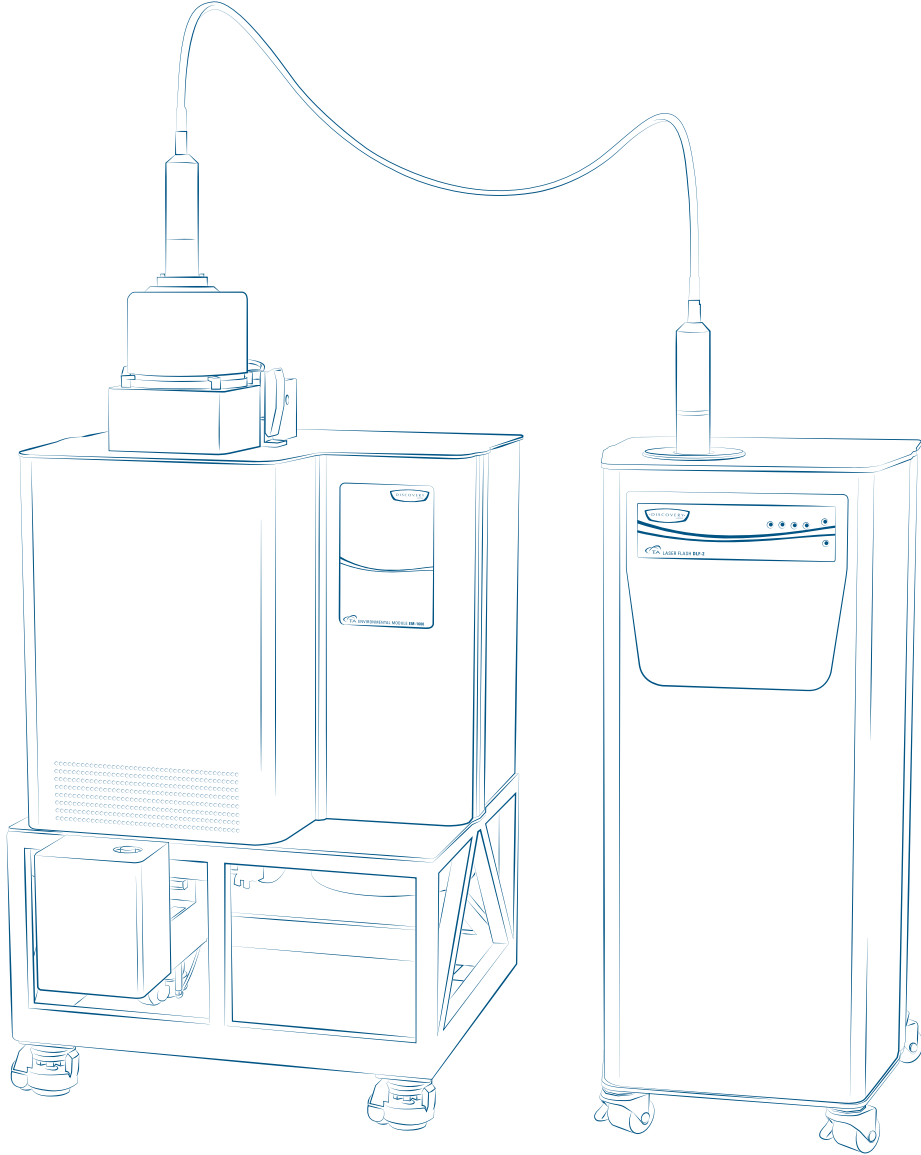




Waters™

TA<sup>®</sup>  
Instruments

THERMAL CONDUCTIVITY  
AND THERMAL DIFFUSIVITY



## Discovery Light Flash Analyzers

The light flash technique provides information on a material's ability to store and transfer heat through measurements of thermal diffusivity, thermal conductivity, and specific heat capacity. Thorough understanding of these properties is critical for any process or material which experiences a large or fast temperature gradient, or for which the tolerance for temperature change is exacting. Accurate values of these properties are essential for modeling and managing heat, whether the component of interest is called on to insulate, conduct, or simply withstand temperature changes. Information about these properties is routinely used in heat transfer models of all complexities. Heat transfer property measurements also reflect important information about material composition, purity and structure, as well as secondary performance characteristics such as tolerance to thermal shock.

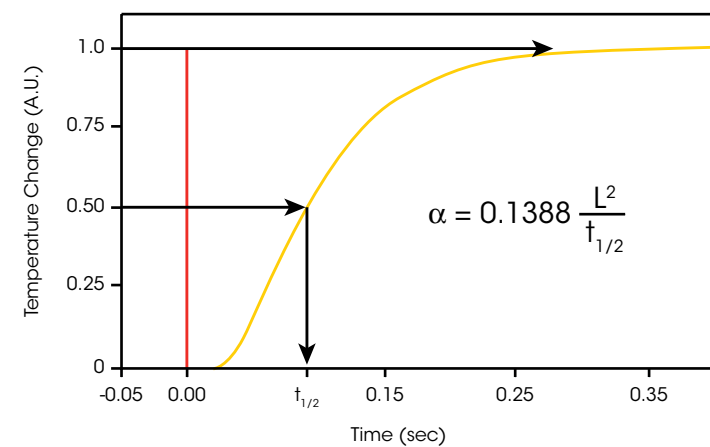
TA Instruments provides a full range of benchtop and floor-standing Laser and Xenon Light Flash Diffusivity Analyzers for the precise and accurate measurement of heat transfer properties of a wide range of material types and temperatures. Only Discovery Flash instruments employ unique proprietary light source, light transfer, detector, and furnace technology for the most accurate measurements by the Flash Method.

# FLASH METHOD and THERMAL DIFFUSIVITY

The fundamental measurement of the Flash Method is Thermal Diffusivity, the thermophysical property that defines the speed of heat propagation by conduction: the higher the thermal diffusivity, the faster the heat propagation. As thermal diffusivity is temperature-dependent, it is usually measured over the same range of temperatures in which the material material will be required to operate. The thermal diffusivity is related to the thermal conductivity through specific heat capacity and density.

The most effective method used for measuring thermal diffusivity over a wide range of temperatures is the flash method. This transient technique is an absolute test, i.e. does not require calibration, features short measurement times, is completely non-destructive, and provides values with excellent accuracy and reproducibility. The flash method involves uniform irradiation of a specimen over its front face with a very short pulse of energy, up to the temperature range to be covered; the light source generating the pulse can be either a Xenon lamp or a laser.

The time-temperature history of the rear face of the sample is recorded by high-speed data acquisition from a temperature detector with very fast thermal response. Based on the time-dependent thermogram of the rear face, the sample's thermal diffusivity is determined from the thickness ( $L$ ) of the sample and the time the thermogram takes to reach half of the maximum temperature increase ( $t_{1/2}$ ).

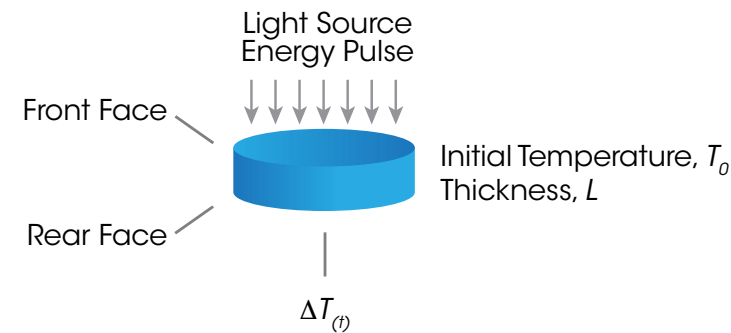


Thermal Conductivity

$$\alpha = \frac{\lambda}{\rho C_p}$$

Thermal Diffusivity

$\lambda$ : Thermal Conductivity  
 $\rho$ : Density  
 $C_p$ : Specific Heat Capacity



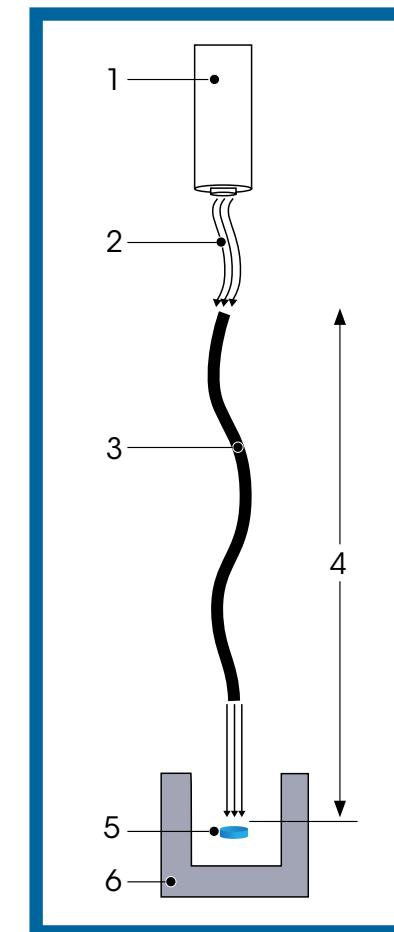
## Understanding Flash Pulse Sources: Laser vs. Xenon

Only TA Discovery Flash instruments are available with choice of proprietary high-energy Laser or Xenon pulse sources. The selection of the best source for an application depends on a number of variables including sample dimensions ( $L, w, t$ ), thermal conductivity, and temperature range. TA Instruments offers the widest choice of instruments with laser and Xenon sources to ensure the right solution for any application.

