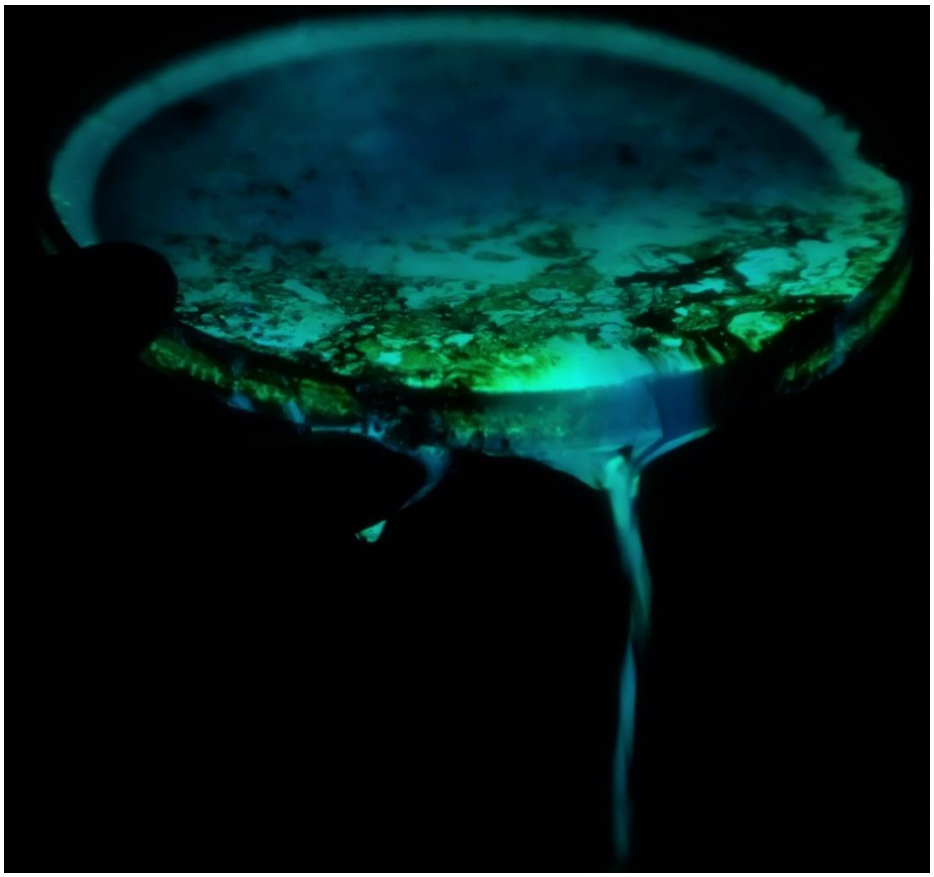

Team Second Report

Brandon Toves

Flow Visualization: 4151-4200-001

Intro

The image depicted below displays green and blue glow stick fluid mixed with ferrofluid being disposed of after our experiment. The purpose of the image was to reveal the different features of flow phenomenon within fluid dynamics as well as reveal that at any point within an experiment you can witness different flow phenomenon. This report outlines the different phenomenon that may have occurred to create the observed fluid flow. Figure 1 shows the point at which the disposal was poured at a constant rate.

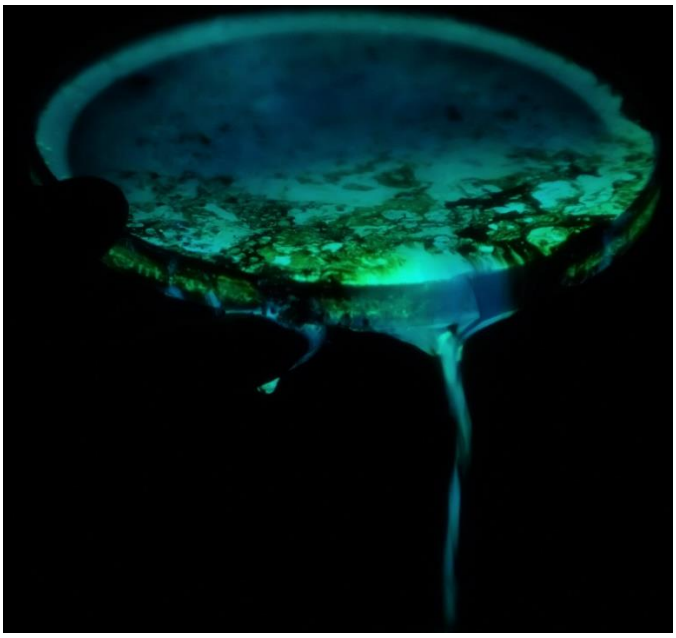

Figure 1: Mid-disposal of glow-stick / ferrofluid mixture

Set Up

The materials needed were ferrofluid, a quart container lid, a magnet, blue and green glow sticks, a tripod, and several cameras. The experiment occurred in the ITLL in a dark room with the window shades drawn during sunset. No external light sources were utilized to highlight the flow.

