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Team Image 3
Flow Visualization
23 April 2013

Laser Sheet Vortex Rings:

Purpose:
This image was created for the third team image in flow visualization. Alex Meyers and I choose to help each other create our images for this project so that we could create an interesting image. The original intent for this project was to sync the pulse of the laser with the frame rate of the camera so it would seem that the laser was providing a continuous sheet. We wanted to make a video of vortex rings as well as convection patterns in the room. The flow patterns of vortex rings and the wake they generate are really impressive and we wanted to capture the activity in a 2-D version in the laser sheet.

Experimental Setup:
The image was taken in Professor Hertzberg's lab on the University of Colorado campus in the basement of the Mechanical Engineering wing. The materials used were a vortex ring generator, stage fog machine, and a Solo PIV Nd: YAG laser [1], laser light traps, and an oscilloscope. We connected the oscilloscope to the output of the laser console and read the waveform. We could tune the frequency of the lasers between 0 and ~15.4 Hz. First we tuned the laser pulse frequency until it read 15 Hz and then we turned on both lasers so that the combined pulse rate was 30 Hz. Then we began to film with the camera shooting at 30 frames per second. Unfortunately the frequencies did not match up and the camera would "scan" each time a bright vortex ring entered the frame. This resulted in a black bar across the video every time a ring came through the video and thus the flow could not be visualized. From past groups in flow visualization we saw that people filmed vortex rings but the pulsing nature of the light seemed distracting to view the phenomena. Unfortunately we could not get a video that appeared to be continuous with the laser.

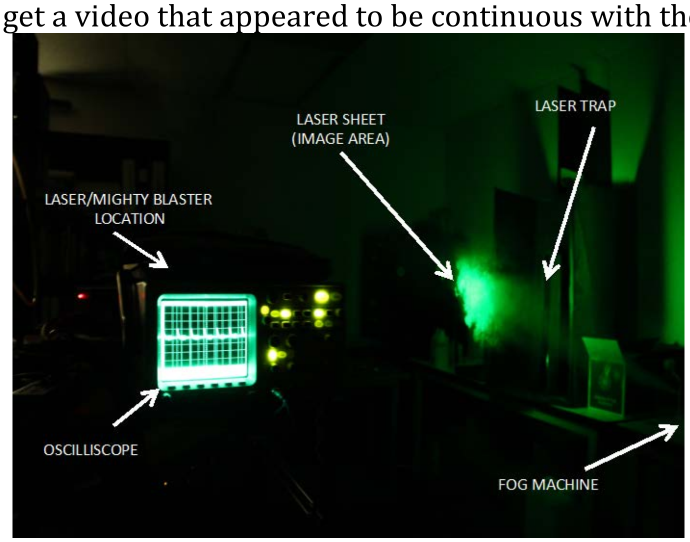

Figure 1: Experimental Setup

We then switched our experiment to just capture the vortex rings with still images using the camera. Stage fog was blown continuously through the laser sheet to focus the camera in the right location for the fog rings. Next the Zero Toys Mighty Blaster [2] fog cannon was filled with the stage fog machine. The fog was shot from the upper left corner of the laser console into the sheet and it would hit the laser trap at the end. Several shots could be fired with the Mighty Blaster fog cannon before more fog was required. It was difficult to capture the ring in the fog because about 50% of the time the camera would shoot while the laser was off and there was no light.

The translational motion of the vortex ring is perpendicular to the profile of the ring. The vortex ring generated by the Mighty Blaster is caused by pushing the fluid through the barrel of the toy. The walls of the barrel interacting with the moving fluid initiate the ring motion and it is propagated when it reaches the open air. [3] Vortex rings are self-inducting because each part of the ring tries to get the other parts of the ring to rotate around it. Each part of the ring moves forward at the same translational speed. [4] One interesting thing about vortex rings is that unless they are perfectly spherical they will fluctuate shapes. For example, if they are elliptical, they oscillate between the major and minor axis. [5] This is because the higher curvature parts move faster than the small curvature parts. This is why vortex rings translate faster as the ring diameter decreases. [6] The mathematics behind vortex rings is quite complex but I think the qualitative physics behind the rings is shown quite well in the photo.

Visualization Technique:
The flow was visualized using stage fog and a laser sheet. The fog marked the fluid motion. The laser had high interaction/scattering with the stage fog particles and no interaction with the room air. The light scattered off of the stage fog and marked the vortex ring and the resulting wake. The fog machine and fog juice were acquired from Professor Hertzberg in her lab. The lights in the room were off and it was completely dark. The only light in the room was the pulsing laser that only illuminated the stage fog. There was no flash used to create the pictures.

