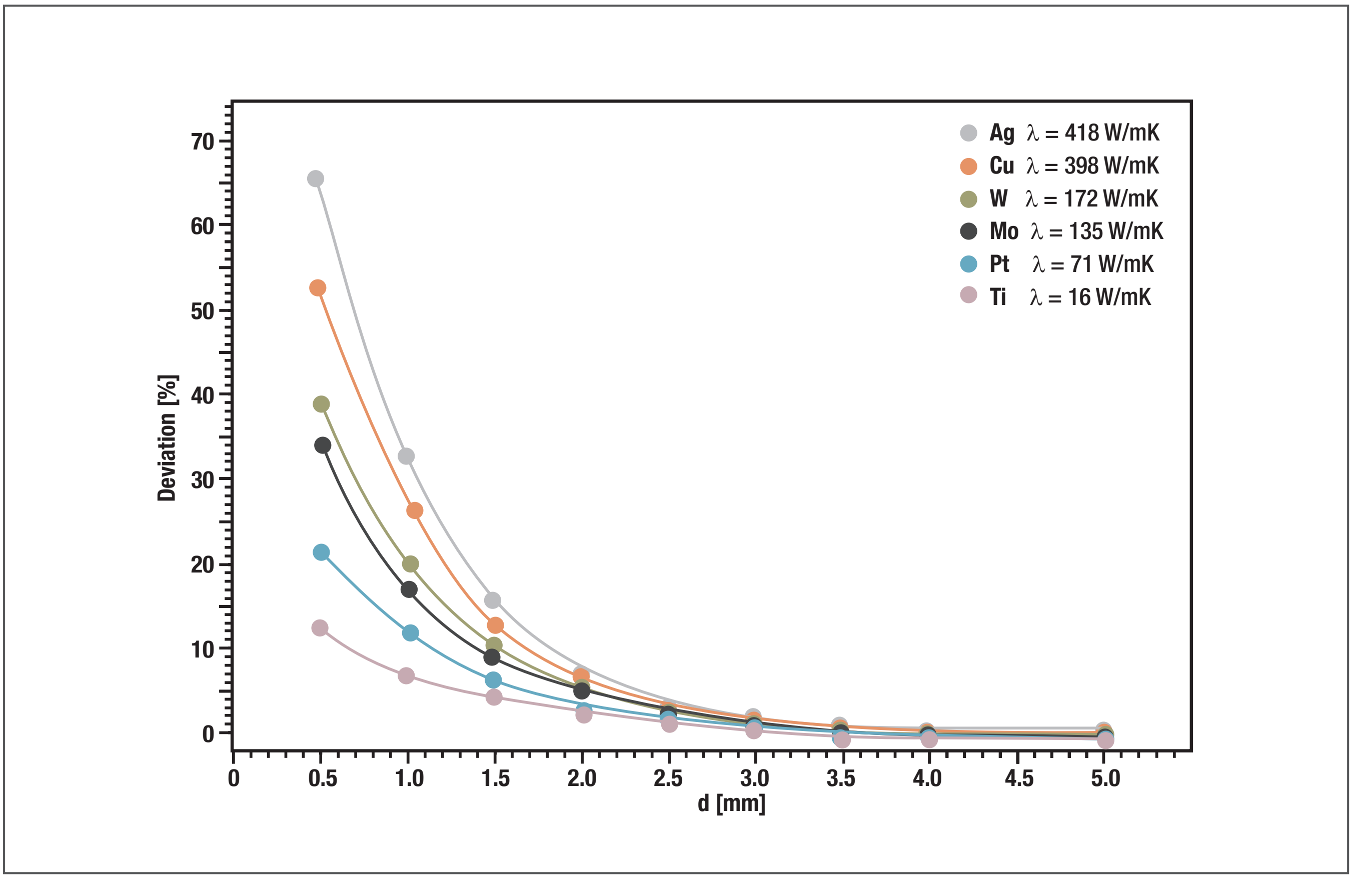
# Laserflash technique



## Description of the standard Laserflash technique

A sample is positioned on a sample holder, located in a furnace. The furnace is then held at a predetermined temperature. At this temperature the sample surface is then irradiated with a programmed energy pulse (laser or xenon flash). This energy pulse results in a homogeneous temperature rise at the sample surface. The resulting temperature rise of the rear surface of the sample is measured by a IR detector and thermal diffusivity values are computed from the temperature rise versus time data. The resulting measuring signal computes the thermal diffusivity.

