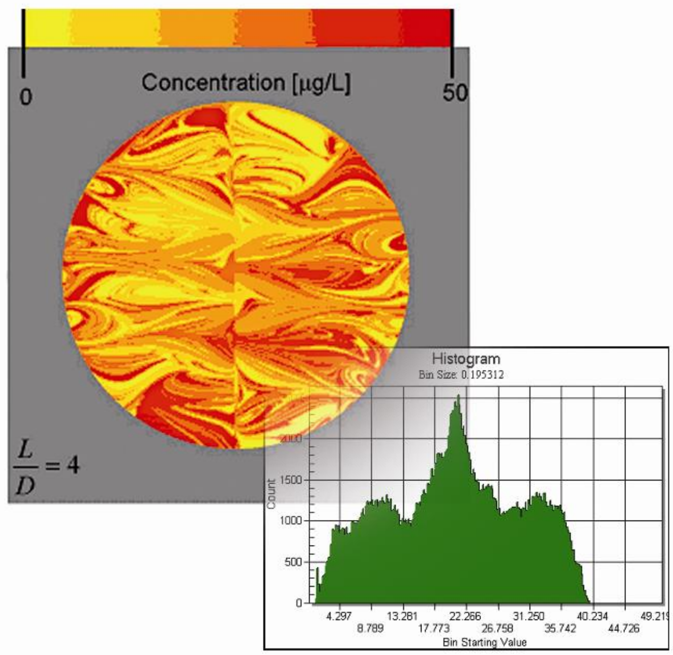
# QUANTIFICATION OF LAMINAR MIXING PERFORMANCE USING LASER-INDUCED FLUORESCENCE

APPLICATION NOTE PIV-012




PLIF measurements of mixing appear across a range of disciplines (including combustion diagnostics, fundamental turbulence and fluid mechanics, microfluidics, environmental engineering, contaminant hydrogeology, and industrial mixing processes) for a range of different flow applications (such as turbulent flow analysis, laminar mixing, IC engine flows, micron scale flows, wake flows, and injector flows). Although the measurement goals vary according to the specific application, the measured parameters are all similar in that they act.

The performance of industrial laminar mixing devices was studied using PLIF along with the *INSIGHT* 3G™ software and the PowerView™ 14-10 camera. The objective was to demonstrate the ability of the system to provide rapid, quantitative validation of mixing performance in industrial measurements. The mixer was positioned in a vertical pipe with fluids flowing upward through the device. Two unmixed fluid streams were introduced immediately below the static mixer. One fluid stream was a glucose solution seeded with Rhodamine 6G as a fluorescent tracer species, while the other stream was unseeded glucose solution. A tracer concentration of 50 µg/L was used. Separate measurements were performed to determine the binary diffusion coefficient between the unseeded fluid stream and the stream seeded with the Rhodamine 6G tracer, for comparison to CFD simulations of the mixing process.

The 532 nm output of a frequency doubled Nd:YAG was formed into a horizontal laser light sheet using a -25 mm cylindrical lens, with a 500 mm spherical lens to produce a narrow waist (thickness) of the sheet at the measurement region. The typical light sheet thickness at the measurement region was approximately 400 μm. The light sheet illuminated a horizontal cross section. Above the measurement region, the flow was diverted radially by a transparent plate. A peltier-cooled CCD camera (TSI PowerView™ 14-10) equipped with a 550 nm long wave pass filter was oriented vertically, viewing downward at the region illuminated by the laser light sheet. All hardware timing, and image capture, processing, and display operations were performed with the PLIF system software (INSIGHT 3G™ software.

Rhodamine 6G was chosen as the tracer species due to the relatively high fluorescence yield, as well as the broad absorption feature with a peak near 525 nm (near the readily available 53 2nm YAG harmonic) and emission feature with a peak near 560 nm. The raw PLIF images were corrected for extraneous background signals and were processed using calibration images captured at uniform concentration values.

The raw PLIF images were corrected for extraneous background signals and were processed using calibration images captured at uniform concentration values. An array of statistical properties, such as concentration histograms, line profiles, and COV were calculated for a range of mixing lengths, with clear indication of the change in the extent of mixing. Because the dominant structures in this flow were preferentially oriented parallel to the limiting dimension (perpendicular to the light sheet plane), the spatial resolution of the PLIF measurement was increased beyond the 400 μm thickness of the laser light sheet. Fluid layers as small as 200 μm to 300 μm were observed. The non-dimensional mixing length, L/D, was varied from 4 to 8, and changes in the concentration field were examined. The coefficient of variation decreased from 0.46 to 0.073 as the mixing length increased from 4 to 8, and the minimum thickness of the fluid layers decreased from above 1 mm to less than 400 μm.

(Courtesy Sulzer Chemtech Ltd.).

## Reference

Pust, O., Strand, T., Mathys, P., Rutti A.;"Quantification of laminar mixing performance using laser-induced fluorescence," *13th Int. Symp. on Appl. Laser Techniques to Fluid Mechanics,* Lisbon, Portugal, June 26–29, 2006.

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