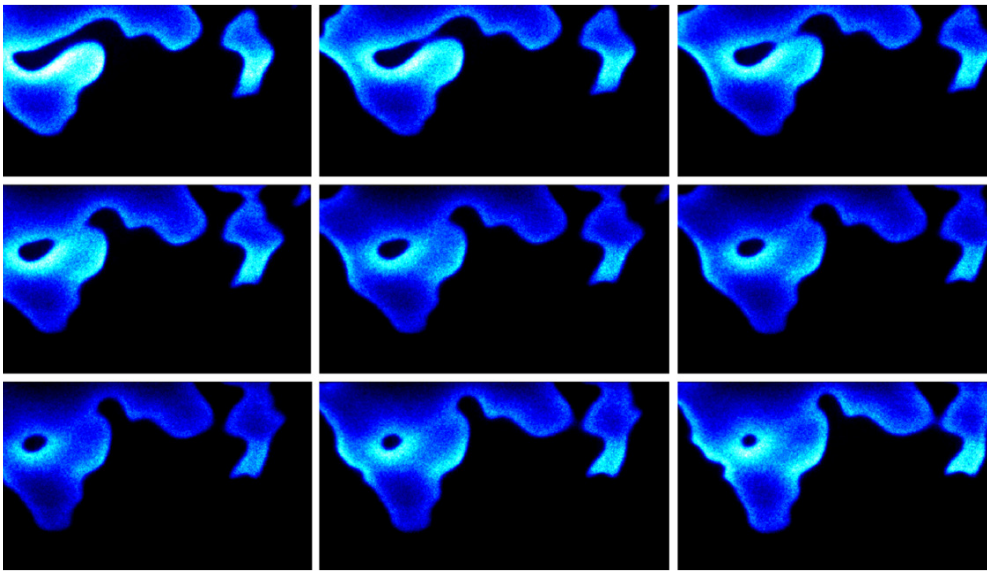
SOLUTION SHEET

DANTEC DYNAMICS

Time-resolved OH LIF System

High-speed flame front imaging in turbulent combustion



The state-of-the-art solution for time-resolved flame front imaging

Flame front visualization by means of OH planar Laser-induced Fluorescence (LIF) can now be performed at frame rates high enough to capture the rapid dynamics in a variety of combustion applications, such as ignition phenomena, flame propagation and local extinction events. Our time-resolved planar OH LIF system integrates the latest developments in high-speed imaging and laser technology with user-friendly software for handling high-speed data acquisition and analysis of even the most demanding turbulent combustion processes.

Key benefits

- Advanced Nd:YAG and tunable dye lasers designed for repetition rates up to 10 kHz
- High quality UV light-sheet optics
- Wide range of high-speed CMOS cameras
- UV-sensitive high-speed image intensifiers
- Synchronizer with ultra-high temporal precision in the sub-nanosecond range
- Complete software platform for system set-up, data acquisition, data analysis and visualization of results

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A powerful tool for studies of turbulent combustion phenomena

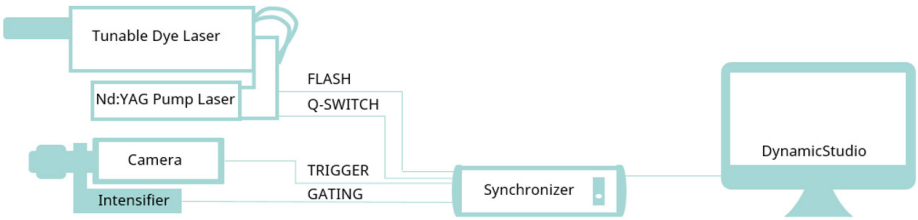
Our time-resolved OH LIF system utilizes a non-intrusive (optical), two-dimensional measurement technique based on the Laser-induced Fluorescence emission of thehydroxyl radical, OH, produced during combustion. The beam from a high-speed tunable laser is formed into a light-sheet which illuminates a thin planar section of the combustion process and excites the OH radicals, which subsequently emit fluorescent light. The fluorescence is recorded by an intensified camera, creating a map of the OH or flame front distribution in the plane.

Through user-friendly hardware and software, the user quickly gains full confidence to operate the system. As the backbone of our systems, DynamicStudio is the most comprehensive imaging software for optical diagnostics. From within our software, you can easily control the measurement system and perform advanced image data analysis to extract valuable information and a better understanding of the combustion process being studied.

