Visualizing Turbulent Flow Using Stage Fog and Sheet Lasers

11/19/25 - Team Third

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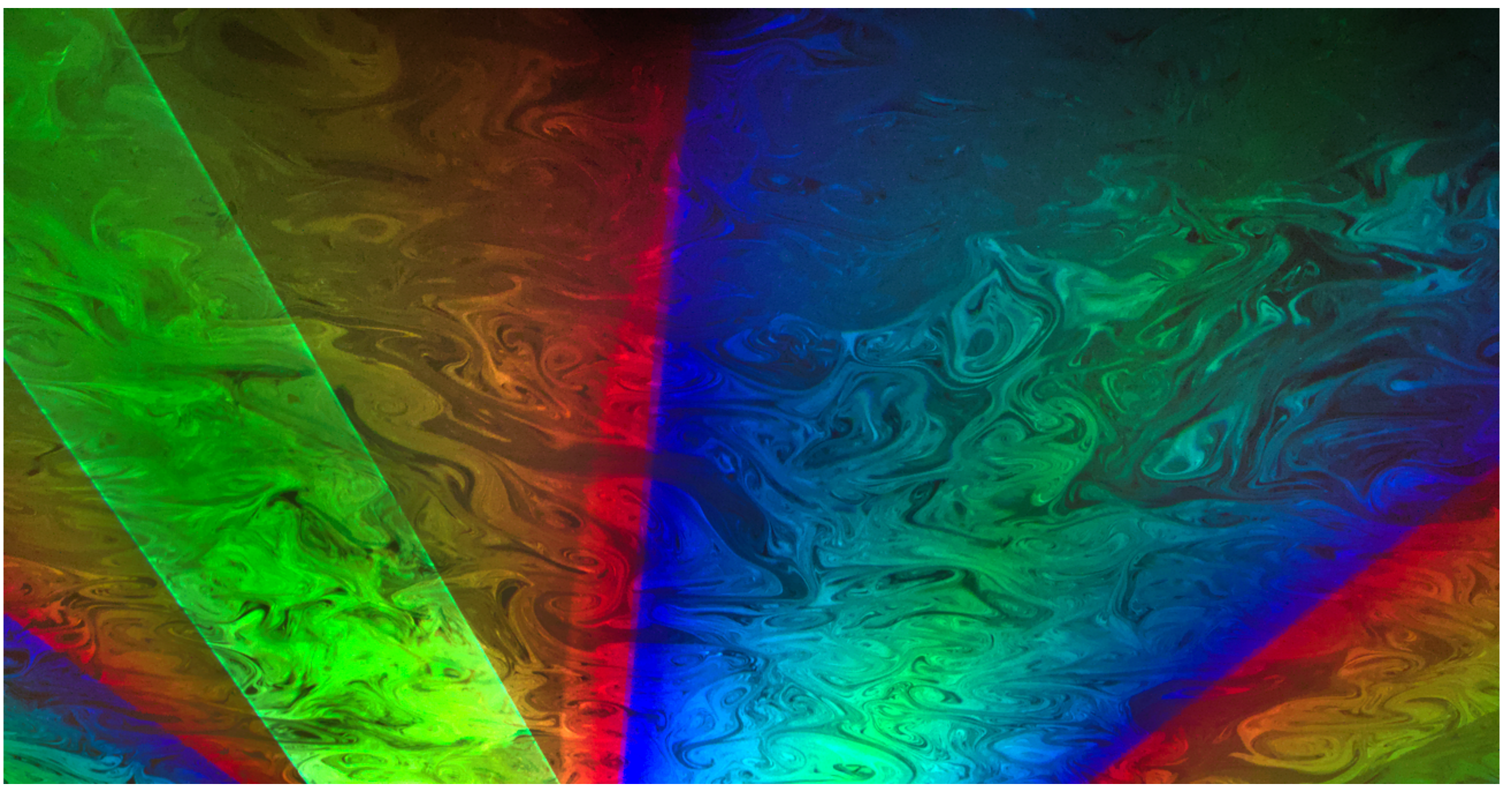
Flow Visualization - 002



Introduction

The purpose for this image was to capture the flows in the air around us every day. The photo was taken for the Team Third assignment for Flow Visualization, and was made in partnership with my teammate Cody Popelka and with help from Jeremy Osowski from Fiske Planetarium. Thanks to him Cody and I were able to come to Fiske for some time to take photos while Jeremy worked the fog machine and ran the patterns that the lasers were showing.

Flow Apparatus

The apparatus for this flow was quite large in technicality. The entirety of Fiske Planetarium was used to visualize the turbulence in the air around us by filling it with fog and illuminating that with powerful sheet lasers. Jeremy ran the lasers and played around with cool color combinations and shapes while Cody and I moved around and snapped pictures of anything and everything for approximately an hour.

