Ferrofluid Drops

Studying Ferrofluids with High Speed Video

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Today's Agenda

Background

- Ferrofluids & Magnets
- Goals of the Experiment

Qualitative Results

- Procedure
- Observations of Fluid Behavior
- Ways to Improve

Quantitative Results

- Procedure
- Analysis of Drop Data
- Ways to Improve

Future Work

- Future work on ferrofluids

Background - Ferrofluids

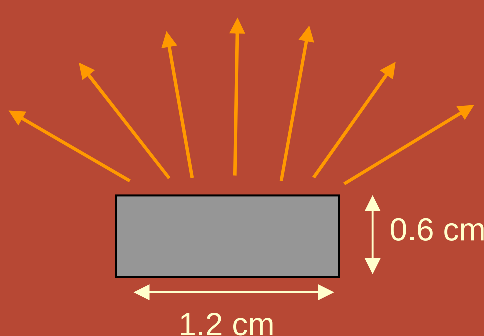
- Unique class of liquids that are magnetic
- Composed of nanoscale magnetic particles suspended in a carrier fluid
- Ferrofluid we used was EPH1
  - Hydrocarbon based
  - Non-toxic
  - Stains clothes and some lab equipment!

Background - Ferrofluids

Picture taken with Nikon D100 digital camera. Aperture: 3.5, Focal Length: 24mm, Exposure Time: .0016s

Background - Magnets

- For qualitative results, used a number of magnets to create maximum normal field
- For quantitative results, used Neodymium Iron Boride (NdFeB) magnet



Field at surface = .45T

Assuming point charge:

$Field = M * 1/ r^2$

$.45 = M * 1/(.006)^2$

$Field = 1.62E{-5}/r^2$

This will not be perfect as we are working in near field

Background – Our Goals

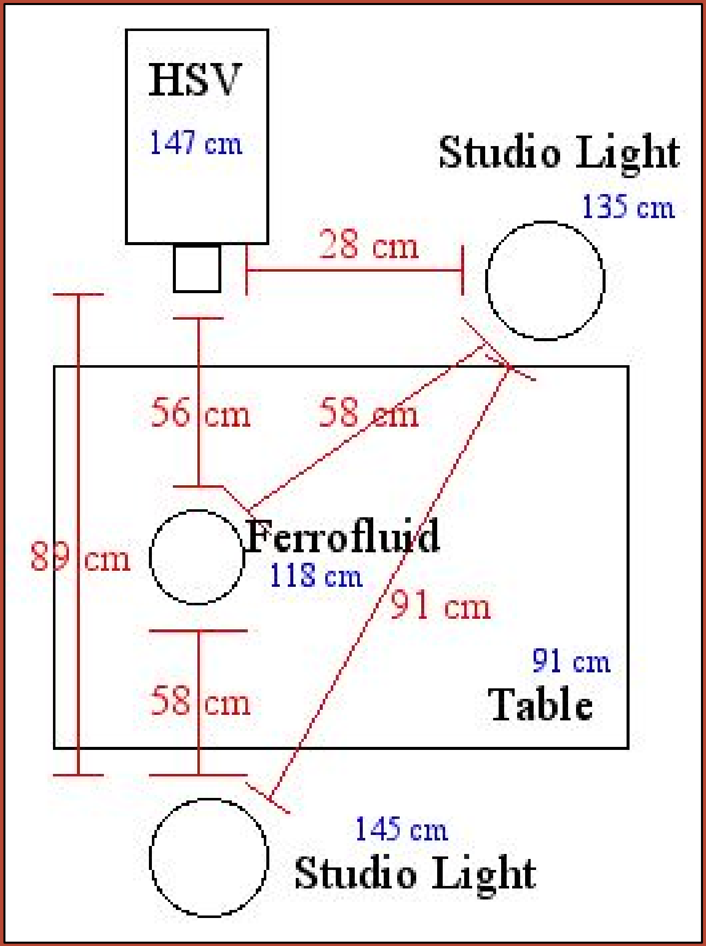
- Determine what interesting properties HSV or other imaging techniques can show us about ferrofluid drops
- Make a series of qualitative observations about ferrofluid drops in magnetic fields
- Identify and study quantifiable features in more depth

Qualitative - Procedure

- Observed how ferrofluid's splash was affected by a magnet

- Tested with and without magnet:
  - Ferrofluid into Soy Milk
  - Soy Milk into Ferrofluid
  - Ferrofluid into Ferrofluid
  - Ferrofluid onto Glass

Qualitative – Setup



Red numbers indicate distances while blue numbers indicate heights.