When required, the system can also control a second laser and camera e.g. for synchronized velocity measurements by PIV.

The TR OH LIF solution in brief

The system is comprised of a state-of-the-art Nd:YAG-pumped, tunable dye laser specially designed for applications at high repetition rates, a high-speed CMOS camera equipped with a UV sensitive image intensifier, advanced electronics for hardware synchronization, and software for straightforward data acquisition and analysis.



Overview of the different components.

Laser light source and light sheet optical components

As laser pulse energy is a critical property for time-resolved LIF systems, the choice of laser source is of great importance. Time-resolved OH LIF measurements are carried out using an advanced Nd:YAG-pumped, tunable dye laser to generate laser pulses for OH excitation at around 283 nm.

The Nd:YAG pump source is a diode-pumped laser with short pulse duration in the range of 10 ns and is designed to work in conjunction with a tunable dye laser. To ensure that the laser fulfils functional requirements, every single laser is optimized for the repetition frequency and pulse energy according to the application at hand.

To gain the highest energy level outputs, the dye laser is equipped with a dedicated Second Harmonic Generator (SHG) unit optimized for conversion of visible light into UV. In order to select the desired absorption peak of OH, the laser output is fine-tuned by scanning the wavelength. The SHG allows tuning of the output beam within the range of 220-320 nm.

The SHG mount is motorized so that crystal phase matching is done automatically throughout the wavelength scan. This means that the you will always have optimum pulse energy out of the dye laser without the need of manual adjustments. This allows you to focus on the application rather than on the measurement equipment.

The dye laser features:

- Linewidth 0.06 cm^{-1} at 580 nm, providing more efficient excitation of narrow absorption lines, and thus increased signal-to-noise ratio
- Digital wavelength selection making it easy to control from a computer
- Automated crystal phase matching throughout wavelength scanning and thus no need for manual adjustments

UV / visible parallel light sheet optics

Optical devices used to form parallel UV light sheets are included with the system. Light sheet dimensions are approx. 50 mm x 0.1 mm (when used with a beam waist adjuster) with a focal length of 600 mm.

To ensure a secure working environment, UV and visible light - from the Nd:YAG laser to the location at which the light sheet is formed - is contained in a closed environment. Laser alignment goggles and protective goggles are also available.

Cameras, Image Intensifiers and Lenses

We offer several types of CMOS cameras with different frame rate, pixel size, light sensitivity and inter-frame shutter speed characteristics. Among the highest performance cameras recommended for time-resolved planar-LIF measurements, you will find the SpeedSense 1212. With a full sensor resolution of 1,280x800 pixels, it can handle acquisition speeds of up to 12.6 kHz. In combination with the large pixel size (with high light sensitivity), the SpeedSense 1212 is an excellent choice for time-resolved LIF measurements.

SpeedSense CMOS camera

The camera and image intensifier are separate units which allows existing hardware systems to be upgraded for combustion applications. This solution is ideal for laboratories dealing with multiple applications such as PIV as well as LIF in liquid and gaseous phases including combustion processes, microscopy and spectroscopy.

The image intensifier units are designed for UV, visible and near-IR applications using a broadband photocathode in order to cover a wide range of applications. The units offer full control over gain and gate time options ranging from continuous to ultra-fast. For high-speed applications two options are available: The L Series with a minimum gate time of 40 ns and a maximum repetition rate of 100 kHz, and the H Series with a minimum gate time of 10 ns and a staggering 200 kHz repetition rate. The short gate time of the H series makes it the best choice for ultra-fast and light intensive applications such as sparks and ignition events.

To match the intensifiers, a 100 mm camera lens with optimized transmission for UV light is available. For OH fluorescence detection, a dedicated, narrow, band-pass interference filter is included.

High Performance Synchronizer

Synchronization between laser pulses, cameras and image intensifiers is handled by our High Performance Synchronizer fully controlled via the DynamicStudio software.

The High Performance Synchronizer

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”.

