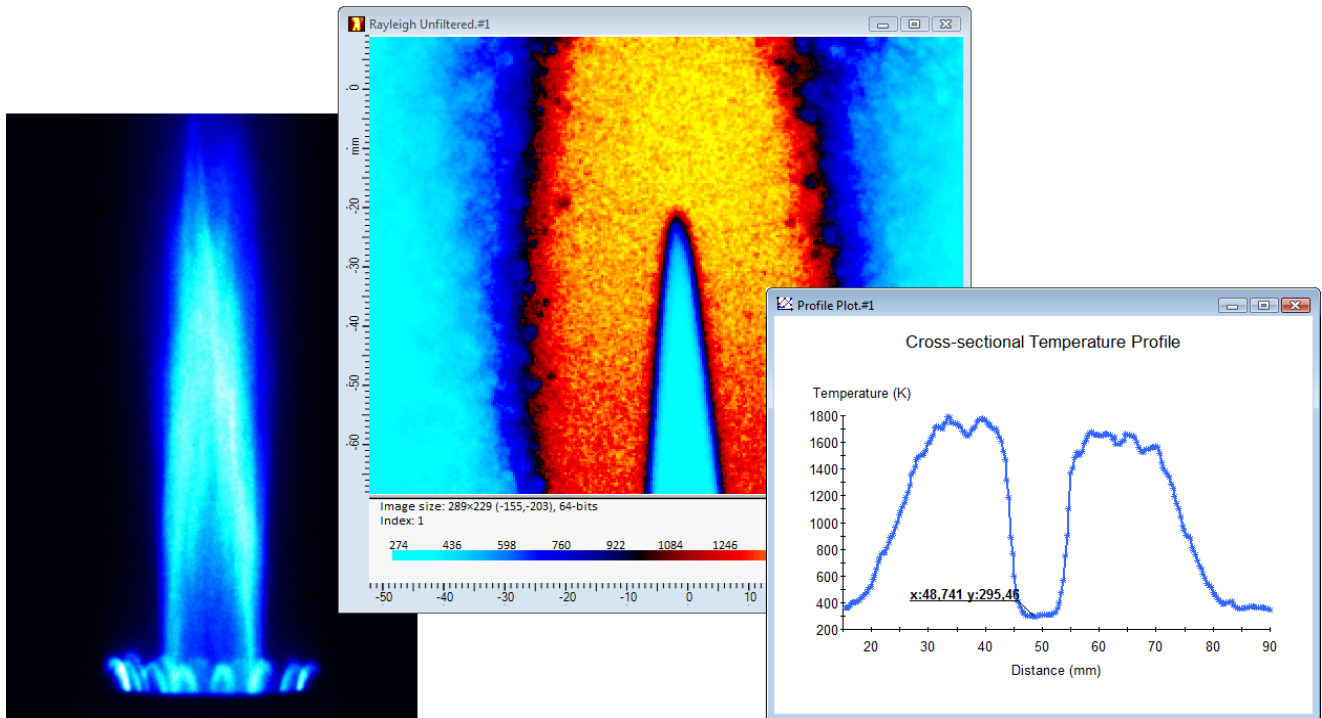


Rayleigh Thermometry System

Temperature imaging measurements using Rayleigh scattering



Powerful yet easy-to-use system for temperature imaging

With powerful hardware and a comprehensive processing software interface, our Rayleigh Thermometry system offers non-contact, non-intrusive global measurement of temperature in flames. It is well suited for instantaneous and time-averaged planar temperature imaging in a variety of clean, particle-free combustion processes as well as gas flows with high temperature gradients.