Picture taken with Nikon D100 digital camera. Aperture: 3.5, Focal Length: 24mm, Exposure Time: .0016s

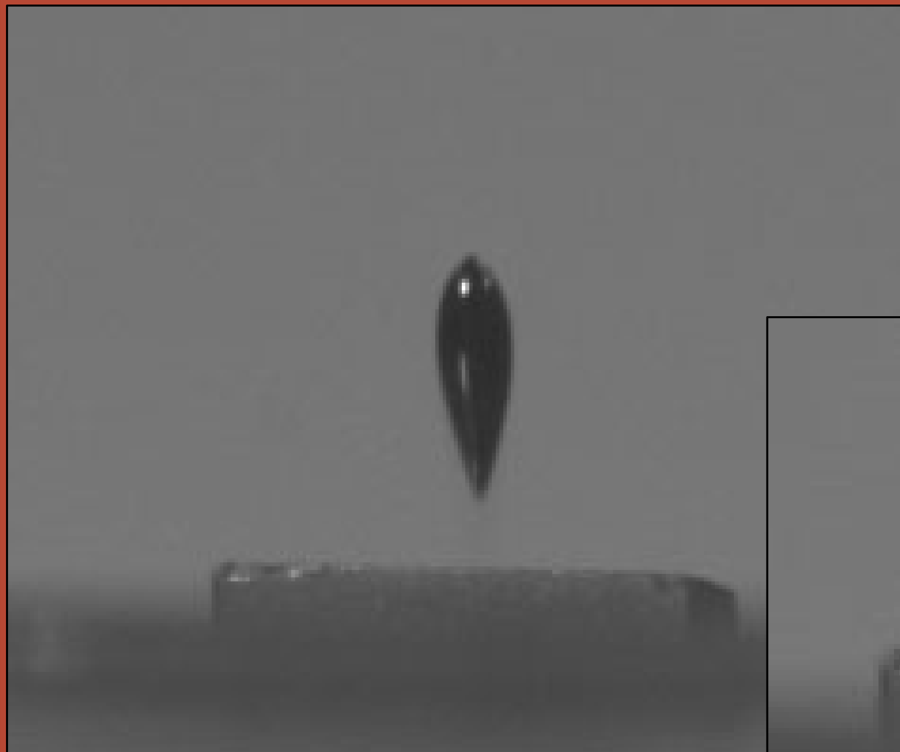
Qualitative – HSV Settings

- Resolution: 1024x1024
- Sample Rate: 1000 pps
- Exposure: 100 microseconds
- Post trigger: 1 pixel
- Duration: 1 second
- Lens: 200mm with aperture f/5.6

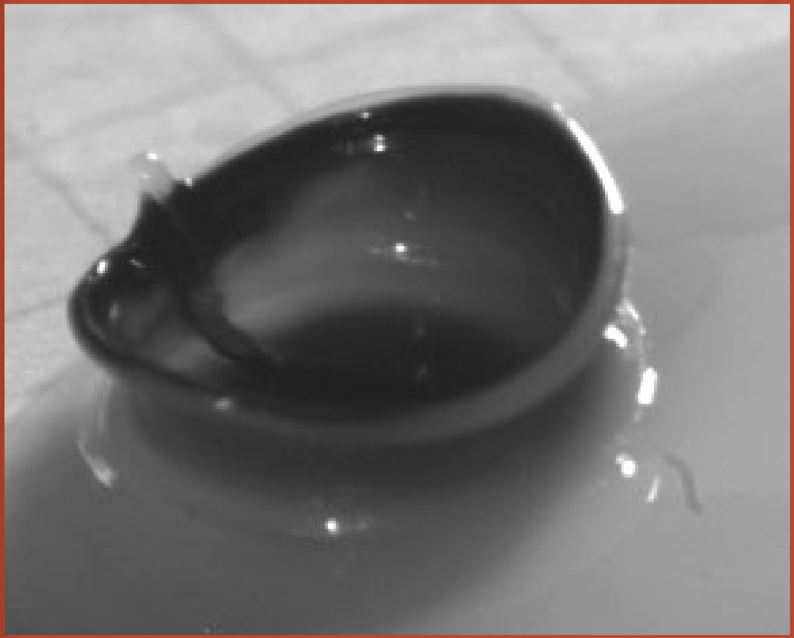
Qualitative – Observations

- Magnetic Fields on Ferrofluids lead to:
  - Elongation of drop
  - Skewing of drop toward magnet
  - Increased impact force
  - Change in crown behavior