For thin layers in the µm or nm range, this arrangement of the standard laser flash technique is no more sufficient, as the time scale of the experiment is too fast for the used components. The heating pulse duration is too long and the data aquisition too slow. This problem exacerbates for materials with higher thermal diffusivity (see Fig. below).




*The graph from Schoderböck et. al., Int. J. Thermophys. (2009) illustrates the limitation of the classic Laserflash technique. Samples with a thickness of less than 2mm (depending on the thermal diffusivity of the material) already show a significant deviation from literature values.*

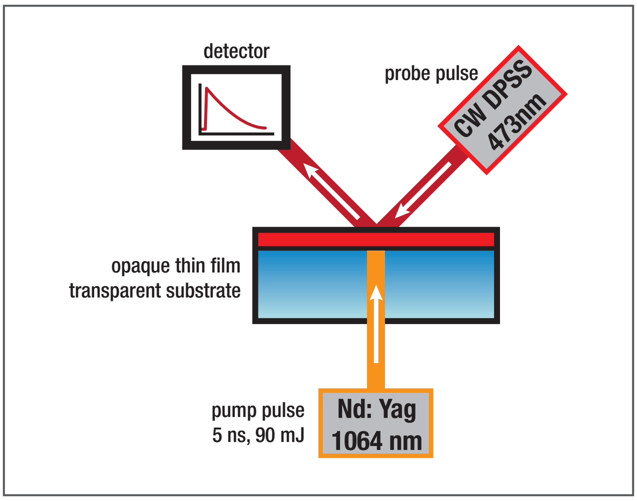
# Description of the Thin-Film-Laserflash technique

As thermal properties of thin layers and films differ considerably from the properties of the corresponding bulk material a technique overcoming the limitations of the classical Laserflash method is required: the "High Speed Laserflash Method".

**High Speed Laserflash Method**

Rear heating Front detection (RF)

The measurement geometry is the same as for the standard Laserflash technique: detector and laser are on opposite sides of the samples. Because IR-detectors are to slow for measurement of thin layers, detection



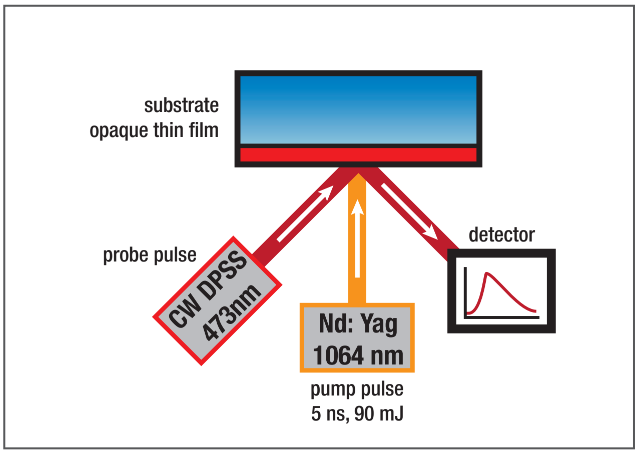

is done by the so called thermoreflectance method. The idea behind this technique is that once a material is heated up, the change in the reflectance of the surface can be utilized to derive the thermal properties. The reflectivity is measured with respect to time, and the data received can be matched to a model which contains coefficients that correspond to thermal properties.