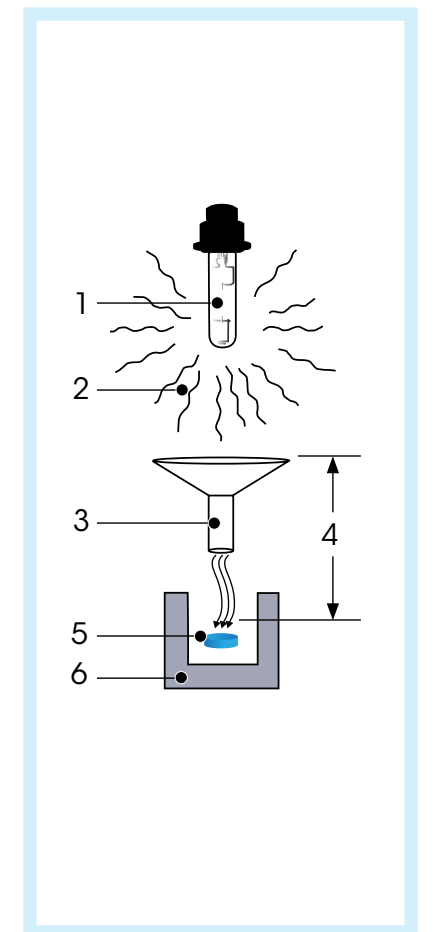
Comparison of Laser and Xenon Flash Designs

Parameter	Laser	Xenon Light
1 Source	Monochromatic (single wavelength) Coherent (unidirectional) Collimated (parallel)	Multiple Wavelengths Diffused (multi-directional) Diverged (not parallel)
2 Light Source Energy	High to low	Medium to low
3 Pulse delivery system	Optical fiber delivers more homogeneous radiation (up to 99%)	Optical system based on lenses to collimate, focus, and deliver pulse to sample
4 Relative source to sample distance	Farther, allows higher temperatures	Closer, limits the range to moderate temperatures
5 Sample	Thin to very thick samples, materials of low conductivity, and low surface emissivity	Thin to moderately thick samples, limited by material conductivity and surface emissivity
6 Maximum Temperature	Design allows for higher, >2000 °C	Design limits to moderate temperatures, <1000 °C

Laser Flash Configuration



Xenon Flash Configuration



## DISCOVERY LASER FLASH | DLF 1600 and DLF 2800

The Discovery Laser Flash DLF 1600 and DLF 2800 are advanced freestanding platforms for the measurement of thermal diffusivity and specific heat capacity of materials at high temperature. The distinctive design incorporates a proprietary laser, laser optics, detector, and furnace technologies, and unique multi-position sample carousel, which together ensure unprecedented measurement accuracy and sample throughput. With the ability to operate in a variety of atmospheric conditions, including inert gas or under vacuum, the DLF 1600 and DLF 2800 are capable of characterizing a wide variety of materials, including polymers, ceramics, carbons, graphite, composites, glasses, metals, and alloys.



# The Most **POWERFUL** System for **ACCURATE** and **PRECISE** **THERMAL DIFFUSIVITY**

### Features and Benefits:

- Powerful laser provides 40% more energy than any competitive design for the most accurate testing to the highest temperatures and widest range of samples, regardless of thickness and thermal conductivity
- Proprietary fiber optic wand delivers a 99% homogeneous beam at the sample for increased measurement accuracy
- Unique multi-position carousel\* for unmatched throughput and accurate heat capacity measurements
- Flexible carousel design configurable with a variety of sample holders, adapters and special fixtures over the widest testing range
- Advanced furnaces for uncompromised temperature performance from RT to 1600°C or 2800°C, and measurements in inert gas or vacuum.
- High sensitivity IR detector for optimum signal to noise ratio, delivering the highest accuracy over the entire temperature range
- Real-time pulse mapping for unmatched accuracy of thermal diffusivity for accurate testing of thin and highly conductive materials
- Meets a variety of industry standard test methods including:  
ASTM E1461, ASTM C714, ASTM E2585, ISO 13826, ISO 22007-Part4, ISO 18755, BS ENV 1159-2, DIN 30905



Discovery Laser Flash DLF 2800

\*US Patent No. 6,375,349 B1

## High Power Laser and Advanced Optics

Both DLF 1600 and DLF 2800 feature the industry's most powerful and robust laser light source and most efficient delivery system. The proprietary Class 1 Neodymium-Phosphate Glass laser and fiber optic power wand system, with built-in alignment, ensure effective generation and delivery of laser energy to the sample.

- **Proprietary Laser Designed and Manufactured by TA Instruments**

Unlike competitive designs, which use "third-party off-the-shelf" lasers, the DLF floor-standing laser was specifically designed by TA Instruments and completely optimized to provide the most powerful and efficient delivery system for unmatched accuracy in light flash diffusivity measurements. This robust laser is manufactured by TA Instruments to the highest quality standards.

- **40% more Energy than the Closest Competitor**

More light pulse energy delivered to the surface of the sample during a measurement means enhanced signal quality at the detector. Only the DLF 1600 and 2800 laser can generate 35 Joules of power, providing significant benefits for light flash measurements. Thicker samples, or samples of low conductivity or surface emissivity (shiny surface), are easily tested. Higher power enables more accurate testing up to 2800°C further extending the capabilities beyond competitive laser or Xenon light designs.

- **99% Homogenized Laser Energy Profile**

To be effective, the light pulse from the laser must be efficiently delivered to the surface of the sample. A proprietary fiber optic delivery wand, designed and manufactured by TA Instruments, ensures a 99% homogenized laser energy profile which improves measurement accuracy by 50%.

- **Noise-Free Design**

The laser system is separated from the furnace and detector module to eliminate the effect of electromagnetic interference from the laser on the detecting system, and to ensure long-term optical alignment stability. The separation of the modules also provides ease of maintenance.

- **Dual-Pyrometer Temperature Reading**

The DLF 2800 incorporates a proprietary Dual-pyrometer design guaranteeing unrivaled high temperature precision and accuracy. This unique feature also enables uninterrupted sample testing from room temperature to 2800 °C. Above 900 °C, a two-color pyrometer provides a second temperature reading, eliminating the possibility of uncertainty due to changes in the emissivity of the sample, degradation of the optical windows, or the alignment conditions of optical paths.

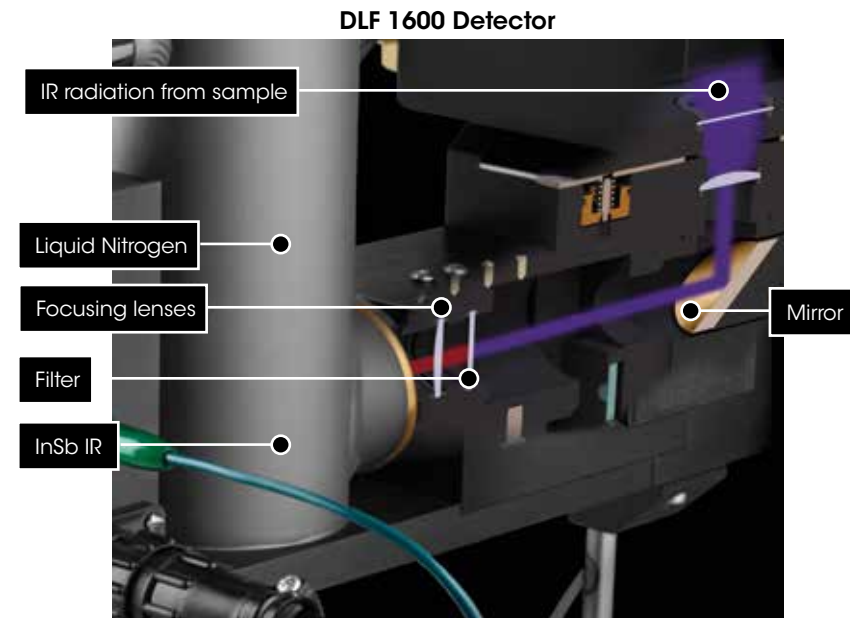
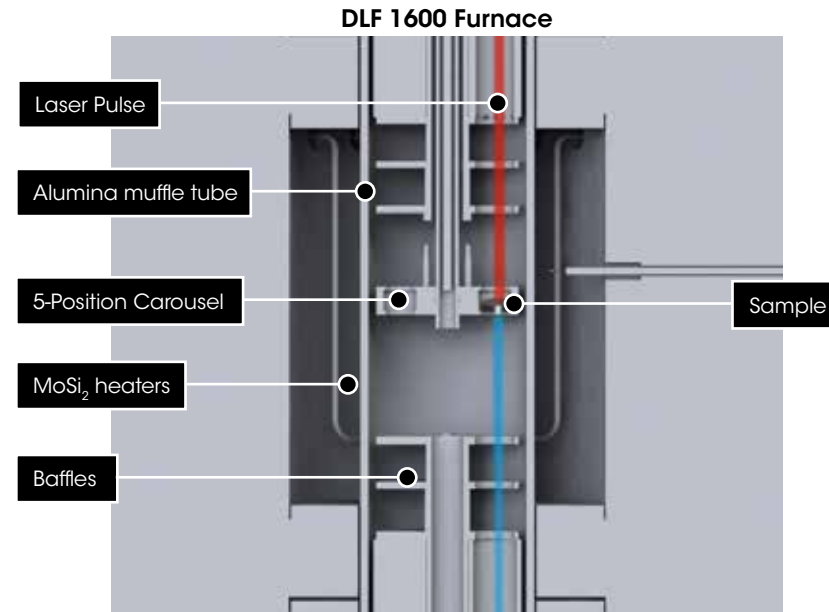


## Furnaces

The floor-standing high-temperature flash systems can be configured with either an alumina furnace with a maximum temperature of 1600 °C, or a graphite furnace with a maximum temperature of 2800 °C. The intelligent design of these high temperature systems sets them apart from competitive light flash analysis instruments in every aspect of temperature performance. Both furnaces employ high quality heating elements, a muffle tube, and multiple baffles along their length preventing thermal disturbances. These furnace designs provide the most stable and uniform heating for reliable control of the sample even at the extreme temperature. During operation, every sample in the carousel absolutely reaches and maintains the programmed temperature from ambient up to the maximum temperature of the furnace throughout the testing time. To guarantee the temperature measurements are always accurate, the DLF 2800 features two pyrometers, one of which is a dual-wavelength pyrometer which ensures maximum instrument safety at high temperatures. The result is the most reproducible thermal diffusivity measurements available from RT to 2800 °C. Sample testing can be conducted in static or dynamic atmospheres, including vacuum or inert gas purge. DLF 1600 can also operate in air and oxidative atmospheres.

## Precision IR Detector and Optics

Both instruments include a high-sensitivity liquid-nitrogen-cooled indium antimonide (InSb) IR detector with an optimum signal-to-noise ratio over the entire temperature range. A built-in liquid nitrogen dewar provides unattended 24-hour operation for uninterrupted extended experiments. Just as important as the detector, the optics in the detector path ensure uniform and accurate measurement of the sample thermogram. The IR detection area covers more than 90% of the sample surface, and representative data is collected without contributions from extraneous radiation, including edge effects such as flash-through caused by imperfect sample preparation.