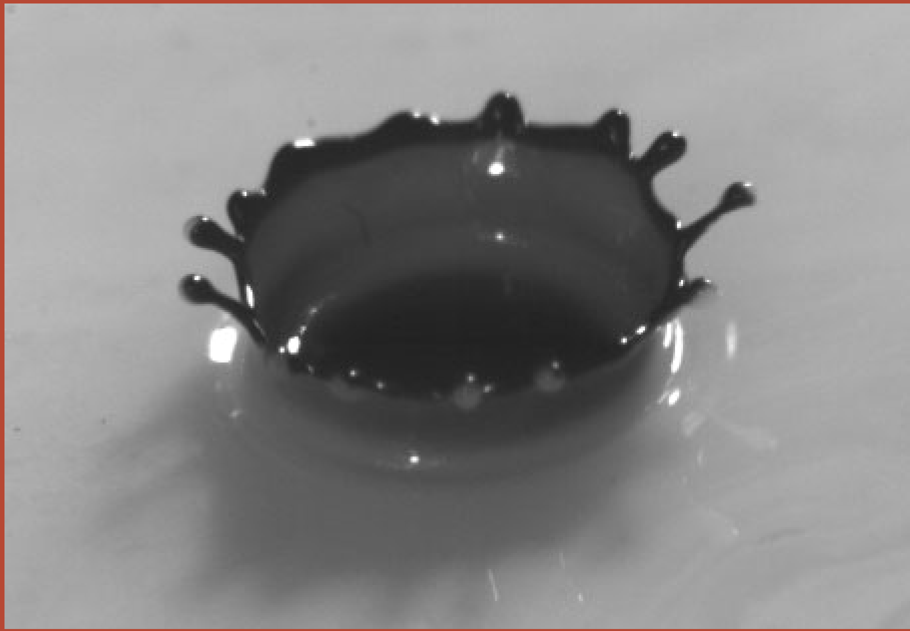
Qualitative – Observations



Qualitative – Observations

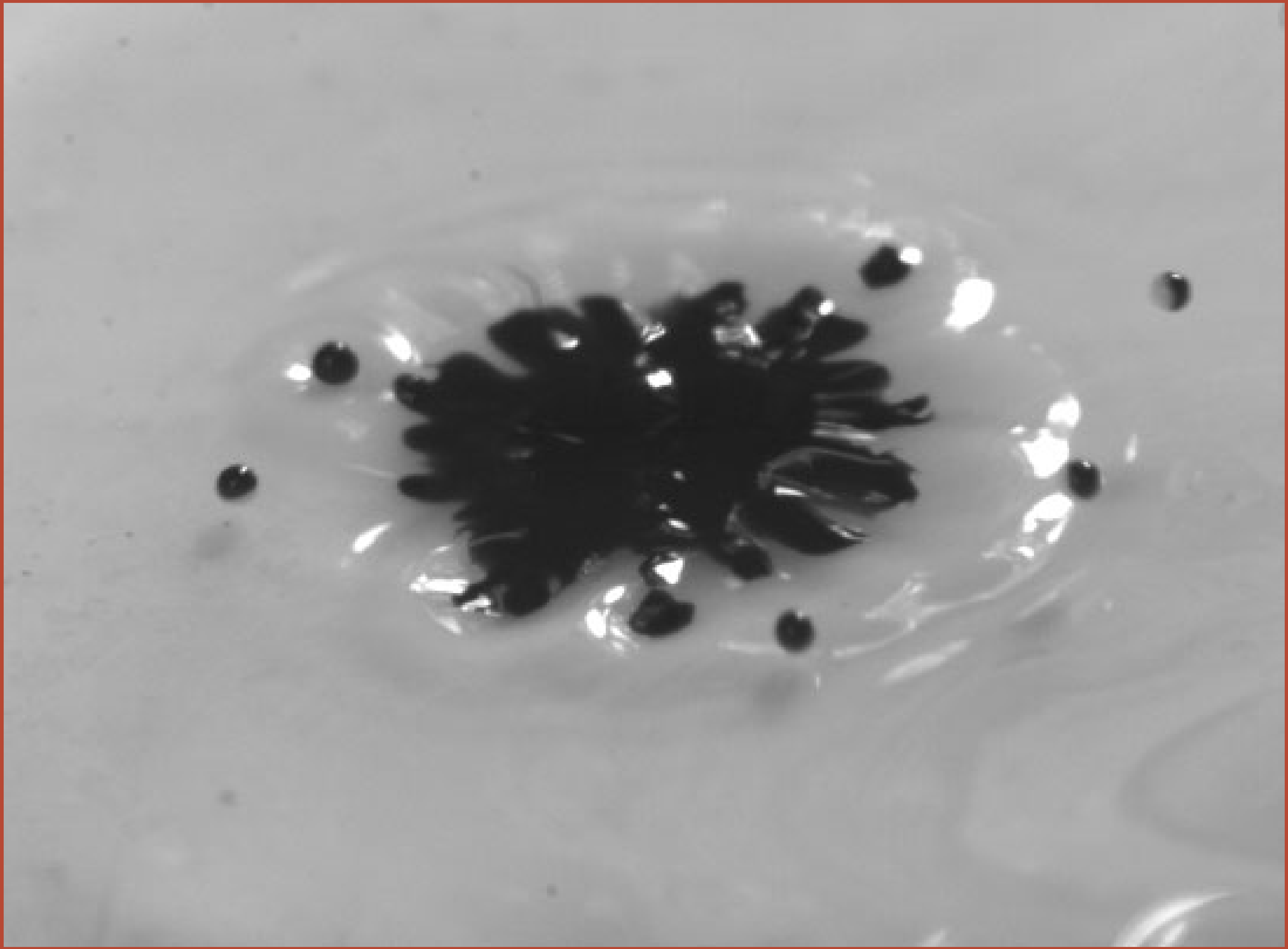


Magnet

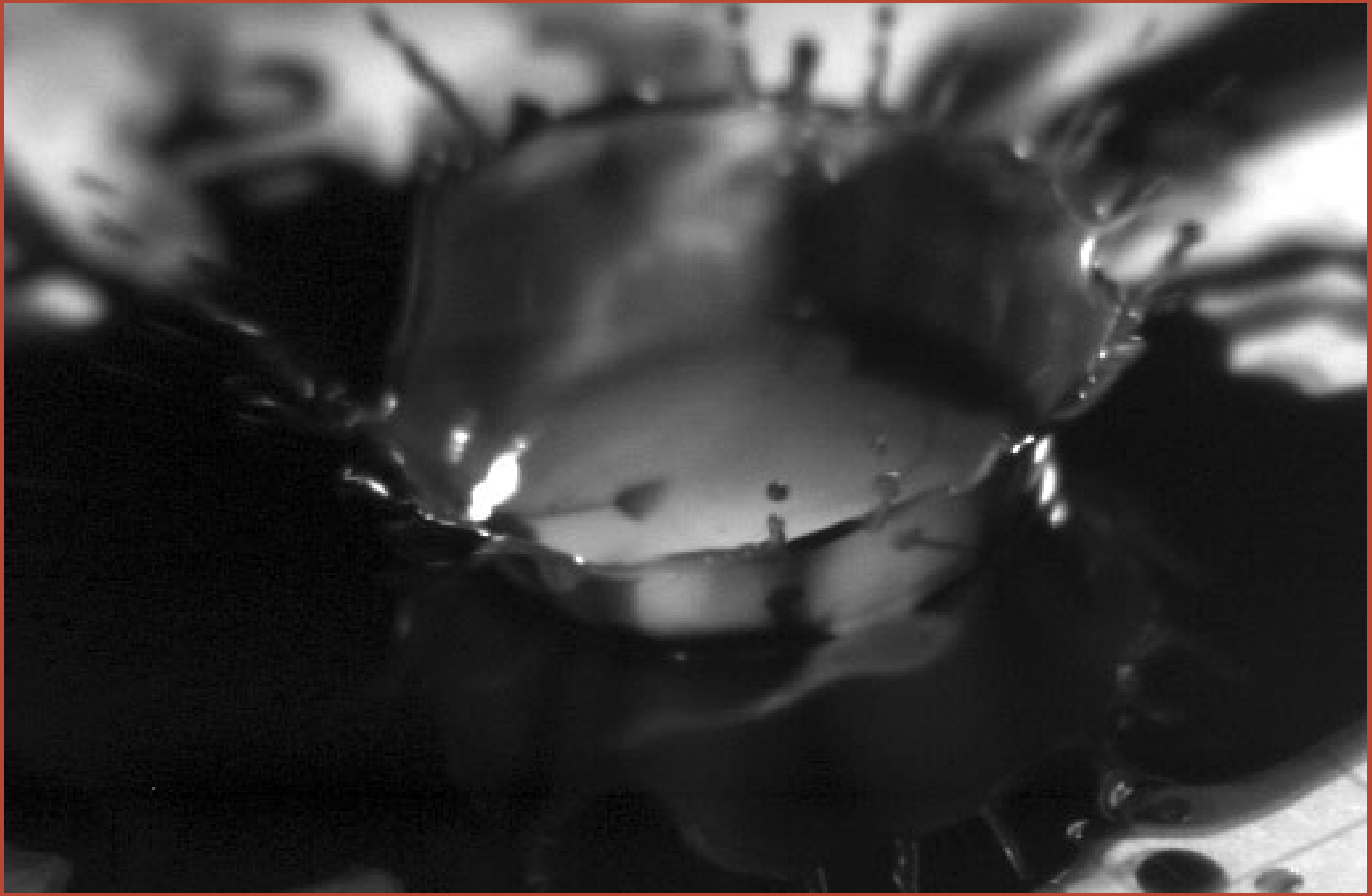


No Magnet

Qualitative – Observations



Qualitative – Observations



Better Images

