Diffusion in Microfluidic Mixers

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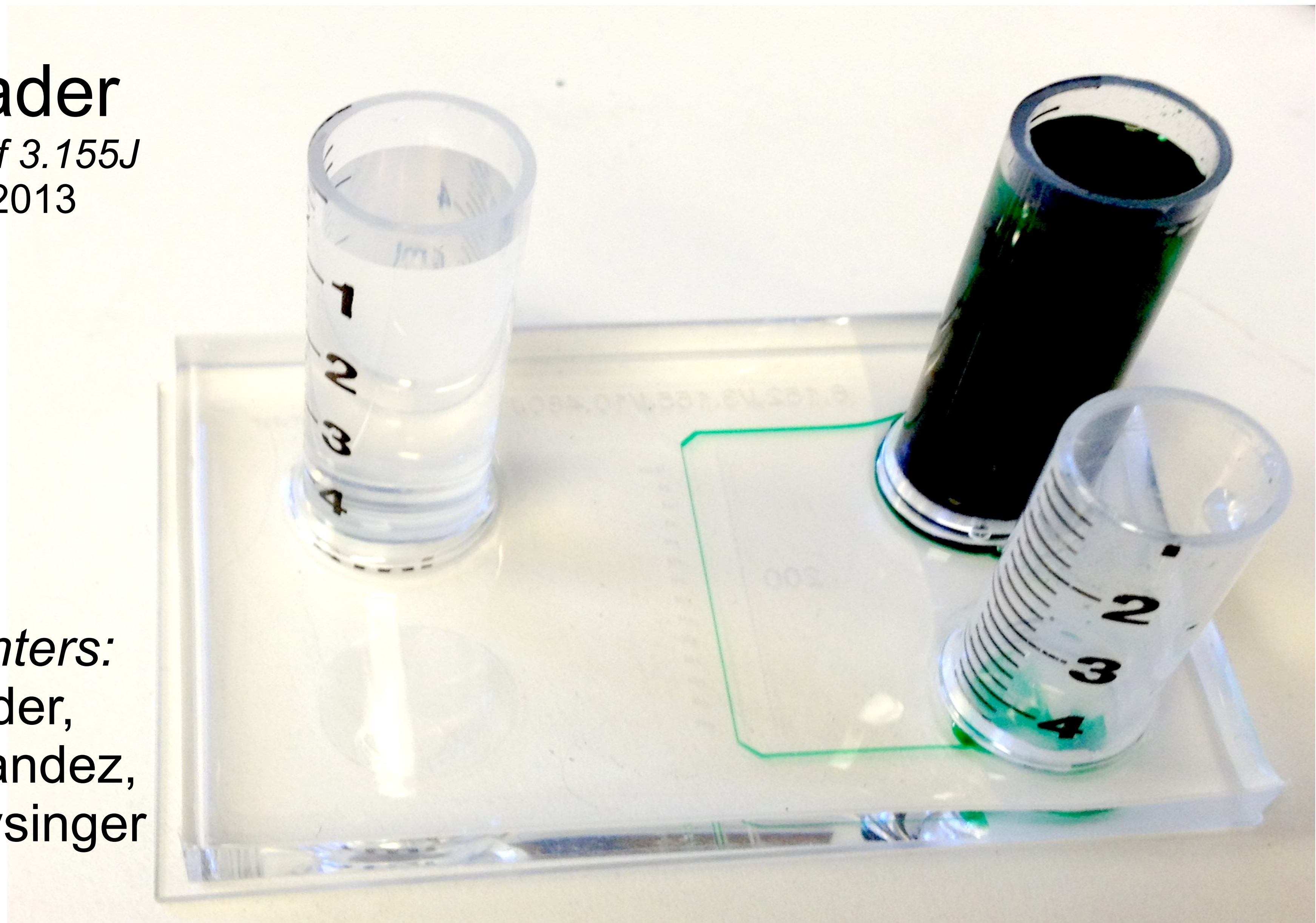
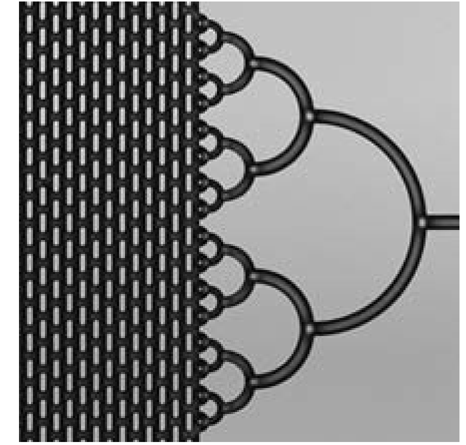
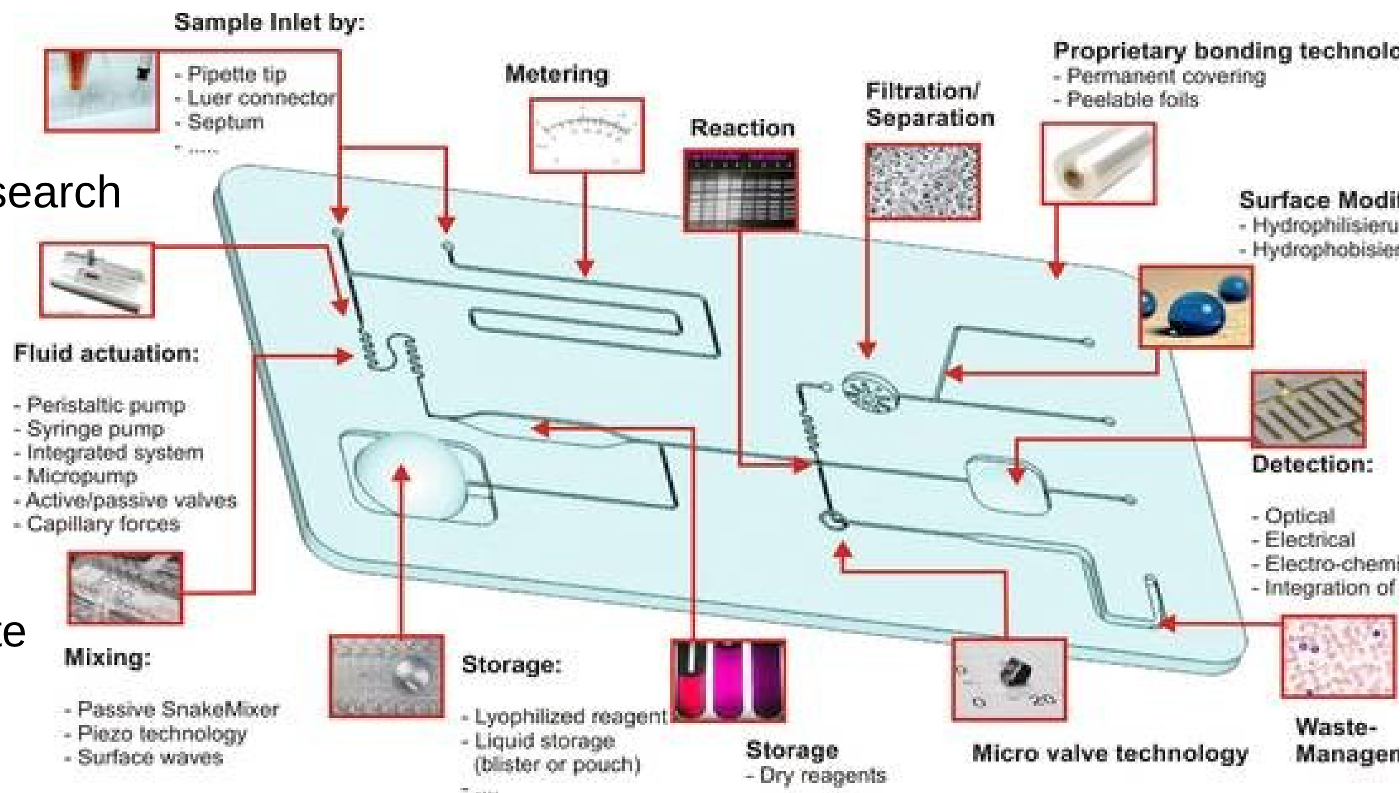


