Università degli Studi di Padova

Dipartimento di Fisica e Astronomia ''Galileo Galilei''

Master Degree in Physics

Introduction to research activities

Study of the droplet shape and motion in a microfluidic channel

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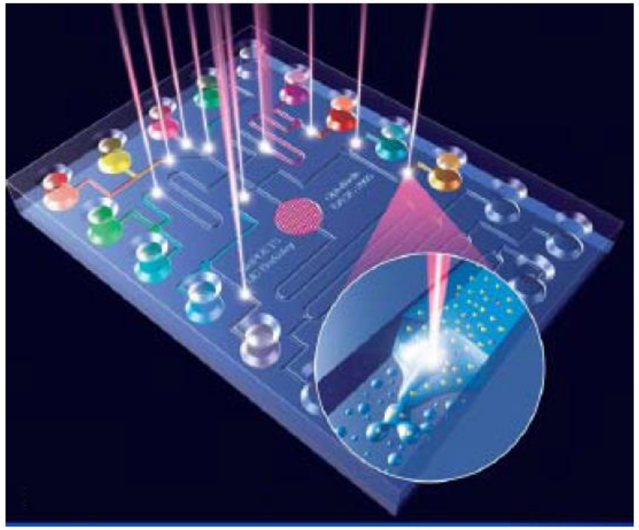
Microfluidics

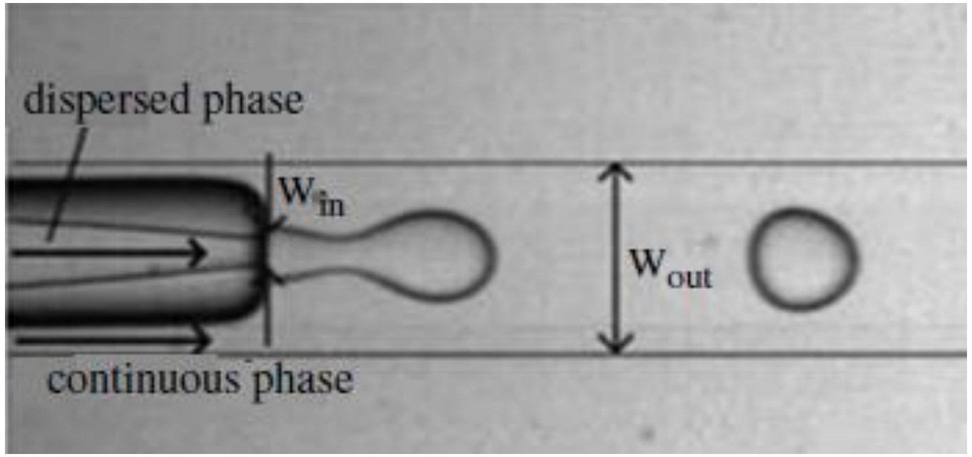
- ❖ Microfluidics is the science and technology of systems that process or manipulate small (pL – nL) amounts of fluids, using channels with dimensions of 10-100μm.
- ❖ Portable systems, easy control of parameters, real time control, less volumes of reagents and samples.

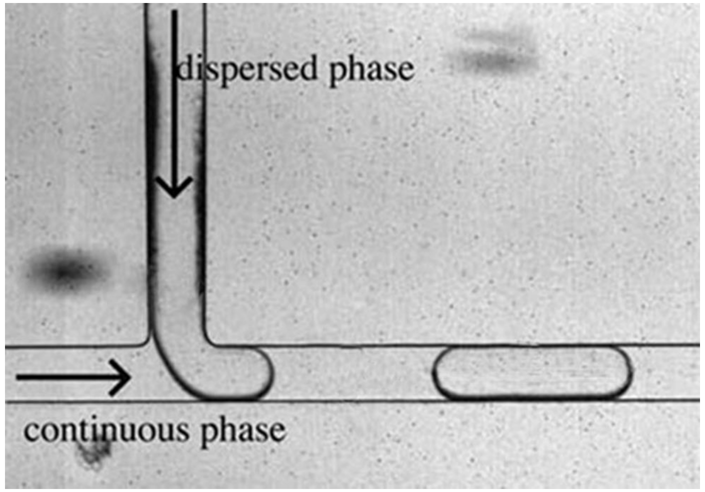
Lab-on-a-chip →

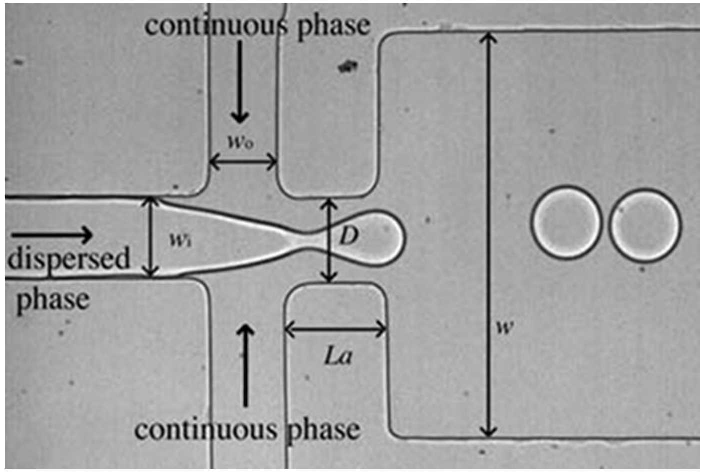


Droplets microfluidics

- Emulsions
- Monodispersed size
- No interaction between droplets and wall
- Rapid mixing inside of the droplet



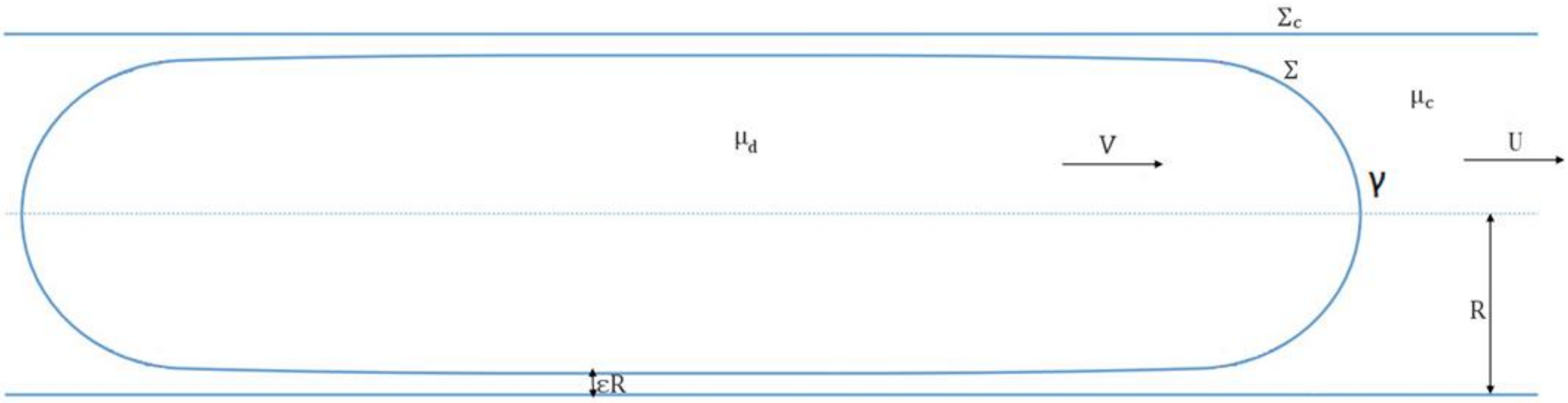




Droplets microfluidics

- Questions related to the motion of the drop are still open: it is not known what is the dominant contribution between **viscosity** and **surface tension**.

- Not much is known about the shape of the droplets in microchannel.



Goal of the experiment

- Investigate the effect of viscosity and surface tension on the deformation of the drops.

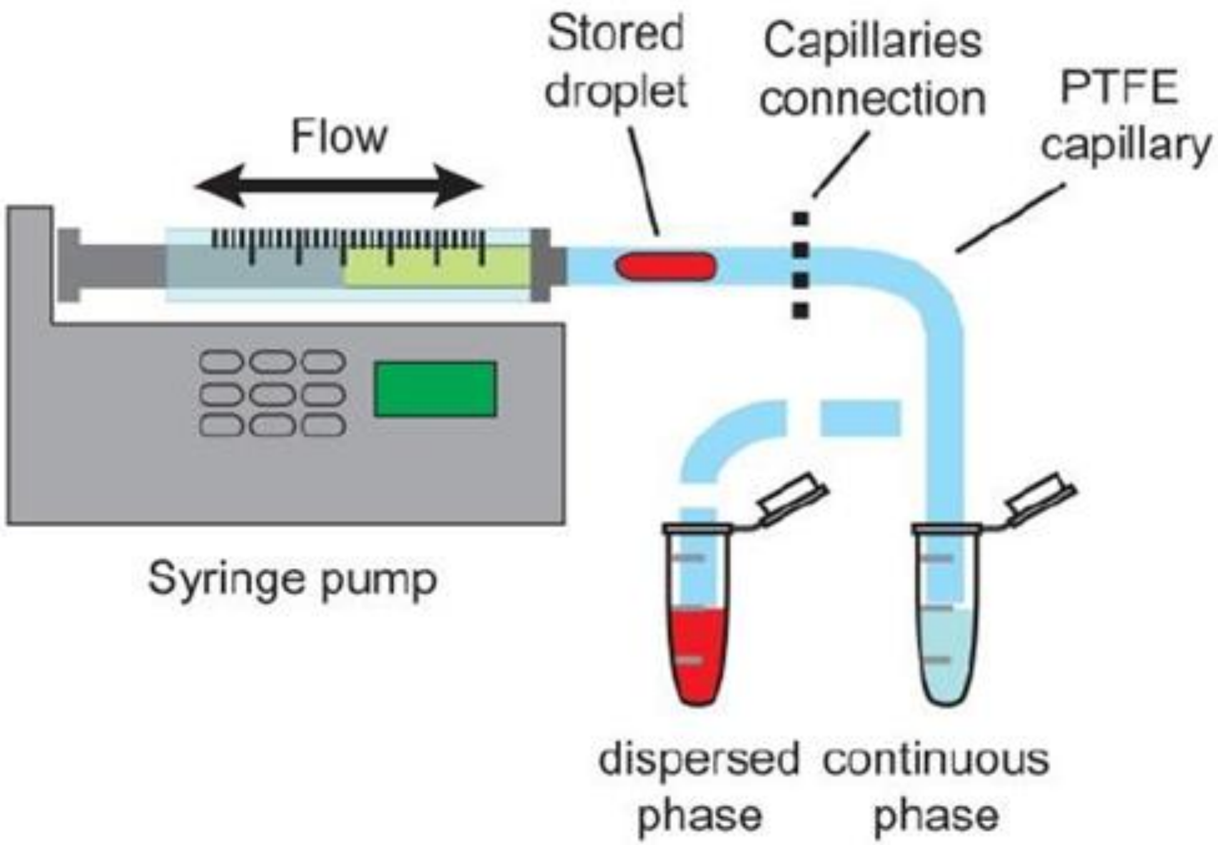
- Study of the speed trend of the drops as a function of the relative elongation for different viscosities and interfacial tensions.