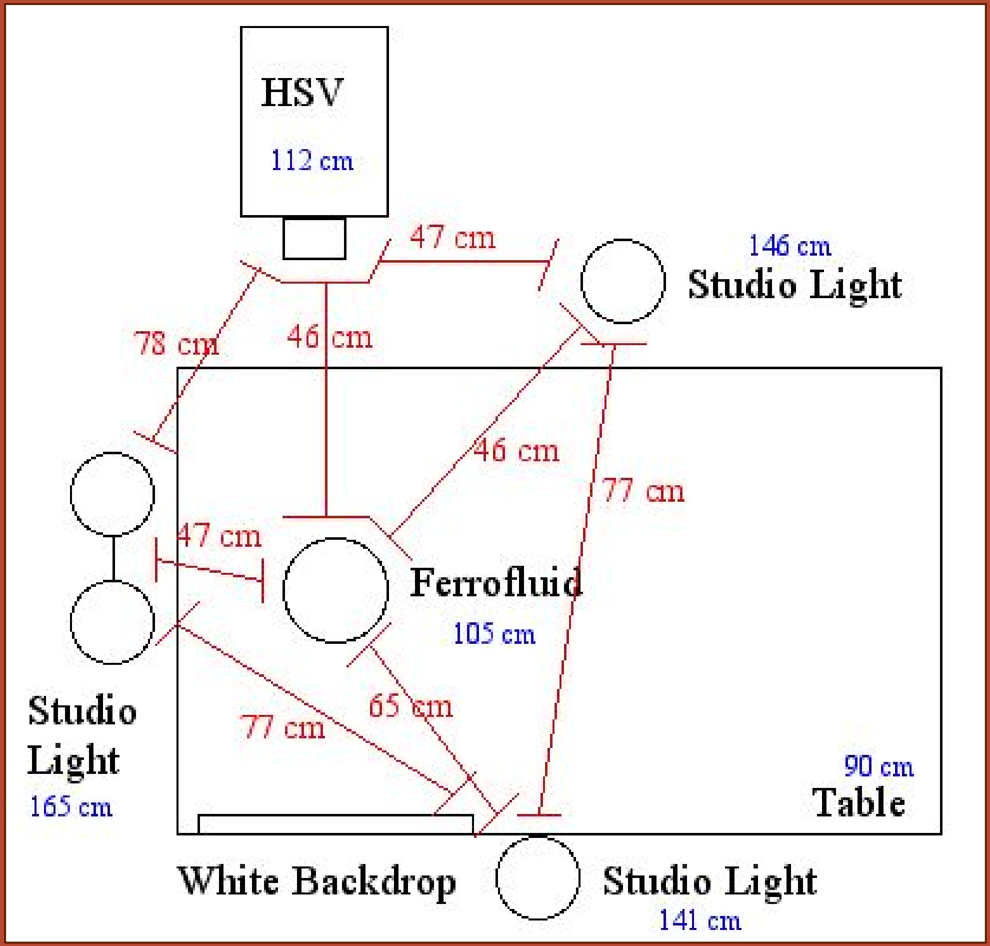
- Use a dish with lower edges
  - Some edges are necessary!
- Need less blur and more depth of field
  - Will require more and cooler lights
- Other techniques were not options:
  - Sync-&-Delay Trigger Broken
  - Color HSV would require too much light