Experimenters:
Sam Bader,
Juan Hernandez,
William Baysinger

Why Microfluidics?



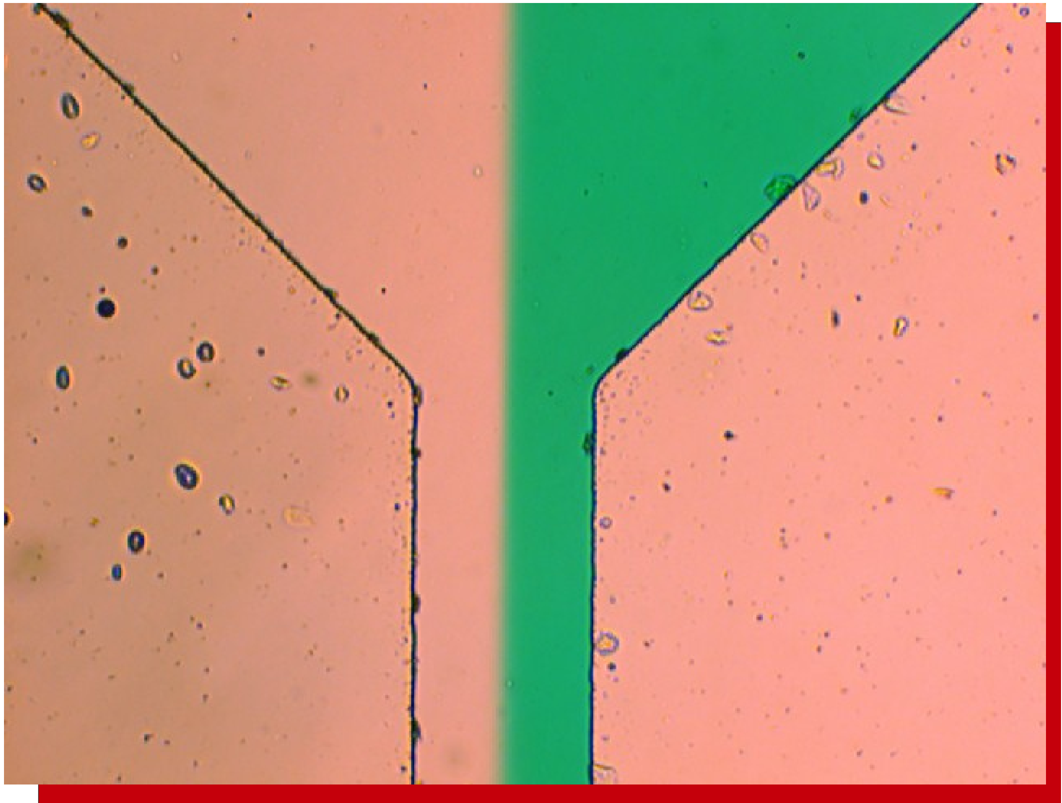
- **Applications of microfluidics:**
  - Printing
  - Chemical and medical research
  - Cooling electronics
- **Advantages:**
  - Compact
  - Easy to integrate, automate
  - Use smaller samples
  - Lab-on-a-chip