Continuous phase	Dynamic viscosity [mPa·s]
Pure FC40	4.14

Dispersed phase	Dynamic viscosity [mPa·s]	Interfacial tension γ [mN/m]
Pure water	0.89	51.2
gly/w 63%	10.71	46.2
gly/w 87%	100.33	38.7
EtOH/w 10%	1.35	32.1
EtOH/w 40%	2.33	14.7

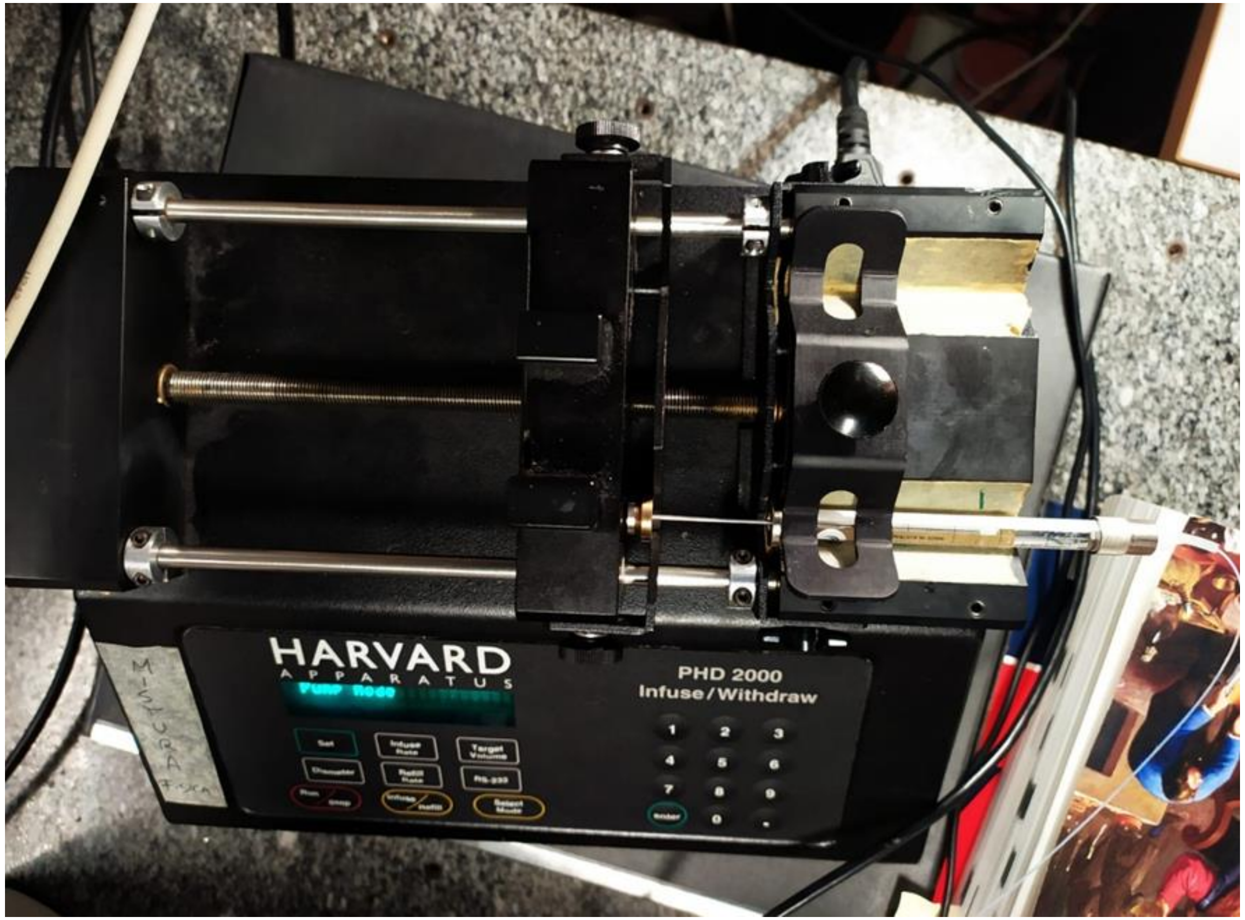
Experimental setup

❖ Setup 1: droplets generation



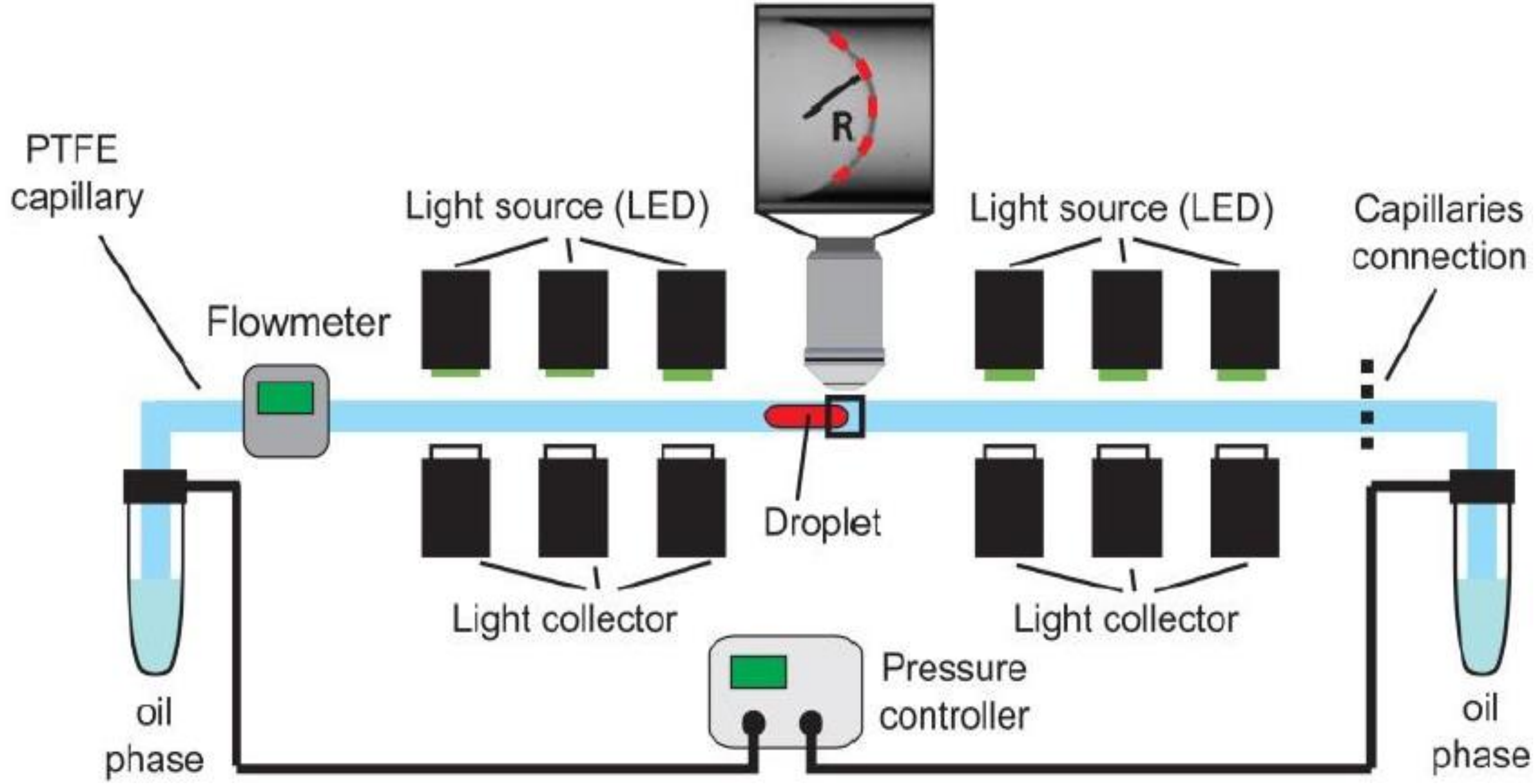
Experimental setup

- Setup 1: droplets generation



Experimental setup

❖ Setup 2: speed measurement and acquisition of the shape of the moving drops



Experimental setup

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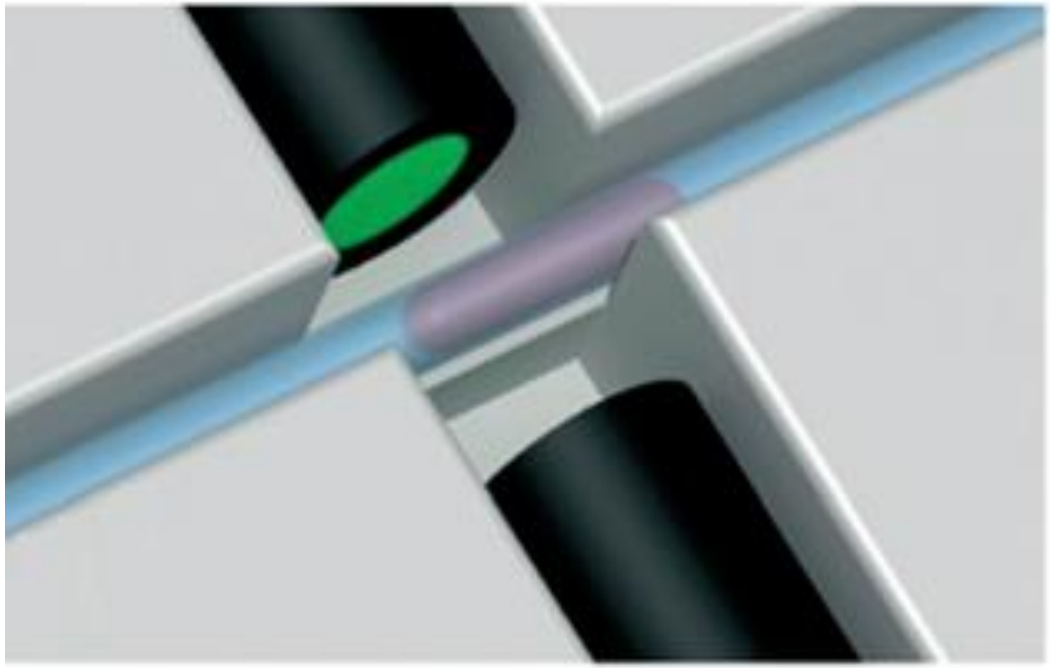