**Time Domain Thermoreflectance Method**

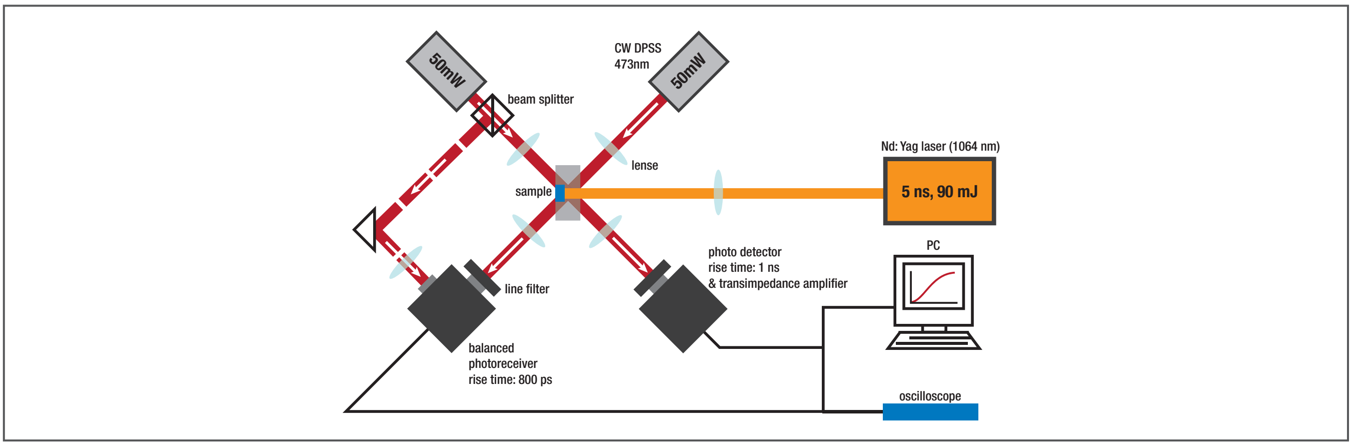
Front heating Front detection (FF)

**Description of the Time-Domain Thermoreflectance technique**

The measurement geometry is called "front heating front detection (FF)" because detector and laser are on the same side of the sample. This




method can be applied to thin layers on non-transparent substrates for which the RF technique is not suitable. For the measurement, a heating pulse applied to the front side of the sample and the temperature rise at this spot is measured with a detection laser comming from the side. The thermal diffusivity of the sample layer can be calculated by using falling edge of the normalized temperature rize in combination with a multilayer modell developed by Linseis in cooperation with Prof. David G. Cahill of the Univerity of Illinios.




**Combined High Speed Laserflash RF and Time Domain Thermoreflectance Method FF**

# Software

All thermo analytical devices of LINSEIS are PC controlled, the individual software modules exclusively run under Microsoft ® Windows® operating systems. The complete software consists of 3 modules: temperature control, data acquisition and data evaluation. The Linseis 32 – bit software encounters all essential features for measurement preparation, execution and evaluation, just like with other thermo analytical experiments. Due to our specialists and application experts LINSEIS was able to develop this easy understandable and highly practical software.