Flow Physics

This experiment was extremely interesting because it showed in vivid detail what flows are happening around us constantly. The fog particles are so small and light that they follow any flows in the air very closely, meaning that the patterns seen in my image are happening in every room, building, or enclosed area you're ever in even though they aren't usually visible to the naked eye. The main phenomenon that is revealed with this imaging technique is turbulent flow, which we can quantify using the Reynolds number:

$$Re = \frac{\rho \nu L}{\mu} = \frac{VL}{\nu}$$

- Characteristic length (L): 10 - 20 m
- Bulk Air Velocity (V): ~0.05-0.3 m/s
- Dynamic viscosity of air (ν): $\sim 1.5 \times 10^{-5}$ m^2/s

Using these numbers, which unfortunately have a large variability because of the scale and large number of factors that contribute to the flow, I calculated the Reynolds number to be between 33,000 and 400,000. These numbers show that the flows that can be seen are fully turbulent, since Re >> 4,000. Because the Reynolds number is so high, it tells us that the viscosity plays very little role in the formation of flow phenomena. The Reynolds number can also be used to tell us the Turbulent Cascade scales using the following equation:

$$\frac{L}{\eta} = Re^{3/4}$$

Where L is the largest length scale and η is the Kolmogorov Microscale. This value ranges from 460:1 at Re = 30,000 up to 2,500:1 when the Reynolds number is 400,000. These scales mean that the flow has a rich energy cascade, where large circulation patterns break down into progressively smaller eddies until the viscosity to flow-scale ratio is large enough to finally dissipate them at the Kolmogorov microscale.[3,4]

- Time resolution = 1/30 second
- Spatial resolution = (0.05m/s) * (1/30 s) = 1.7 mm **-or-** (0.3m/s) * (1/30 s) = 1 cm

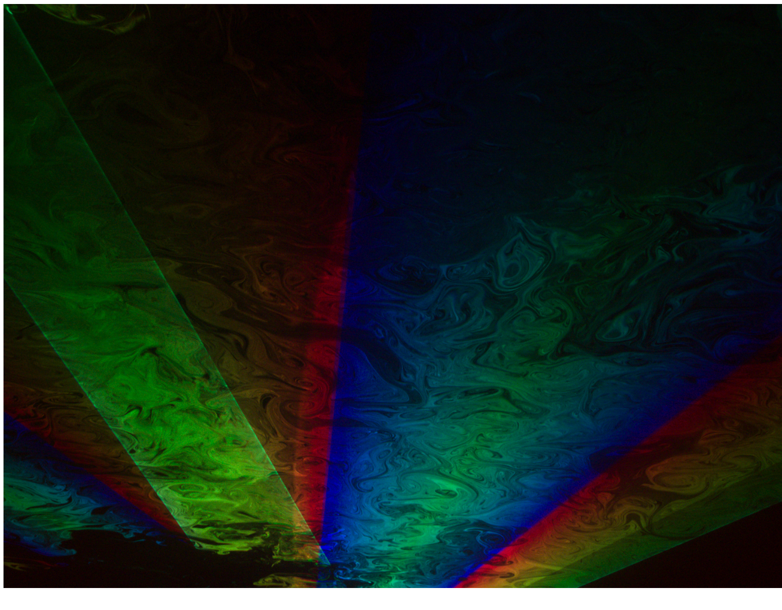
Visualization Technique

The visualization technique that was used to create this image was a marked boundary technique. For a visualization like this you need to have 2 fluids of similar densities, each with a distinct color. In the case of the photo I took, the two fluids are air and stage fog (which is just small aerosolized particles suspended in air), and since the stage fog refracts light it glows brightly when hit by a laser sheet. Since the fog glows and the air doesn't, you can clearly see the boundaries between tons of individual flow cells. For this specific experiment the environment it is conducted in plays a huge role in the kinds of flows that will be seen. In Fiske Planetarium the air is relatively still, only being disturbed by slight jets from climate control vents and the small movements of the three people in the room. This minimal disturbance allowed the lasers to show flow figures as they change over long periods of time.

Photographic Technique

To take this photo the Olympus OMD E-M5 MKii was used, along with the M.Zuiko 14-42mm f/3.5-22 lens from Olympus. The below settings were chosen in order to guarantee that the laser sheet was in focus, while reducing the rolling shutter effect.

- ~5 feet from laser sheet "surface"
- Digital Mirrorless
- 4639 x 3471 px original
- 4640 x 2401 px post-crop
- f/10.0, 1/30 s, ISO 2000, ~40° FOV
- Editing: Crop, Exposure, Tone Equalizer, Profile Denoise



Analysis and Possible Improvements

This image is easily the one that I am most proud of this semester. The bright colors are incredibly interesting to the eye, the flow phenomena are shown extremely crisply, and having it fill the entire image gives a watercolor-like effect. The thing that I think really sets this image apart from the other pieces that I've produced is that there is next to zero editing done to the colors, only lowering the darks slightly to highlight the vortices within the turbulent flow. If I were to redo this experiment I would want to make sure my camera is on burst mode, and possibly attempt to find a way to take images with an even higher f/ to hone in the focus even more. The one hurdle with doing this is balancing the exposure, since a smaller aperture lets in much less light, a longer shutter speed could introduce motion blur, and increasing ISO too high can lead to unwanted noise throughout the image.

References

1. Van Dyke, M. (1982). *An Album of Fluid Motion.* Parabolic Press
2. Smits, A. J. (2012). *Flow visualization: techniques and examples*. World Scientific
3. Hinze, J. O. (1975). *Turbulence*. 2nd ed., McGraw-Hill
4. Tennekes, H., and J. L. Lumley (1972). *A First Course in Turbulence*. MIT Press