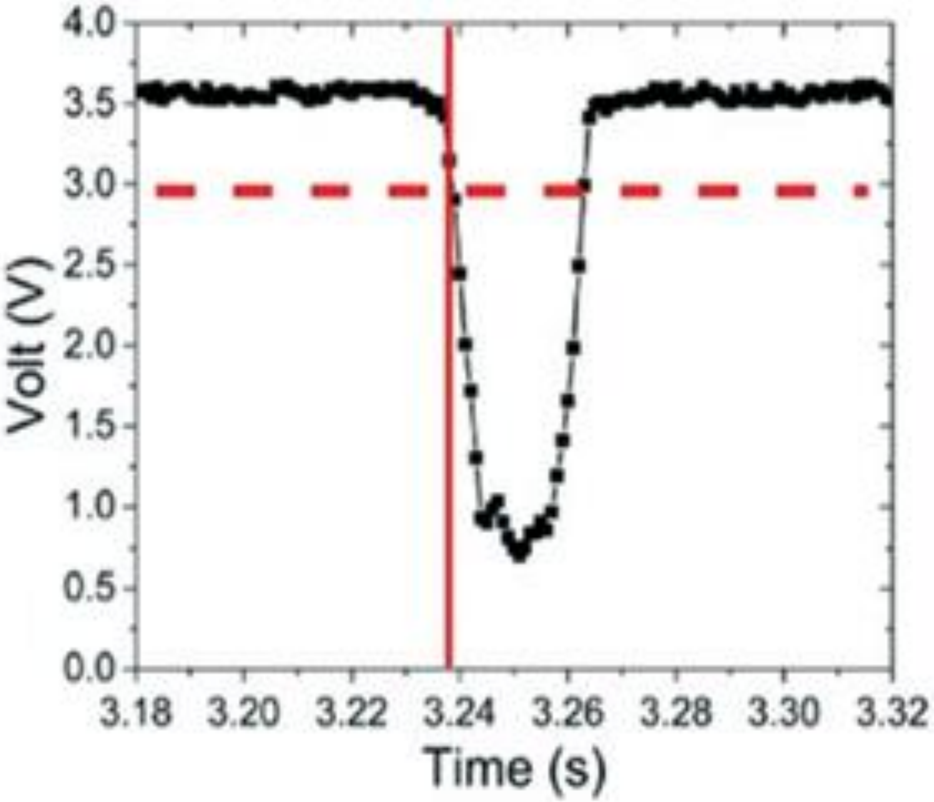

Experimental setup

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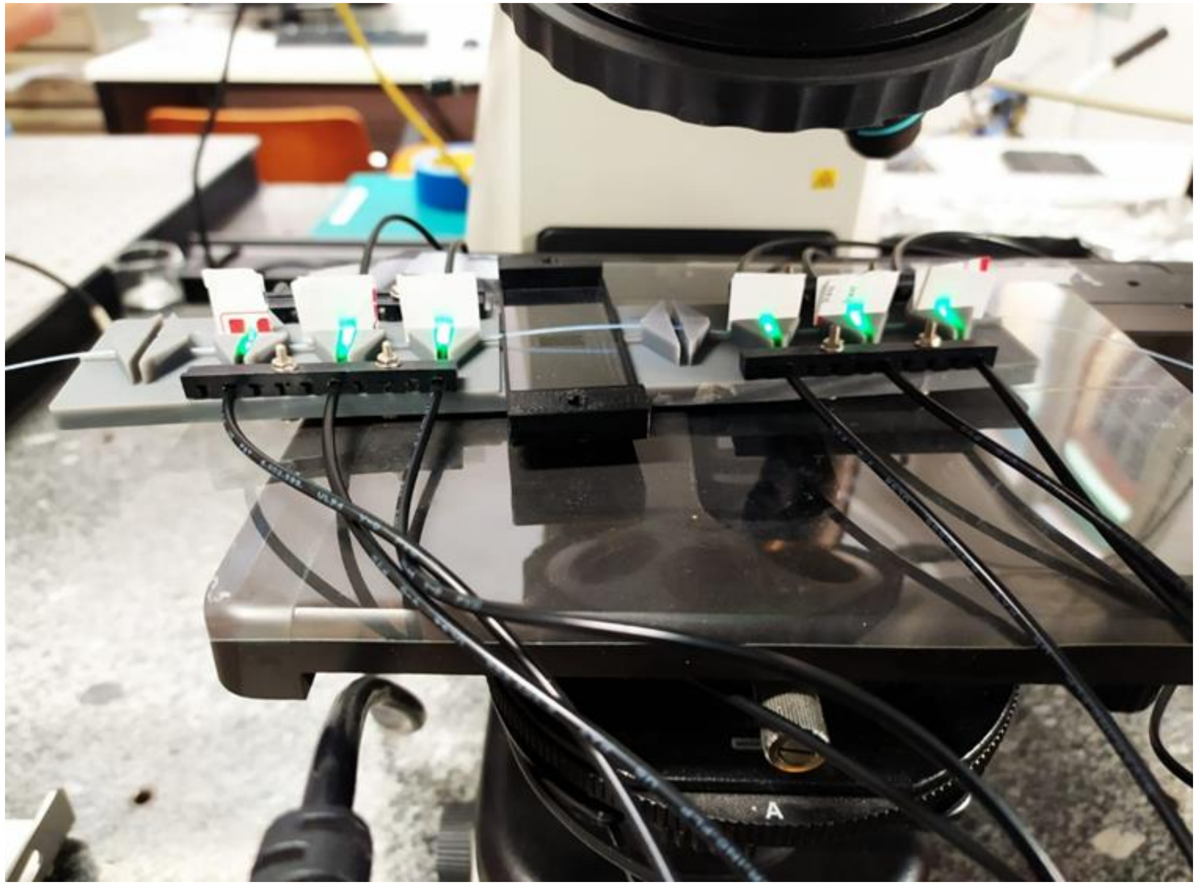
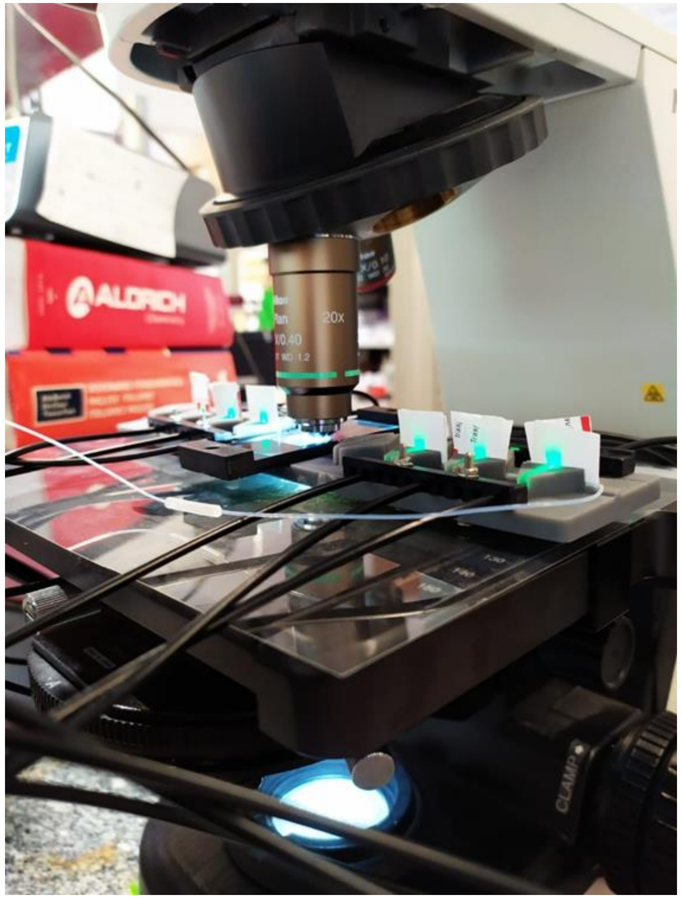
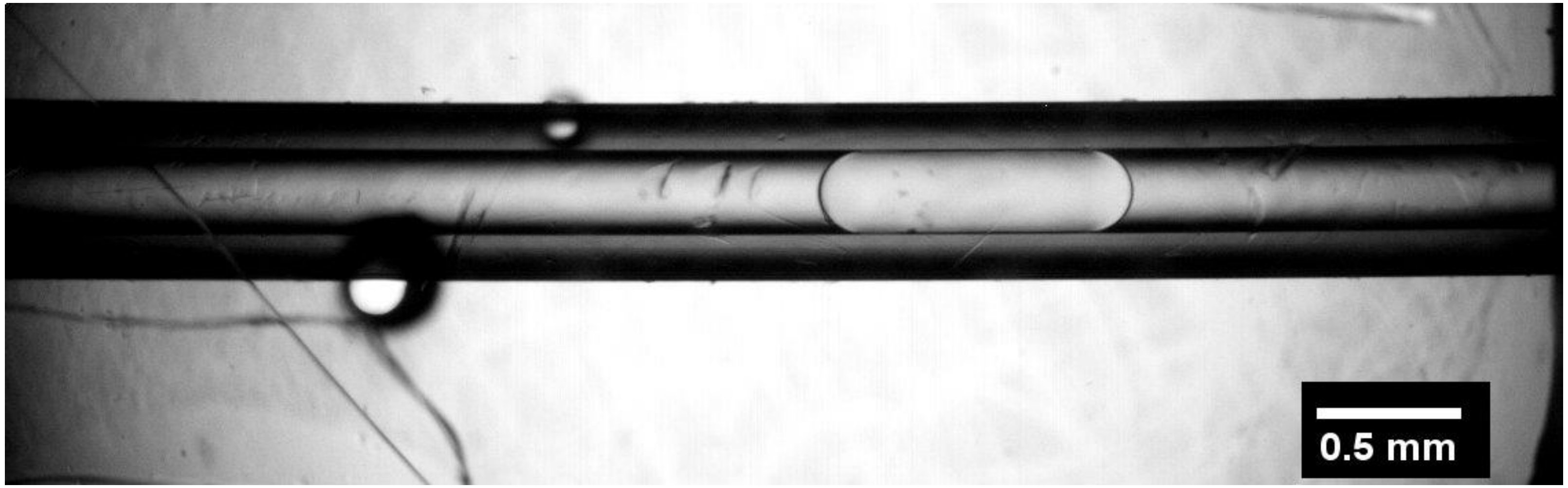
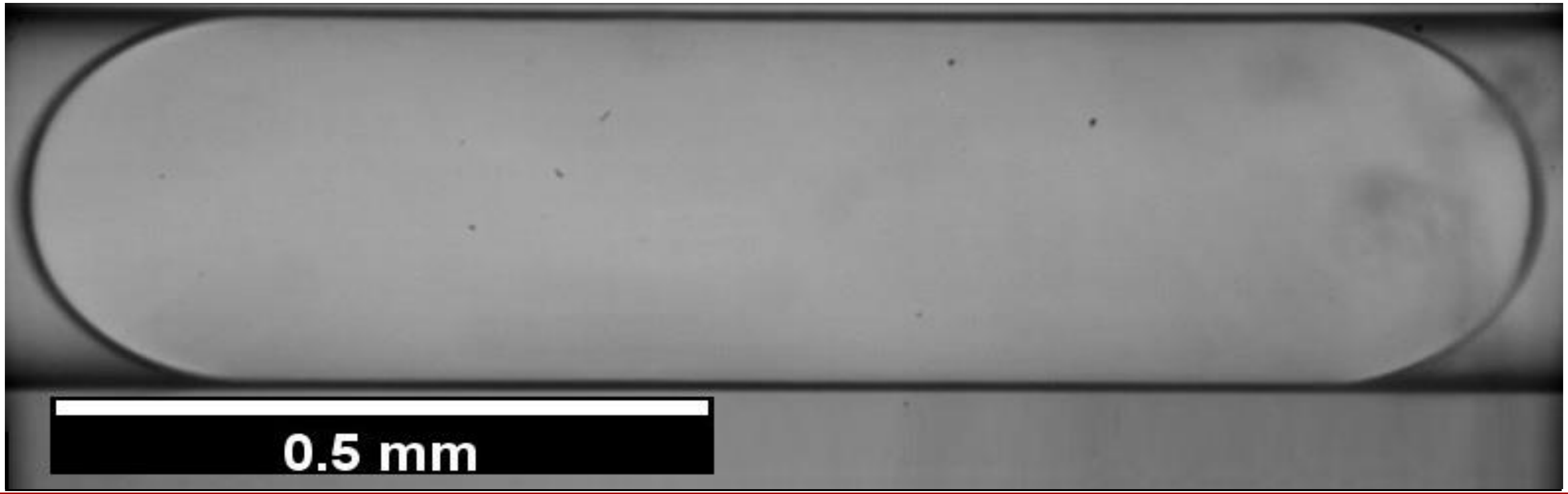