## General Software

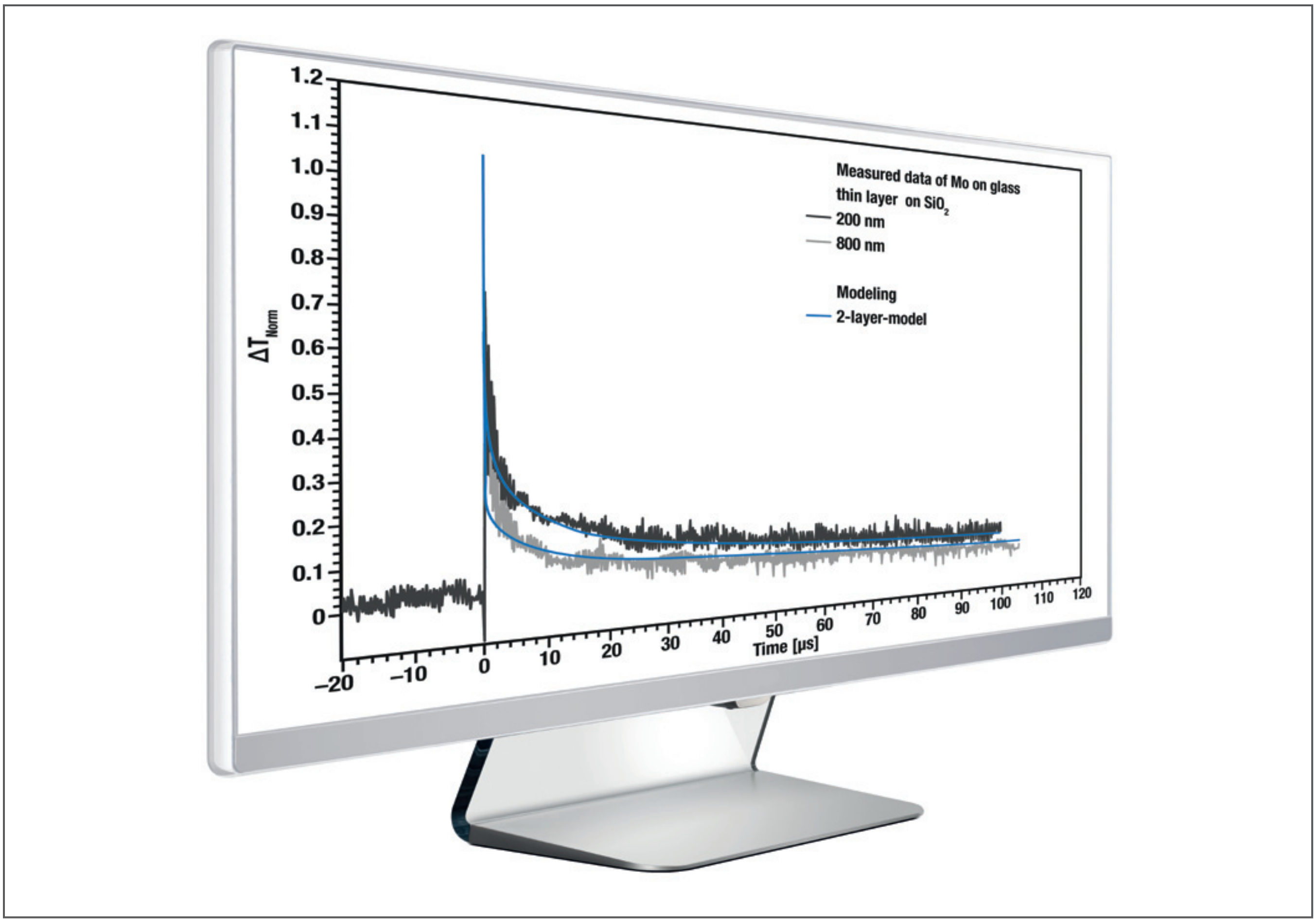
- Fully compatible MS® Windows™ 32 – bit software
- Data security in case of power failure
- Thermocouple break protection
- Evaluation of current measurement
- Curve comparison
- Storage and export of evaluations
- Export and import of data ASCII
- Data export to MS Excel

## Evaluation Software

- Automatic or manual input of related measurement data: (density), Cp (Specific Heat)
- Model wizard for selection of the appropriate model
- Determination of contact resistance

## Measurement Software

- Easy and user-friendly data input for temperature segments, gases etc.
- Software automatically displays corrected measurements after the energy pulse
- Fully automated measurement