## Flexible High Productivity Sample Carousel

- Five Times Higher Productivity**  
 Of the high-temperature Flash Method instruments on the market, only the DLF 1600 and DLF 2800 come standard with a carousel for the simultaneous testing of up to five or six samples, respectively, in a single experiment. This multi-sampling capability significantly increases throughput and avoids unnecessary downtime between experiments.
- The Most Accurate Heat Capacity (Cp) Measurement**  
 Measurements of heat capacity by the flash method rely on comparing a sample and reference tested under identical conditions. With the multi-sample carousel, the sample and reference can be measured sequentially under identical thermal and environmental conditions leading to faster and more accurate results. This in turn leads to the correct determination of Thermal Conductivity.
- Flexible Sample Accommodations**  
 The carousel accepts samples up to 15.9 mm diameter and 10 mm thick, 20% larger and 50% thicker than any competitive high-temperature light flash instrument. The removable tray design allows simplified sample loading at or away from the instrument. Optional trays and adapters can accommodate a variety of sample dimensions and shapes, including round or square, and specialty sample holders for liquids, powders, pastes, laminates, and in-plane testing of thin films.

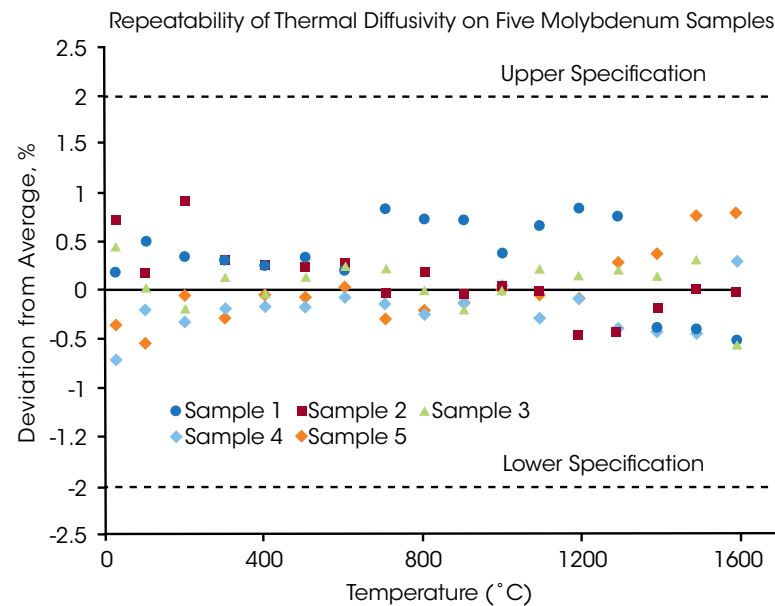
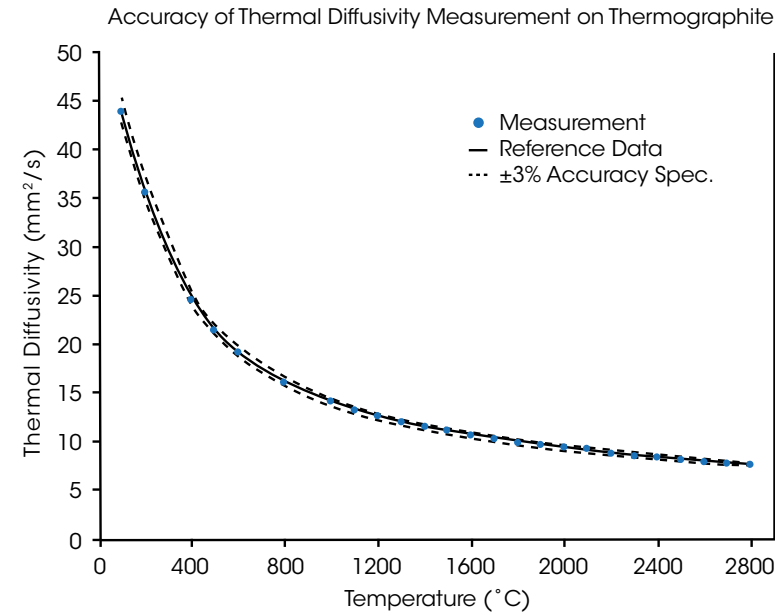


Patented Multi-sample Carousel with Flexible Tray and Adaptors

## Unmatched Accuracy and Repeatability of DLF High Temperature Systems

Accuracy, which defines how close a set of measured data are to the true value, is paramount in understanding how well an instrument performs under known conditions. The figure to the top right shows results of a graphite sample tested to 2800 °C compared to the reference value. The data show the accuracy is better than ±3% across the entire temperature range.

The repeatability, or precision, of a measurement system is determined by the variation of multiple measurements on the same instrument under the same conditions. The bottom figure to the right shows measurement repeatability on five molybdenum samples tested from room temperature to 1600 °C at intervals of 100 °C. The deviation from the average is less than ±1% with almost 80% of the results within ±0.5% of the average. These results are well within the specification of ±2%, across the entire temperature range demonstrating the unmatched repeatability of the DLF high temperature systems.

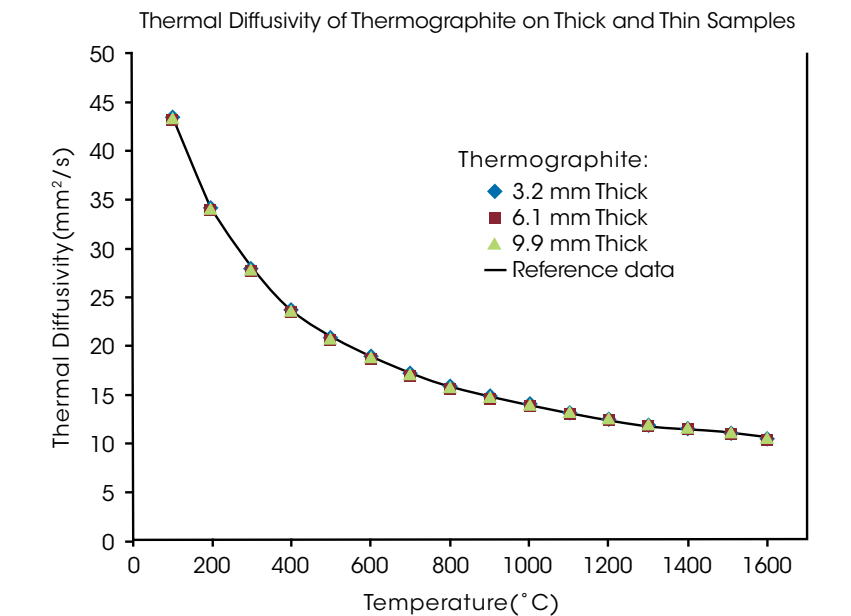
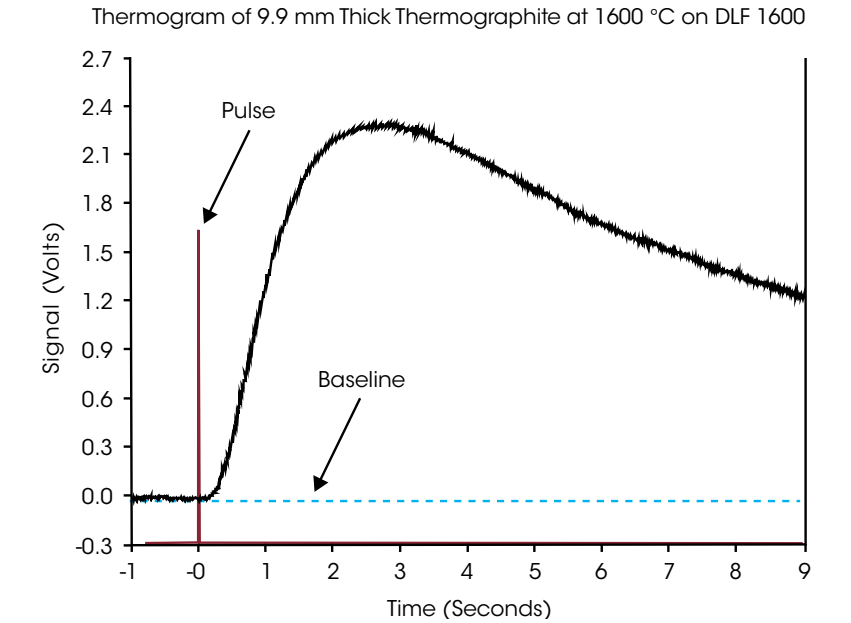


## Designed for the Most Accurate Diffusivity Measurements - Even Under the Most Extreme Conditions

The ability of any instrument to make an accurate measurement relies on all design elements working together efficiently as a system. On a light flash instrument, these components include the light source, the pulse delivery, the detector, and the furnace. A good way to understand the performance of a light flash system is to evaluate a sample under conditions that push measurement limits of all components simultaneously. Such an extreme case for light flash is a sample at the maximum thickness and the maximum temperature.

A 9.9 mm thick thermographite sample, **65% thicker than the maximum allowed on competitive instrumentation**, was tested on the DLF 1600 from 100 to 1600 °C at intervals of 100 °C. The raw data thermogram is shown for the most difficult measurement at 1600 °C in the top right figure. It can be seen here that the DLF 1600, with its combination of high energy proprietary laser and pulse delivery, high temperature furnace with uniform heat zone, sensitive IR detector, and 16-bit data processing, yields high signal-to-noise ratios for excellent thermogram results under the most demanding conditions.

The graph to the lower right shows the results of the thermal diffusivity of the 9.9 mm thick thermographite sample compared to two thinner samples, 3.2 mm and 6.1 mm thick, superimposed with reference data. The results in the figure clearly show the superior design of the DLF 1600 to make accurate measurements over the widest range of conditions. All values reported fall well within ±2% of the reference. **Even under the most extreme conditions, at maximum thickness, over 50% of the thermal diffusivity measurements show a deviation of less than 1%.**



## DISCOVERY LASER FLASH | DLF 1200

The Discovery Laser Flash DLF 1200 is a compact benchtop instrument for measurement of thermal diffusivity, thermal conductivity, and specific heat capacity of materials from room temperature to 1200°C. It features a proprietary laser source with 17 Joules of energy for testing the widest range of samples under the most demanding conditions. Productivity is no problem with the four-sample tray design. It is the only benchtop light flash instrument available with a laser pulse source for enhanced precision, accuracy, and capabilities beyond competitive Xenon light source designs.



