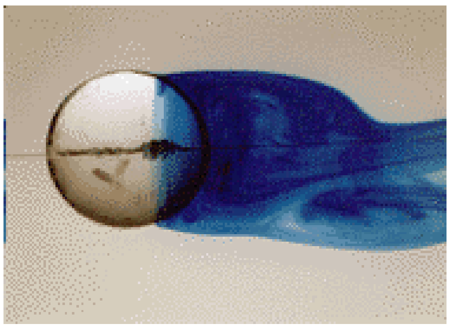
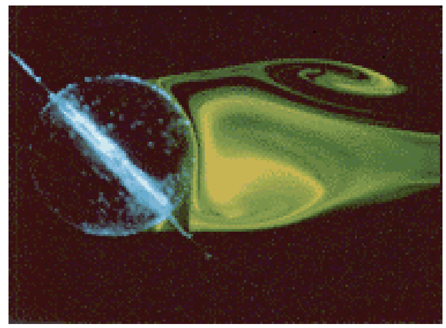
Laser-Induced Fluorescence (LIF)

Fluorescent dyes (molecules) can absorb light at one frequency and subsequently re-emit (fluoresce) light at a different frequency. In experiments, the dyes are excited by laser light whose frequency closely matches the excitation frequency of the dye. For example, Fluorescein (maximum excitation at 490 nm) is best excited by an Argon-Ion, Blue-Green laser which predominantly emits wavelengths 488 (blue) and 514 (green) nm. Once excited, Fluorescein's maximum emission is at 520 nm. Because the fluoresced light is of a different frequency than the excitation light, the latter can be filtered out. Furthermore, only the dye that is exposed to the laser fluoresces, so specific planes within a flow field can be visualized.



Blue Dye



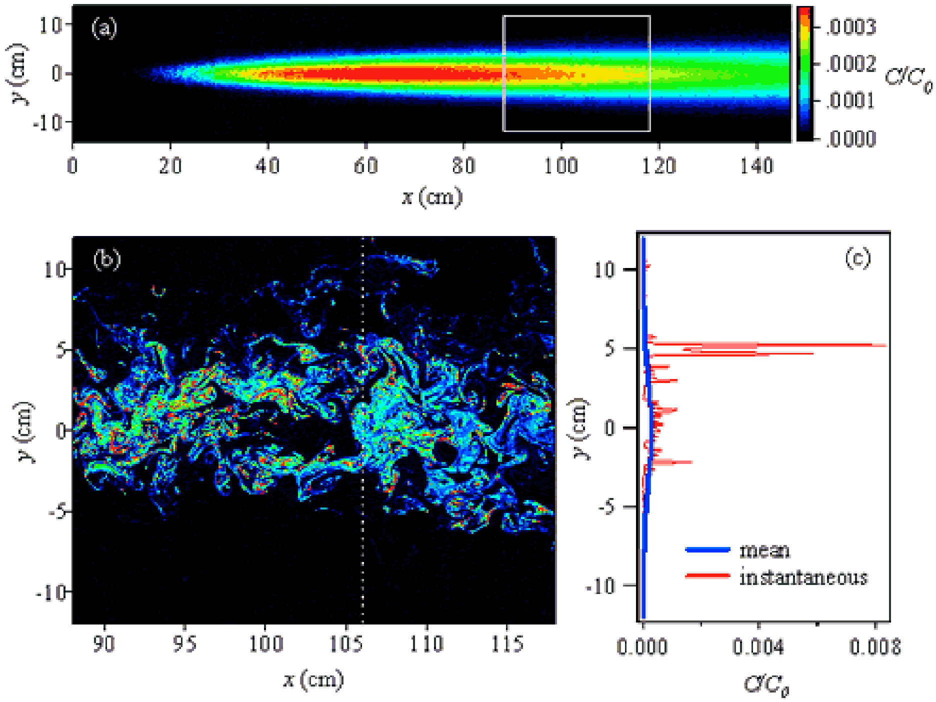
Fluorescent Dye

Comparison of a planar visualization, accomplished with LIF, to a volumetric visualization accomplished with a non-fluorescing blue dye. From V. C. Patel & T. A. Johnson http://www.iihr.uiowa.edu/projects/low_reynolds/

To illuminate the specific plane, the laser beam is expanded into a sheet using either a cylindrical lens or a scanning mirror. The cylindrical lens produces a light sheet with a Gaussian profile of light intensity. The scanning mirror produces a light sheet with a uniform profile of light intensity. This difference is important, if quantitative estimates of dye concentration are desired, as described below.

The intensity of light emitted from a dyed region of flow is proportional to the intensity of excitation energy and to the concentration of dye. If the excitation energy is locally uniform, then the emitted light intensity will be linearly related to the dye concentration. Then, with a simple calibration the emitted light intensity can be directly converted to dye concentration. Two conditions affect the spatial uniformity of the excitation intensity. First, as described above a light sheet constructed from a scanned beam will be more uniform than that constructed from a cylindrical lens. Second, the intensity of the laser sheet is diminished as it passes through and is absorbed by dye. This is called quenching. Quenching can be minimized by limiting the extent of the dyed region and by using an excitation source whose intensity is sufficiently large compared to the potential quenching, so that any quenching that occurs generates only a small change in overall excitation intensity.

As shown in the figure below, the images resulting from LIF contain significant spatial detail of the concentration field that reveals physical structure. Averaging over several image frames reveals the expected Guassian structure of the mean concentration plume. Instantaneous images reveal the spatial and temporal scales of the turbulence.



Plume structure visualized using planar laser-induced fluorescence.
(a) mean structure, (b) instantaneous structure, and (c) instantaneous slice

From Analysis of Spatial and Temporal Structure in Turbulent Plumes, Prof. John Crimaldi, University of Colorado http://ceae.Colorado.EDU/~jcrimald/research/spatial.html

Other LIF examples
http://www.efluids.com/efluids/gallery/eddies.htm
http://ojps.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=PHFLE6@stand/S9_1.pdf&idtype=standpdf
http://www.efluids.com/efluids/gallery/wing.htm
http://ceae.Colorado.EDU/~jcrimald/research/spatial.html
http://www.efluids.com/efluids/gallery/vortex_dislocate.htm
http://www.amath.unc.edu/faculty/rmm/vortex2.jpg
http://www.lehigh.edu/~fluids/tjp3/flowpics/fluoresce.jpg
http://www.visiblesolutions.com/gallery2.html
http://www.amath.unc.edu/faculty/rmm/digital_pics/jet.JPG

Studies using LIF
http://www.egr.msu.edu/~huhui/research/lif-piv-lobe/lif-piv-lobe.html
http://ceae.Colorado.EDU/~jcrimald/research/spatial.html
http://www.fluid.tue.nl/WDY/vort/vortrings/vortrings.html

Additional References for LIF
Ferrier, A., D. Funk, and P. Roberts. 1993. Application of optical techniques to the study of plumes in stratified fluids. *Dyn. of Atmosph. Ocean.*, **20**:155-183.
Guilbault, G. 1973. Practical Fluorescence. New York: Marcel Dekker, Inc.
Hannoun, I. and E. List. 1988. Turbulent Mixing at a shear-free density interface. *J. Fluid. Mech.*, **189**:211-234.

Walker, D. 1987. A flourescence technique for measurement of concentration in mixing liquids. *J. Phys. E: Sci. Instr*., **20**:217-224.