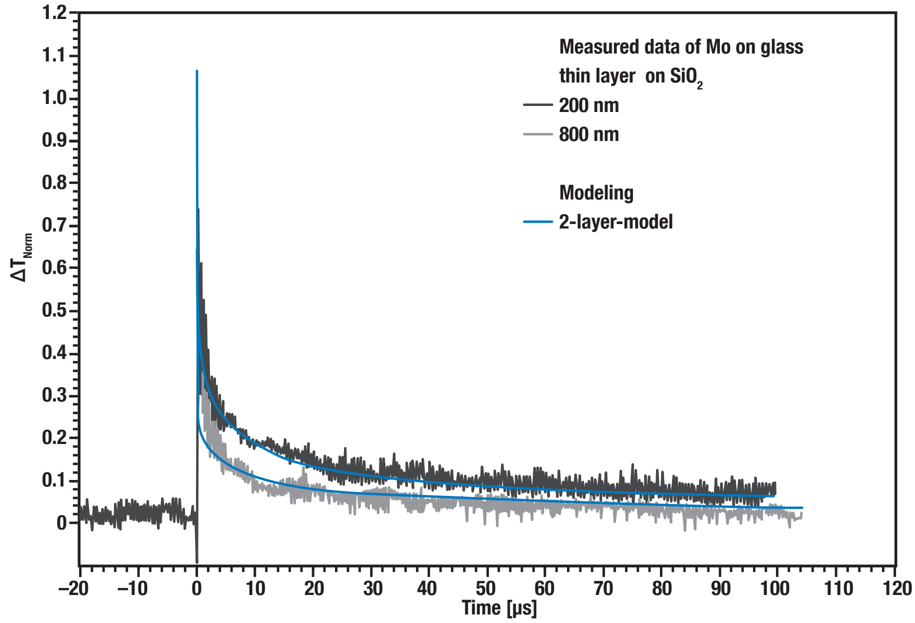


# Technical Specifications

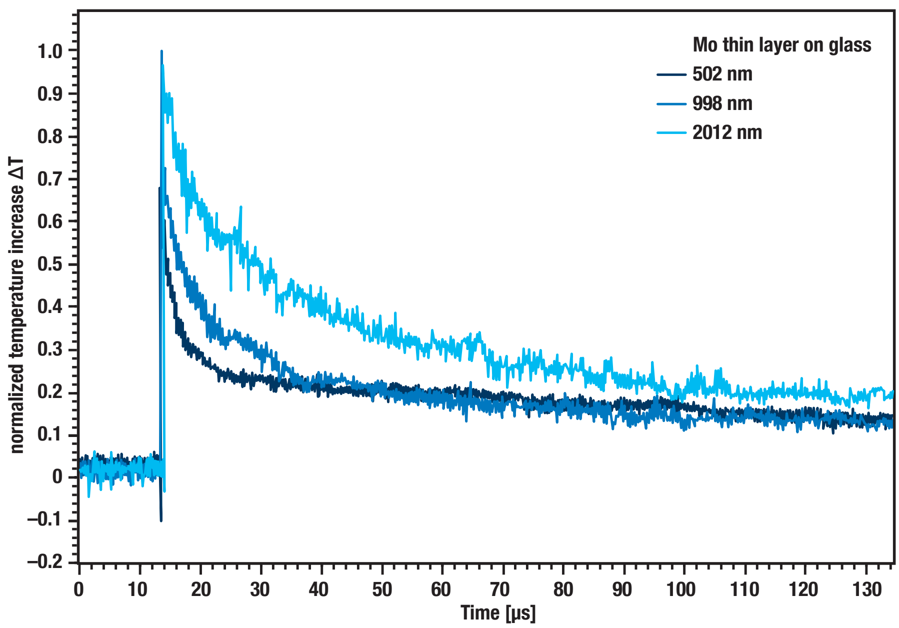
| Thin-Film-LFA | |
|---|---|
| **Sample dimensions** | Round with a diameter of 10mm to 20mm |
| **Thin film samples** | 80nm up to 20µm (depens on sample) |
| **Temperature range** | RT, RT up to 500°C or -100 to 500°C |
| **Heating and cooling rates** | 0.01 up to 10°C/min |
| **Vacuum** | up to $10^{-4}$mbar |
| **Atmosphere** | inert, oxidizing or reducing |
| **Diffusivity Measuring range** | 0,01mm$^2$/s up to 1000mm$^2$/s |
| **Pumplaser** | Nd:YAG Laser (1064 nm), maximum pulse current: 90mJ/pulse (software controled), Pulse width: 5 ns<br>spot size 2-4 mm (depends on arrangement) |
| **Probe-Laser** | DPSS CW Laser (473 nm, 50 mW) |
| **Frontside-Thermoreflectance** | Si-PIN-Photodiode, active diameter: 0.8mm, bandwidth DC … 400MHz, risetime: 1ns |
| **Rearside-Thermoreflectance** | Photoreceiver, active diameter: 0.4mm, bandwidth DC … 650MHz, risetime: 800ps |