Several cameras were used to record and capture the experiment as it was performed. For this image, the shutter speed was set to ¼ second, the aperture to 1.4, and the ISO to 2500. These settings allowed for the flow to be captured with the glow stick emitting as the primary light source.

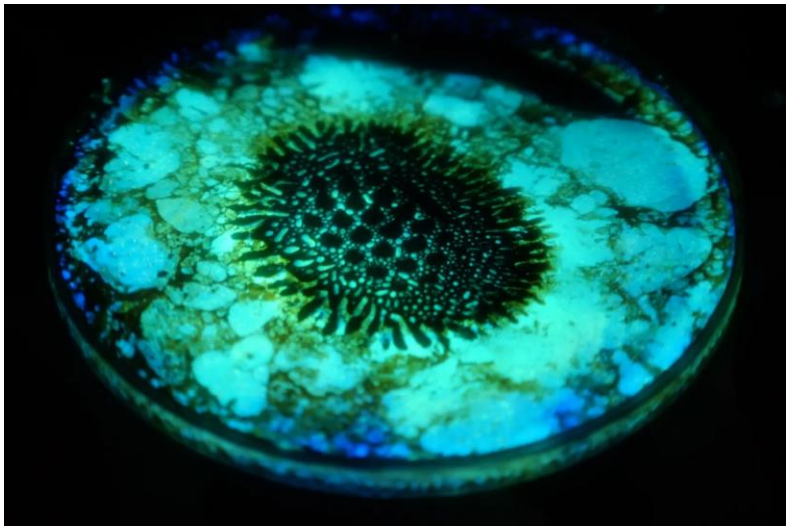

Figure 2: Magnet held still horizontally below lid during experiment

Experiment

The experiment was performed several times. Initially, a tablespoon of ferrofluid was poured into the lid with space lit by fluorescent room lights. Two blue glow sticks were cut open and mixed into the fluid, utilizing a 2-inch bar magnet as the apparatus for mixture. The green glow stick fluid was then added and mixed in a similar fashion. The experiment was very messy, as we had difficult stabilizing the lid while still allowing access to the magnet. Three rolls of scotch tape were used to elevate the lid and create a temporary flat surface, allowing gaps to rotate and move the magnet.

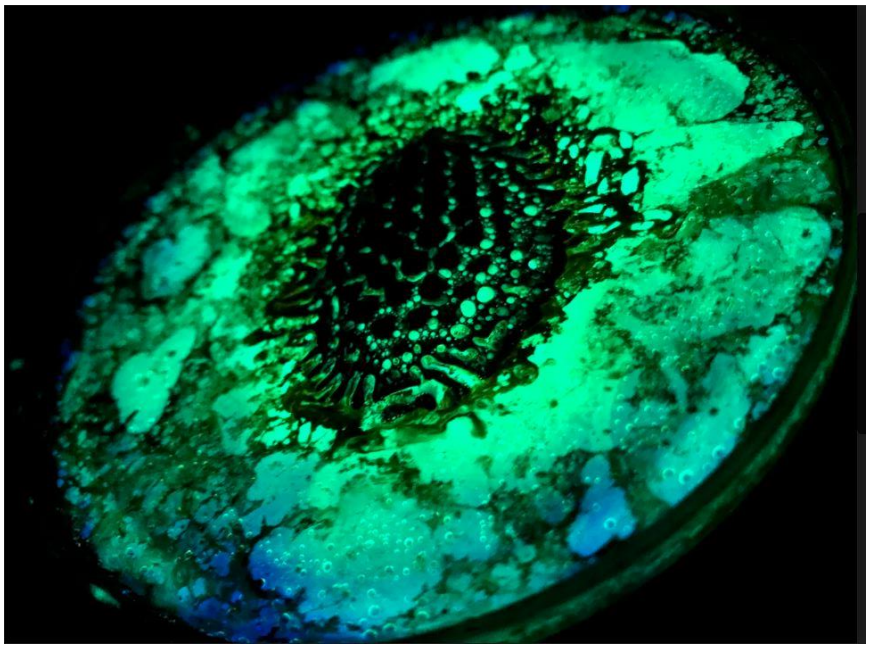

Figure 3: Further mixed fluid with magnet held still horizontally

I rotated and moved the magnet to obtain all the experiment images in all the different phases. Zach was the main pourer during the experiment, ensuring the fluids were poured slowly onto one another. Abbie cut the glow sticks and assisted Garrett and Summer in capturing the flow.

Flow

The glow sticks illuminated the spikes and troughs of the ferro cell, creating a pattern matching the magnetic field presented by the magnet. Glow sticks have an ampoule of phthalic ester and hydrogen peroxide, with fluorescence anthracene dye and phenyl oxalate bordering. When the center ampoule cracks, the chemicals react forming carbon dioxide and phenol, and the other subsequent reaction allows the fluorescent dye to react and thus emit light.

Ferrofluid is mostly carried liquid, with surfactant and magnetic solid nanoparticles making up its remaining volume. When ferrofluid is exposed to a strong magnetic field, the surface rises and creates “spikes” from the imposed force field, which is known as the normal-field instability.

