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Team 5 Project 2

Laser Sheet

In this project we set out to utilize laser sheets to reveal flow dynamics in fog. The original goal was to cut a turbulent plume of fog down to two dimensions by illuminating a plane with a high-powered pulse laser. This lead to exploration of what was possible to visualize with the laser sheet and eventually included vortex rings and ambient flow around a calm room. Our group utilized Professor Hertzberg's flow visualization laboratory and equipment to create these images and videos. This provided us with an ideal location to create a range of flows in a controlled environment with precision equipment. The results were nothing short of spectacular; we were rewarded with extremely fine time and spatial resolution in videos that captured the motion and physics of the flow superbly.

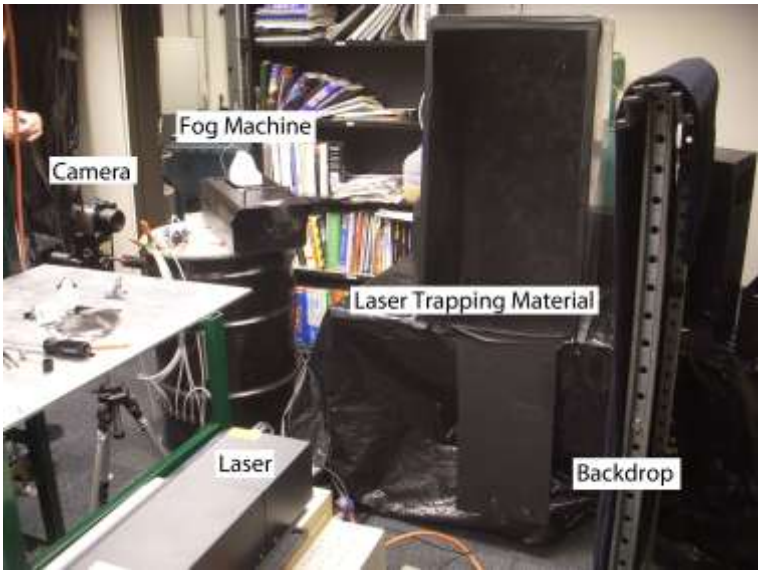

figure 1

The setup consisted of an enclosed room to shoot in, a laser, and a fog machine. For safety reasons laser trapping material was necessary. A backdrop was added to ensure a neutral background for shooting. These elements were placed as shown in Figure 1, though the fog machine was moved to the floor and shot upwards at an angle in the final setup. As seen in the figure the laser was placed upon a table and aimed at the laser trap to ensure that no strong specular reflections would be encountered. The fog machine was aimed upwards at a 45% angle shooting perpendicular to the laser to reduce the possibility of damage to the laser.

This setup allowed for a range of flows to be produced in the area between the laser and the laser trap. In this open space we were able to produce turbulent plumes by firing the fog machine upwards into the plane of the laser, vortex rings by firing a ”Mighty Blaster” by Zero Toys into the plane of the laser, and ambient room flow by simply allowing residual fog in the room to move naturally across the plane of the laser. The laser plane was created by placing +1000mm, -15mm, and -25mm lenses on the laser. As the sheet continued to grow as it moved away from the laser. The final field of view in the video was only a section of this sheet, approximately 18 inches wide and 13.5 inches tall.

Within this plane it was possible to create the three different, unique flows. The first of these flows was the one decided upon to be visualized for this project: the turbulent plume. At its core this is a basic flow, nothing more than a jet of fluid through a nozzle into a less turbulent space. While the formation of such a flow is simple the physics behind it are complex and varied. This can be seen in the chaotic nature of the flow, many different eddies are superimposed on one another and interact in a

spontaneous and unstable configurations. The result is a highly complex system of eddies and vortices which become unstable and dissipate as quickly as they form.

The next flow that was observed was the vortex ring. This is a classic flow visualization phenomenon known widely as a smoke ring, though it can be formed out of other mediums as well. The vortex ring was generated using a "Mighty Blaster" from Zero Toys. This device uses a piston to accelerate a column of air through a smaller opening. As the air passes through into open air it is endowed with forward motion from the piston and is also imparted with curl from the lip of the opening.

A column of air is pushing forwards through the center of the ring, moving it forwards. Inertial forces dominate this mechanic. A shear force is also acting along the outside of the ring, pushing it in the direction opposite of propagation. This induces more curl, spinning the outside of the ring into its distinct shape. The ring is formed by the combination of these elements, creating almost a 3 dimensional eddy, symmetric about the axis through the center of the ring. As the ring moves forwards air is pushed through the center of the ring and is subsequently pushed backwards by viscous shear forces, curling it back into the center column. This process is happening constantly as the ring moves forward and it will hold its shape until it slows down enough to become unstable.[1]

The final flow captured in the submitted video was laminar flow in a room. This was captured after a series of plumes had been fired into the laser, and was comprised of residual fog moving lazily about in the plane of the laser. While small eddies did form in this flow, most likely from the motion of individuals moving around the room, the majority of the flow remained smooth and laminar.

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1 "Vortex Ring Formation." UM Mathematics. Web. 05 Apr. 2011.

To ensure that these flows were entirely visible the laser sheet was utilized. This consisted of passing fog through the plane of the laser in any of the aforementioned manners. A fog machine that is available in the flow visualization laboratory produced the fog for this project. To ensure optimal performance and longevity the machine was cleaned, used, and then cleaned once again. The fog produced was nearly neutrally buoyant, as the particles were denser than air but they were at an elevated temperature after being vaporize in the fog machine. The temperature in the lab was approximately 20°C. The lighting was achieved solely through the use of the laser, which was set on low power and fired at approximately 10 Hz. This provided substantial lighting once the lab's lights had been turned off.

To capture the flow a Panasonic Lumix FZ35 was used. This 12.1 megapixel camera has a 27-486mm wide-angle 18x optical zoom. When used for recording, the product was a 3-megapixel resolution video for an overall size of 1280x720 pixels at 30 frames per second. This camera was set up on a tripod approximately 24 inches away from the laser sheet. No data was taken for the aperture, focal length, shutter speed, or ISO settings. Final Cut Pro was used to edit the various clips that were shot. The effects I used consisted of speed manipulation, color keying, and dissolves.

I am happy with the flow that was displayed and feel that the video captures the flow phenomenon quite nicely. I was originally caught off guard with the pulsing nature of the laser, but the effect gave flicker like feel to the work that I grew to love. Editing the film came together quickly and I produced the sound in a short amount of time. Capturing the laser properly took time and a group effort, but I feel that we successfully accomplished this task.

If I were to try and improve this video I would spend more time editing to fine tune some of the transitions. I was in China shortly after filming so I was unable to devote enough time and attention to the project, but I did the best I could considering the constraints set upon me. I would have also liked to use other lasers that produce a more steady beam of light. Perhaps a better delivery method for the fog would also improve the final product. I am still pleased with the results regardless of time constraints or difficulties with equipment.

Works Cited

1. "Vortex Ring Formation." UM Mathematics. Web. 05 Apr. 2011. <http://www.math.lsa.umich.edu/~krasny/vortex_ring.html>.