Quantitative – Procedure

- Measured how velocity of ferrofluid increased in the presence of a known magnet field
  - Compared against water drops

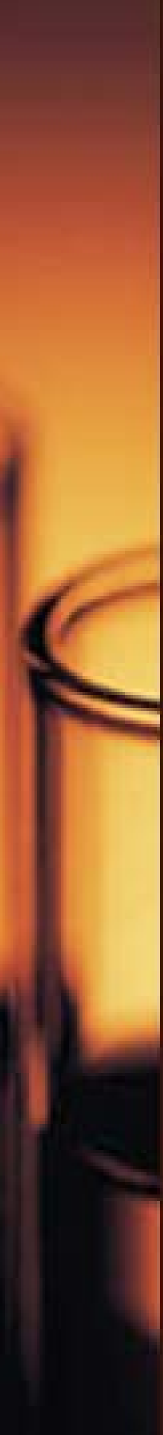
- Measured horizontal distance at which ferrofluid is unaffected by a magnetic field (quantitative analysis pending).

Quantitative – Setup



Red numbers indicate distances while blue numbers indicate heights.

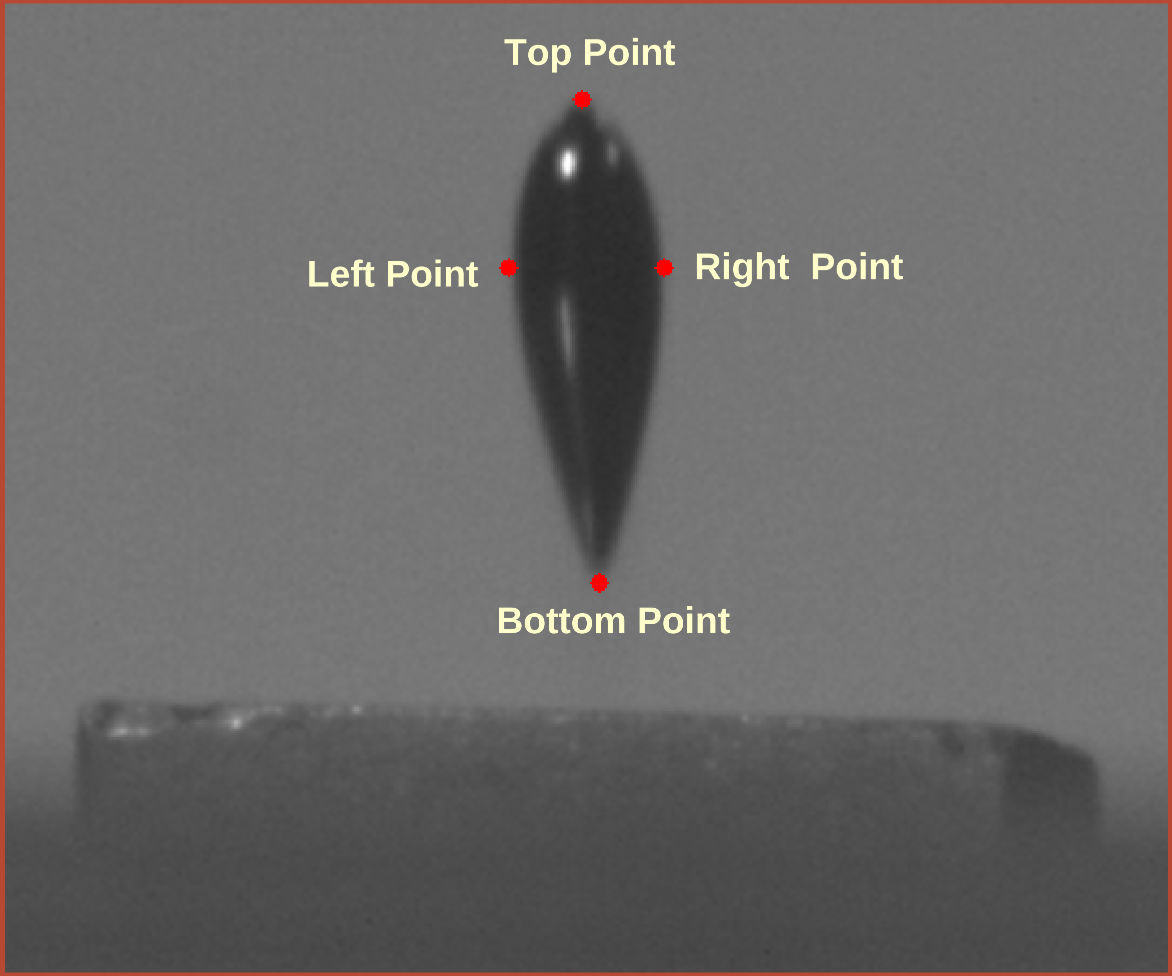
Picture taken with Nikon D100 digital camera. Aperture: 3.5, Focal Length: 24mm, Exposure Time: .0016s