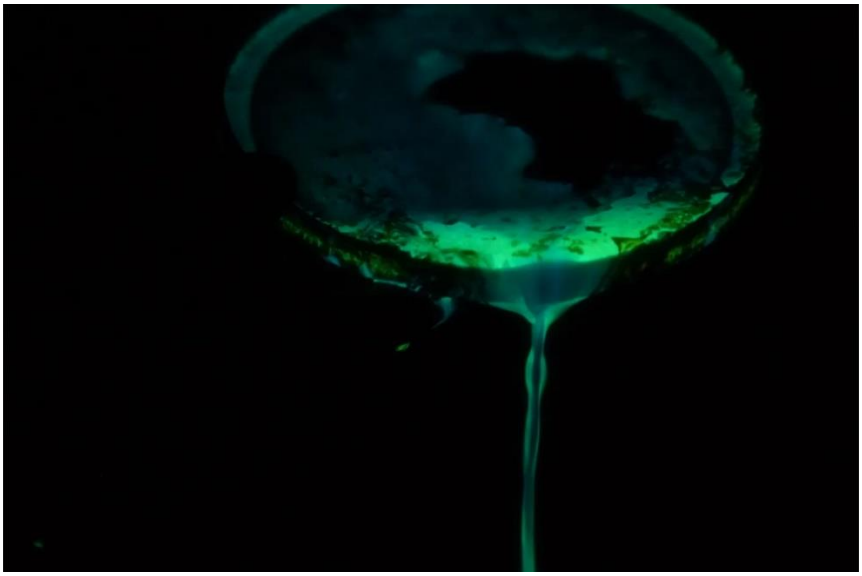

Figure 4: Disposal of the mixture with the glow stick surrounding the ferrofluid.

The glow stick did not mix due to density differences, or the Rayleigh-Taylor instability. The glow stick fluid being less dense, would mix with the other dyed glow stick and not the ferrofluid. While disposing of the fluid, it was clear that these different fluids did not mix as the glow stick fluid sat atop the ferrofluid as it was poured out. This can be seen in Figure 4 above the ferrofluid at the core is surrounded by the glow stick fluid.

Post-Processing

The image I selected was captured during different phases of the disposal. Summer took the photo using her Fujifilm X-pro 1 with a X2 Makinon teleconverter, a 50mm Nikkor 1:1.4 lens, with a minimum focus distance of 2 feet, and a mount convertor. A tripod was used for stabilization and the camera was place about 2 feet from the fluid. The lid was 6 inches in diameter, with the field of view being about 8 inches wide. The image dimensions were 3456 by 2304 pixels. I cropped in the image to

focus in on the outflowing stream, as well as manipulated the contrast and brightness to further pop out the color differences.

Conclusion

I learned a lot from the experiment about the characteristics of ferrofluid and how utilizing different fluids to highlight the flow phenomena can aid in visualizing. The team contributed immensely in framing the image and in setting up / cleaning up the experiment. The images we captured represent all the different phases and flows observed throughout our experiment.

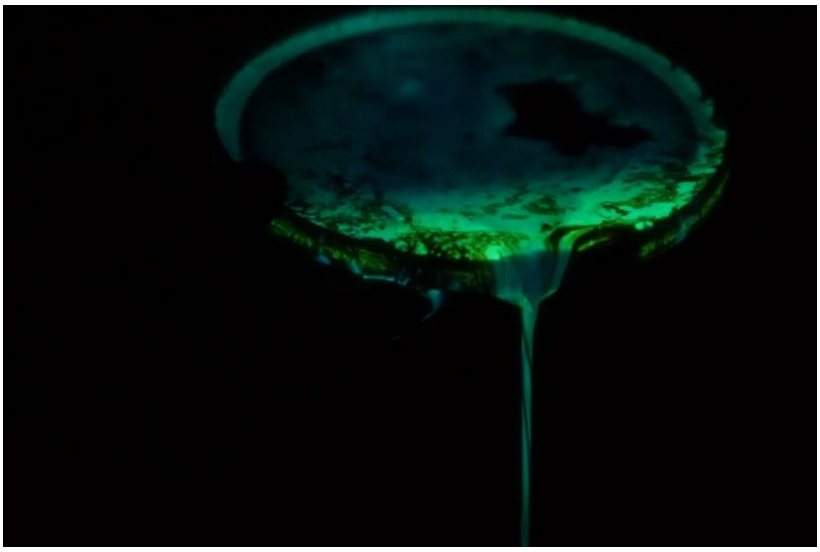

Figure 5: Post experiment disposal

Sources:

Thomas, G.P. "What Is Ferrofluid? A Guide to the Theory, Properties and Applications of Magnetic Fluid." *AZoM.com*, 1 Aug. 2017, www.azom.com/article.aspx?ArticleID=6726.

"The Chemistry of Glow Sticks." Compound Interest, Compound Interest, 9 Nov. 2016, www.compoundchem.com/2014/10/14/glowsticks/.