User-friendly imaging software platform - Straightforward data analysis

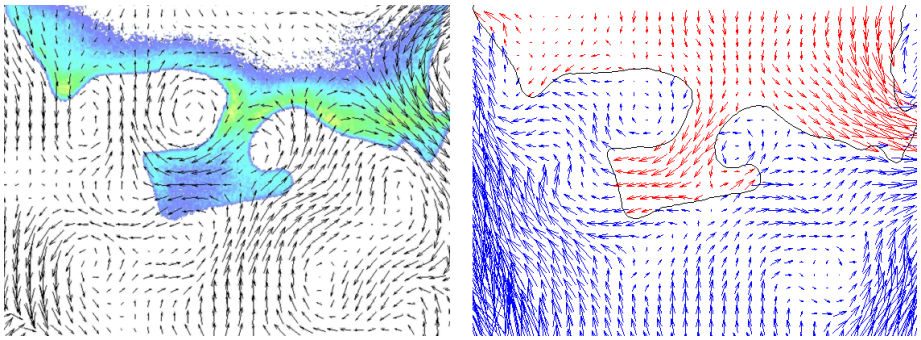
The image acquisition system is based on DynamicStudio, a comprehensive and user-friendly software platform for imaging applications. It features an advanced plug-and-play-based distributed system, making it easy for you to have full control over the hardware for image acquisition. Data acquisition as well as

analysis is supported within the same software, so there is no need to spend time exporting the data for further analysis.

With easy access to numerous numerical methods as well as quick and accurate calibration and processing methods, users will experience the benefits of working with a truly user-friendly software platform.

Numerical methods available with the software:

- Processing based on:
  - ◊ LIF signal filtering and amplification correction
  - ◊ Energy correction (including light sheet profile correction, fluence and energy budget)
  - ◊ The physics of fluorescence based on combustion radical being studied - Options include state population calculations, emission frequency, and absorption cross-section coefficient.
- Statistics on LIF images and scalar maps
- Flame Front / Phase Boundary Detection
- For combined PIV and OH LIF measurments: Flame front detection followed by high resolution velocity analysis across the flame front.



Left: A single frame from simultaneous TR OH LIF and TR PIV in a lifted flame. Right: Flame front detection using OH LIF (black line), allowing phase separated PIV analysis in the burnt (red) and unburnt (blue) regions, for improved PIV result.

The software features many automated options such as laser pulse energy correction (on each individual LIF image), hardware calibration and processing routines etc. DynamicStudio also features an Image Processing Library (IPL), which is a comprehensive “electronic catalog” of numerical methods; offering quick access to image quality enhancement, image filtering and other more advanced numerical processing to get the best possible results from LIF images. Processing is fully automated and includes macro-analysis capability (i.e. sequence of processing methods).

Boosting analysis capabilities with analysis sequences and MatLab® Link

The data analysis is further strengthened by the possibility of defining analysis sequences and performing batch processing which significantly speeds up the process of working with 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 of first exporting the data.

Animation and AVI movie creation

The acquired and/or processed image data can be browsed immediately at reduced frame rates for quick visualization of the process and evaluation of the data quality. When needed, AVI movies can be created (with full control over frame rate).

Simultaneous control of multiple systems

The modular design of the systems allows the user to control several different systems at the same time from one master computer. In this way, a combustion LIF system can be combined with a PIV system for simultaneous combustion species measurements and flow velocity measurements. Alternatively, two LIF systems can be combined to measure two species simultaneously.

Specifications

Pump laser	
Wavelength (nm)	532
Pulse energy (mJ)	9 (from 0-10kHz)
Pulse duration (ns)	<10
Repetition rate (kHz)	0-15

Tunable dye laser	
Fundamental tuning range, 2400 l/mm grating	330-740 nm
Linewidth	< 0.06 cm[1] at 580 nm
UV extension unit	External frequency doubling unit incl. 4 Pellin-Broca
Frequency doubling crystal	BBO 220-320 nm

Camera	SpeedSense Lab 310	SpeedSense 1212
Speed (fps)	3,260	12,600
Sensor resolution (pixels)	1280 x 800	1280 x 800
Pixel size (µm)	20	28
Lens mount type	F	F

Image intensifiers	H Series High-speed [1]	L Series High-speed
Maximum repetition rate	200 kHz	100 kHz
Minimum gate time	10 ns [1]	40 ns
Photocathode diameter	23.9 mm	25 mm
Photo cathode material	Multialkali [2]	S20 [2]
Phosphor screen	P46	P46

Software	
DynamicStudio	Base package
	Combustion LIF Add-on for DynamicStudio
	Liquid and Gas LIF Add-on for DynamicStudio

[1] Best choice for ultra-fast and light intensive applications such as sparks and ignition events.
[2] Both Multialkali and S20 has a wide spectral response from the ultraviolet to near infrared region.

DANTEC DYNAMICS Turn Measurements into Knowledge

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