Key benefits

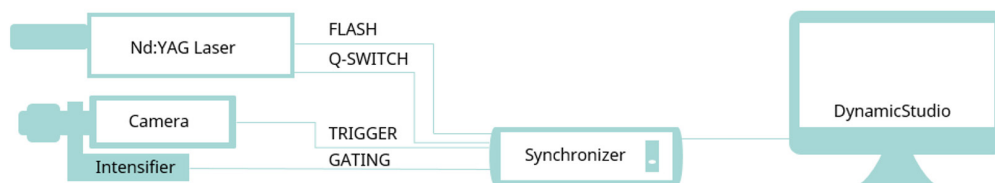
- Non-intrusive imaging technique for measurements of temperature in flames
- Compact yet powerful laser solution with excellent beam quality
- High-sensitivity camera
- Advanced synchronization with temporal precision down to the sub-nanosecond range
- Complete software platform for system setup, data acquisition, data analysis and visualization of results
- Advanced software module for processing and analyzing image data from laser Rayleigh scattering

Temperature imaging for combustion applications

Global temperature distribution is an important parameter for the analysis and optimization of combustion processes. By using laser Rayleigh scattering, two-dimensional temperature maps can be derived from measurements in clean combustion and hot gas flows. Our Rayleigh Thermometry system and software provides all the tools needed for the determination of the temperature distribution in combustion and heat transfer studies. The system utilizes green laser light instead of UV light. With this approach we minimize the risk of exciting fuel components or combustion intermediates which can be problematic when using UV light. The software package has an intuitive and user-friendly interface with a single dialog for nearly all parameters used in the data processing. Advanced data analysis and calibration routines are also provided.

The Rayleigh Thermometry system in brief

Rayleigh Thermometry data is obtained in a plane by illuminating the process under investigation with a thin laser light sheet. The elastically-scattered light from the gas molecules is then recorded by an intensified camera placed perpendicular to the light sheet. Since the intensity of the scattered light is directly related to the gas density, we can use the grey level data from the images to determine the temperature throughout the imaged area. The DynamicStudio software allows users to easily acquire data with full control of all hardware from a single interface.



Overview of the different components, timing and data flow.

Laser light source

As Rayleigh scattering is a relatively weak light scattering process, the laser pulse energy is a critical property for Rayleigh Thermometry, and thus the choice of laser source is of great importance. The Nd:YAG laser, optimized for 10 Hz repetition rate, is equipped with a temperature stabilized 2nd harmonic generator which provides 430 mJ at 532 nm. The 2nd harmonic unit comes with intelligent auto-tuning to maintain optimum phase matching and maintain maximum output energy over time. The laser is easy to operate and does not require external water-cooling or other complex infrastructure.

Our robust Light Sheet Optics are included with the system which provide a parallel laser sheet for consistent light intensity. A parallel light sheet is required to assure that the intensity distribution, over the laser sheet height, is the same over the observed length of the Field-of-View. Light sheet dimensions are approx. 50 mm x 0.1 mm (when used with a beam waist adjuster) with a working distance of 600 mm. To ensure a secure working environment, laser alignment goggles and protective goggles are also available.

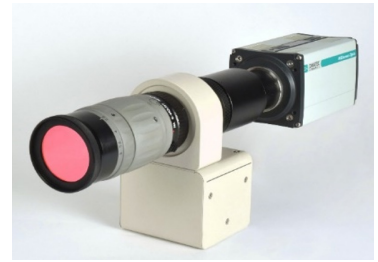
Cameras, Image Intensifiers and Lenses

The standard camera for Rayleigh Thermometry is the HiSense Zyla camera (USB or frame grabber version), featuring high sensitivity and low noise levels.

The image intensifiers are designed to have the highest possible quantum efficiency for visible light using a GaAsP or S20 photocathode, which are ideal for detecting Rayleigh scattering. The unit offers full control over gain and gate time options, ranging from continuous to ultra-fast, with a minimum gate time as low as 3 ns

depending on the model. Relay optics used to adapt the camera to the image intensifier are also included.

We offer a wide range of camera lenses for visible light, together with an adapter ring for fitting filters to the selected lens. Each system includes a lens to optimize the magnification and field-of-view for the scope of the measurement along with an interference filter for Rayleigh Thermometry. The camera and image intensifier are separate units, allowing for flexible use of the hardware. This solution is ideal for laboratories dealing with multiple applications such as Rayleigh Thermometry, LIF, PIV, microscopy and/or spectroscopy.