Execution of the experiment

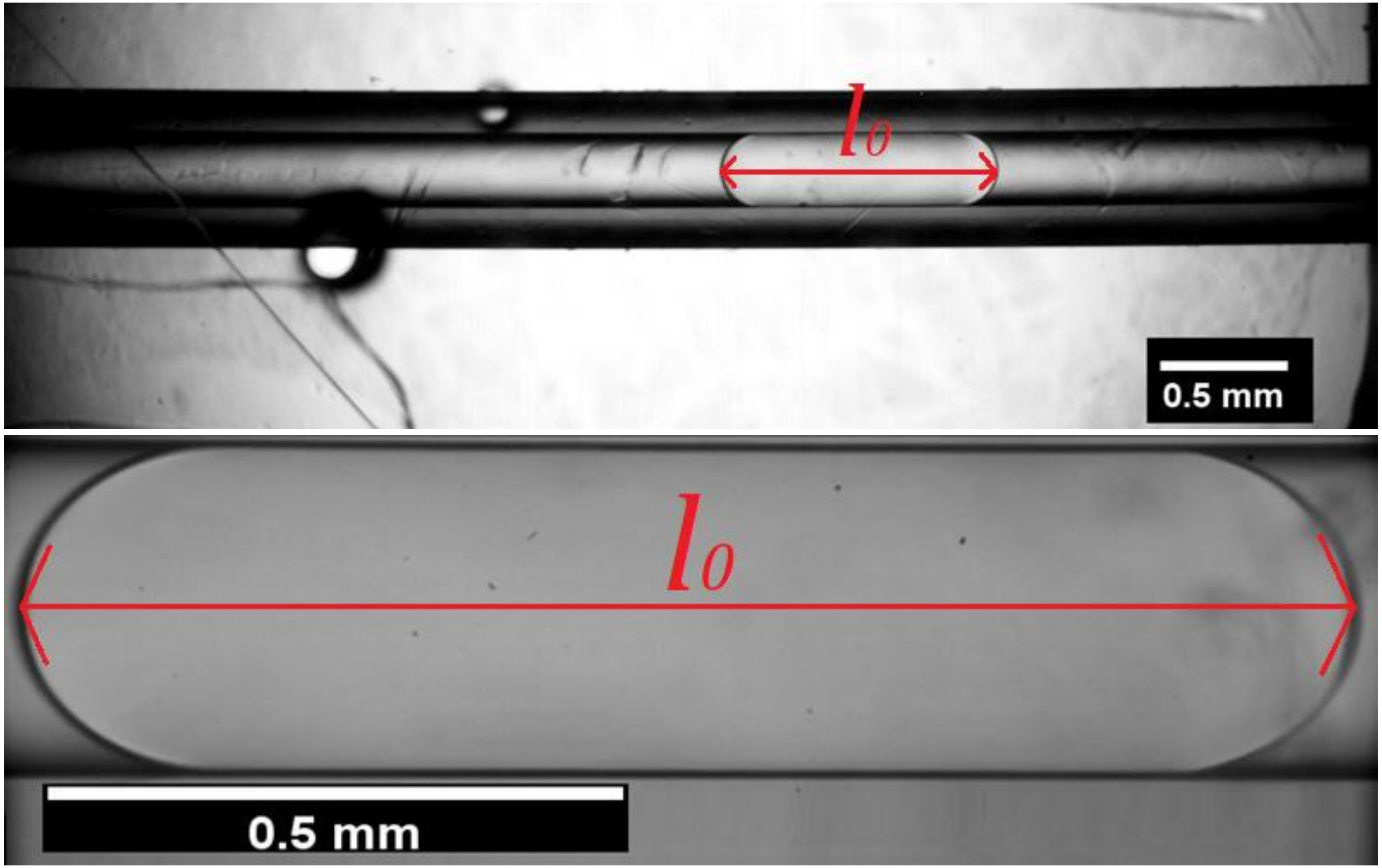
❖ Droplets observation





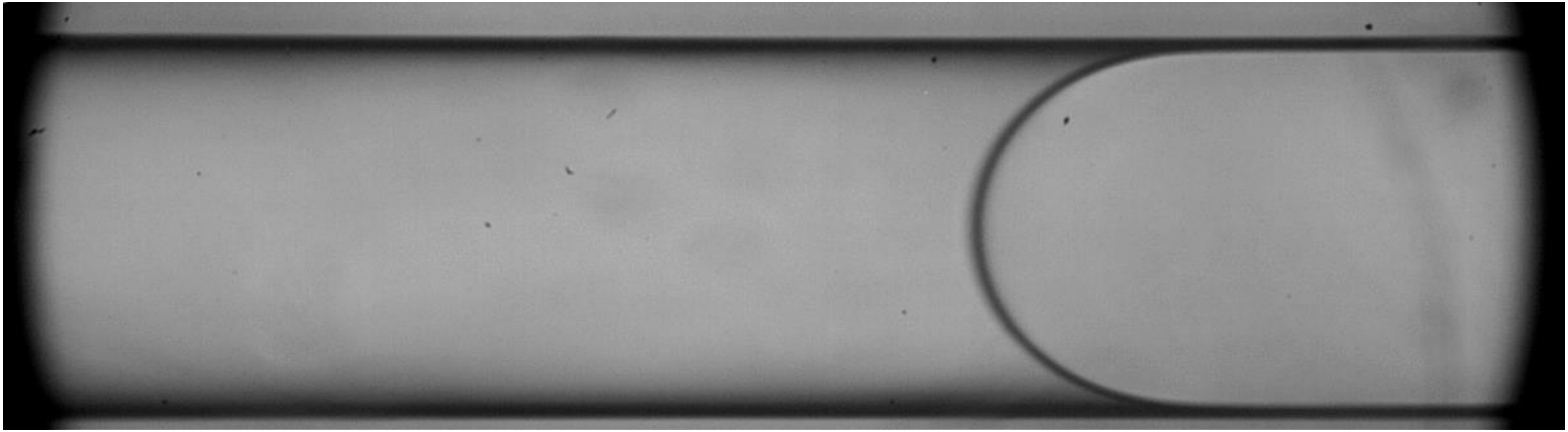
Execution of the experiment

❖ Droplets observation



Data Analysis

❖ Image analysis with ImageJ. Evaluate the length of the drops.



❖ Image analysis with ImageJ. Setting the threshold.

