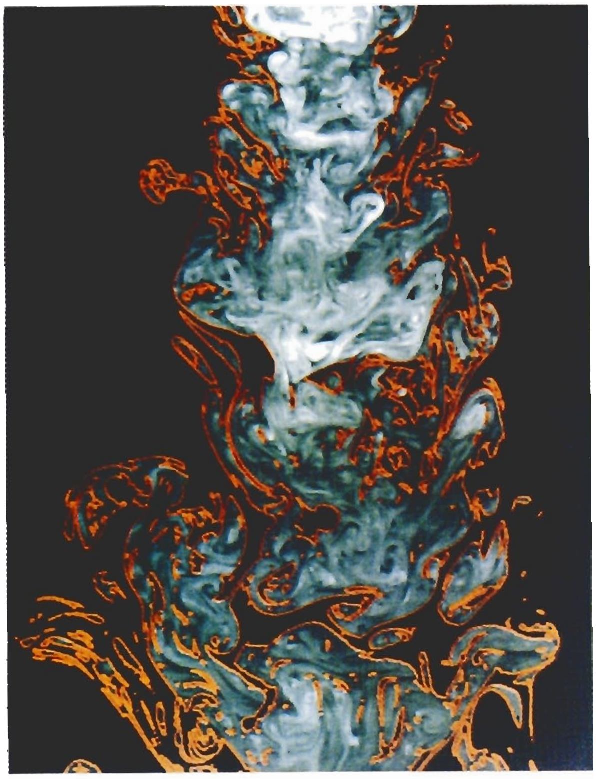

Figure 1

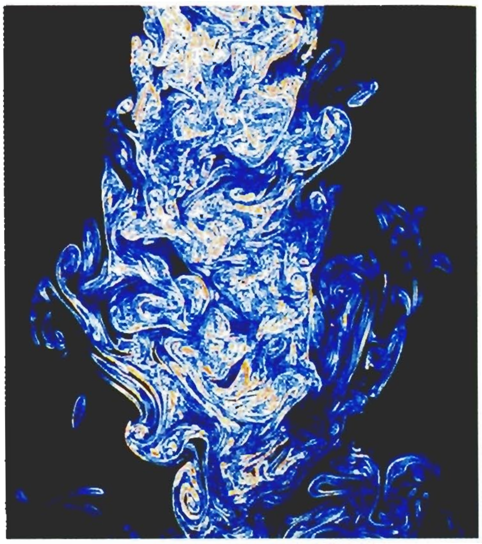

Figure 2

Figure 3

FRACTAL FACETS OF AXISYMMETRIC WATER JETS

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Laser-induced fluorescence (LIF) can be used as a powerful tool for visualization of fluid flows. It provides quantitative information regarding the concentration of the fluorescing dye. If the dye is mixed by turbulence, the fluorescence can be thought of as marking regions of turbulence. As used here, LIF visualization involves illuminating a thin two-dimensional section of the fluid flow (doped with a fluorescent dye) by a sheet of light from a pulsed Nd:YAG (pulsed) laser. The resulting fluorescence, if not saturated, is directly proportional to the concentration of the dyed fluid. This technique has been used here to visualize axisymmetric water jets. In these experiments, the laser sheet was 200–250 μm thick and the nozzle Reynolds number about 4000. The fluorescence intensity was imaged using a 1300 (axial) $\times$ 1000 (radial) pixel array. Figure 1 shows such a visualization on a plane along the jet axis. The visualized region extends from 8–24 diam downstream of the nozzle, with each pixel corresponding to a flow volume of $150 \times 150 \times 200\ \mu m^3$. The Kolmogorov scale was estimated to be of comparable size. The boundary between the jet and tank fluid can be calculated by setting an appropriate threshold on pixel intensity. This boundary (marked in red) is also shown in Fig. 1. Its fractal dimension is 1.35 and the scaling range is on the order of 1.7 decades. Similar LIF visualizations have also been made along other planes.The boundaries of such pictures, as well those of other flows similarly visualized, are also 1.35, leading to the conclusion that this number is a general property of turbulent flows. Broad arguments to this effect can in fact be constructed.[6]

One of the useful quantities that can be obtained from LIF visualizations is the "dissipation" field of jet fluid concentration. Figure 2 shows the "dissipation" field in a jet section similar to Fig. 1, but extending only from 8–18 diam downstream of the nozzle. The "dissipation" field of concentration is approximated by the sum of the squares of the concentration gradients in two orthogonal directions. It is color coded to range from deep blue through red as magnitude increases. This "dissipation" field can be described quite well by a multifractal, which is merely an interwoven set of many homogeneous fractals; the array of generalized (or Renyi) dimensions and the singularity spectrum for this multifractal have been measured.[7]

Individual concentration gradients may also be computed using LIF visualizations. Figure 3 shows the calculated concentration gradient along the streamwise direction for the jet section from which the "dissipation" field shown in Fig. 2 was constructed. It is color coded such that red indicates positive gradients, black indicates negative gradients, and white indicates zero gradients. The apparent three-dimensional effect in this figure is probably due to the color contrast between red and black.

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