# Applications

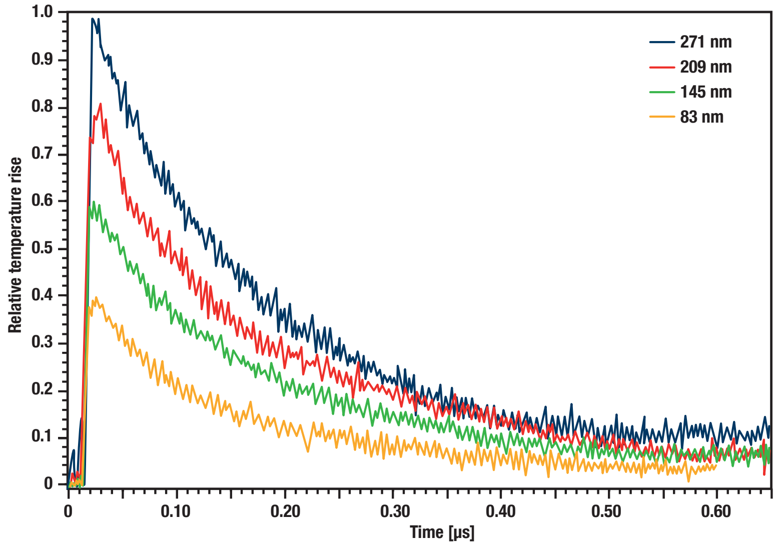
## Comparison of measured and calculated curves (2-layer model)

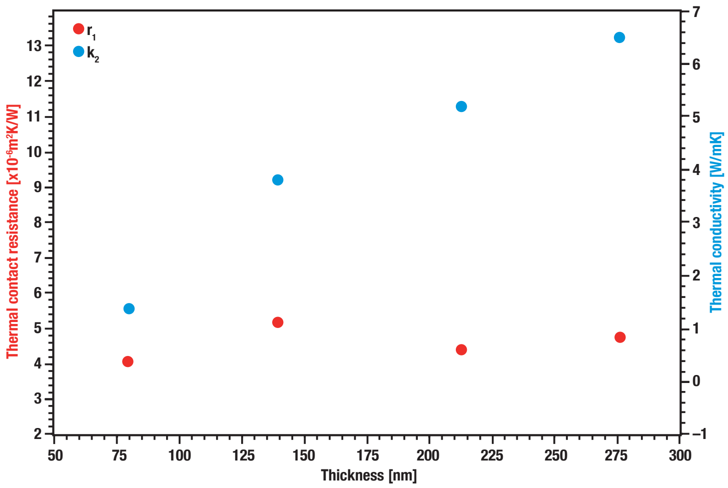



## Mo thin layer on $SiO_2$; Temperature-time-curve of samples of different thickness



## Temperature-time-curve of ZnO-samples of different thickness




### Measured thermal conductvity and thermal contact resistance of ZnO thin films

| Thickness $d_2$ [nm] | $r_1$ [$10^{-8}$m$^2$K/W] | $k_2$ [W/mK] |
|---|---|---|
| 271 | 4.81 | 6.5 |
| 209 | 4.46 | 5.2 |
| 145 | 5.22 | 3.8 |
| 83 | 4.15 | 1.4 |

Bulk ZnO: $k_2$ ~ 100 W/m K

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**Services:** Service Lab, Calibration Service

05/17