## POWERFUL LASER FLASH

Performance in a compact

## AFFORDABLE BENCHTOP DESIGN

### Features and Benefits:

- Powerful laser, with 65% higher energy compared to competitive Xenon systems, for the most accurate testing of the widest range of samples, regardless of thickness and thermal conductivity to 1200°C
- Laser is inherently coherent and precisely irradiates only the sample surface, eliminating the need to correct for lateral heat transfer from over-flash onto sample holder
- Autosampler with patented four-position alumina sample tray for maximum productivity
- Wide variety of sample trays accommodates Mullite sample sizes (up to 25.4 mm), shapes, and special fixtures (liquids, powders, laminates, films, etc.) for maximum sample testing flexibility
- Advanced resistance heated furnace provides best-in-class temperature stability and uniformity across sample from RT to 1200°C and enables measurements in air, inert gas, or vacuum
- High sensitivity IR detector for optimum signal-to-noise ratio, delivering highest accuracy over the entire temperature range
- Real-time pulse mapping for superior thermal diffusivity of thin and highly conductive materials
- Designed to meet industry standard test methods including:  
ASTM E1461, ASTM C714, ASTM E2585, ISO 13826, ISO 22007-Part4, ISO 18755, BS ENV 1159-2, DIN 30905, and DIN EN821



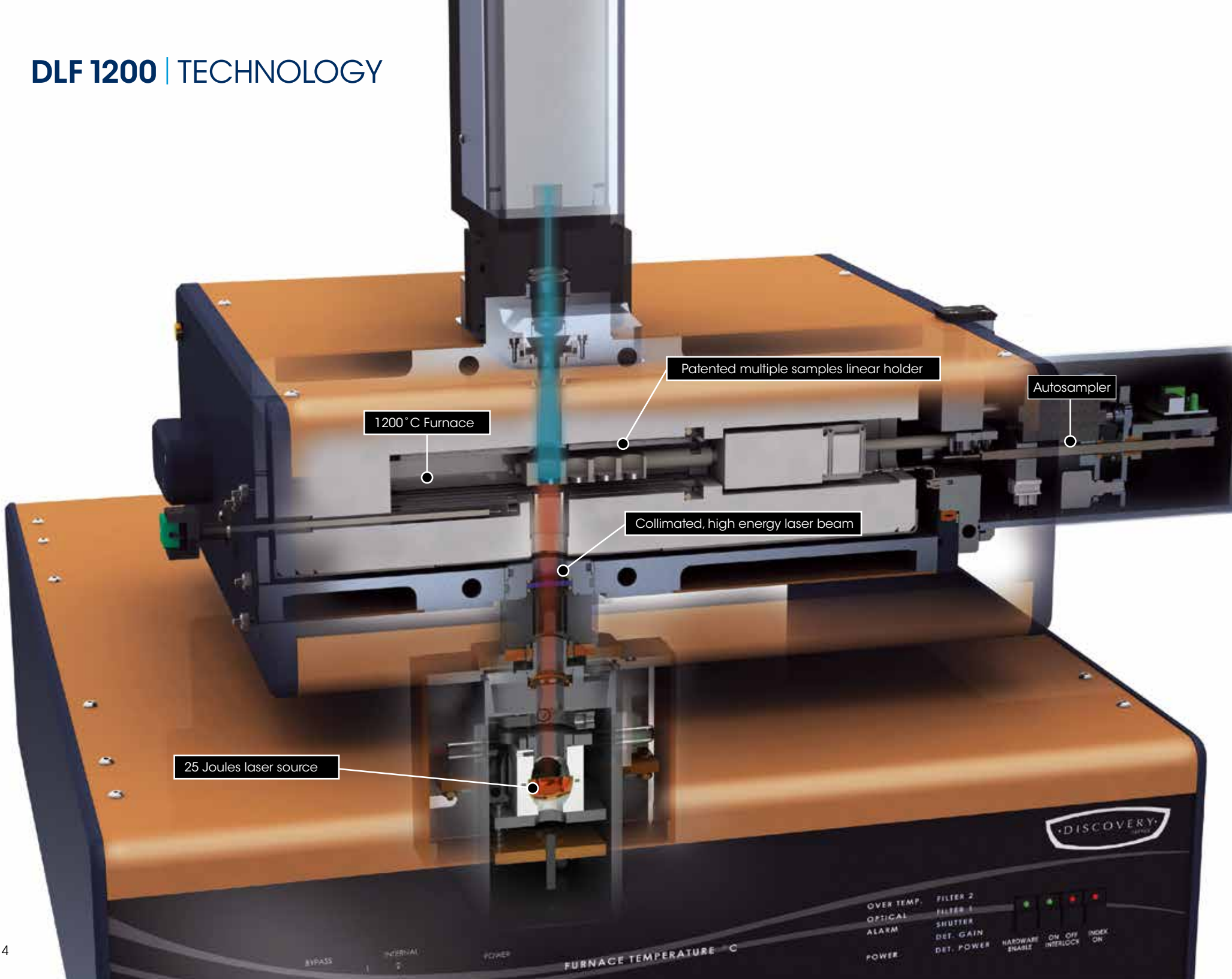
Discovery Laser Flash DLF 1200



# HIGH ENERGY

laser source in a

# BENCHTOP DESIGN



## High Energy Laser Source in a Benchtop Design

The DLF 1200 pulse source is a Class I Neodymium:Glass (Nd:glass) laser with 17 Joules of energy. It delivers an inherently collimated, monochromatic pulse to the sample surface. Designed and manufactured by TA Instruments, the safe, compact, and factory-aligned design requires no special maintenance.

## 65% More Energy than Xenon Flash Instrument Designs

More light pulse energy delivered to the surface of a sample during a measurement means enhanced signal quality at the detector. Only the DLF 1200 can provide 17 Joules of power providing significant benefits in a benchtop light flash design. Thicker samples, or samples of low conductivity or surface emissivity (shiny surface), are more easily tested. The higher power enables more accurate testing to 1200°C further extending the capabilities beyond Xenon light designs.

## Efficient Energy Delivery without Complex Optics

The DLF 1200 laser is in close proximity to the sample, which ensures the efficient delivery of an inherently coherent pulse to the surface of the specimen. The result is a homogeneous, high quality radiation pulse precisely focused on the sample. The design eliminates the need for complex optics to collimate and deliver light as required by Xenon light systems.



DLF 1200 Laser Delivery

## DLF 1200 | TECHNOLOGY

### 1200°C Furnace

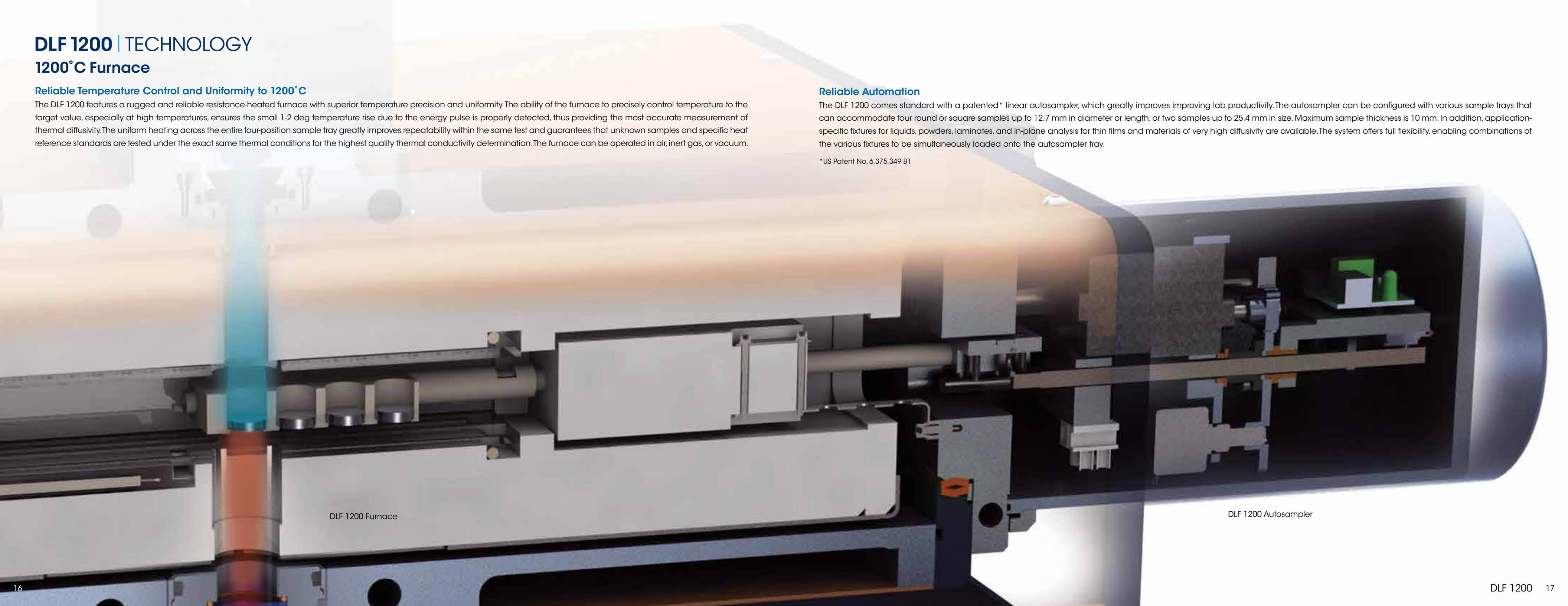
#### Reliable Temperature Control and Uniformity to 1200°C

The DLF 1200 features a rugged and reliable resistance-heated furnace with superior temperature precision and uniformity. The ability of the furnace to precisely control temperature to the target value, especially at high temperatures, ensures the small 1-2 deg temperature rise due to the energy pulse is properly detected, thus providing the most accurate measurement of thermal diffusivity. The uniform heating across the entire four-position sample tray greatly improves repeatability within the same test and guarantees that unknown samples and specific heat reference standards are tested under the exact same thermal conditions for the highest quality thermal conductivity determination. The furnace can be operated in air, inert gas, or vacuum.

#### Reliable Automation

The DLF 1200 comes standard with a patented\* linear autosampler, which greatly improves lab productivity. The autosampler can be configured with various sample trays that can accommodate four round or square samples up to 12.7 mm in diameter or length, or two samples up to 25.4 mm in size. Maximum sample thickness is 10 mm. In addition, application-specific fixtures for liquids, powders, laminates, and in-plane analysis for thin films and materials of very high diffusivity are available. The system offers full flexibility, enabling combinations of the various fixtures to be simultaneously loaded onto the autosampler tray.