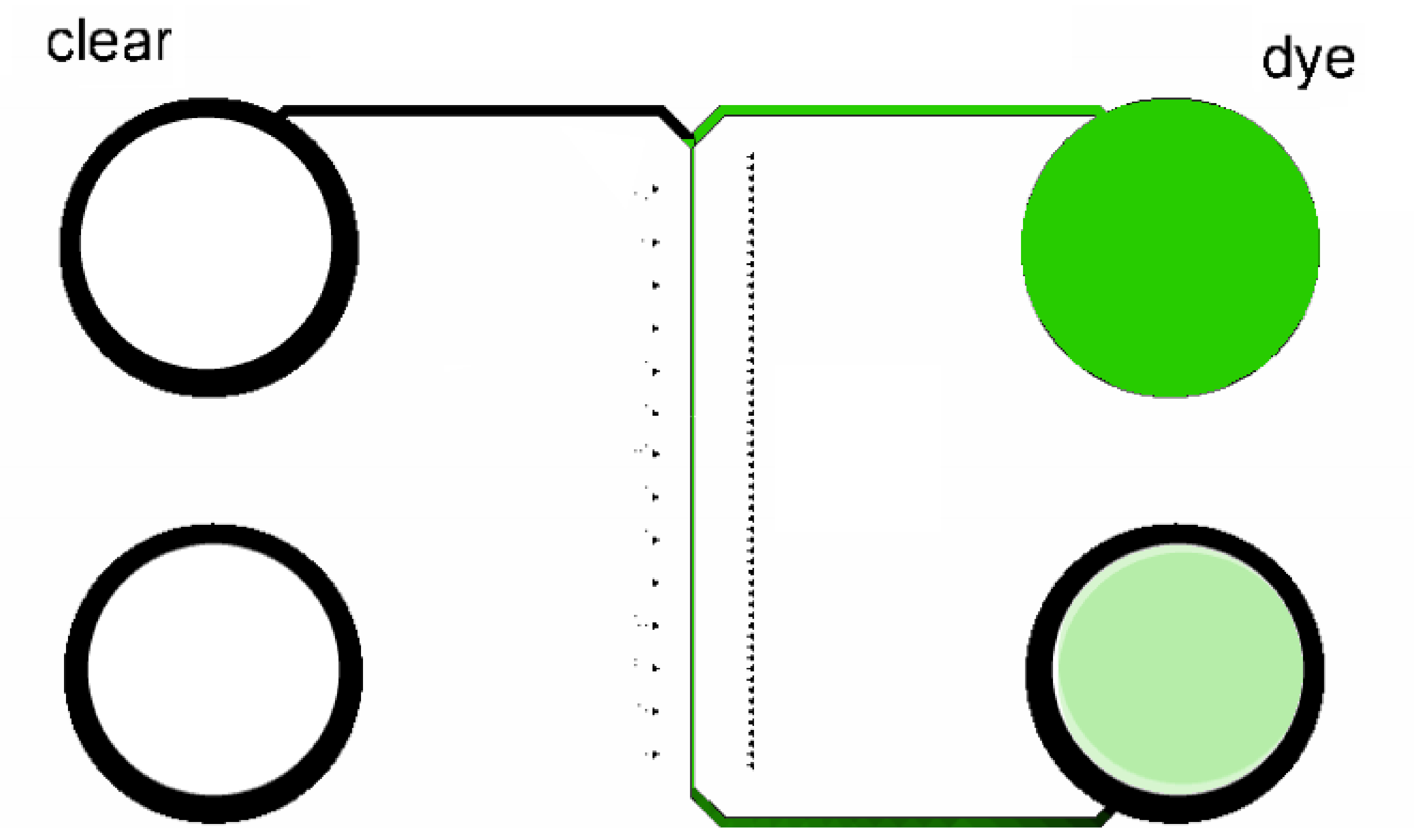
Diffusion is Vital

- ***Micro* is *different*:**
  - Small Reynold's number, and complex flow patterns
  - Scaling: surface and entrance effects important
  - In absence of turbulence,

