Team Third Report

Jacob Lanier

MCEN 4041-001

5/2/18

Context

This image demonstrates magnetic fields generated by a set of ceramic rubber strip magnets. The magnetic field is visualized with ferrofluid, and the bright highlights really help illustrate the interesting banded polarization present in the magnets used. Ferrofluid is a liquid that becomes strongly magnetized when exposed to a magnetic field, so it is ideal to determine patterns and shapes in magnets. The way that the polarization pattern was highlighted and seemed to swirl across the fluid looked really cool to me, and reminded me almost of white chocolate drizzled over a tray of dark chocolates.

Flow Analysis

Ferrofluid is known as a colloidal fluid, and is composed of nanoscale (>10nm diameter) ferromagnetic particles suspended in either water or some other solvent like kerosene, which is then coated in a surfactant to prevent clumping in the fluid[1]. When this fluid interacts with a magnetic field it will form ridges along the field lines as the particles are drawn to the filed. It is useful in visualization of the fields surrounding magnets, and other objects. In this experiment, the ferrofluid was used in conjunction with a set of triangular ceramic rubber strip magnets. Magnets of this rubber classification are generally manufactured in two different ways: as extruded magnetic profiles, and as flexible magnetic sheets[2]. The magnets used by our team were from flexible magnetic sheets, but both manufacturing processes result in similar products. What this means is that both methods result in magnets created in such a way that strips of negative and positive charge run down the magnet. This effect can easily be seen in my image, but another form of visualizing this effect can be seen in Figures 1 and 2.

Figure 1: Rubber magnet horseshoe polarity arrangement[3]

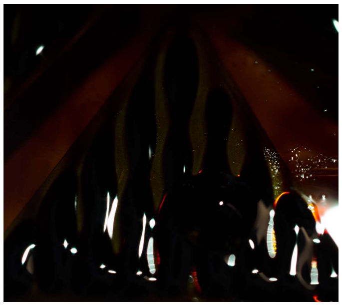


Figure 2: Ferrofluid coalescing into the bands of the rubber magnet

---

[1] M. (2015, January 31). What is a ferrofluid? Retrieved from https://www.magcraft.com/blog/what-is-a-ferrofluid

[2] How Are Flexible Magnets Made. (n.d.). Retrieved from https://www.first4magnets.com/tech-centre-i61/information-and-articles-i70/flexible-magnet-information-i86/how-are-flexible-magnets-made-i116

[3] Physics by the Fridge: Zip Magnets. (n.d.). Retrieved from http://www.physicscentral.com/experiment/physicsathome/zipmagnets.cfm

In general, these ‘polarity stripes’ are applied to rubber magnets to create a Halbach Array in the magnets. This array makes it such that the magnetic field on one side of the array is stronger, while nearly totally cancelling out the field on the other side of the array[4]. Interestingly, the magnets used for this experiment, while rubber magnets with the horseshoe polarity arrangement, were magnetized on both sides, negating any field strengthening that a Halbach Array may have created. Rubber magnets have much weaker magnetic fields when comparing to rare earth magnets, but they have the advantage of being low cost, and easy to add together over a large surface area to increase their force. A magnet’s maximum energy output is given in units of GOe (Gauss-Oersted), and while neodymium magnets have a max energy output of around 42 MGOe, rubber magnets generally only get to between 0.6-1.6 MGOe[5]. Furthermore, when discounting the effect of the Halbach Array, I estimate that the magnets used were only around 0.4-0.9 MGOe.

When taking the picture, the team used a Petri dish on top of a piece of white printer paper, which covered the magnets. Ferrofluid was poured into the dish, and we experimented with several setups to see what looked the most interesting. The materials used in this photo can be seen in Figure 3.

Figure 3: Materials Used

The setup was lit with both natural and fluorescent light, and I found that the fluorescent lights overhead created interesting highlights in the peaks of the ferrofluid formations. I could keep my ISO low and shutter speed reasonable because this was a static flow, and there was a reasonable amount of light. I didn’t need a tripod due to the good shutter speed. The camera itself was situated about 0.5-1.5 feet away from the ferrofluid. The static nature of the fluid, and proximity to the camera help ensure the image is well resolved in both time and space. The setup for this image can be seen in Figure 4.