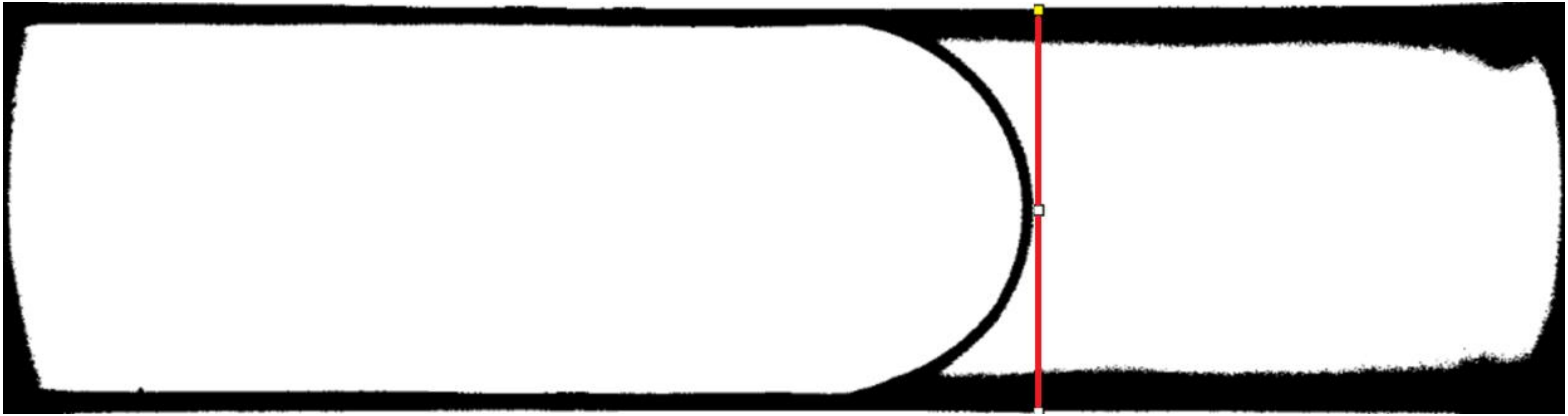
Data Analysis

❖ Image analysis with ImageJ

$$FPS = 250 \qquad T = \frac{\#Frame}{FPS} \qquad l = v \cdot T$$

Data Analysis

❖ Image analysis with ImageJ

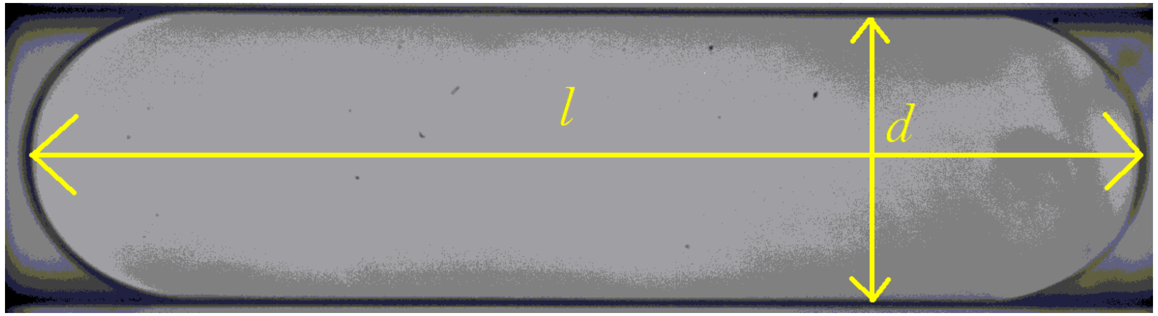


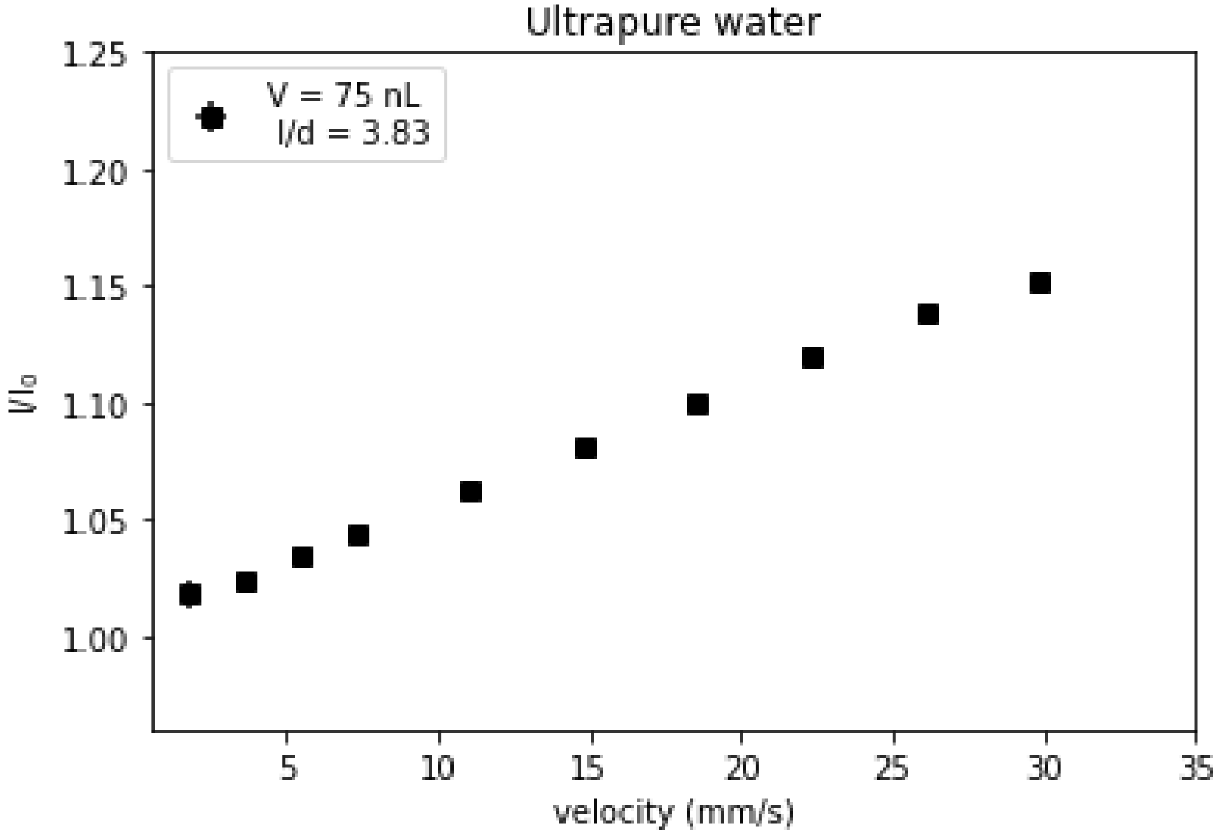
$FPS = 250$

$$T = \frac{\#Frame}{FPS}$$

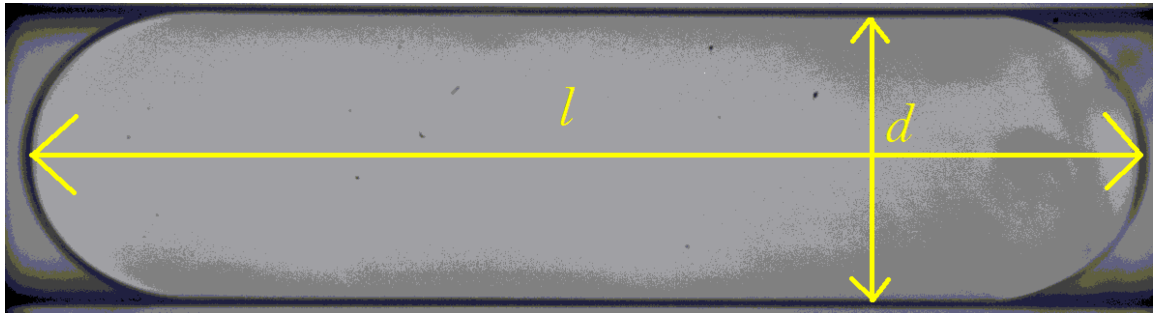
$l = v \cdot T$

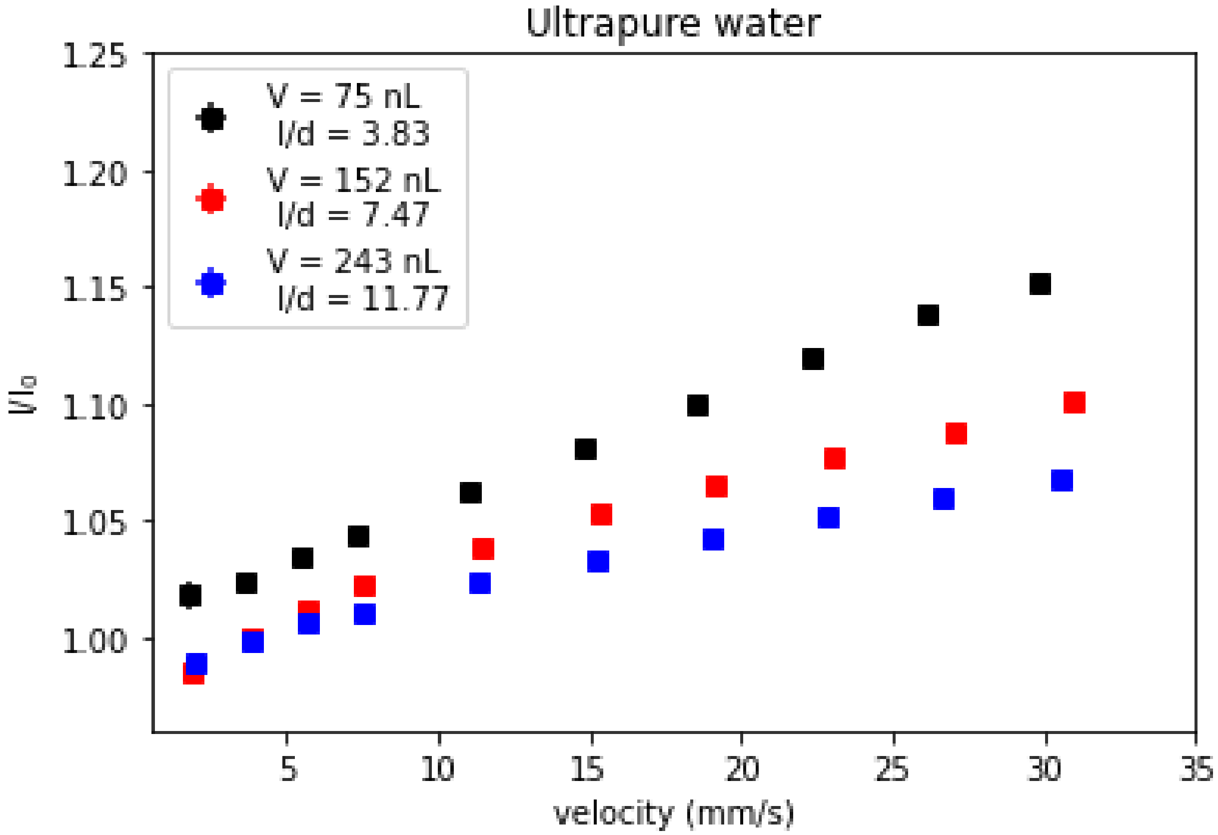