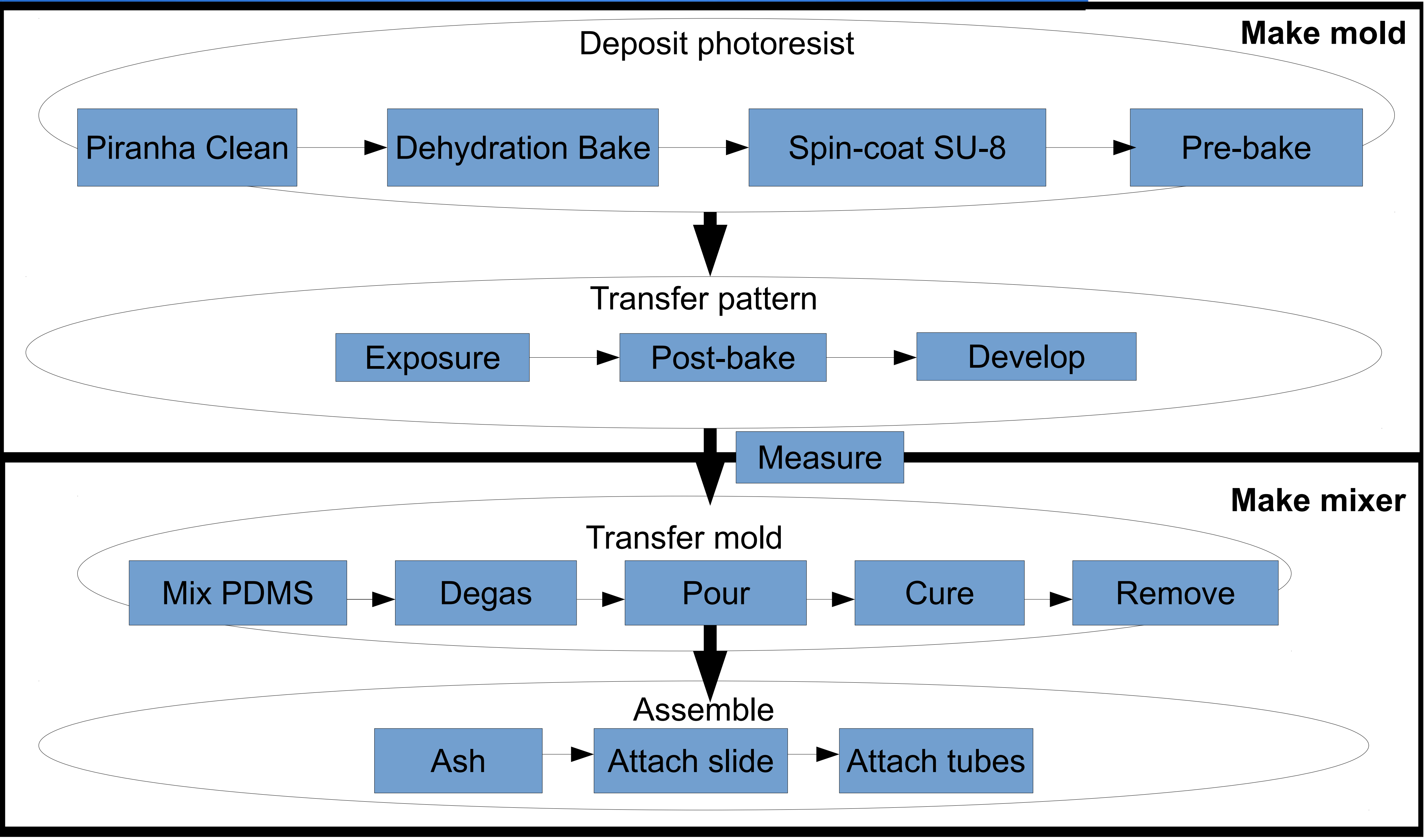
    mixing occurs by diffusion



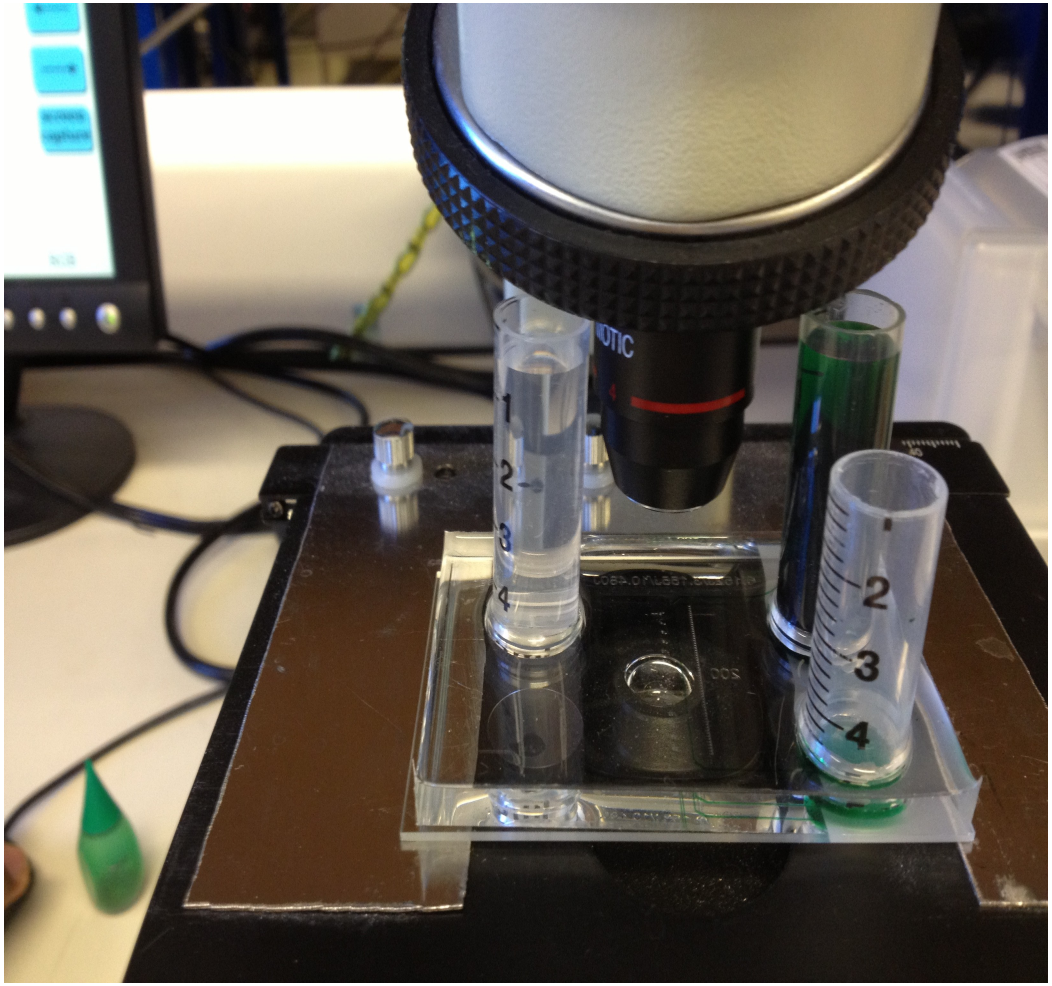
Characterize the diffusive mixing

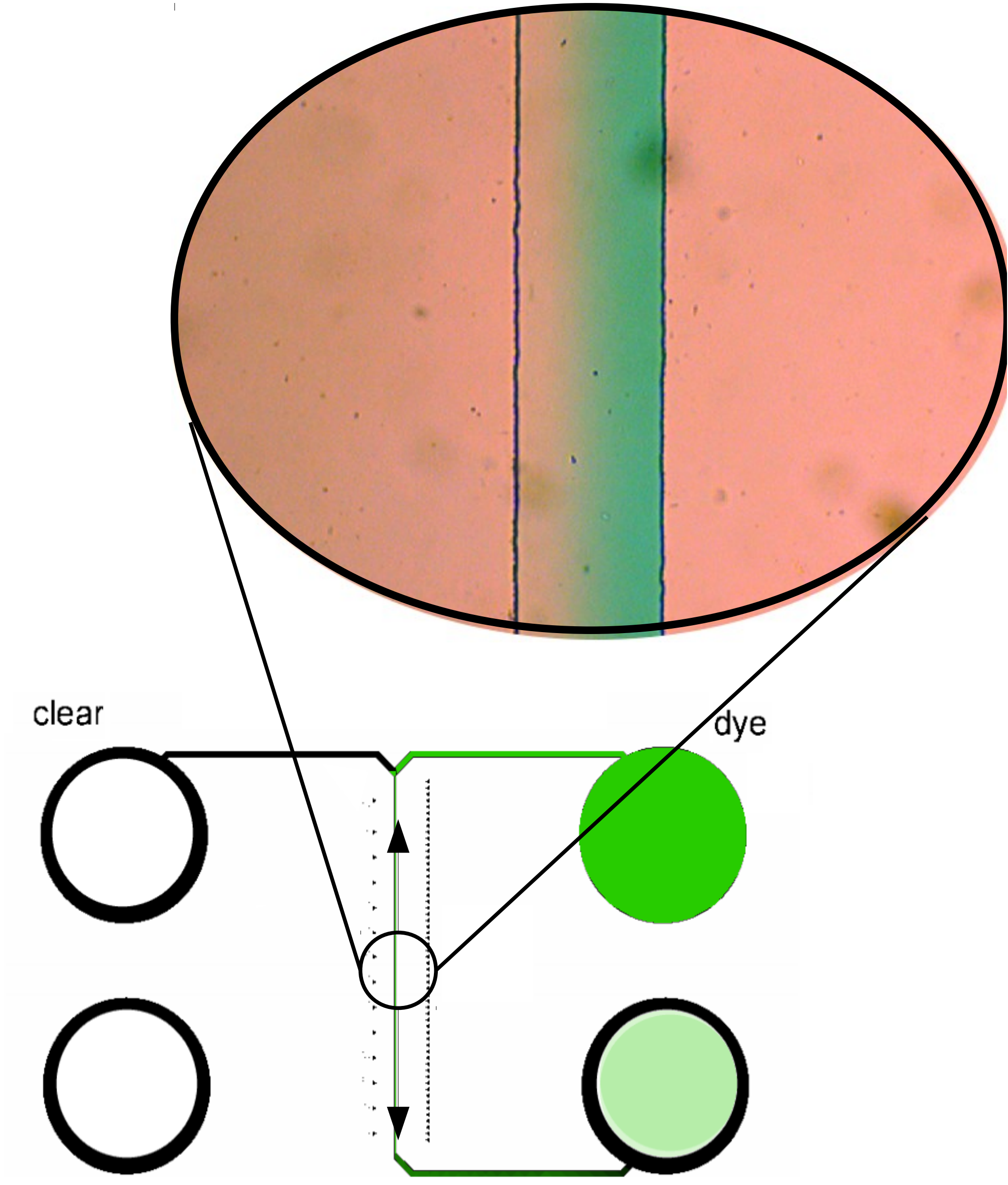


Fabrication