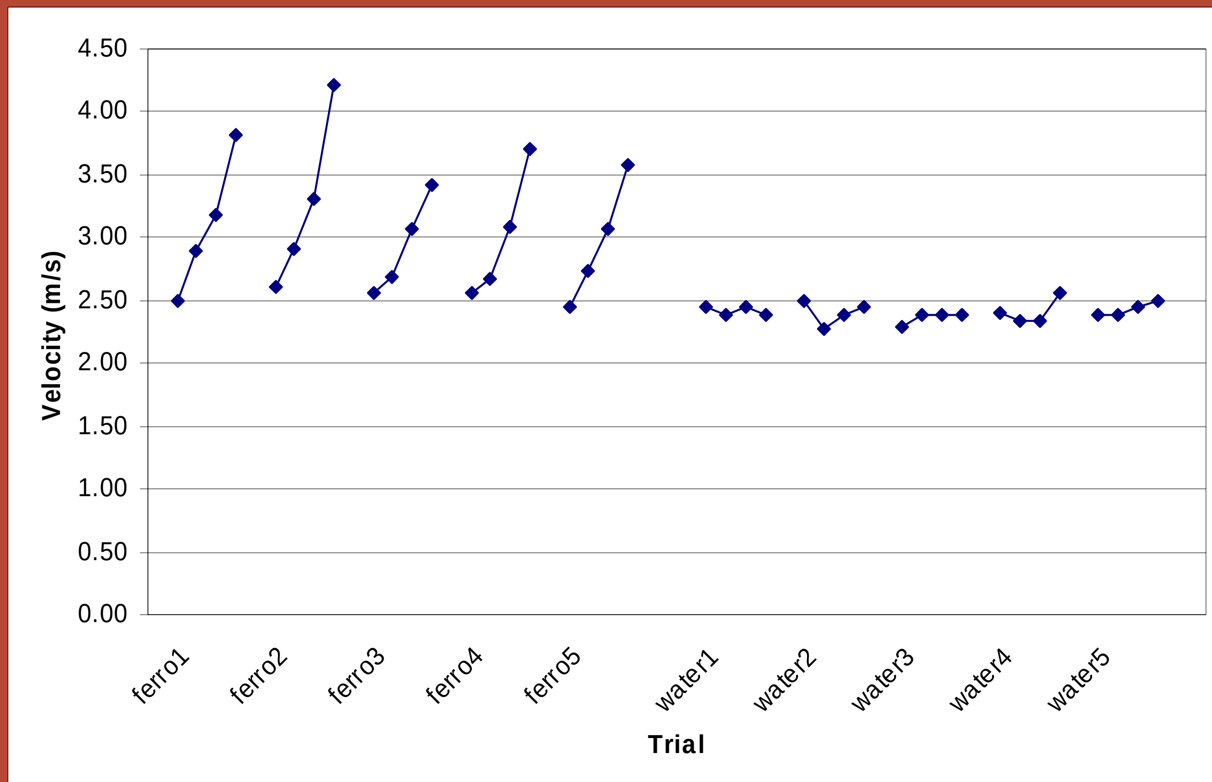
Quantitative – HSV Settings

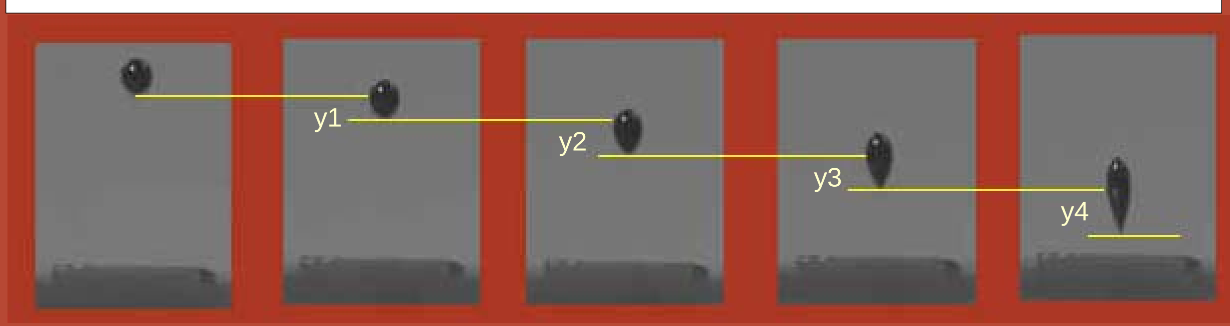
- Resolution: 1024x1024
- Sample Rate: 1000 pps
- Exposure: 100 microseconds
- Post trigger: 1 pixel
- Duration: 1 second
- Lens: 105mm with aperture f/4