Data Analysis



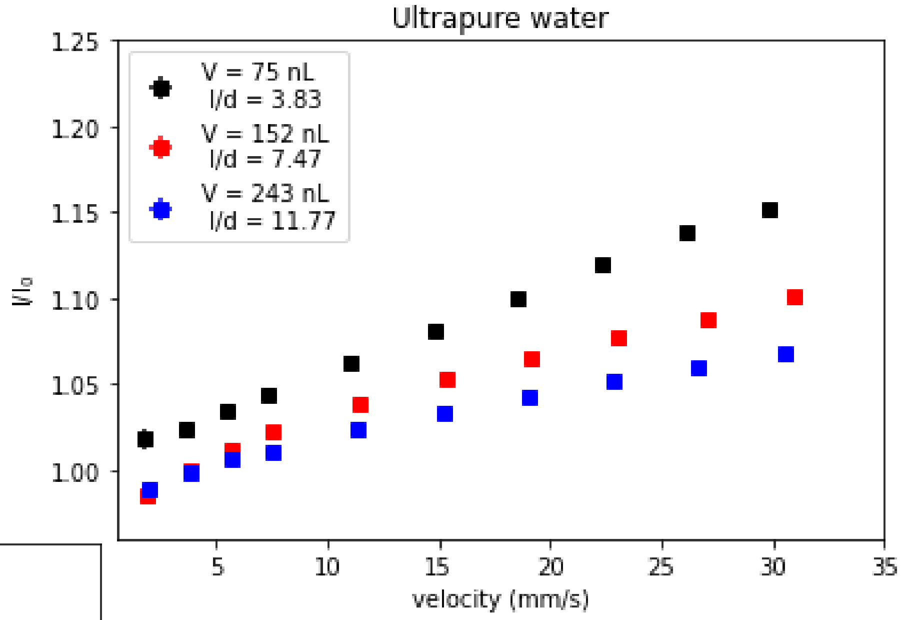


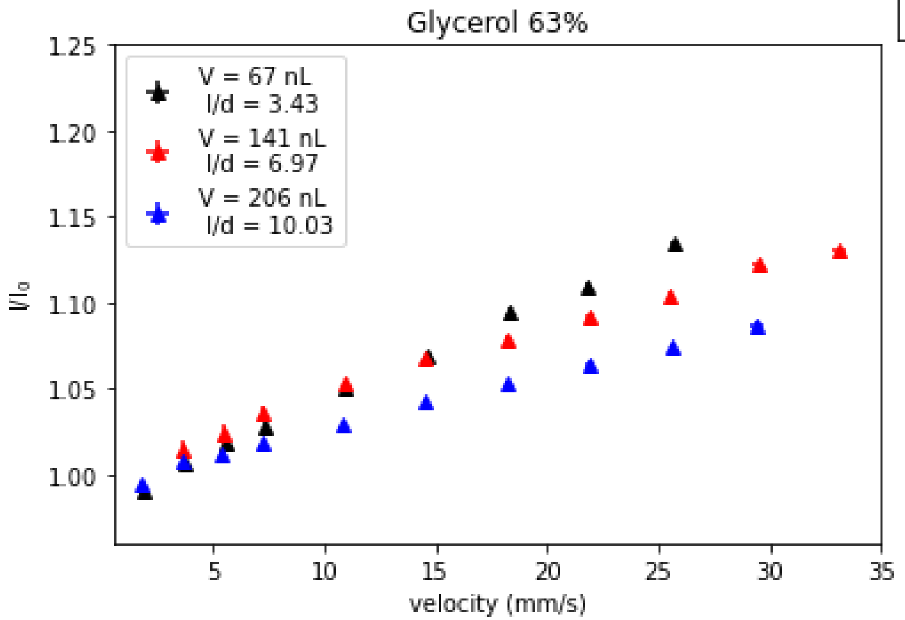
Data Analysis

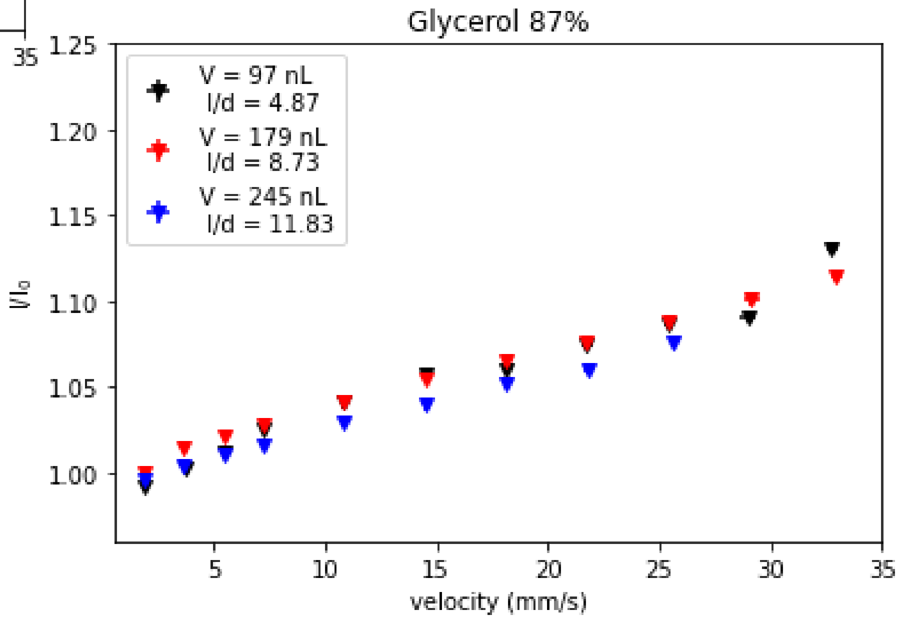




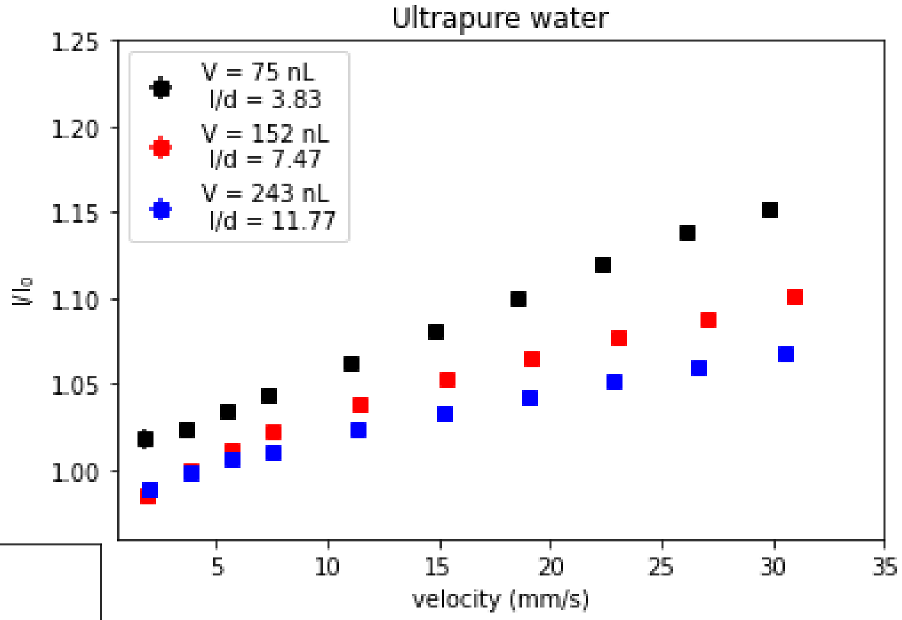
Data Analysis

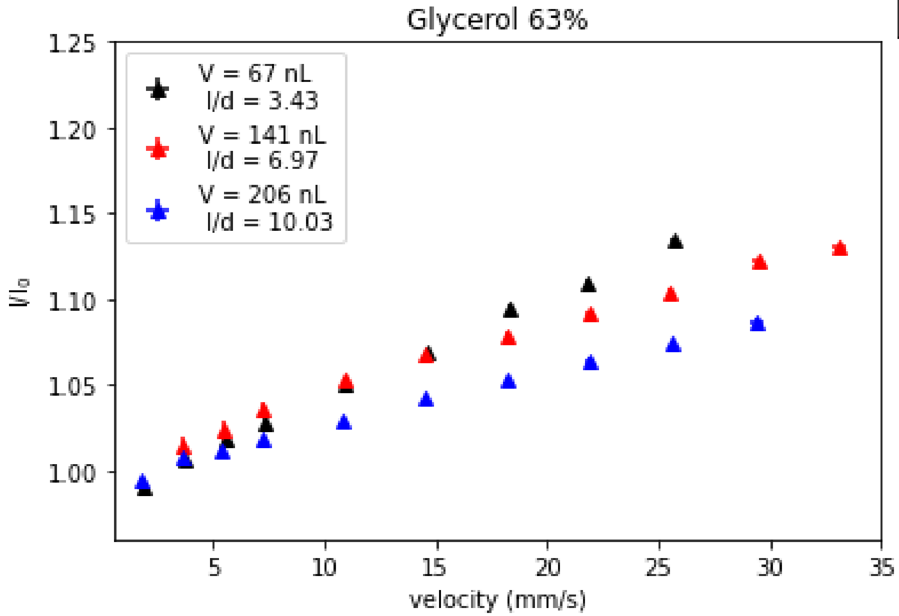


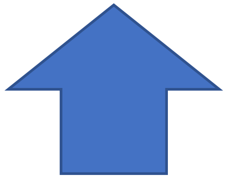




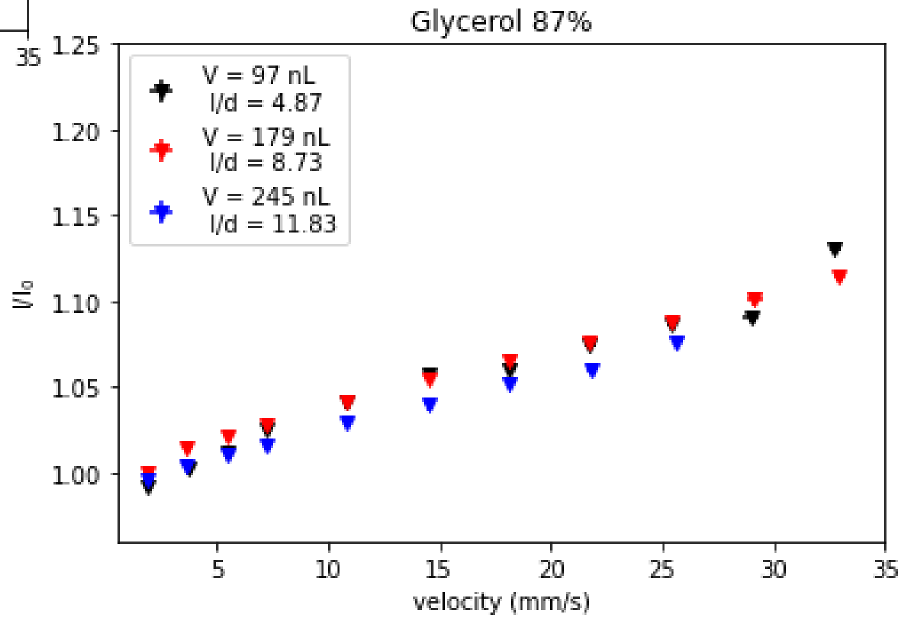
Data Analysis





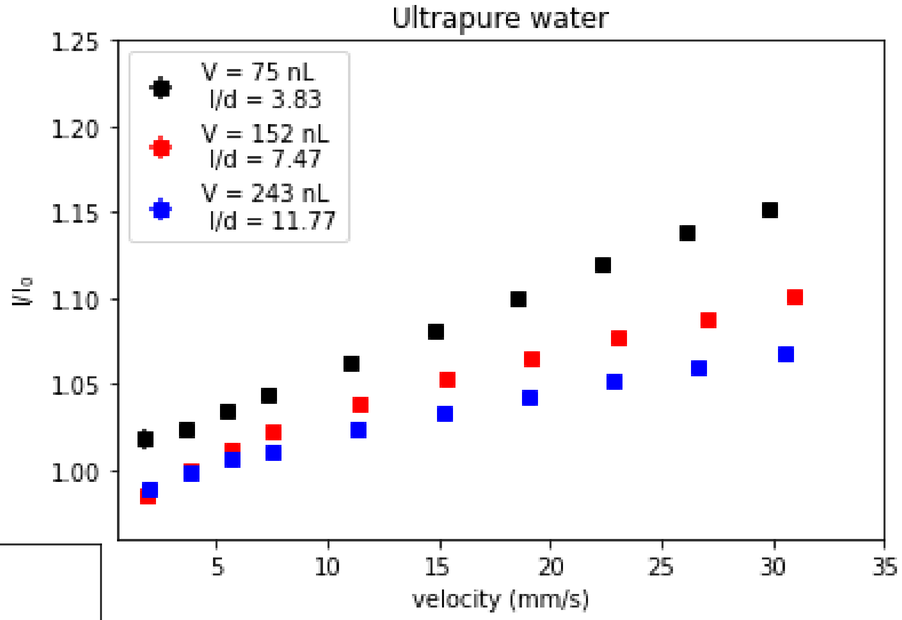