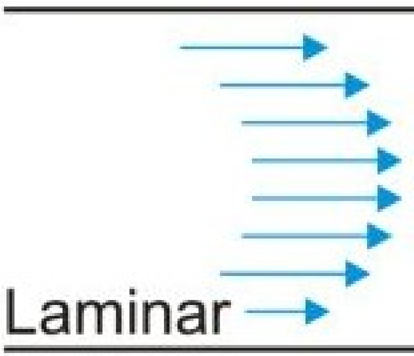


Experiment and Observe





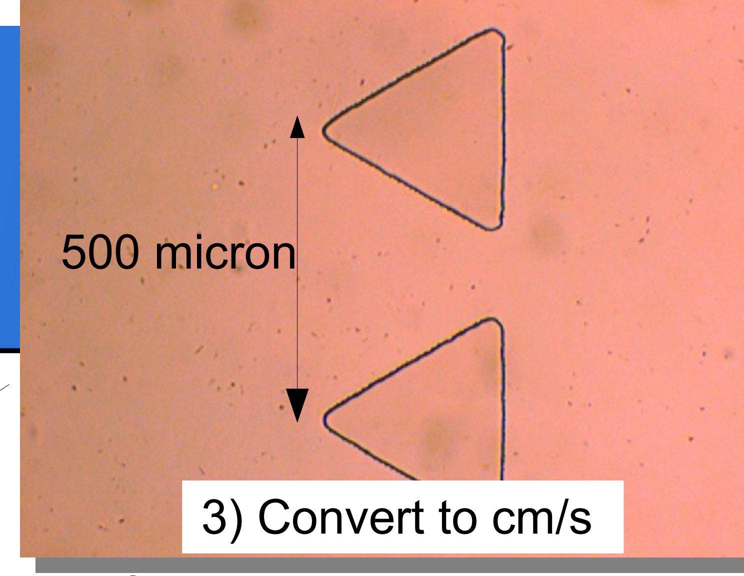
Determine fluid velocity

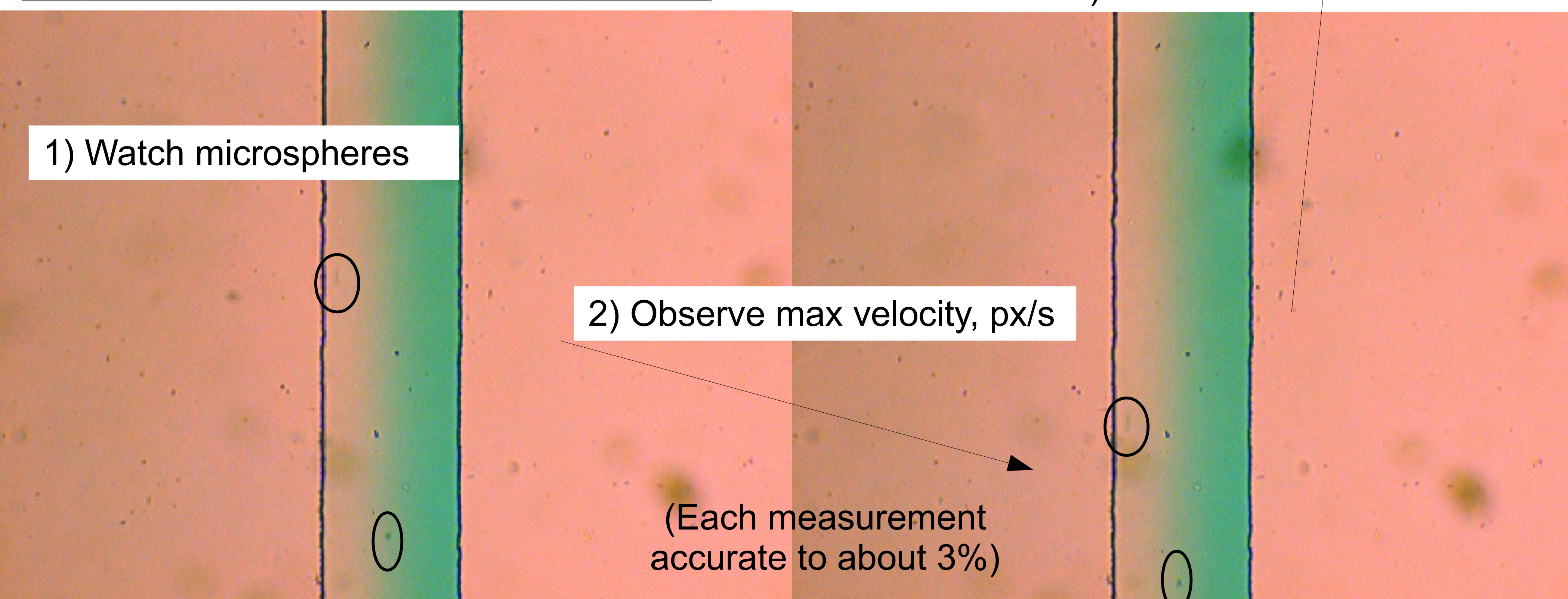


4) Convert to mean fluid velocity