Photographic Technique:
The field of view in the original photo is approximately 2.5 x 3 ft. The distance from the object to the lens is approximately 2.5 ft. The focal length of the lens was 25.0mm. The photo was taken with a Canon EOS 60D digital camera. The original image is 5184 x 3456 pixels; the final photo is 2056 x 1128 pixels and both photos are shown in the figure below. The camera settings for the photo were shutter speed 1/15 s, manual exposure, F-Stop f/5.0, and an aperture of f/5.0, ISO 500. Since the vortex ring was so faint, post processing was very important to visualizing the fluid flow. I used the curves command in Photoshop to increase the contrast in the photo. Since it is a laser and only produces a certain wavelength of light it was easier to adjust the contrast and keep the background completely black. I used the noise reduction tool in the photo and I also increased the saturation. It took a lot of time to process the image how I wanted it and I wish I had more Photoshop experience to manipulate the original image.

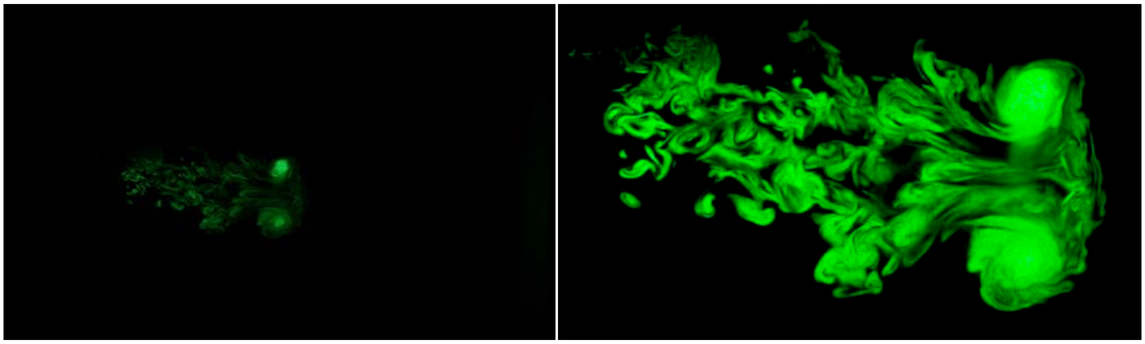

Figure 2: Initial and Final Images

Conclusion:
I am quite proud of the final product of this project. I think it is a very interesting visualization of a 3D Vortex ring sliced into a 2D photograph. I'm glad that I was able to capture the turbulence in the vortices in the rings as well as the resulting wake. I think the rotation of the vortex ring and the translational motion is very apparent even though it is a still photo. If time permitted I wish we could have tuned the frequency of the laser to the frame rate of the camera. We were so close but could not figure out why the camera would scan when a ring passed through the frame. The vortex rings looked so cool in the photo and it was really interesting to watch it propagate through the space so I wish I could have captured a video of the photo.

References:

[1] New Wave Research. "Solo PIV Nd: YAG Laser System Operator's Manual." New Wave Research, Jan. 2005. Web. 22 Apr. 2013.

[2] "ZeroToys.com - Manuals." *ZeroToys.com - Manuals*. N.p., n.d. Web. 29 Apr. 2013.

[3] "Vortex Ring." *Wikipedia*. Wikimedia Foundation, 26 Apr. 2013. Web. 29 Apr. 2013. <http://en.wikipedia.org/wiki/Vortex_ring>.

[4] Hertzberg, Jean, Dr. "Vortex Dynamics. Spatial and Temporal Resolution Part 1." *Flow Visualization: A Course in the Physics & Art of Fluid Flow*. University of Colorado, n.d. Web. 29 Apr. 2013. <http://www.colorado.edu/MCEN/flowvis/course/Lecture2013/11.Vorticity-Resolution1.pdf>.

[5] Dhanak, M. R., and B. DE Bernardins. "The Evolution of an Elliptic Vortex Ring." Imperial College, London, n.d. Web. 29 Apr. 2013. <http://journals.cambridge.org/download.php?file=/FLM/FLM109/S0022112081001006a.pdf>.

[6] Helm, J. L. "What Is the Speed of a Perturbed Vortex Ring." Newcastle University, n.d. Web. 29 Apr. 2013. <http://research.ncl.ac.uk/quantum-fluids/files/helm-mmath.pdf>.