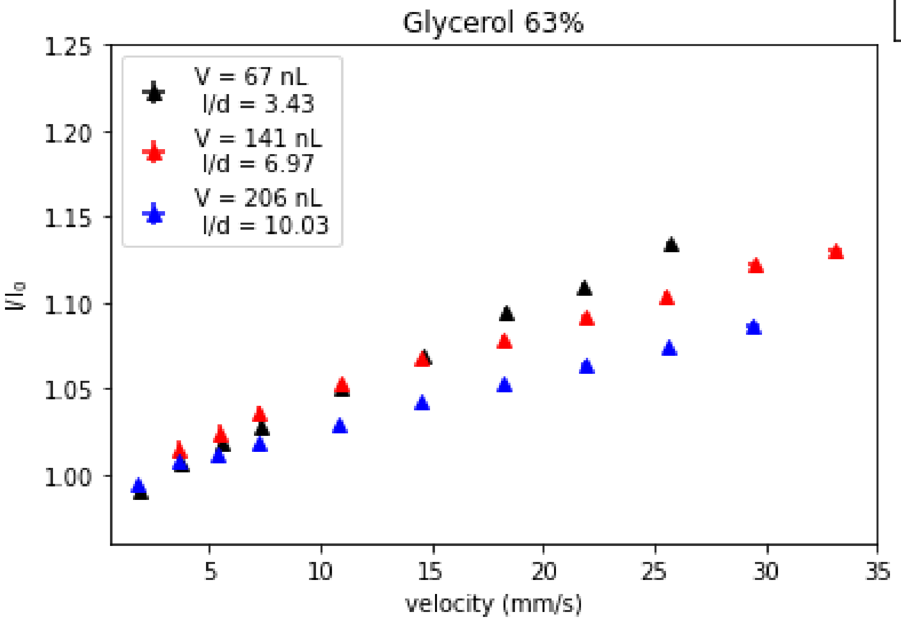
0.89 mPa·s



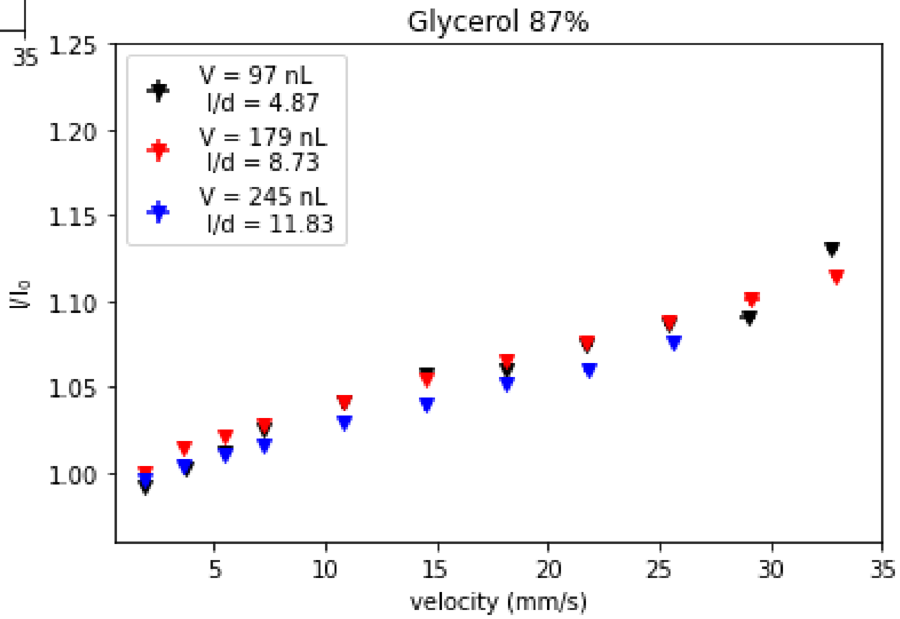
Data Analysis

10.71 mPa·s

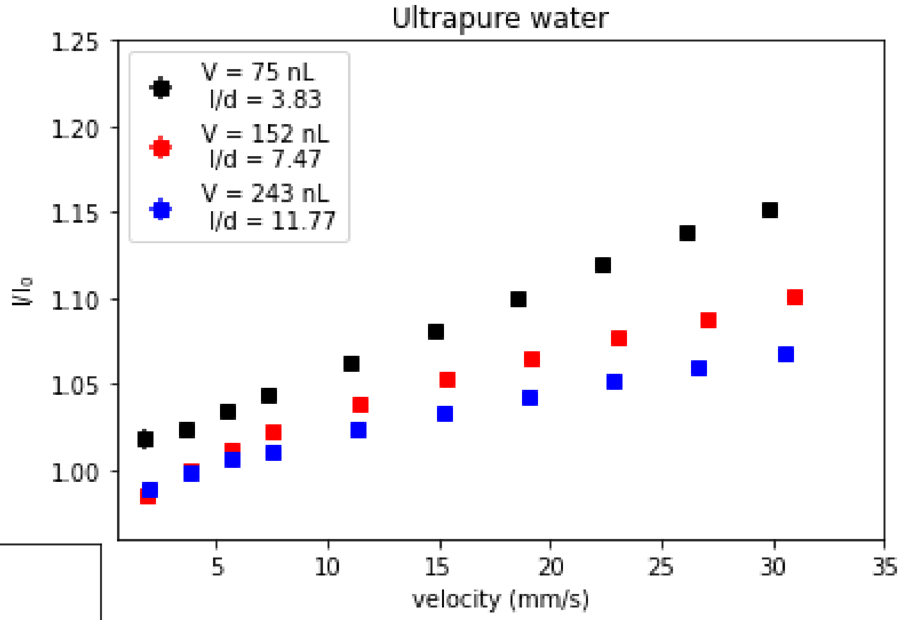




0.89 mPa·s

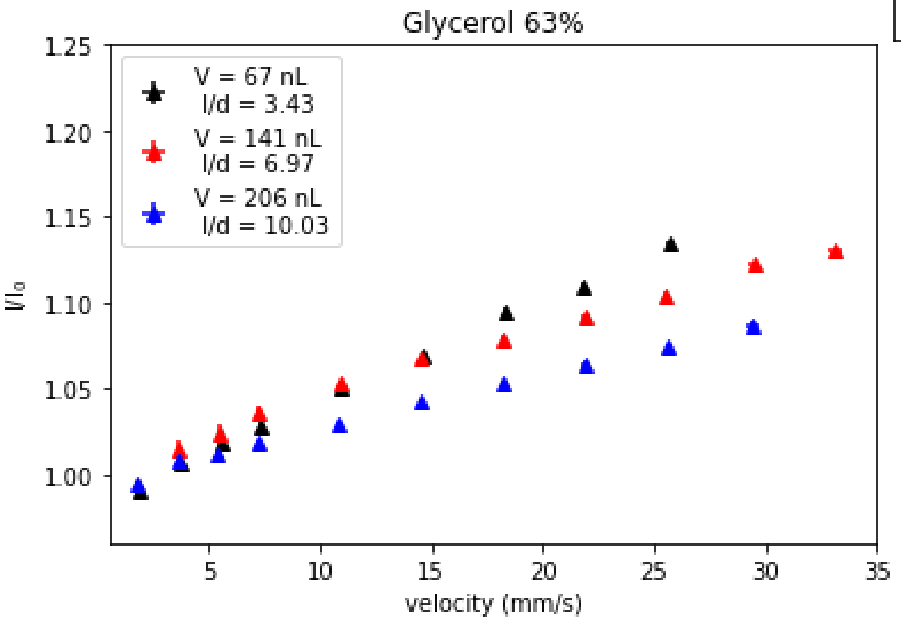


Data Analysis

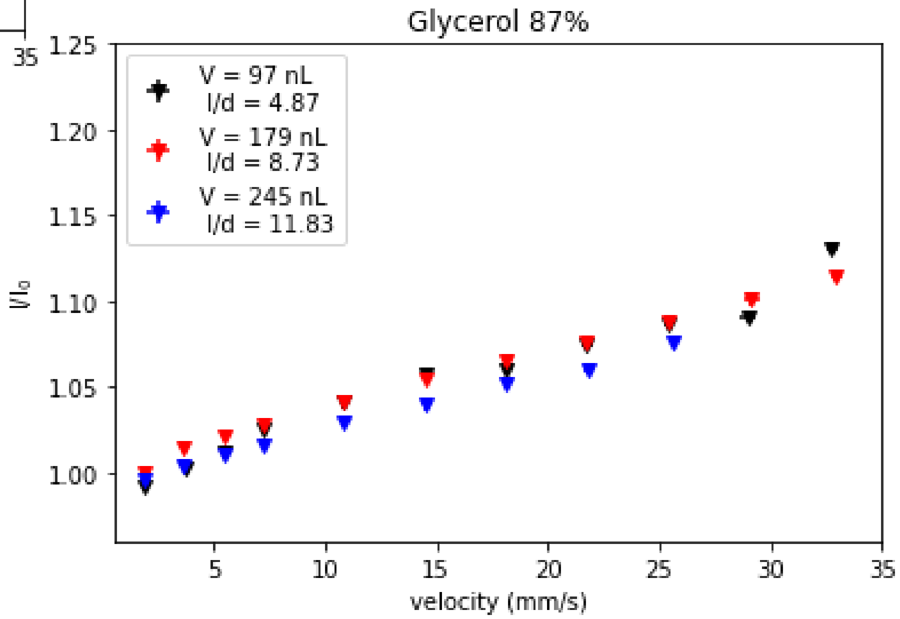


0.89 mPa·s

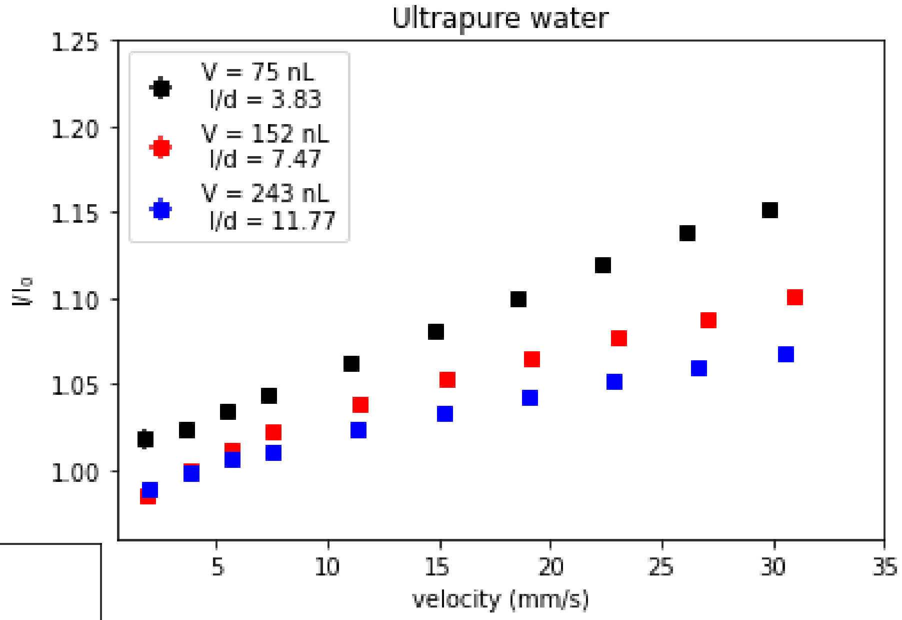
10.71 mPa·s

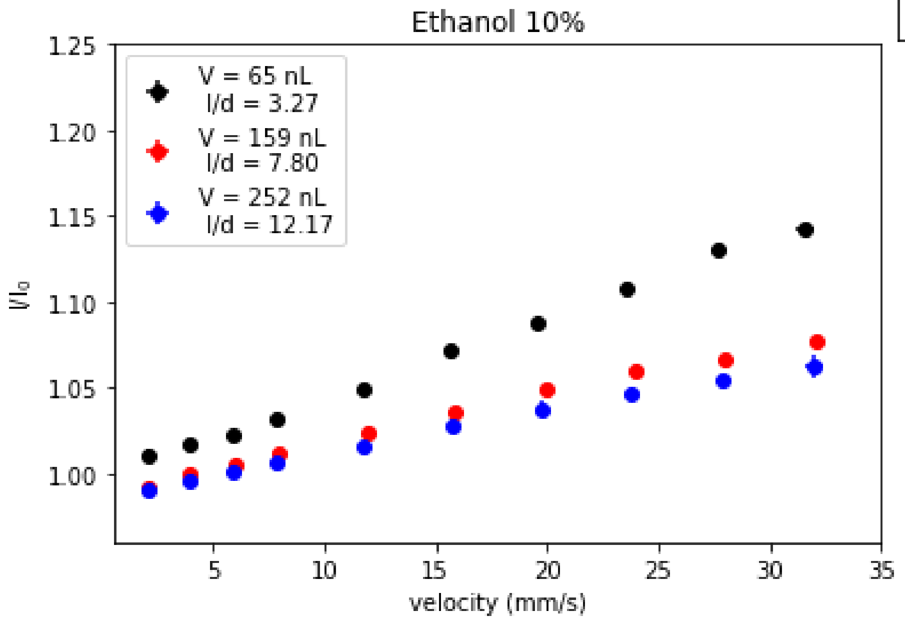


