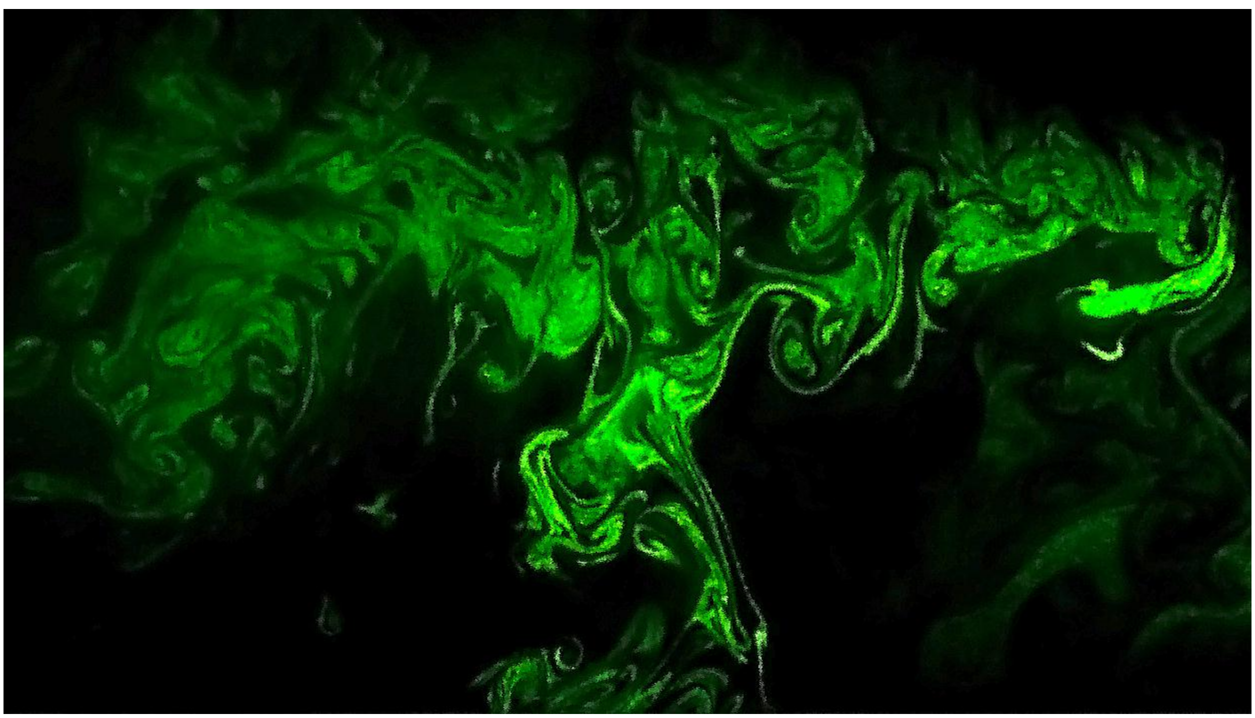
FLOW VISUALIZATION

Turbulent Laser

Utilizing Lasers to Image Turbulent Jets

Kyle Manhart

4/5/2011



The photograph was taken for the second group project assignment for the Flow Visualization 2011 course. The objective of the photo was to capture the cross section of a turbulent jet in an effort to better understand the physics involved with the flow. The group hoped to capture the cross section of a turbulent jet shot directly upward by shooting a laser sheet through the flow in a dark room. Multiple variations were considered with several of the ideas being implemented. Initially, the jet was to be created by shooting a jet of fog from a fog machine through the laser sheet.

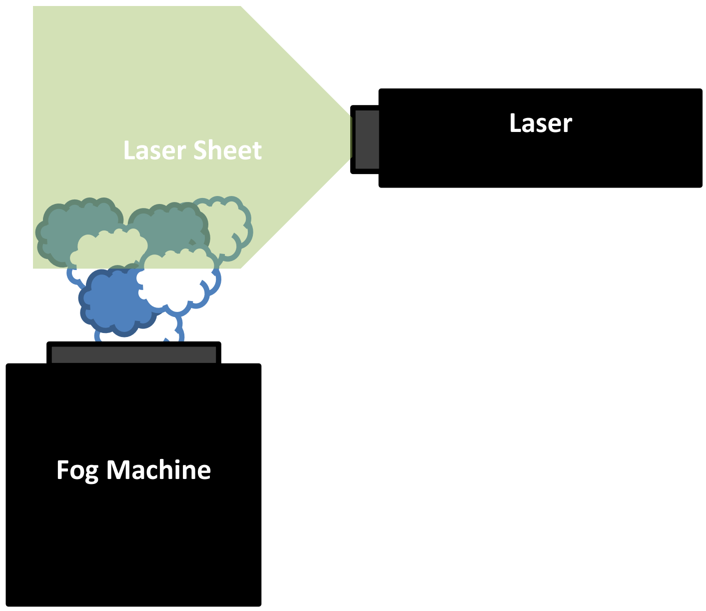


Figure 1. Jet shooting up through laser sheet diagram.