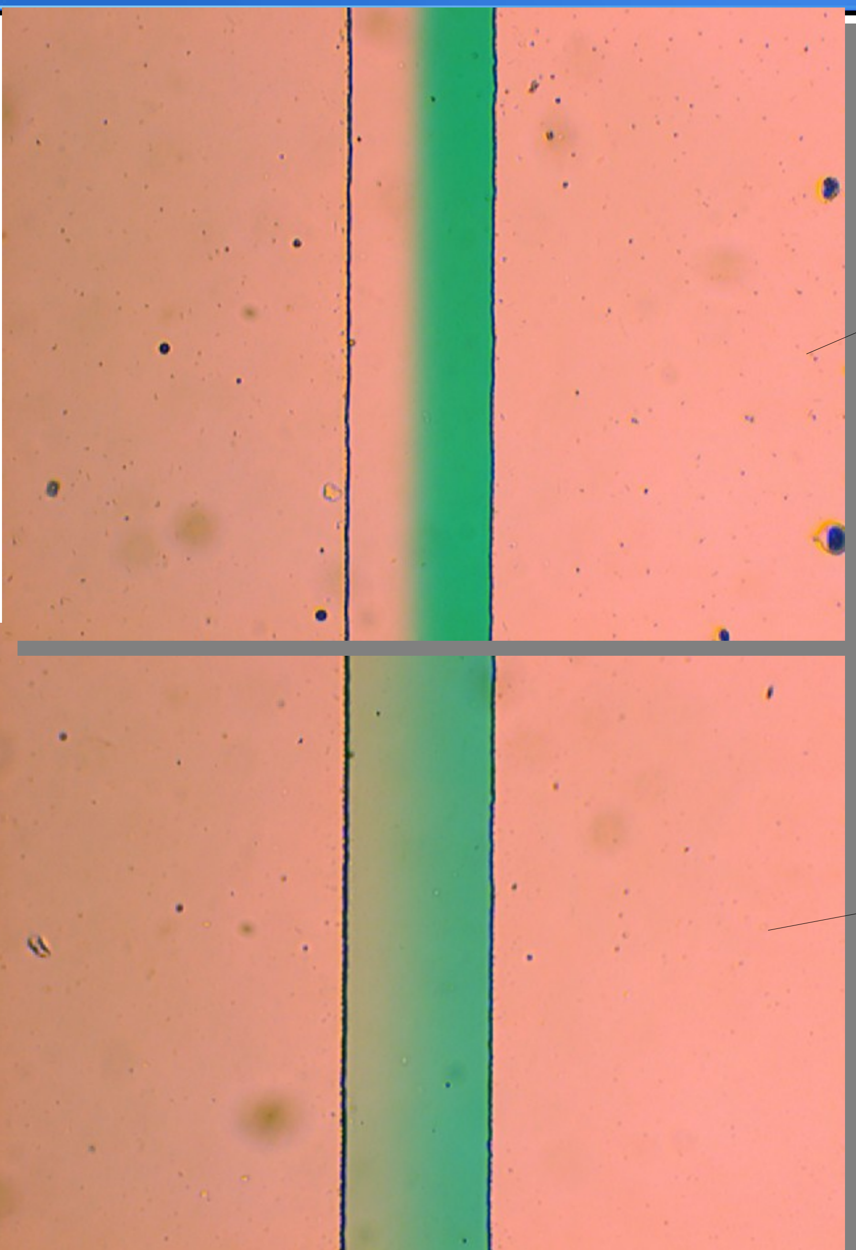
$$U_{avg} = \frac{2}{3} U_{max}$$

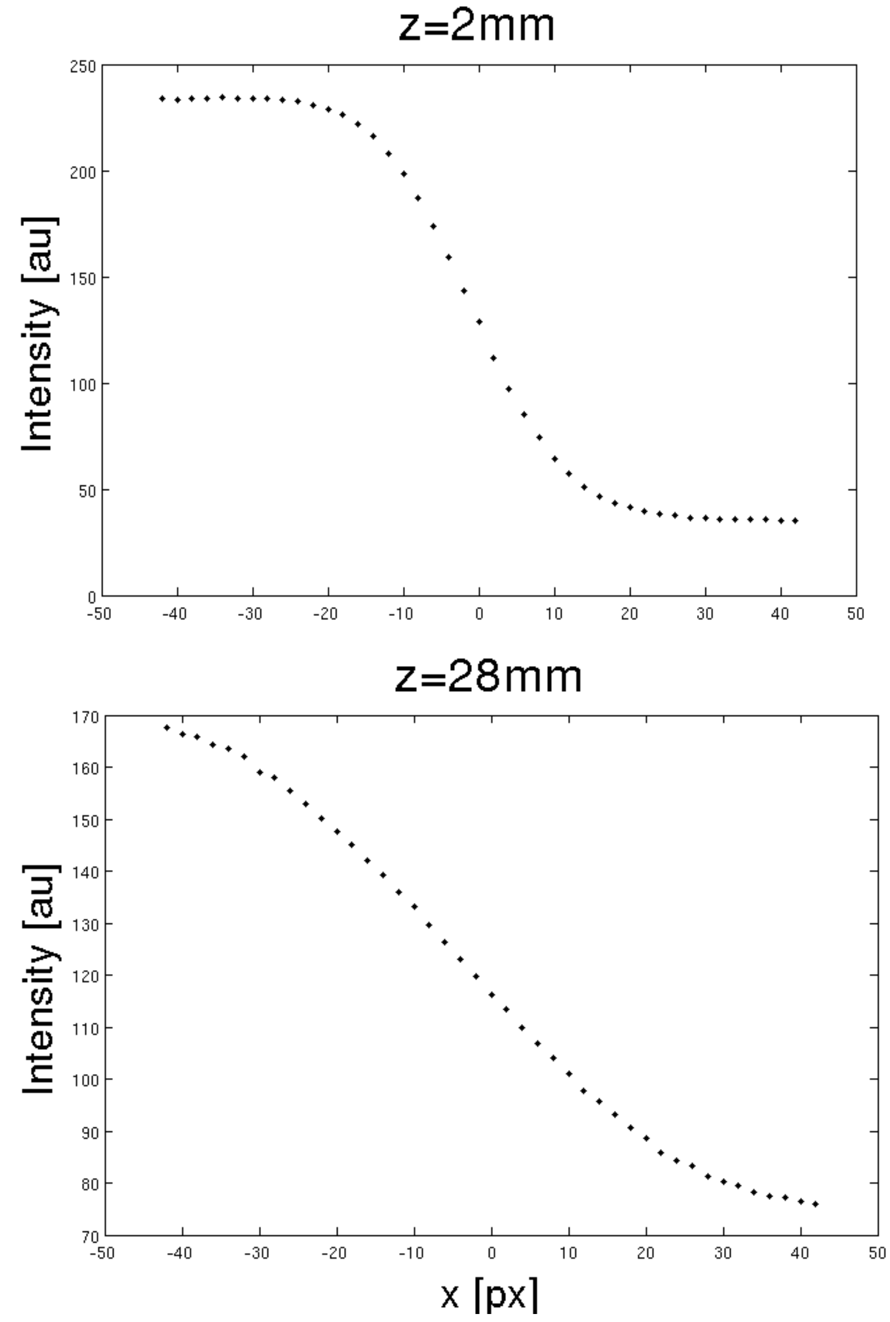
(Determination of maximum relatively robust because of this distribution)