\*US Patent No. 6,375,349 B1



DLF 1200 Furnace

DLF 1200 Autosampler

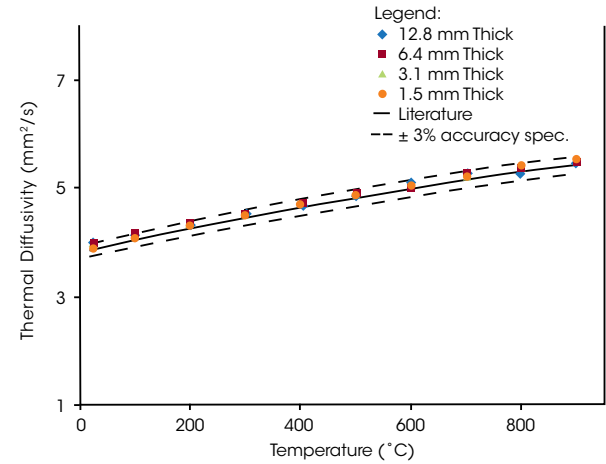
## The Benefits of a Powerful Laser for Data Accuracy

Accuracy defines how close a set of measured data are to the true value. It is typically assessed by repeatedly testing the same sample under the same conditions and comparing results to reference data. For a light flash instrument, the ability to make an accurate measurement relies on all design components working together efficiently as a system. These components include the light source, the pulse delivery, the detector, and the furnace. A laser light source provides a system advantage because of the power of the light pulse. As the thickness of a sample increases, laser power is important as more energy is required to transfer through the sample and detect a temperature rise on the opposite side.

To demonstrate the superior capabilities of the DLF 1200, four samples of a very well-characterized material, stainless steel 304L, ranging from approximately 1 to 10 mm in thickness, were tested and compared to the literature values.

In the graph on the upper right, the thermal diffusivity results for the four samples are shown in comparison to the literature values for the stainless steel along with error bars of  $\pm 3\%$  of the literature value. The accuracy is consistently better than the instrument specification of 3% for samples spanning an order of magnitude in thickness demonstrating the superior performance of the world's most powerful benchtop light flash instrument.

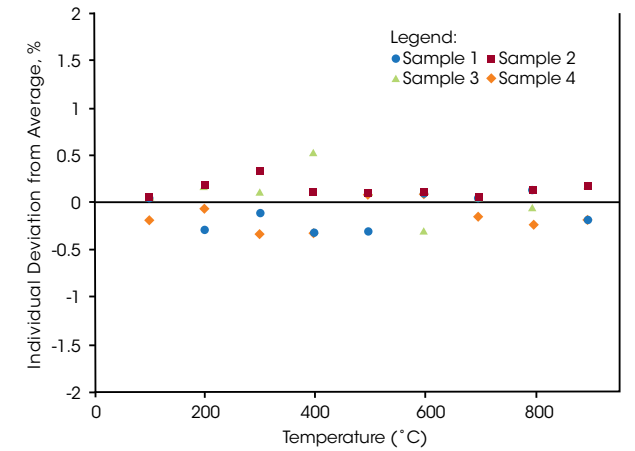
Thermal Diffusivity of 304L SS at Different Thicknesses



## Reliable Results with Patented Autosampler

When conducting flash measurements, alignment of the sample in the path of the light pulse and detector is critical for obtaining accurate results. The patented linear four-position autosampler of the DLF 1200 was designed for precision positioning of each sample in succession to ensure this condition is met. The graph to the right shows four samples of stainless steel loaded in the autosampler and tested in sequence from ambient to 900°C. All the thermal diffusivity values are within  $\pm 0.5\%$  of the expected value, well below the repeatability specification of  $\pm 2\%$ . Various configurations of Autosampler trays are shown below.

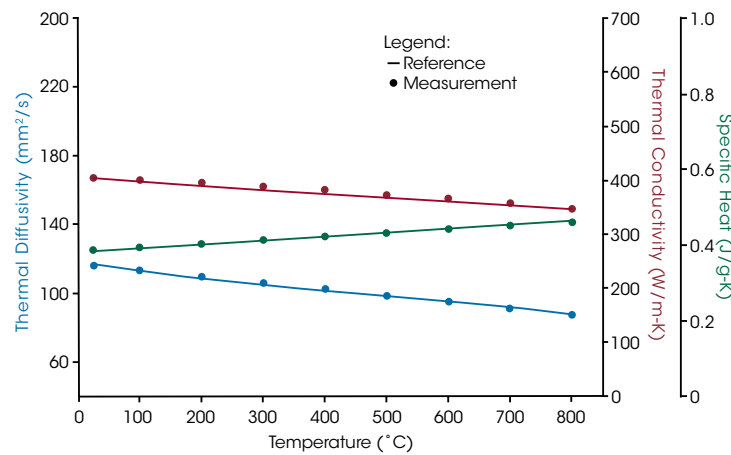
Four Stainless Steel Samples Tested with Autosampler



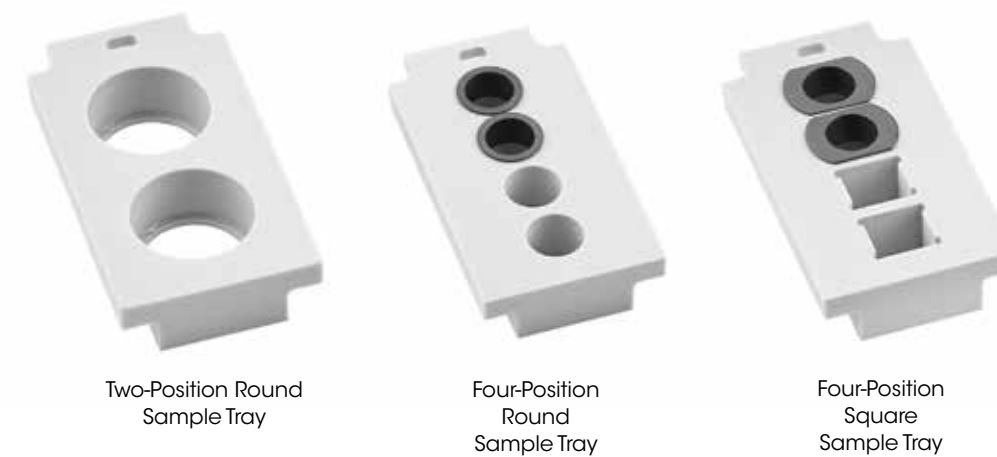
## High Quality Thermal Conductivity

Oxygen-free high thermal conductivity copper (OFHC) is a well-characterized material typically used as a reference sample when evaluating the quality of measurements of thermophysical properties from light flash instruments. The figure on the lower right displays the thermal diffusivity, specific heat, and thermal conductivity of OFHC copper samples tested on the DLF 1200. The thermal diffusivity and specific heat results are in excellent agreement with the reference values over the entire applicable temperature range. The high quality of these results in turn provides outstanding calculated results of the thermal conductivity within 3% of the expected data.

OFHC Heat Transfer Properties



Autosampler Tray Options



Four-Position Autosampler Tray



## DXF | XENON FLASH

The Discovery Xenon Flash platform features a patented High Speed Xenon-Pulse Delivery™ source (HSXD) and Multi-Faceted Light Pipe. Together these optics deliver a light pulse of unsurpassed power and uniform intensity to the specimen while preventing sample holder over-flash. Only TA Instruments high energy Xenon design is capable of testing samples to a diameter of 25.4 mm over a temperature range from -175°C to 900°C. The use of large samples diminishes errors associated with inhomogeneity and permits representative measurements of poorly dispersed composites. The DXF platform is designed for research and development programs as well as production control.

# Patented technology for the **Most Sensitive** **Powerful Xenon Platform**

### Features and Benefits:

#### DXF 200+/500/900 Models

- Patented High Speed Xenon-Pulse-Delivery system provides 50% more energy than competitive designs for the highest degree of accuracy on widest range of samples regardless of thickness or thermal conductivity
- Wide variety of sample trays accommodates multiple sample sizes (up to 25.4 mm), shapes, and special fixtures (liquids, powders, laminates, films, etc.) for maximum sample testing flexibility
- Patented Light Pipe for the most effective collection and collimation of light and homogeneous delivery of radiation to the sample
- Can test samples with maximum diameter of 25.4 mm diameter for easier sample preparation and handling, as well as improved results for inhomogeneous materials
- Real-time pulse mapping for superior thermal diffusivity of thin and highly conductive materials
- Designed to meet industry standard test methods including: ASTM E1461, ASTM C714, ASTM E2585, ISO 13826, ISO 22007-Part4, ISO 18755, BS ENV 1159-2, DIN 30905, and DIN EN821

#### DXF 200+ Model Only

- Subambient temperature system with highly efficient liquid nitrogen cooling system and solid state PIN detectors for measurement stability and accuracy to an industry leading -175°C
- Easily swappable autosampler trays can accommodate up to twelve samples 12.7 mm diameter or six 25.4 mm diameter samples, plus many more sizes and shapes.
- Software enabled PIN control can be adjusted to maintain perfect contact regardless of sample thickness.