HiSense Zyla camera, image intensifier unit and front lens

High Performance Synchronizer

Synchronization of laser pulses, cameras and image intensifiers is mastered by a High Performance Synchronizer, fully controlled via the DynamicStudio software. The synchronizer is a multi-channel delay and signal generator with ≤ 1 ns resolution. The 32 output channels are programmed independently; thereby offering comprehensive synchronization and triggering facilities for highly demanding processes. It also features four input channels for synchronization with external devices or events, two analog inputs with up to 500 kHz sample rate, and four analog outputs. For further details, please consult separate data sheet on "Imaging Synchronizers".



High performance synchronizer

User-friendly imaging software platform - Straightforward data analysis

The image acquisition system is based on DynamicStudio, a comprehensive and user-friendly software platform for imaging applications. It features an advanced plug-and-play based distributed system, making it easy to get full control over the hardware for image acquisition. Data acquisition and analysis are supported within the same software, so there is no need to export the data for post-processing.

ROI selection

Frame selection

Measurement image properties

Reference image properties

Automated background subtraction

Output temperature clamping

The Rayleigh Thermometry dialog in DynamicStudio gives the user a full overview of all parameters used in the data processing.

The Rayleigh Thermometry processing dialog allows you to input the values of the test parameters such as pressure, laser pulse energy and scattering cross-section for the gas mixture in both the reference images and measurement images. This gives you full overview of the processing from a single screen. Background subtraction can be done automatically on all images within the Rayleigh Thermometry processing to ensure that there is no systematic error in the calculation due to camera detection noise or offset levels.

The main Rayleigh Thermometry processing features:

- Quick and robust methods to process multiple raw data sets, using the reference image.
- Easy access to the measurement data properties for taking parameter changes into account, e.g. pressure and scattering cross-section.

Species and Mixtures libraries

To make the data analysis even more straightforward, the software also includes two libraries; one that includes several molecular species and their corresponding scattering cross-sections, and one that includes relevant mixtures of the species found in the first library. The global scattering cross-section for the gas mixtures are automatically calculated and the user only needs to define what mixture was used in the experiment, and the software takes the different scattering cross-sections into account in the data processing. Of course the user is also allowed to add new species to the library and create new mixtures to create libraries tailor-made for his specific applications.

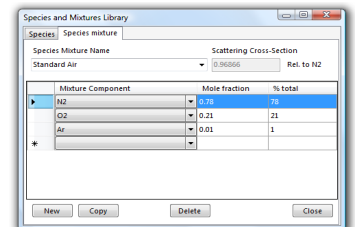
Boosting analysis capabilities with analysis sequences and MATLAB® Link

The data analysis is further strengthened by the ability to define analysis sequences and perform batch processing which makes quick work of processing large data sets. And with the MATLAB Link in DynamicStudio, you can tailor your analysis by calling up your personally designed MATLAB scripts directly from DynamicStudio, allowing you to process the data directly in the database without the need to export.

Option

Pulse Energy Monitor

A proven method of reaching higher accuracy is to measure the laser pulse-to-pulse fluctuations by means of a Pulse Energy Monitor and subsequently compensate for this during image analysis. The Pulse Energy Monitor is mounted between the laser output and light-sheet optics.



The software includes a Species and Mixtures library making the temperature analysis more intuitive.

Technical specifications

Laser	
Wavelength (nm)	532
Pulse energy (mJ)	430
Pulse duration (ns)	~5
Repetition rate (Hz)	10

Light Sheet Optics	
Wavelength range	UV and visible
Light sheet height	50 mm

Camera	HiSense Zyla
Speed (fps) with frame grabber/with USB	49/40
Resolution (MP)	5.5
Sensor resolution (pixels)	2560 x 2160
Pixel size (µm)	6.5
Lens mount	F-mount or C-mount

Image intensifiers*	H Series 18 mm	L Series 18 mm
Minimum gate time		3 ns
Photocathode diameter		18 mm
Photo cathode material	GaAsP	S20
Phosphor screen		P43
Camera attachment		C-mount
Lens attachment		F-mount

Camera lenses and filters	
Focal length and aperture	50mm f/1.4, 85mm f/1.4, 100 mm f/2.0
Filter adapter	Adapter for 62 mm filter included
Lens mount	F mount

High Performance Synchronizer	
Time resolution	<= 1 ns
Synchronization outputs	32, TTL
Synchronization inputs	4, TTL

Software	
DynamicStudio	Base package Rayleigh Thermometry Add-on