This produced too much fog in front of the sheet causing blur of details and giving little useful information. The fog machine was re-orientated to shoot into the laser sheet rather than from the bottom. The apparatus consists of a laser set on a horizontal surface, table, with the rest of the setup designed this positioning. Due to the cost and fragility of the laser against the other components the laser was never moved. The fog machine was set slightly below and to the left and therefore did not shoot directly perpendicular to the sheet. The fog machine was place approximately 1.2 meters from the sheet and the jet was controlled utilizing the fog machine control panel to manually control burst length.

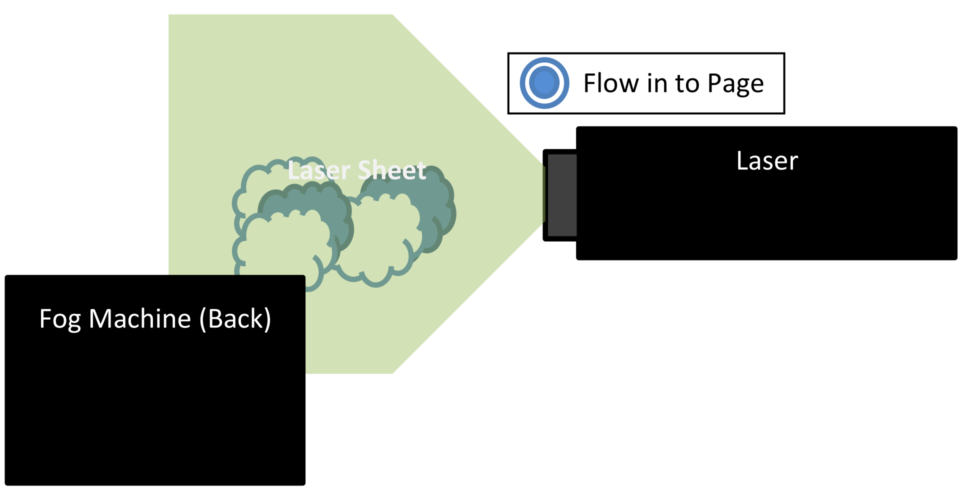


Figure 2. Jet shooting perpendicular to sheet diagram.

Black surfaces were used to capture the laser so as to prevent reflections as this posed a serious danger to those producing the image. Additionally, the laser safety manual should be referenced for proper safety and operations instructions. The laser contains two lasers, for this experiment laser one was utilized. To create the laser sheet, 15mm, 25mm, and 100mm spherical lenses were implemented from the laser in that order to produce a .610 m sheet .660 m from the lense.

Whenever a moving fluid enters a quiescent body of a second fluid velocity shear is created between the two fluids. This shear produces turbulence and mixing within the fluids. Turbulent jets depend on the geometry of the flow domain and the forces acting on the fluid. Generally the envelope of the turbulent jet adopts a conical shape and therefore the radius is proportional to the radius. Because of this the opening angle is almost always constant, approximately 11.8^o thus producing 24^o from side to opposite side. The proportionality constant is then calculated as tan(11.8^o)≈1/5.[1]