Quantitative – Measurements



Quantitative – Velocity of Ferrofluid vs. Water



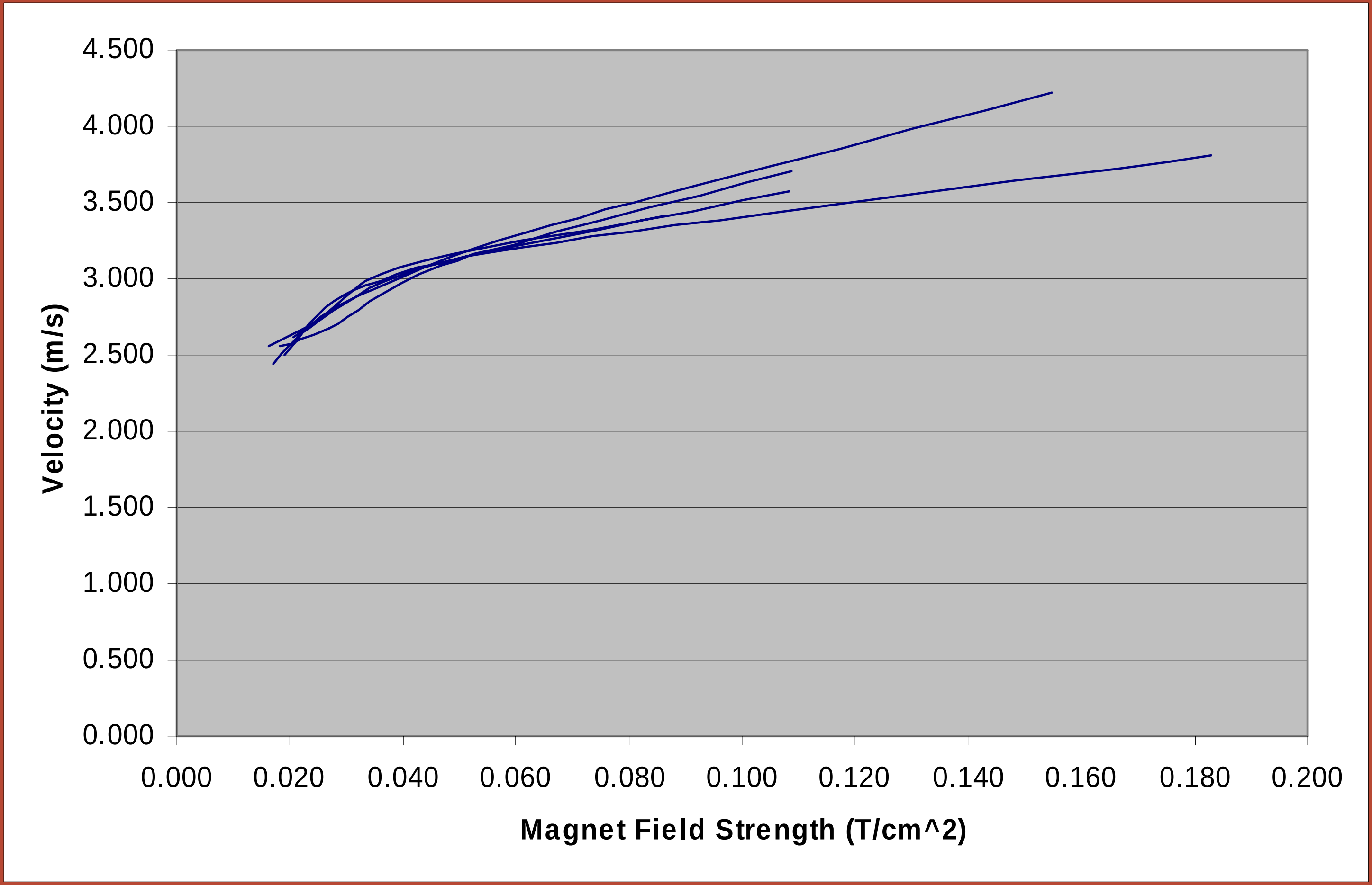


Average change in ferrofluid velocity over 3 ms: 1.244 m/s

Quantitative – Ferrofluid Drops (contd.)

