# SLEEK SPIKES: REPORT

**Martin Allsbrook // IV 2: Team First // ATLS 4151-001 (Undergrad)**

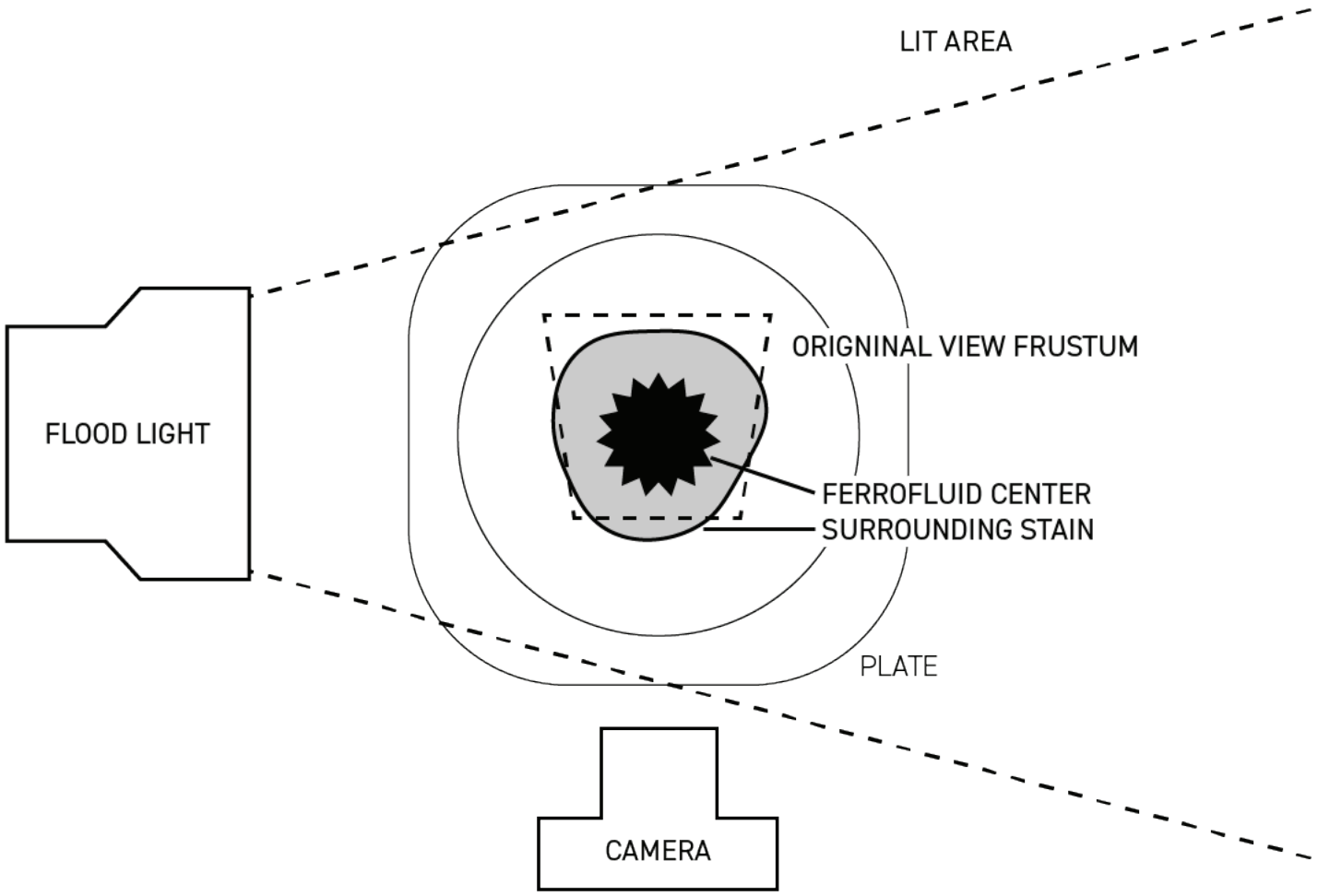
# BACKGROUND

This image was taken on 09/20/22 with help from team members Lucas Fesmire and Isaac Martinez. The image shows a macro view of the spikes that form in ferrofluid when in the presence of a powerful magnet. Originally we planned on imaging the ferrofluid in a small jar of water, potentially with fast moving magnets moving around the container. We found that the diffraction of light through the water and walls of the jar made it extremely difficult to image, and we eventually decided to pour the ferrofluid on a ceramic plate and image it open to the air. We were then able to put the magnet under the plate and have spikes form on the surface of the palace without reaching the magnet.

# SETUP

This image was taken with the ferrofluid sitting on a ceramic plate about half a centimeter thick. Underneath the plate there was a 1 in^3 (16*10^3 mm^3) pure neodymium magnet oriented so that the magnetic field went down into the plate. A poker chip was placed between the magnet and plate as a spacer, making the total separation between the magnet and ferrofluid about 1cm. About 20ml of ferrofluid were placed on the plate, and the mound it produced after being exposed to the magnet was about 8cm across and 3cm tall.

A flood light diffused through a sheet of printer paper was used to light the scene. The printer paper was taped to the front of the floodlight and covered it entirely, and the floodlight was positioned 90 degrees clockwise from the camera, about 30cm from the ferrofluid and 10cm above it., The camera was much closer probably around 10-15cm from the ferrofluid, looking down at about 30 degrees



# PHYSICS

Most of the physics behind this phenomenon are caused by the Normal Field instability, a phenomenon discovered by R. E. Rosensweig. The Normal Field instability is caused by the ferrofluid attempting to flow towards its lowest potential energy, similar to a ball rolling into a valley. In the case of the ball rolling into the valley there is one force at play, gravity, which is constantly pulling the ball down into the valley, and gives the ball a potential energy relative to the bottom of the valley while being held above it. In order for the ball to minimize its potential energy it rolls to the bottom of the valley.

