Team Second Report: Ferrofluids

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This photograph was taken for an assignment in the course *Flow Visualization* at the University of Colorado Boulder during the 2023 fall semester. The idea behind this assignment was to experiment with a particular fluid phenomenon and capture the image using manual photograph techniques to get an image that captures it well. The image was meant to display what a ferrofluid looks like in close proximity to a magnet.

The image was created by pouring a small amount (roughly 1 milliliter) of ferrofluid onto a circular mirror of about a 5 centimeter (cm) diameter. A circular magnet with a diameter of 2 cm was placed under the mirror with the repelling side of the magnet pointing in the direction of the ferrofluid (figure 1).

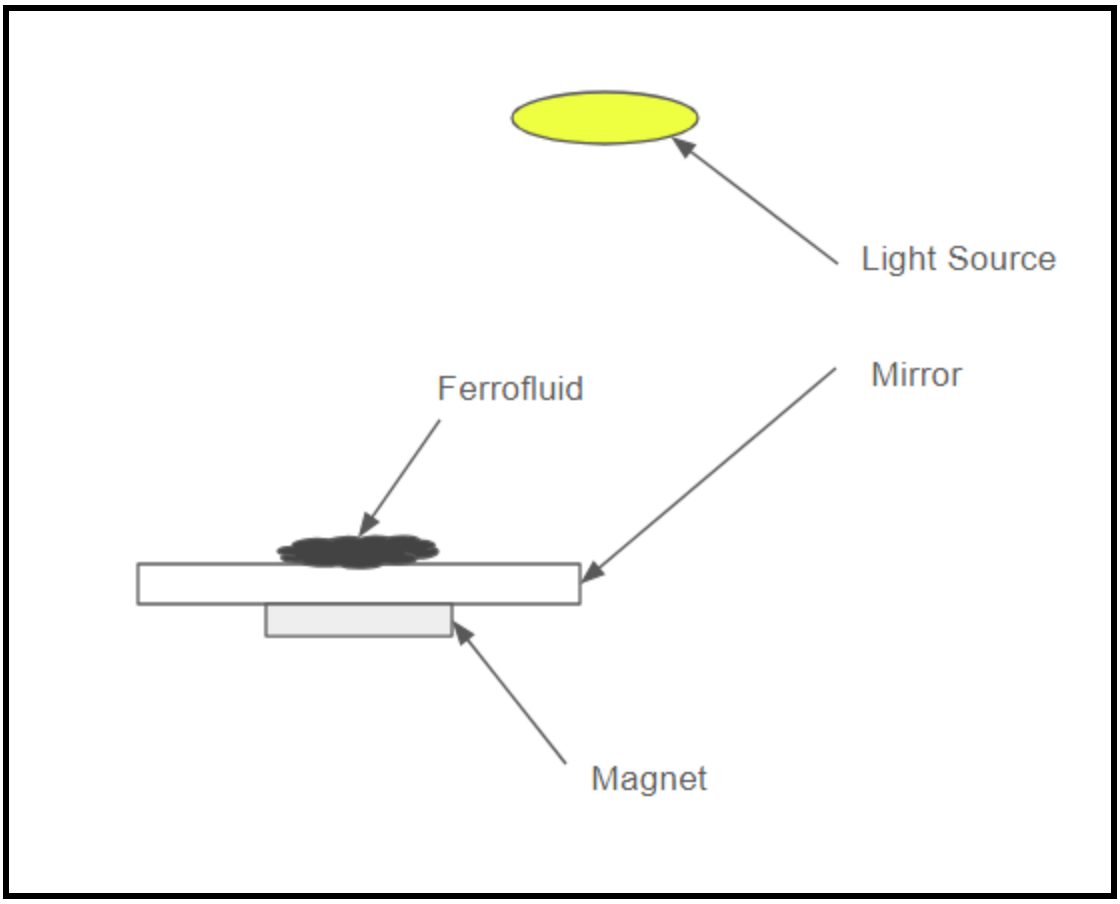

Figure 1: Experimental Setup

The physics behind this particular fluid phenomenon can be explained through defining a ferrofluid and discussing the normal field instability. A ferrofluid is a colloidal mixture of ferromagnetic particles suspended in a liquid (1). With the particles mixed in the fluid, it is subject to manipulation within the proximity of a magnet. The effect of the magnet causes the ferrofluid to be distributed into peaks and valleys, where the maximum repelling force occurs in the fluid as a peak and other parts of the fluid are attracted to the height of the peak and are essentially drawn into it creating a valley. This effect minimizes the energy of the total system, leading to stability (2).

The ferrofluid was moved around the mirror several times by moving and changing the angle of the mirror. The trail of this movement appears as a stain on the mirror. The fluid was illuminated with a fluorescent light from above. This was done by placing the mirror with the ferrofluid on the countertop underneath the countertop lights near the sink on the 1B level of the ITLL. The color was manipulated using the photo editing software, *Darktable*.

Several photographic and editing approaches were made to create this image. The picture was taken with a Canon EOS 40D on the 50 mm lens setting. The field of view is roughly 4.84 cm^2. The distance of the ferrofluid to the lens was about 15 centimeters. The ISO setting was 1600; the shutter speed, 1/200s; and the aperture, f/4.5. As previously mentioned, editing

of the image was done through the program *Darktable*. The image was also cropped through the program. The following edits were made along with their adjustments:

- Hue shift: -42.94° (which provided the color change).

  Linear Chroma Grading
- Global chroma: +3.59%
- Shadows: +12.84%
- Highlights: -50.46%

  Perceptual Saturation Grading
- Global Saturation: +25.69%
- Shadows: +30.28%
- Mid-tones: +9.17%
- Highlights: +19.27%

  Perceptual Brilliance Grading
- Global brilliance: +8.00%
- Shadows: +18.35%
- Highlights: +11.93%

Thes effects these adjustments had on the original image can be compared to figure 2.

Figure 2: Unedited Image

The image reveals the repelling force of the magnet on the ferrofluid and the ridges that occur with the normal field instability. As I was playing around to get the shots, I noticed that at a

certain angle of capturing the shot, the ferrofluid formation looks similar to an eye. That is what I eventually captured within the pattern. I also like that there is light reflection at the bottom of the circle, displaying the shine of the ferrofluid. If I was to take the image again, I would manipulate the lighting and see the effects of the light at different angles. Ultimately, I believe I achieved my goal of getting a picture that is interesting to me with ferrofluids.

References

1) https://ferrofluid.com/index.php/en/
2) Ohleson, et al. *Approaches on Ferrofluid Synthesis and Applications: Current Status and Future Perspectives*, ACS Omega 2022, 7, 4, 3134–3150. https://pubs.acs.org/doi/10.1021/acsomega.1c05631