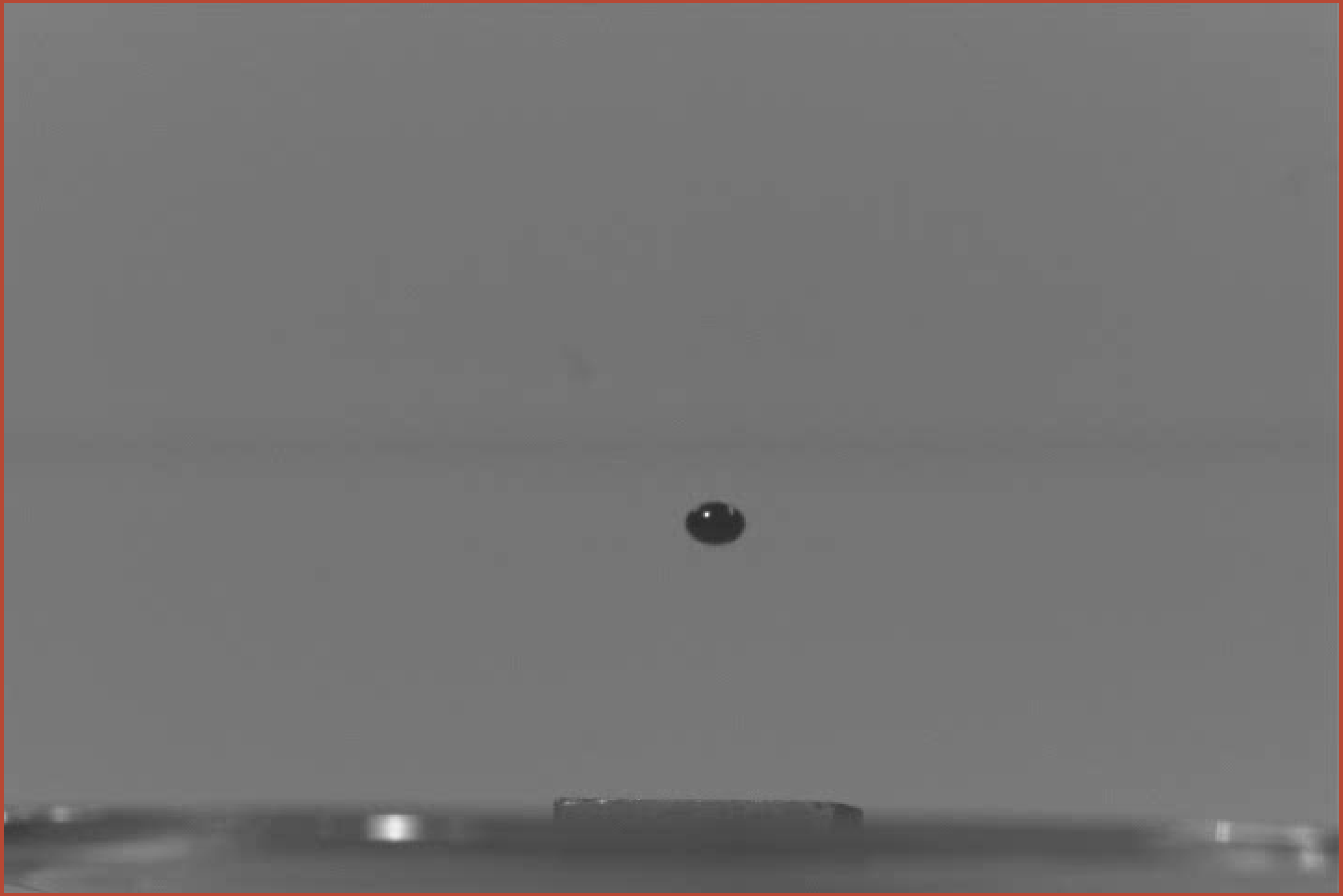
- Acceleration due to gravity was negligible due to short (5 millisecond) time frame
  - Velocity of water dropping over same time period remained the same
- Average acceleration for ferrofluid drops was approximately 414 m/s^2
- Ferrofluid's magnetic dipoles align almost instantaneously with external magnetic force
  - Magnetic field strength is inversely proportional to square of distance

Quantitative – Velocity of Ferrofluid and Magnetic Field Strength



- Ferrofluid drop velocity correlates with applied magnetic field strength

Quantitative – Skew Studies

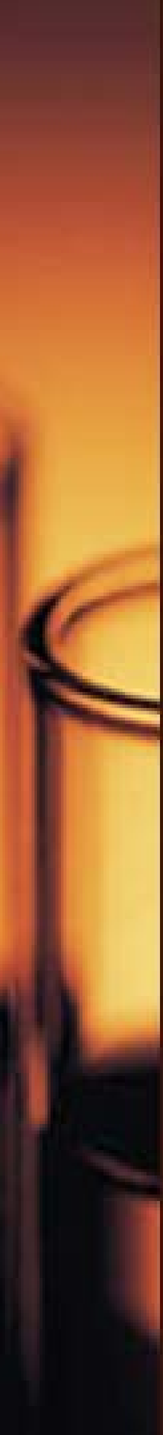


Quantitative – Improving Results

- Control drop size better
- Capture at a higher frame rate
  (5 frames provides limited data)
- Use a more ideal magnetic field
- Improve pictures (as already discussed)

Future Work on Ferrofluids

- Try using an electromagnet
  - Exact control on field strength
  - Ability to vary field strength
  - Suspending drop in mid air.
    - Spiky or spherical?
- Horizontal uniform magnetic field
- Drop multiple drops simultaneously



Strobe has been fun! Thank you Dr. Bales, Christina, and classmates!