---

[4] (n.d.). Retrieved from https://www.kjmagnetics.com/blog.asp?p=halbach-arrays

[5] What Are Flexible Magnets. (n.d.). Retrieved from https://www.first4magnets.com/tech-centre-i61/information-and-articles-i70/flexible-magnet-information-i86/what-are-flexible-magnets-i118

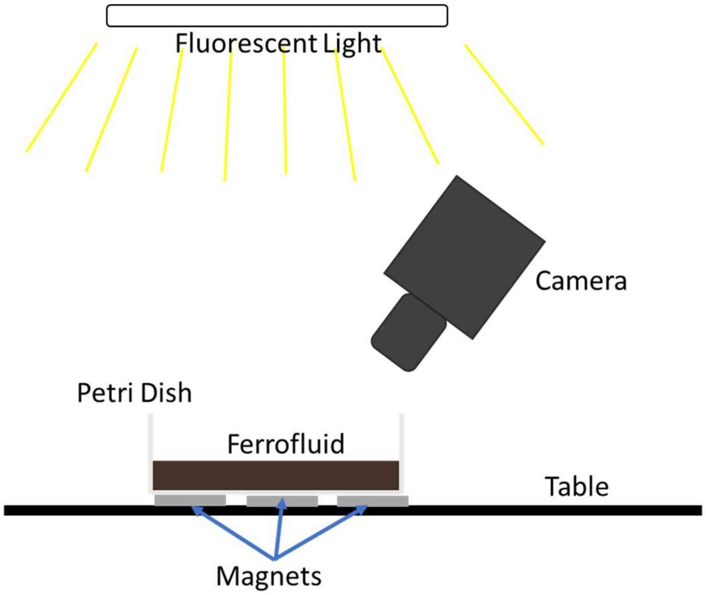


Figure 4: Ferrofluid Setup

Setup

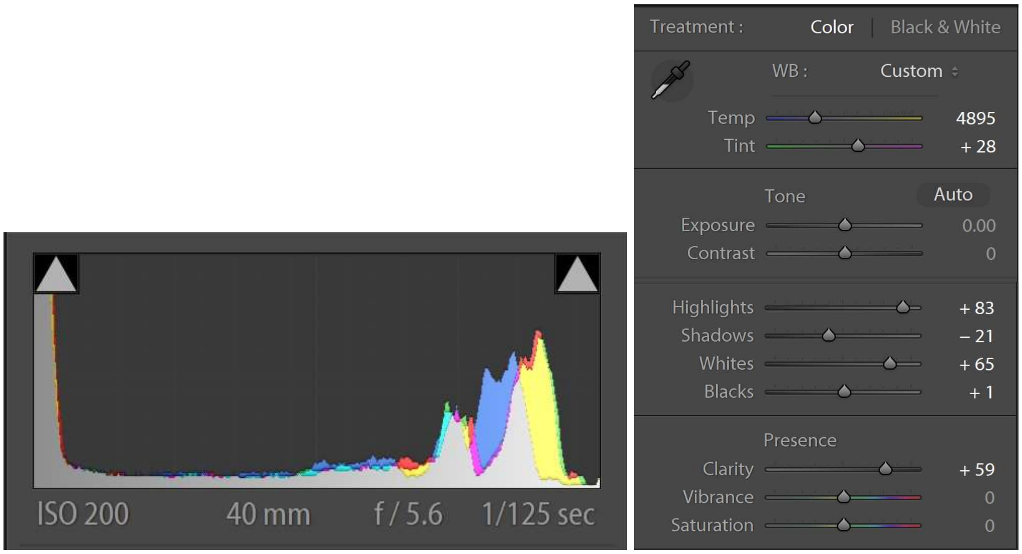
To create this image, we used natural light from a window nearby, an iPhone camera's built in flash, and most importantly, an overhead fluorescent light in normal air. To create these formations the only materials we used were a petri dish, a set of triangular ceramic rubber magnets, a piece of printer paper to conceal the magnets, and the ferrofluid. The image was taken in a standard room temperature room, at a standard Colorado level of humidity.