$$R(x) = \frac{1}{5}x$$

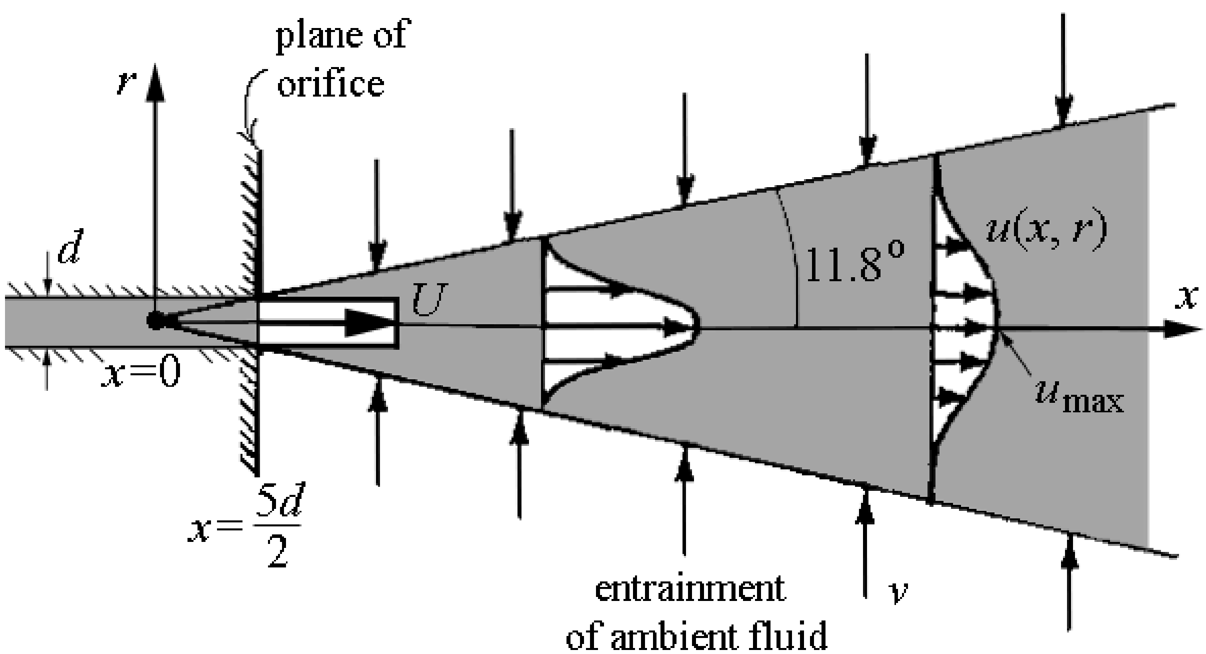


Figure 3. Diagram of turbulent flow.[1]

. The initial jet radius is not zero and so to account for this the initial jet radius is equal to one half the exit diameter and is referred to as the virtual source. X is then calculated a distance 5d/2 into the conduit. The average velocity of the jet can be estimated utilizing the following relationship.[1]

$$u_{average} = \frac{5d}{2x} U^{[1]}$$

Where U is the velocity at the orifice exit. This value was un-obtained in testing but is estimated to be approximately 20 m/s with an exit velocity of 30m/s. A Reynold's number over 10^5 is considered turbulent. Estimating the Reynold's number for this flow at the orifice outlet gives the following.

$$Re = \frac{\rho VD}{\mu} = \frac{7.8*30*.16}{1.571E-5} = 2{,}392{,}979$$ [2][3]

The technique used to capture the image was to utilize a laser sheet to capture the cross sectional of a fog turbulent jet. The laser was fired on the lowest power setting for safety purposes and a black backdrop was used to capture the laser and reduce reflections. All polished surface were covered with black masking tape and all jewelry was removed. No lighting was used yet some ambient light entered the room through a covered glass door. This was located behind the camera, the camera was between this light source and the laser. Between the camera and the laser was the fog machine shot from below the camera into the laser plane. This allowed for a photo with minimal noise in from of the sheet. In this case noise represents fog in front of the sheet reflecting light producing a green blur.

The photograph was taken from a video captured utilizing a resolution of 1280x720 capturing 30 frames/second. The image was cropped in Photoshop and the contrast along with the sharpness was increased. The color curves were also used to bring out the green in the photo. The image displays the vortices common to turbulent flows in various sizes and shapes. It also shows different levels of contrast hinting a various layers and informing the viewer of the direction of flow, into the page. I like the color and how the image displays the physics. In order to produce a better visual of a turbulent jet, I would implement a smaller jet shooting upward through the laser screen so as to reduce noise.

[1] Cushman-Roisin, Benoit. "Turbulent Jets." *Thayer School of Engineering at Dartmouth*. Dartmouth College, 03 2010. Web. 5 Apr 2011. <http://thayer.dartmouth.edu/~cushman/books/EFM/chap9.pdf>.

[2] "Reynolds Number." *Reynolds Number for Pipe*. Engineering Toolbox, n.d. Web. 5 Apr 2011. <http://www.engineeringtoolbox.com/reynolds-number-d_237.html>.

[3] Cengel, Yunus A. *Heat & Mass Transfer*. International. New York: McGraw-Hill, 2003. 854. Print.