LIF Systems for Combustion Diagnostics

Integrated and modular solutions for LIF in combustion

**Applications**

Complete image acquisition and data analysis system for diagnostics of combustion by planar Laser-Induced Fluorescence (LIF):

- Imaging of combustion radical species
- Flame front visualization
- Fuel injection and distribution
- Ignition phenomena

Typical species of interest are OH, NO, CH, CO and HCHO. On request, equipment for other species and tracers can also be made available.

**Features**

- Compact and integrated tunable dye laser and Nd:YAG pump laser systems with improved laser safety and package for narrow band laser radiation
- Light-sheet optics and on-line pulse energy monitor
- High-sensitivity CCD cameras and image intensifiers
- Synchronization electronics with ultra-high temporal precision down to the sub-nanosecond range
- Optical filters for several combustion species
- Dedicated software modules for LIF of combustion radicals and LIF of fuel tracers
- Complete integration of PIV results with camera view alignment, flux calculation etc..

**Introduction**

Dantec Dynamics’ combustion LIF system provides the necessary components for experimental diagnostics of combustion. Designed as a complete, modern and modular system, it is a unique tool for improving the understanding of combustion processes. The system is either acquired as a completely new system or as an upgrade to Dantec Dynamics’ LIF system for diagnostics of mixing and scalar transport (the latter being used to measure concentration of tracers such as acetone for fuel marking, and below 1000 K temperature fields).

Naturally, velocity information from already existing (or complementary) PIV equipment can be integrated for further advanced analyses combining combustion chemistry and fluid mechanics.

**Description**

Dantec Dynamics’ combustion LIF system utilizes a non-intrusive (optical), two-dimensional measurement method based on the laser-induced fluorescence emissions of species with short lifetimes, such as OH and NO, produced during combustion. The system consists of a sophisticated tunable dye laser with adequate light-sheet optics and pulse energy monitor, a camera equipped with an image intensifier for imaging weak UV fluorescence, advanced electronics for hardware synchronization and software for straightforward data acquisition and analysis. Through the user-friendliness of hardware and software controls and settings, the user quickly gains the full confidence to operate the system. And for data analysis, the LIF software package further helps the user to extract valuable information for a better understanding of the process being investigated.
**Laser and light sheet optical components**

**Laser light sources**
Measurements are carried out using a compact, tunable Nd:YAG pumped dye laser covering the 220-750 nm emission range. To gain the highest energy level outputs possible, the dye laser is equipped with dedicated, modular crystals optimized for UV light. These crystals (up to 5) are ordered according to the species of interest and can be added at any time for later hardware/LIF capability upgrade. The output is fine-tuned by scanning the wavelength from the lasers digital controller box, or directly from the acquisition software on the master computer, DynamicStudio.

Depending on application requirements, two laser configurations are made available. Please contact the Dantec representative in your country to determine your needs.

**Pulse energy monitor**
Nd:YAG lasers equipped with harmonic generators and dye lasers typically exhibit shot-to-shot fluctuations of the order of 2-9% and 7-25% respectively, thus greatly reducing the quality of instant planar-LIF data. Measuring the total energy delivered at every laser pulse and compensating for this during LIF image analysis is a proven method of reaching high accuracy levels.

**Beam delivery system**
Composed of mirrors mounted on a traverse system, this ingenious opto-mechanical system gives total freedom to re-direct the beam in any (X, Y, Z)-direction thanks to mirrors operated manually. Additionally, the safety cover offers a completely secure working environment when beam alignment is completed.

**Optical components**
Dantec Dynamics’ optical devices used to form UV light sheets are designed to be easily attached to the head of the laser or the beam delivery optics, making the alignment of the beam light effortless.

**Optics unit for UV and visible parallel light sheet.**
Light sheet dimensions are approx. 35 mm x 0.1 mm with a focal length of 600 mm (please refer to the related Product Information document for further information).

**User safety**
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 for your personnel.

**Imaging components**

**Camera lens**
78 mm and 100 mm camera lenses with optimized transmission for UV light are available together with an adapter ring for fitting interference filters to the selected camera.