Examine diffusion profile





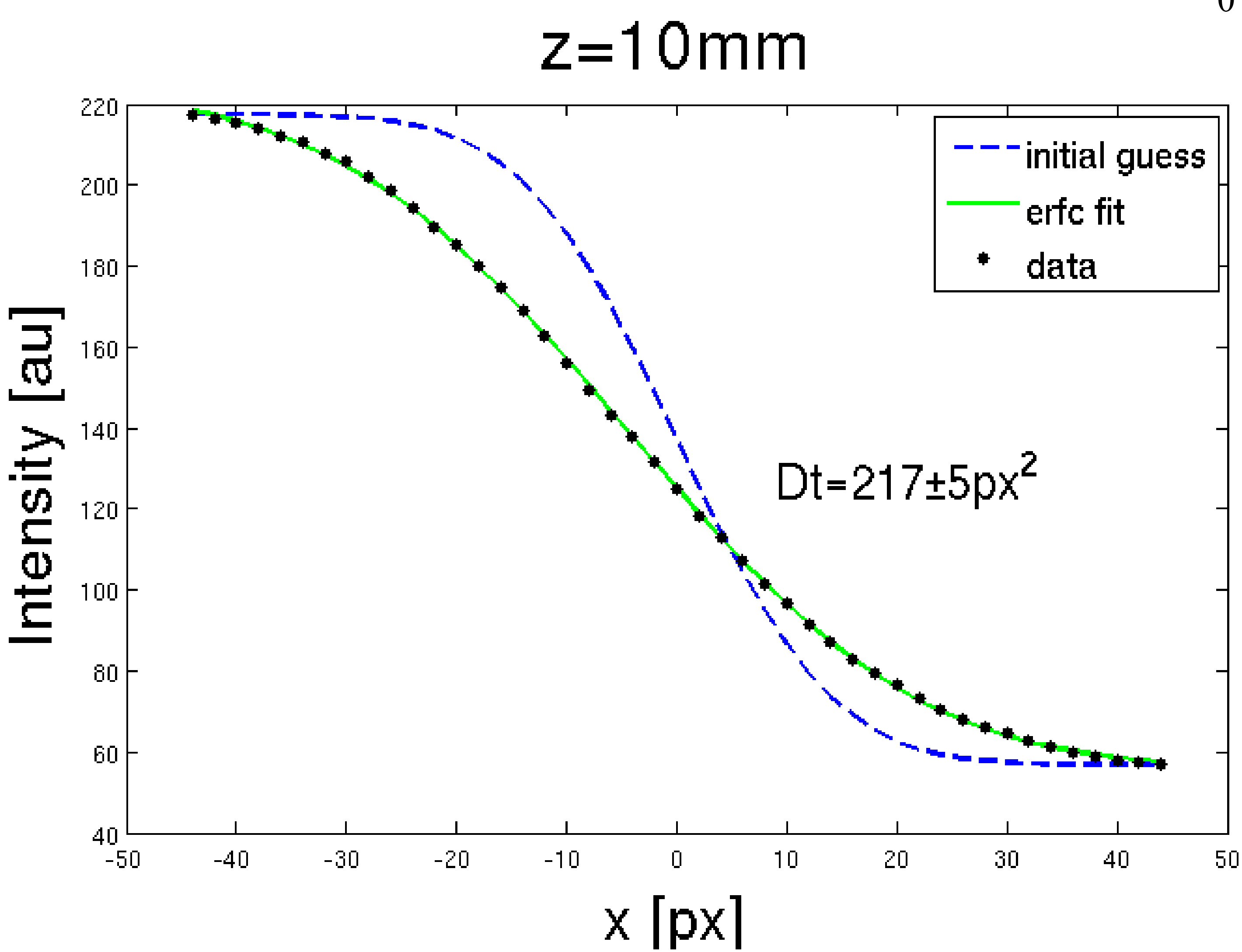
Fit each profile to model

From solving diffusion equation

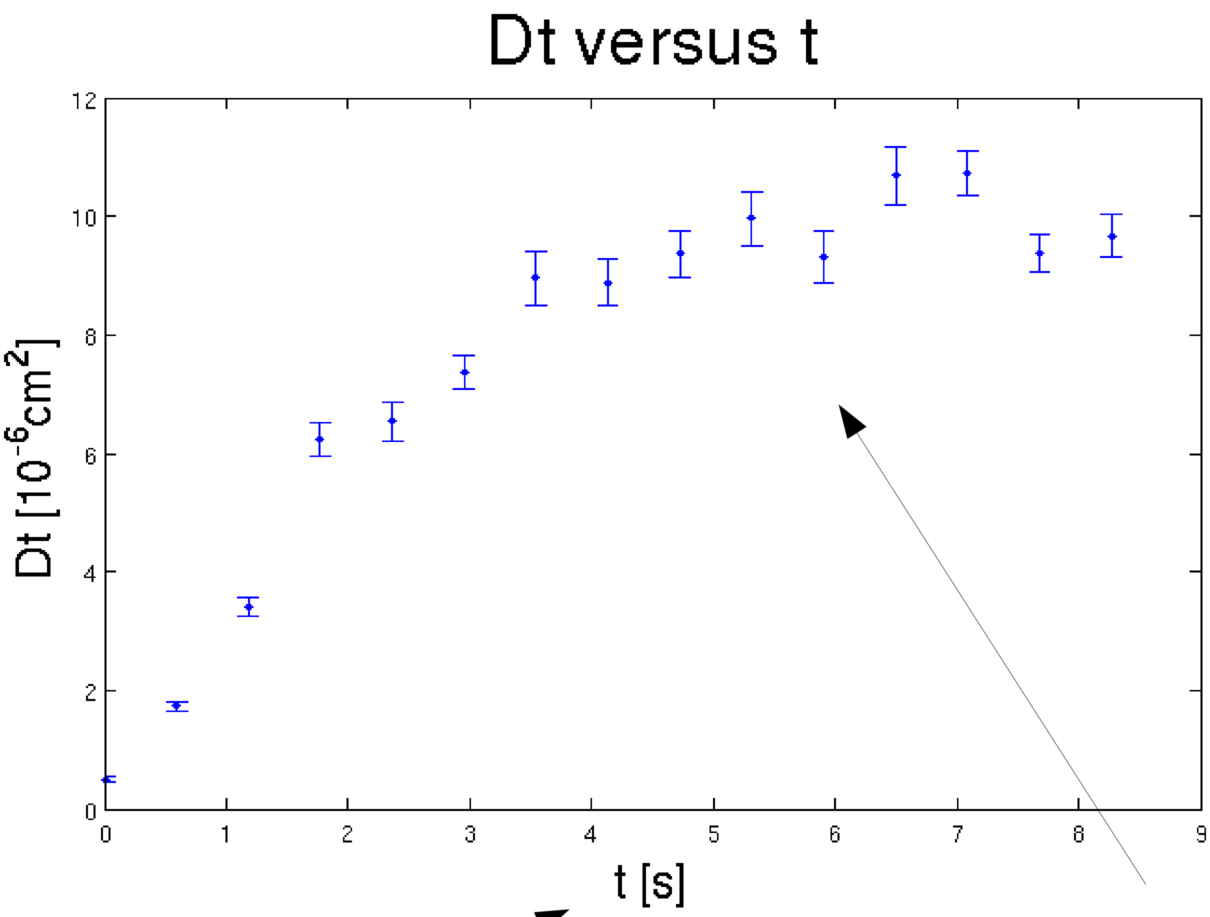
$$I = I_0 - \frac{c}{2}\left(1 + erf\left(\frac{x-s}{l}\right)\right)$$