Photographic Technique

To take this image, I used a fixed FOV 40 mm lens about 1 foot away from the ferrofluid. The photos were taken at an aperture of f/5.6, a shutter speed of 1/125 sec, and an ISO of 200. I used a Nikon D7000 to capture this image. This image is totally time resolved because the flow is frozen. If the camera doesn't move as it is taking the photographs, then everything will stay resolved. I believe that the 1/125 shutter speed ensures that this camera movement is minimized. Due to the close-up nature of this image, it is also well resolved spatially.

The initial image pixel size was both 4928x3264, and the final cropped image was 4645x2923.

For post-processing, I exported the image to Adobe Lightroom 6. I cropped the image to try and frame the petri dish, and adjusted the image's histogram to reduce glare off the liquid, and to darken the darks and brighten the lines of reflected light. The histogram and color balance settings can be seen in Figure 5.



ISO 200 40 mm f / 5.6 1/125 sec

Treatment : Color | Black & White

WB : Custom

Temp 4895

Tint + 28

Tone Auto

Exposure 0.00

Contrast 0

Highlights + 83

Shadows – 21

Whites + 65

Blacks + 1

Presence

Clarity + 59

Vibrance 0

Saturation 0

Figure 5: Histogram and Color Settings

Finally, a comparison between the initial and final images can be seen in Figure 6.

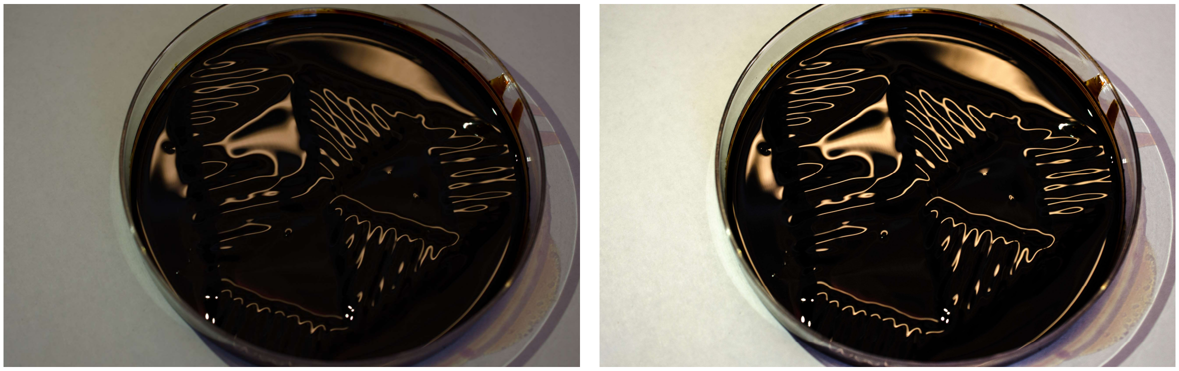


Figure 6: Original Raw vs. Final Edited Image

Conclusion

This image demonstrates the interesting physical properties of rubber magnets, as well as the way that direct overhead lights highlight the reflections off ferrofluid. There is no flow in the image at the time of taking the picture, but when the magnetic field is changing the ferrofluid responds and changes accordingly. I really like the lines of white/yellow in this image. I think the dark fluid and the bright lines create a nice contrast, and almost remind be of dark and white chocolate. I think I could have limited the reflections off the fluid not at the peaks of the magnetic fields, as I feel this detracts a little from the overall piece. The frozen nature of the drops really helps with understanding the mechanics of what this magnet's magnetic field looked like. If I was to develop this further I would like to use different magnets to see the effects, as well as stronger magnets. I would also like to look more into dying the fluid to create a more vibrant and interesting image.