**Cameras and Image Intensifiers**
For imaging LIF in combustion applications, Dantec Dynamics proposes the following cameras and image intensifiers:

The camera and the image intensifier are separate units, thereby allowing existing hardware systems to be upgraded to combustion applications. This solution is ideal for laboratories dealing with multiple applications such as PIV, LIF in liquid and gaseous phases including...
Combustion processes, microscopy and spectroscopy. Typically a camera from our HiSense family is selected, such as the HiSense MkII or the HiSense 610. These cameras feature highly sensitive CCD sensors with low noise levels, and work well together with image intensifiers. (Please refer to the related Product Information document for further information about these cameras)

![Dantec Dynamics' HiSense MkII camera mounted on an image intensifier unit.](image1.png)

The image intensifier units are designed for UV, VIS and near-IR applications using a broadband Multialkali photocathode in order to cover a wide range of LIF applications of different species. The units offer full control over gain and gate time options ranging from continuous to ultra-fast. Two options are available: minimum gate time, 10 ns or 3 ns. Optionally other types of image intensifiers can be provided.

Relay optics is naturally adapted to the camera and image intensifier unit.

**Interference filters**

Interference filters are delivered mounted on a ring for easy fit on the camera lens. The filters are available for measurements of tracers and combustion species. The table below gives a brief overview of the standard filters available (other filters are available on request).

<table>
<thead>
<tr>
<th>Combustion species</th>
<th>Tracers</th>
</tr>
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<tbody>
<tr>
<td>OH</td>
<td>Acetone</td>
</tr>
<tr>
<td>HCHO</td>
<td>3-pentanone</td>
</tr>
<tr>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td></td>
</tr>
<tr>
<td>CH</td>
<td></td>
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Table 1. Examples of combustion species for which detection filters are available.

**Data acquisition & synchronization**

**Imaging software platform**

The image acquisition system is based on the DynamicStudio software platform, which features an advanced plug and play based distributed system. Please refer to the separate brochure for further information.

**High-resolution synchronization unit**

Synchronization between laser pulses, pulse energy monitor(s), cameras and gated intensifier units is mastered by the timer box via the DynamicStudio software.

Optionally, a high-resolution synchronization unit with multi-channel delay and signal generators of 0.25 ns resolution is provided. Channels are programmed independently; thereby offering extended synchronization and triggering facilities for highly demanding processes.

![External synchronization unit – Digital front panel with 8 individually programmable output channels.](image2.png)

**Analog Input option**

The DynamicStudio Analog Input option is a USB solution with a sampling rate of 10 kHz, sufficiently high for imaging applications up to 30 Hz trigger rate. It features 8 individual BNC input channels, which allow sampling of analog signals in your experiment, such as laser pulse energies from the pulse energy monitor and in-cylinder pressure from a pressure transducer.

![DynamicStudio Analogue Input option.](image3.png)
Straightforward data analysis

Combustion LIF software
The DynamicStudio combustion LIF software is designed for both experienced and new users. With easy access to numerous numerical methods and quick and accurate calibration and processing methods, users get the benefit of great simplicity during image processing.

Numerical methods available with the software:
- Calibration (Tracers)
- Processing (Tracers)
- Statistics on LIF images and scalar maps
- Re-sampling
- Reynolds flux

The software features many automated options such as laser pulse energy correction (on each individual LIF image), correction for light-sheet energy profile, hardware calibration and processing routines etc.

Image Processing Library
The main package of DynamicStudio features an Image Processing Library (IPL) software, which is a comprehensive “electronic catalogue” of numerical methods, offering quick access to image quality enhancement, image filtering and other more advanced numerical processing to work with LIF images. Processing is fully automated and includes macro-analysis capability (i.e. sequence of processing methods without limit on the number of filters applied) on full image or user-defined region of interest.

(a) Raw (acetone) concentration map, (b) Noise and local aberration removed, (c) Noise removed/local aberration kept.

Boosting image analysis capabilities with analysis sequences and batch processing
Enhanced data analysis by defining analysis chains and performing batch processing. This functionality is further strengthened by DynamicStudio’s distributed analysis and distributed database.

Software add-on – MatLab® Link
With this add-on, you can design your own image analysis using MatLab scripts directly from DynamicStudio. Structured outputs, e.g. multiple images with fixed and/or floating reference image(s), are supported for PIV and LIF images, scalar maps and other types of data according to special needs.

Additional information
For additional information please contact your Dantec Dynamics representative. Please find a list of current representatives on Dantec Dynamics’ web site www.dantecdynamics.com

The specifications in this document are subject to change without notice.