$$l = 2\sqrt{Dt}$$

So each image gives us a value for *Dt*



Combine estimates

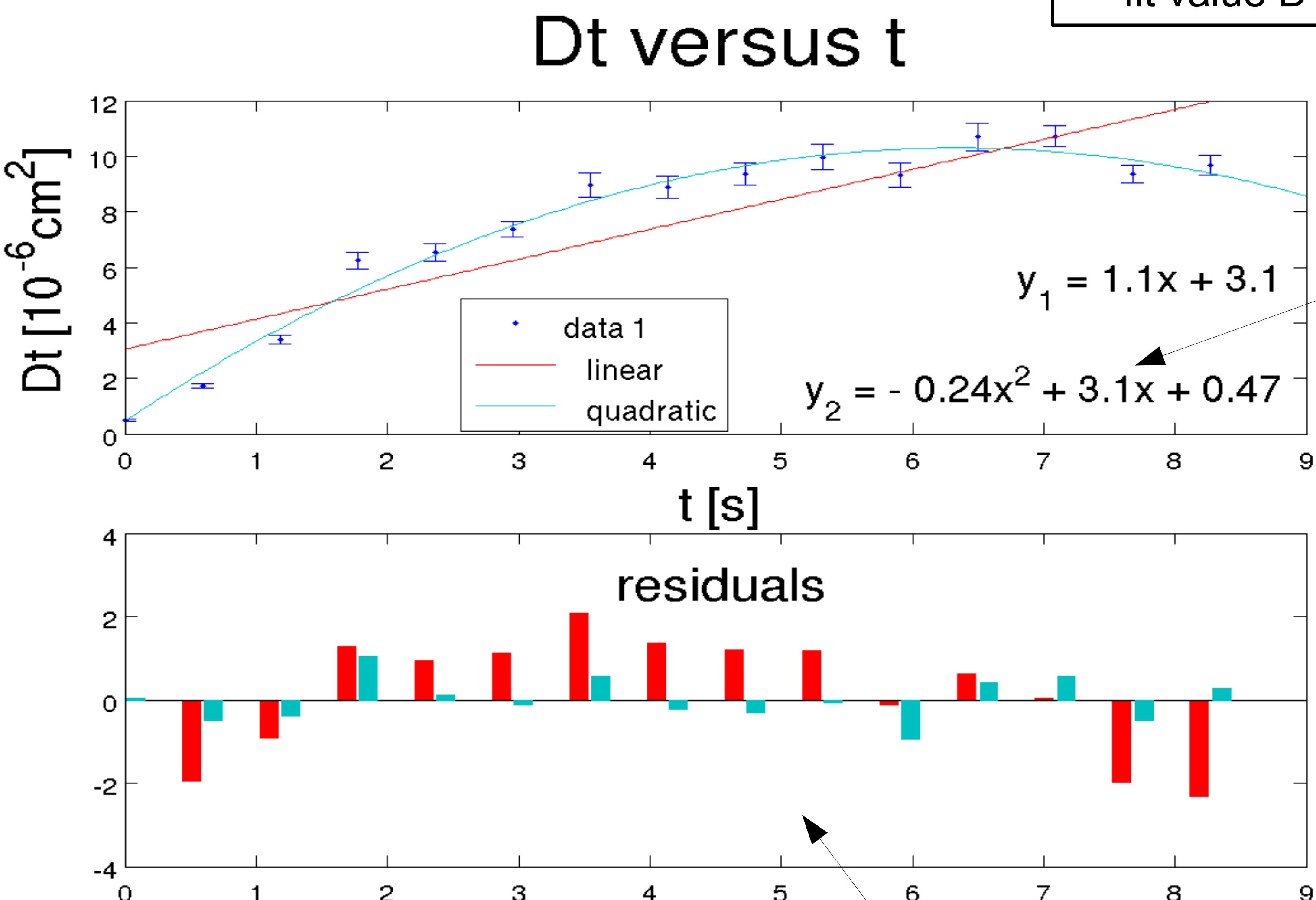


Distinctly non-linear

Use measured velocity
to convert z-axis to time

Fit results

In the extent to which a "diffusion constant" is a reasonable parameter for describing this data,
it would be this linear-term fit value $D=3.1cm^2/s$.



Quadratic fit empirically justifiable

Consider assumptions/ Why is it non-linear?

- Flow velocity is non-uniform
  - Not a 1-D diffusion equation at each cross-section.
- Effect of left boundary down the channel
  - Slows diffusion because no leakage off to infinity
- Absorption is not a linear function of concentration
  - Beer-Lambert law

Other interesting calculations

- Justify choice of flow model with Reynold's number

$$Re = \frac{\rho \, v_{avg} \, D_H}{\eta}$$

$$D_H = \frac{4 \; \text{Area}}{\text{Perimeter}}$$

Our Reynold's number is .32, which means we don't expect any sort of turbulence.

(Re < 1 is typical in microfluidics.)

Other interesting calculations

- Further examine of the validity of the model via pressure predictions:

Measured by scope (to about 3%)

(Easy to measure by eye within 1%)

$$P_{model} = \frac{v_{max} \cdot 8\eta}{h} \cdot l$$

$$P_{actual} = \rho g (H_{clear} + H_{dye})$$

Measured with surface profiler (constant within about to 4%)

$$P_{model} = 712\text{Pa}$$

$$P_{actual} = 804\text{Pa}$$

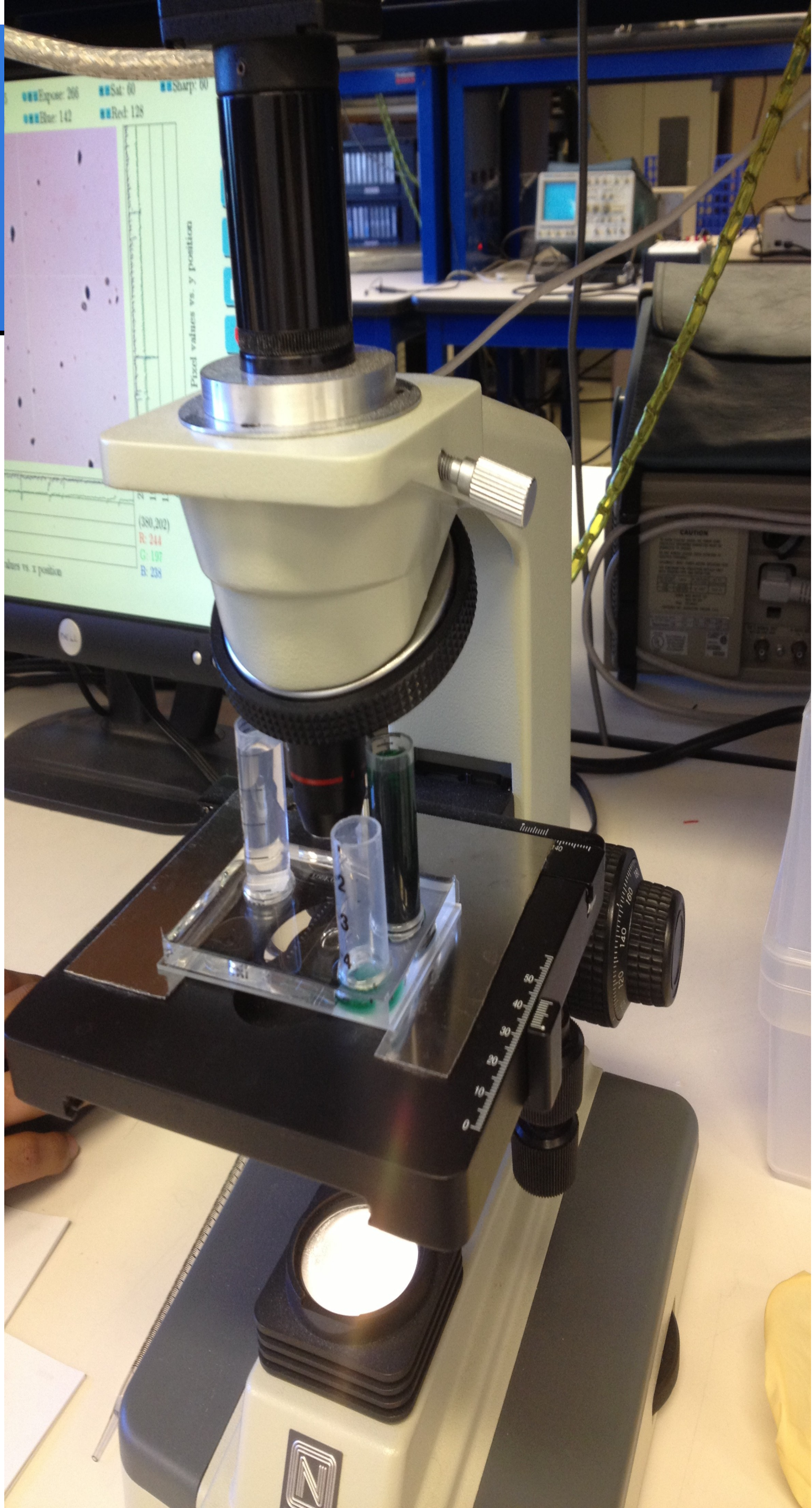
The model is off by about 11%, which is barely beyond our error budget.

In summary

- We found a diffusion coefficient for the system, but found that the diffusion did not proceed linearly as our model would have hoped. We explained possible reasons for this discrepancy.

- We also examined other calculations within the model for consistency, and found reasonable Reynold's numbers and appropriate pressures.

Thank you!



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