#### DXF 500/900 Models Only

- Autosampler with patented\* four-position alumina sample tray for maximum productivity
- Advanced resistance-heated furnace designs providing best-in-class temperature stability and uniformity across sample from RT to 500 or 900°C respectively, and enables measurements in air, inert gas, or vacuum
- High sensitivity IR detector for optimum signal-to-noise ratio, delivering highest accuracy over the entire temperature range

\*US Patent No. 6,375,349 B1



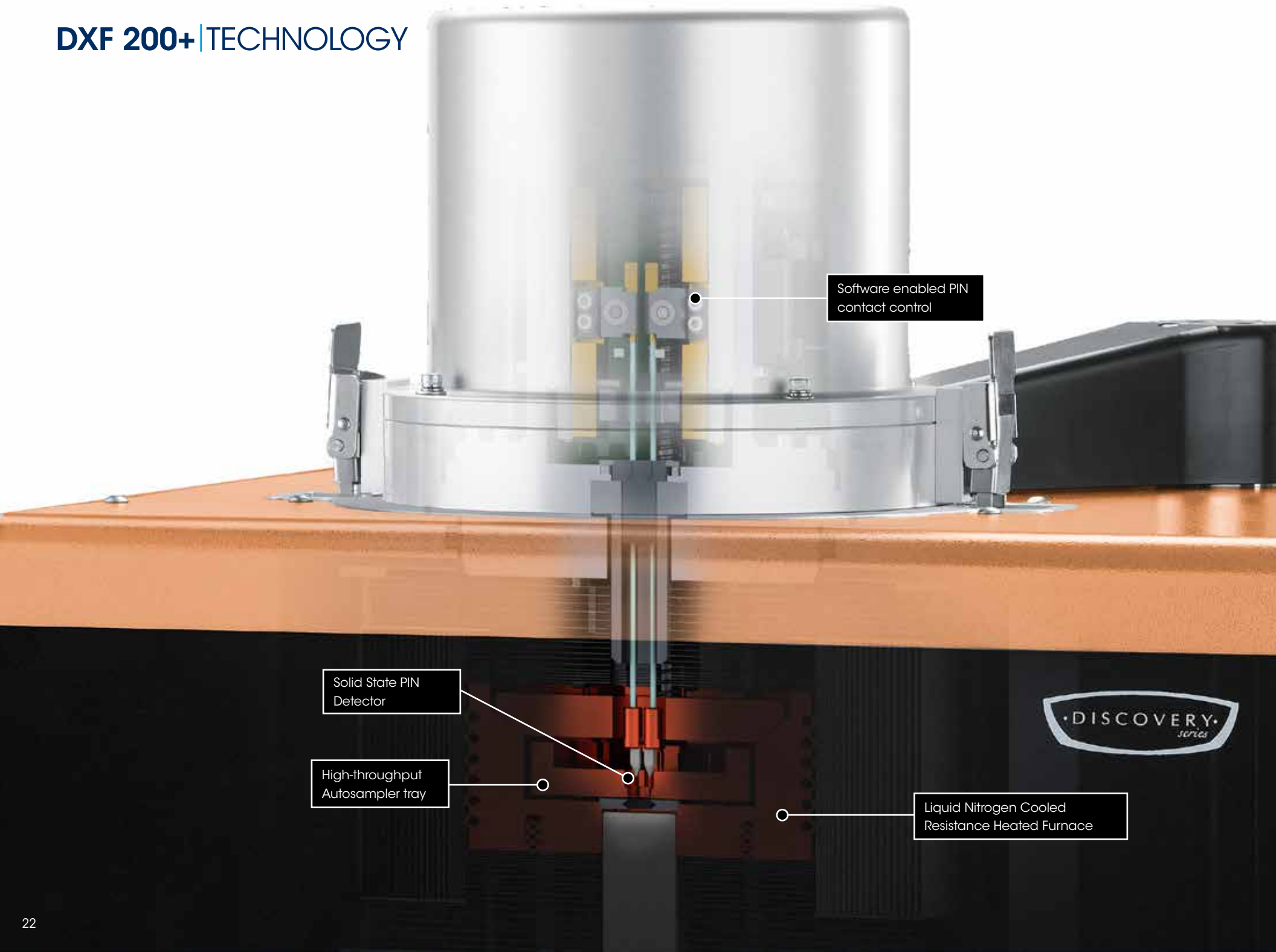
DXF 200+



DXF 500



DXF 900



# Solid State PIN Detector for **Unmatched Sensitivity** **Down to -175°C**

### Lowest Available Temperature Limit: -175°C

The DXF 200+ features a furnace that includes an efficient liquid nitrogen cooling system for stable and accurate temperature control from -175°C to 200°C. Only the DXF 200+ is capable of testing thermal management properties of materials to -175°C making it the clear choice for scientists interested in the cryogenic range.

### Enhanced Temperature Detection from Solid State PIN Detector

The DXF 200+ features a unique, dual PIN detector which provides optimal sensitivity and response time at temperatures below ambient. The amplitude of the signal measured at -175°C by the PIN detector, in direct contact with the sample, is typically five times greater than the signal at the lowest detectable temperature of a traditional IR detector, which is typically 25°C. This eliminates the need for signal amplification required for MCT IR detectors operating at or below room temperature. The result is an improved thermogram with greater signal-to-noise ratio, increased accuracy of specific heat capacity and thermal conductivity measurements, and a reliable data set for effortless post-test analysis.

### Patented High Speed Xenon-Pulse Delivery™ (HSXD) Source

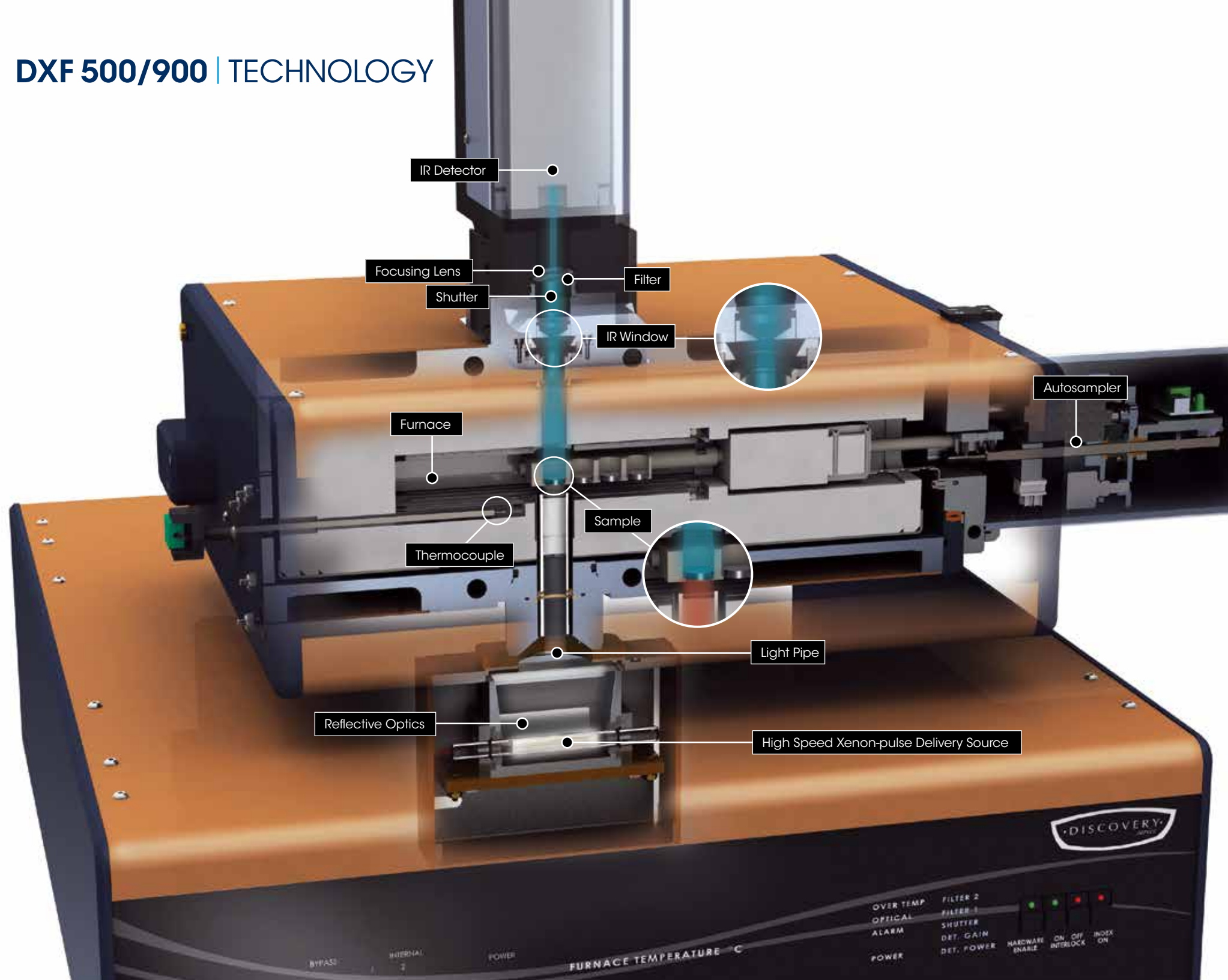
The DXF 200+ features the proprietary High Speed Xenon-Pulse Delivery™ (HSXD) source. With its 15 Joules of energy, the flash produced by the HSXD is the most powerful and most uniform flash of any Xenon system available on the market.

### Large 25.4 mm Sample Diameter for Easy Sample Handling

No other supplier can offer the ability to test up to 25.4 mm diameter samples over such a wide temperature range. Larger samples are easier to prepare and handle, guarantee more representative and reproducible data, and provide improved results for composites or inhomogeneously dispersed materials.

### Real-time Pulse Mapping

The real-time pulse mapping system accounts for the finite pulse width effect and heat losses, which is paramount for data accuracy, especially when measuring thin and highly conductive materials.



# Patented **LIGHT PIPE** for the Highest Performing **Delivery Optics**

### 50% More Energy from Patented High Speed Xenon-Pulse Delivery™ (HSXD) source

All DXF models feature the proprietary High Speed Xenon-Pulse Delivery™ (HSXD) source. The patented design is comprised of a Xenon source located on one mirror that focuses and produces a highly uniform flash. With 15 Joules of energy, the flash produced by the HSXD is the most powerful and most uniform flash of any Xenon system available on the market, and allows the ability to test thicker lower conductivity samples.

### Patented Light Pipe and Neutral Density IR Filters for Unparalleled Accuracy

TA Instrument's patented wave guide Light Pipe collects and collimates the HSXD source flash, efficiently delivering energy directly to the sample. This unique, highly efficient optical path yields a homogeneous, high-quality radiation, maximizing the energy reaching the sample surface.

The IR intensity is tuned to the optimal detector range through the use of neutral density IR filters. Unlike systems that rely on multiple apertures or iris design to attenuate intensity, the neutral density filter provides a uniform moderation of intensity and is free from geometry factors and spectral band distortion. These carefully designed detector optics lead to unparalleled accuracy across the full range of thermal diffusivity.

### Flexible, Multi-Position Sample Holders

The sample containment system utilizes linear sample-holding trays for fast and easy loading. A rim at the bottom of the sample holder supports the specimen, so it is free of any pressure or clamping and well-suited for delicate specimens. The patented\* linear design guarantees a perfect positioning of the sample holder in alignment with the flash radiation.