The Normal Field Instability follows a somewhat similar logic, but with many more forces at play. The most novel of which is the magnetic force, which pulls the ferrofluid towards the magnet. As the ferro fluid is being pulled towards the magnet, it is being magnetized itself and attracts more ferrofluid. If this were the only force at play the ferro fluid would find its lowest potential by forming into thin lines that trace the magnetic field of the magnet. The magnetic force is not alone and both gravity and surface tension both have a strong effect on the ferrofluid as well.

The gravitational force keeps the ferrofluid in its valley, which in this case is the surface of the plate. The ferro fluid now has to find the point at which it minimizes both its gravitational and magnetic potential energy. This prevents it from extending infinitely along the magnetic field lines, and instead produces the spikes we're used to seeing. However if it weren't for surface tension the spikes produced would be much sharper than the spikes we see. In fact, if surface tension was the only force on the ferro fluid it would find its lowest potential energy in the form of a sphere

In the case where all three forces are acting on the ferro fluid it has to find it's lowest potential energy between all three of these forces. The magnetic force wants to pull it into long lines along the field lines. Gravity wants to keep these lines near the ground and turns them into spikes. And finally surface tension wants to pull it into a sphere but while balancing with the other forces is only able to round the peaks and valleys of the spikes. Together they produce the smoth, almost surreal spikes observed.

# VISUALIZATION TECHNIQUES

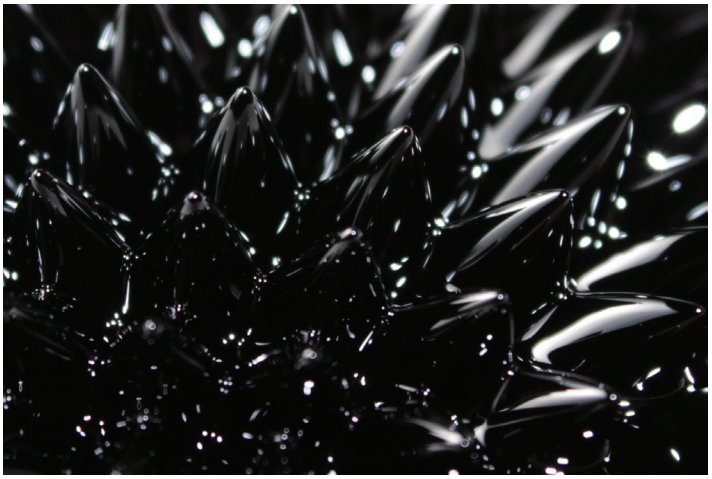
This is a simple boundary visualization, where we are visualizing the boundary between the extremely dark and reflective ferrofluid and the air around it. A single very bright flood light diffused by a sheet of printer paper was used to light the scene. The light was just to the left of the ferrofluid in the image and the reflections are likely directly from the sheet of paper on the light.

# PHOTOGRAPHIC TECHNIQUE

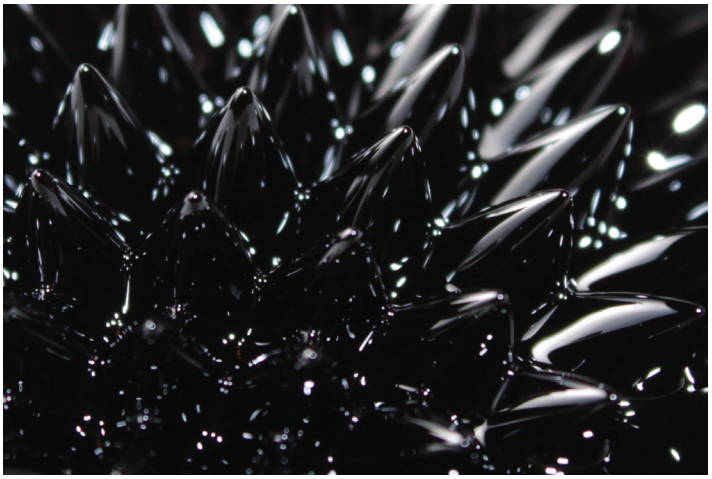
The image was taken with a Canon EOS Rebel T7. The focal length was 55mm, ISO was 800, f-stop was 8.0, and the shutter speed was 1/100sec. I really wanted to get a good macro image of the almost surreal form of the spikes, and primarily focused on getting the largest possible image of the ferrofluid. 55mm is the largest focal length I could produce with my current lense and produced the most magnification. I was then able to crop the image further to get the surreal look I was going for.

I was also very interested in the reflections on the ferro fluid and felt that they had an almost 80s aesthetic. To further accentuate this I increased the contrast in post processing, making the ferro fluid darker and the reflections brighter. I also reduced the saturation to get rid of any slight hues I might not have noticed. In the end I was able to get the surreal and ominous image I was looking for.

**EDITED**



**UNEDITED**



**ORIGINAL**

# REFLECTION

I'm really happy with the image I ended up with for this assignment, it shows everything I find fascinating about ferrofluid. In addition playing with ferrofluid was an awesome experience and something I don't think I'll ever forget. I definitely learned a thing or two about still macro photography as well and if I had a chance to retake this image there are a few things I would change. Primarily I would like to get a tripod for my camera. I had to use a relatively fast shutter speed due to my shaky hands which also resulted in a higher ISO. If I had a tripod I would have kept the ISO as low as possible and opted to slow down the shutter speed instead.