### Wide Range of Sample Holders

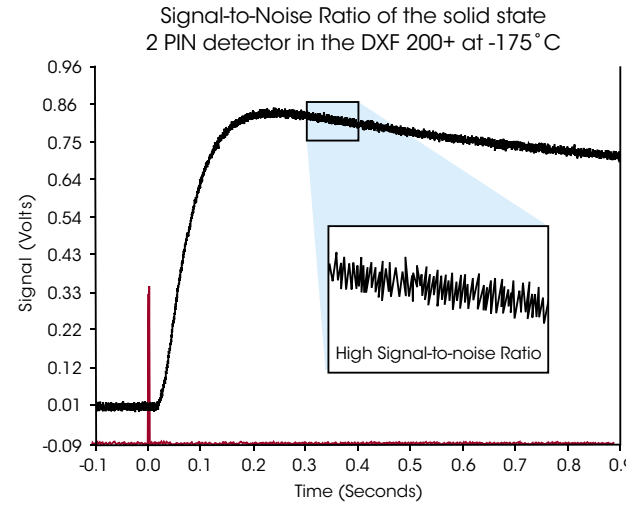
Users can choose between a selection of sample holders which can accommodate two or four samples from 8 mm up to 25.4 mm in size, and of round or square shape. For samples that require specific sample holders, TA Instruments offers a variety of accessories for liquids, powders, laminates, and materials with extremely high thermal diffusivity.

\*US Patent No. 6,375,349 B1

**Lowest temperature with highest Signal-to-Noise Ratio**

The increasing demand of new high-performance materials for the aerospace and defense industries has pushed the demand for Flash Diffusivity instrumentation with lower temperature range and better data quality. The solid state Dual PIN detector can operate down to an industry-leading -175°C with excellent data quality.

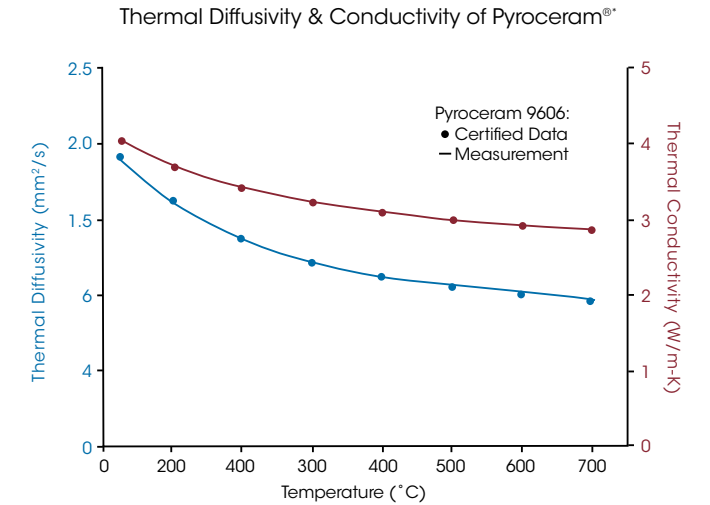
The figure on the upper right demonstrates the quality of the signal-to-noise ratio (SNR) of the DXF 200+ at cryogenic temperatures. Even at -175°C the amplitude of the directly measured signal is approximately five times greater for the solid-state PIN detector than for a traditional IR detector signal at room temperature.



**Accuracy of Xenon Flash**

Pyroceram®, a glass-ceramic used for high temperature applications, has been used for over 30 years as a material for verification of the measurement of thermal heat management properties at high temperature. Pyroceram 9696 was tested on the DXF 900 to a temperature of 700°C. The figure to the top right shows results are in excellent agreement with the standard reference values.

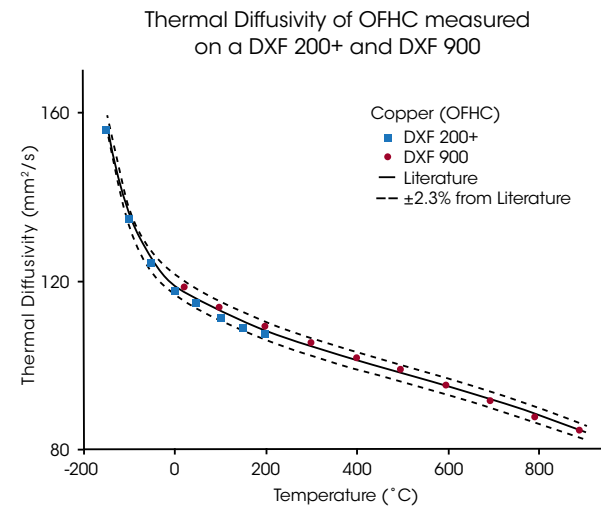
\*Pyroceram® is a registered trademark of Corning Incorporated



**Consistent data from -175°C to 900°C**

Often, high performance materials need to be characterized from extremely low to high temperatures. The graph on the lower right shows an oxygen-free high thermal conductivity copper (OFHC) reference material in which thermal conductivity was measured from -175°C to 900°C with both a DXF 200+ and DXF 900.

All the measurements fall within ±1.5% of the reference values. Note the agreement of the values between ambient and 200°C

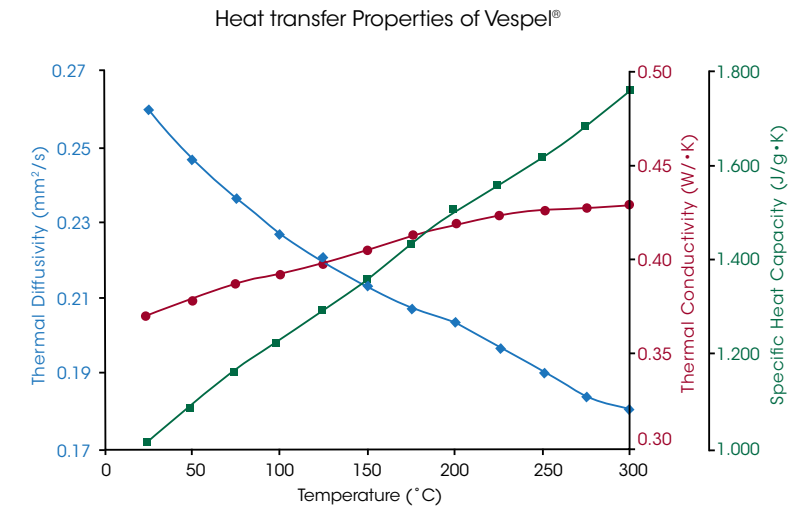


**Thermal Diffusivity of Vespel®**

Vespel® is a polyimide and one of the most commonly used thermal conductivity reference materials due to its consistent thermophysical properties. However, there is very little data available describing its thermal diffusivity and heat capacity.

The figure in the lower right presents data for thermal diffusivity and specific heat capacity for Vespel® obtained using the flash method. The result and the data shows good correlation with values generated using a DSC. From this it is possible to determine thermal conductivity. These results agree favorably with the values directly measured with TA Instruments Guarded Heat Flow Meter, DTC 300.

\*Vespel® is a registered trademark of The DuPont Company



## Specialty Fixtures

Laser and Xenon Light Flash instruments represent the forefront in research and development of high performance materials and the study of thermal management properties. Often, accessories with standard sizes and shapes are just not enough to test that special sample or innovative material.

In cooperation with advanced users of prestigious laboratories, TA has a range of sample holders developed specifically for the analysis of:

- Liquids
- Powders
- Pastes
- In-plane testing of thin films with high conductivity
- In-plane testing of laminates

With the ever-increasing number of new materials requiring heat transfer characterization, TA is committed to working with our customers in the development of fixtures to meet their unique testing requirements.



Laminate



Liquid/Powder/Paste



In-Plane



## The Proven Software Platform for Easy, Accurate Flash Analysis Data

### Functionality just one click away

All Discovery Light Flash instruments include FlashLine™ software for Instrument Control and Data Analysis. The Microsoft Windows-based software features an intuitive table-based format for simple programming of experimental parameters in the instrument control interface. Real-time monitoring allows for immediate assessment of the data quality and instrument performance during each test. The Data Analysis module's automated routines provide users with advanced analysis tools, including models for heat loss correction in both conduction and radiation.

Integrated with the pulse-shape mapping measuring system, FlashLine determines the exact shape of the laser pulse versus time to make pulse shape and width correction. It also identifies the flash zero origin and enables finite pulse effect correction which is critical to guarantee accurate measurements for thin samples and high-diffusivity materials. Additionally, the TA Instrument developed "Goodness of Fit" evaluation tool allows the user to select the best results calculated by different Thermal Diffusivity models.

### Software Features:

- Unlimited temperature segments with user-defined heat ramp steps
- User-selectable laser energy for each sample at each temperature segment
- Data analysis of any already-completed segment during testing
- Determination of the specific heat by comparative method
- Option for automatic multiple-shots selection and averaging
- Correction for radiation component of transparent and translucent samples
- Automatic optimization of flash energy level
- Option for sample skip and precision criterion
- Fast zoom function for X and Y segments
- Thermal diffusivity, specific heat, and thermal conductivity tables and graphs as a function of temperature
- Calculations of all models during testing and available by the completion of testing

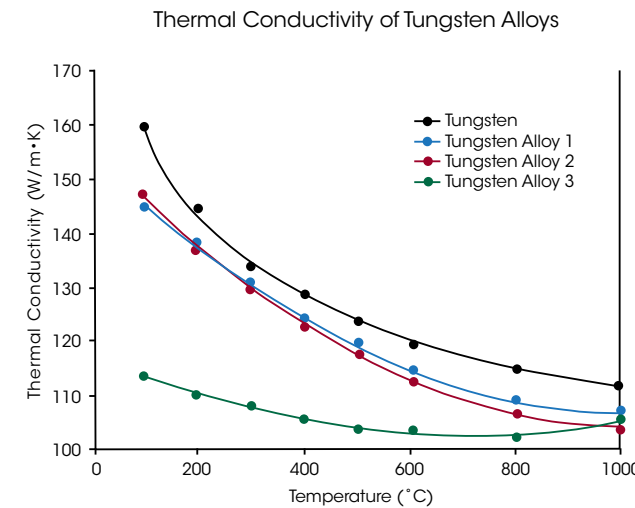
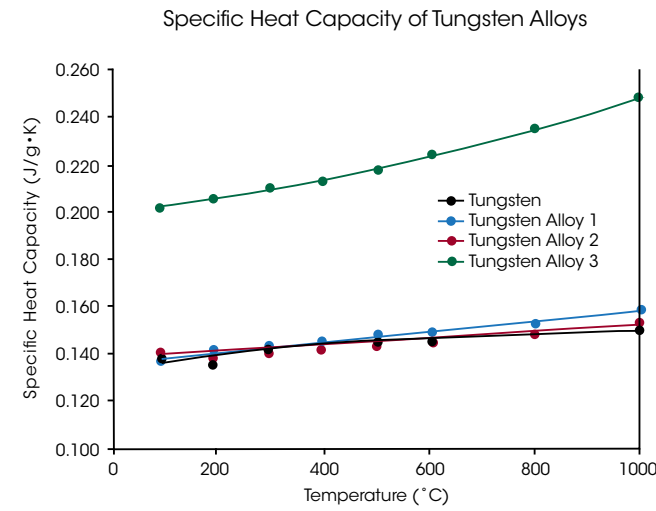
### Standard Models Include:

- Gembarovic for multi-dimensional heat loss correction and non-linear regression
- Goodness of Fit for the best model result selection
- Pulse gravity center to determine  $t_0$
- Pulse length and shape correction
- Two- and three-layers analysis
- Main models: Clark and Taylor, Cowan, Degiovanni, Koski, Least Squares, Logarithmic, Moment, Heckman, Azumi, and Parker
- In-plane analysis



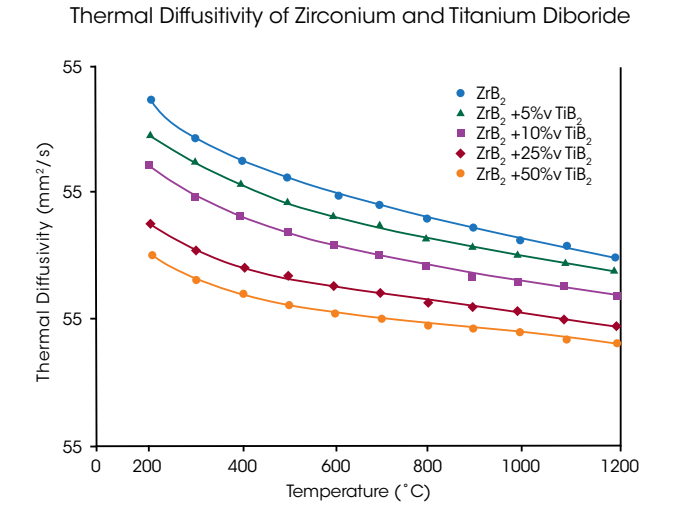
## Tungsten Alloys

Tungsten alloys are valued for their high hardness, which makes them ideal for cutting or abrasion tools, and also rocket nozzles. The data to the right are the result of a study of various tungsten alloys, in comparison to a sample of pure tungsten. Thermal diffusivity and specific heat capacity data were measured on the alloy samples using a DLF 1200. The data demonstrate the variance in the heat transfer properties as a function of even subtle changes in composition. The comparison with pure tungsten data in the top figure shows Tungsten Alloy 3 has a significant deviation in the specific heat capacity value. As a result, the calculated thermal conductivity values in the bottom figure show a difference in both the absolute value as well as temperature dependence.



## Ultra-High-Temperature Ceramics

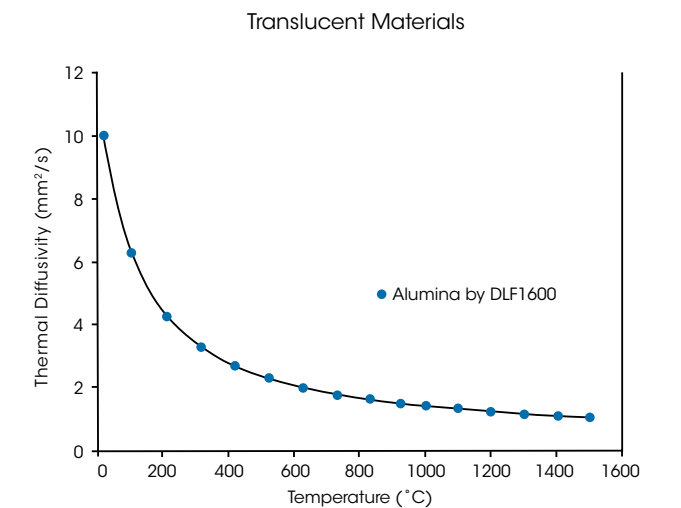
Zirconium diboride ( $ZrB_2$ ) and Titanium diboride ( $TiB_2$ ) are classified as ultra-high-temperature ceramics due to their melting points in excess of  $3200^\circ C$ .  $ZrB_2$  is also remarkable for its high strength, hardness, good chemical stability and high thermal and electrical conductivities. This makes  $ZrB_2$  an attractive option for hypersonic flight and atmospheric re-entry vehicle applications. New high-maneuverability control surfaces experience temperatures in excess of  $2000^\circ C$  due to frictional heating on sharp leading and trailing edges. Knowledge of the thermal properties at high temperatures is critical to managing this heat. As seen in the plot on the upper right, increasing the solid solution content of  $TiB_2$  in  $ZrB_2$  decreases thermal diffusivity over the entire temperature range of the experiment, up to  $1200^\circ C$ . Data was obtained using a DLF 1200.



## Translucent Materials

Some advanced materials are translucent to the laser flash; hence, often the samples need metal coating on both the front and rear surfaces of the sample. However, as temperature increases, the contribution of the radiative heat becomes predominant and causes a shift in the baseline of the thermogram that needs to be normalized.

The thermal diffusivity data of pure alumina material depend significantly on purity, porosity, structure, and sintering history. A pure alumina sample was measured with the DLF 1600 from room temperature to  $1500^\circ C$ . The graph on the right shows the quality of resulting data after FlashLine software compensated for the baseline shift.



# DISCOVERY LIGHT FLASH | SPECIFICATIONS

	DLF 2800	DLF 1600	DLF 1200
<b>Laser Source</b>			
Type	Class 1Nd: Glass, Floor-Standing	Class 1Nd: Glass, Floor-Standing	Class 1Nd: Glass, Benchtop
Pulse energy (Variable)	Up to 35 Joules	Up to 35 Joules	Up to 17 Joules
Pulse width	300 to 400 $\mu$ sec	300 to 400 $\mu$ sec	300 to 400 $\mu$ sec
Proprietary Transfer Optics	Fiber Optic Wand	Fiber Optic Wand	Optic Beam Guide
<b>Furnace</b>			
Sample Temperature Range	RT to 2800°C	RT to 1600°C	RT to 1200°C
Atmosphere	Inert, vacuum (50 mTorr)	Air, inert, vacuum (50 mTorr)	Air, inert, vacuum (50 mTorr)
<b>Detection</b>			
Thermal Diffusivity Range	0.01 to 1000 mm <sup>2</sup> /s	0.01 to 1000 mm <sup>2</sup> /s	0.01 to 1000 mm <sup>2</sup> /s
Thermal Conductivity Range	0.1 to 2000 W/(m*K)	0.1 to 2000 W/(m*K)	0.1 to 2000 W/(m*K)
Data Acquisition	16 bit	16 bit	16 bit
<b>Accuracy</b>			
Thermal Diffusivity	± 2.3%	± 2.3%	± 2.3%
Thermal Conductivity	± 4%	± 4%	± 4%
<b>Repeatability</b>			
Thermal Diffusivity	± 2.0%	± 2.0%	± 2.0%
Thermal Conductivity	± 3.5%	± 3.5%	± 3.5%
<b>Sample</b>			
Round	8, 10, 12.7 mm Diameter	8, 10, 12.7, 15.9 mm Diameter	8, 10, 12.7, 25.4 mm Diameter
Square	8, 10 mm Length	8, 10 mm Length	8, 10, 12.7 mm Length
Maximum Thickness	10 mm	10 mm	10 mm
<b>Autosampler</b>			
Maximum Thickness	Six-Position Carousel	Five-Position Carousel	Four-Position Linear Tray

	DXF 900	DXF 500	DXF 200+
<b>Flash Source</b>			
Type	Xenon, Benchtop	Xenon, Benchtop	Xenon, Benchtop
Pulse energy (Variable)	Up to 15 Joules	Up to 15 Joules	Up to 15 Joules
Pulse width	400 to 600 $\mu$ sec	400 to 600 $\mu$ sec	400 to 600 $\mu$ sec
Proprietary Transfer Optics	Light pipe beam guide	Light pipe beam guide	Light pipe beam guide
<b>Furnace</b>			
Sample Temperature Range	RT to 900°C	RT to 500°C	-175°C to 200°C
Atmosphere	Air, inert, vacuum (50 mTorr)	Air, inert, vacuum (50 mTorr)	Air, inert, vacuum (50 mTorr)*
<b>Detection</b>			
Thermal Diffusivity Range	0.01 to 1000 mm <sup>2</sup> /s	0.01 to 1000 mm <sup>2</sup> /s	0.01 to 1000 mm <sup>2</sup> /s
Thermal Conductivity Range	0.1 to 2000 W/(m*K)	0.1 to 2000 W/(m*K)	0.1 to 2000 W/(m*K)
Data Acquisition	16 bit	16 bit	16 bit
<b>Accuracy</b>			
Thermal Diffusivity	± 2.3%	± 2.3%	± 2.3%
Thermal Conductivity	± 4%	± 4%	± 4%
<b>Repeatability</b>			
Thermal Diffusivity	± 2.0%	± 2.0%	± 2.0%
Thermal Conductivity	± 3.5%	± 3.5%	± 3.5%
<b>Sample</b>			
Round	8, 10, 12.7, 25.4 mm Diameter	8, 10, 12.7, 25.4 mm Diameter	8, 10, 12.7, 25.4 mm Diameter
Square	8, 10, 12.7 mm Length	8, 10, 12.7 mm Length	8, 10, 12.7 mm Length
Maximum Thickness	10 mm	10 mm	10 mm
<b>Autosampler</b>			
Type	Four-Position Linear Tray	Four-Position Linear Tray	Twelve-Position Carousel

\* High Vacuum Option: 0.5 mTorr with turbo pump

# Industry-Leading Sales & Support

TA Instruments' leadership position results from the fact that we offer the best overall product in terms of technology, performance, quality, and customer support. While each is important, our demonstrated commitment to after-sales support is a primary reason for the continued loyalty of our customers. To provide this level of support, TA Instruments has assembled the largest worldwide team of field technical and service professionals in the industry. Others promise good service. Talk to our customers and learn how TA Instruments consistently delivers on our promise to provide exceptional service.

With direct support staff in **24 countries** and **5 continents**, TA Instruments can extend its exceptional support to you, wherever you are.





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