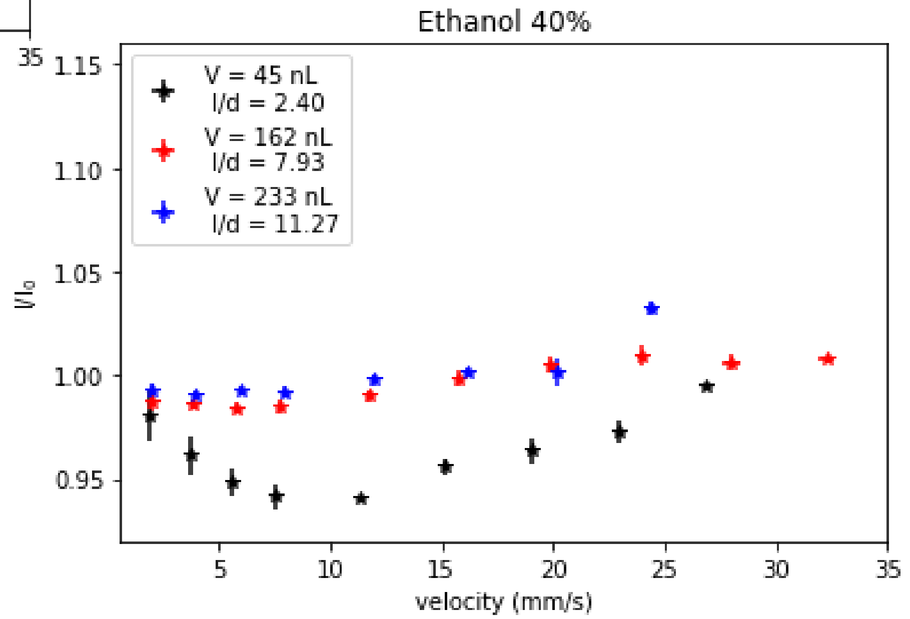
100.33 mPa·s



Data Analysis







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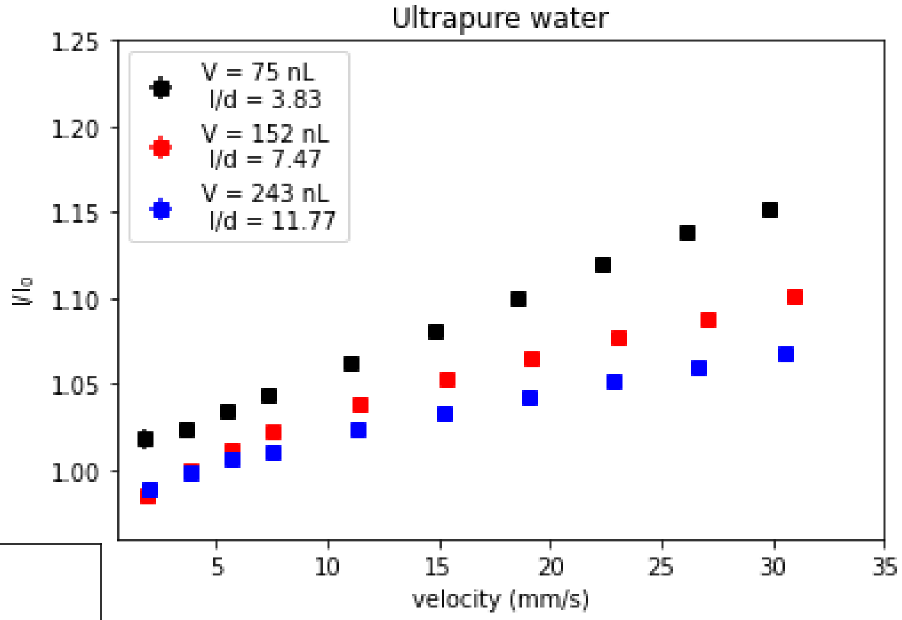
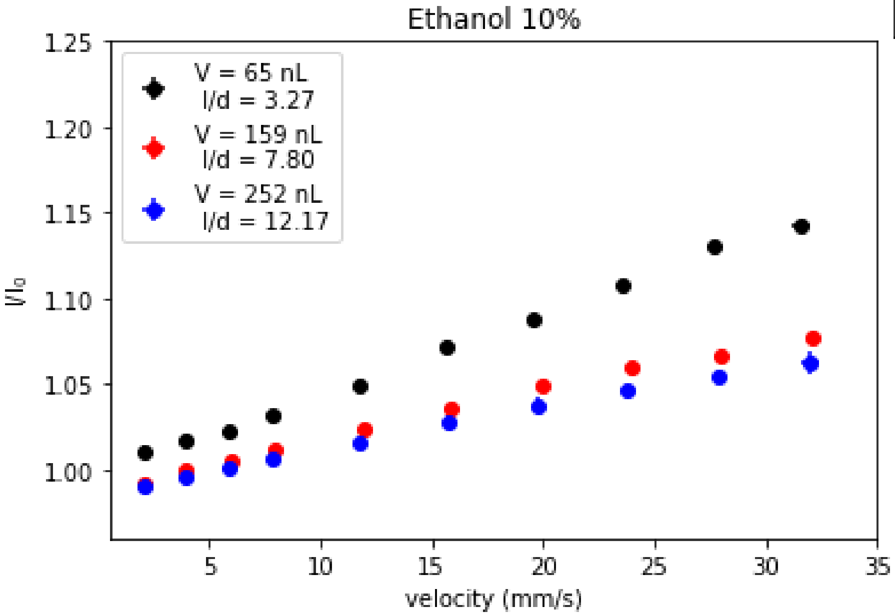
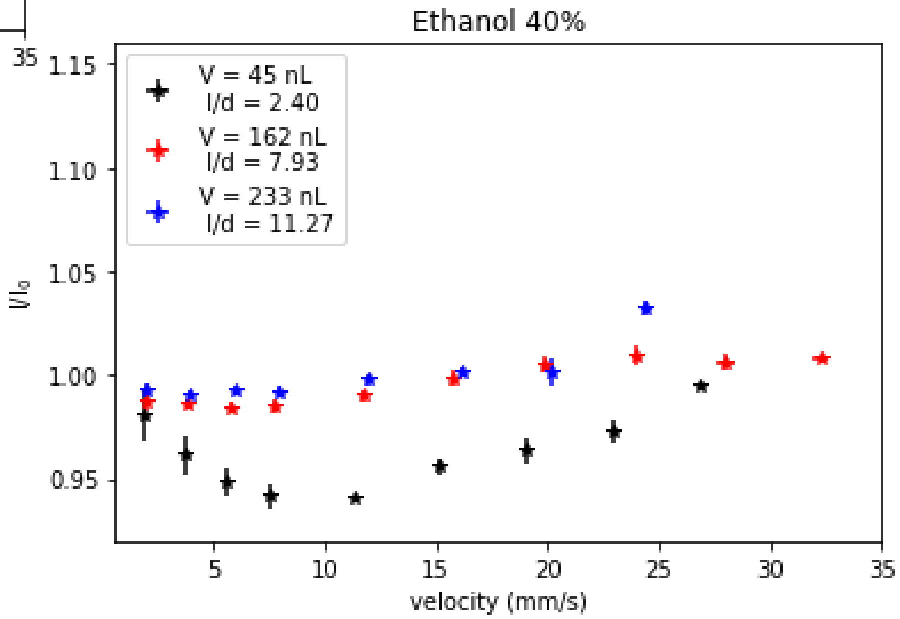


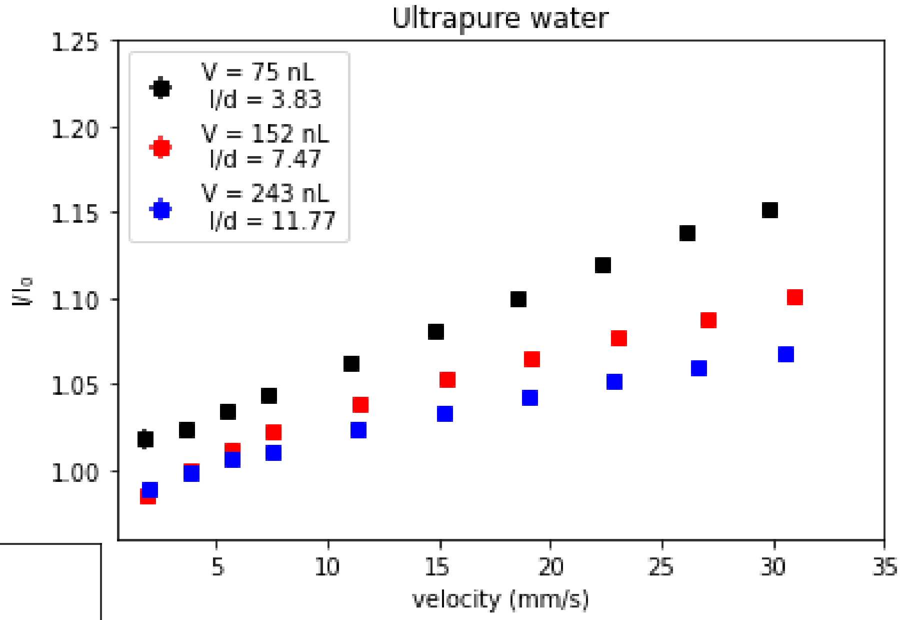


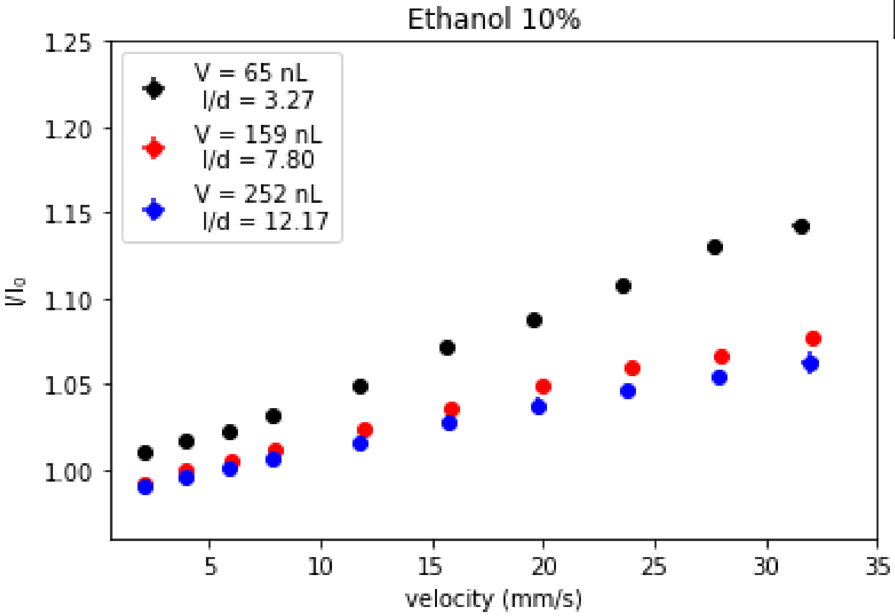
51.2 mN/m



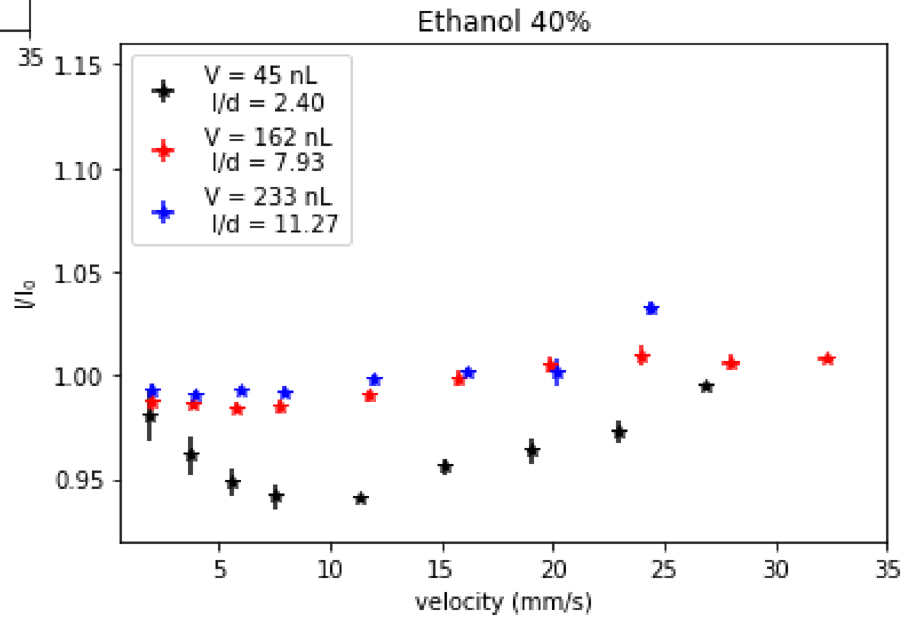
Data Analysis

32.1 mN/m

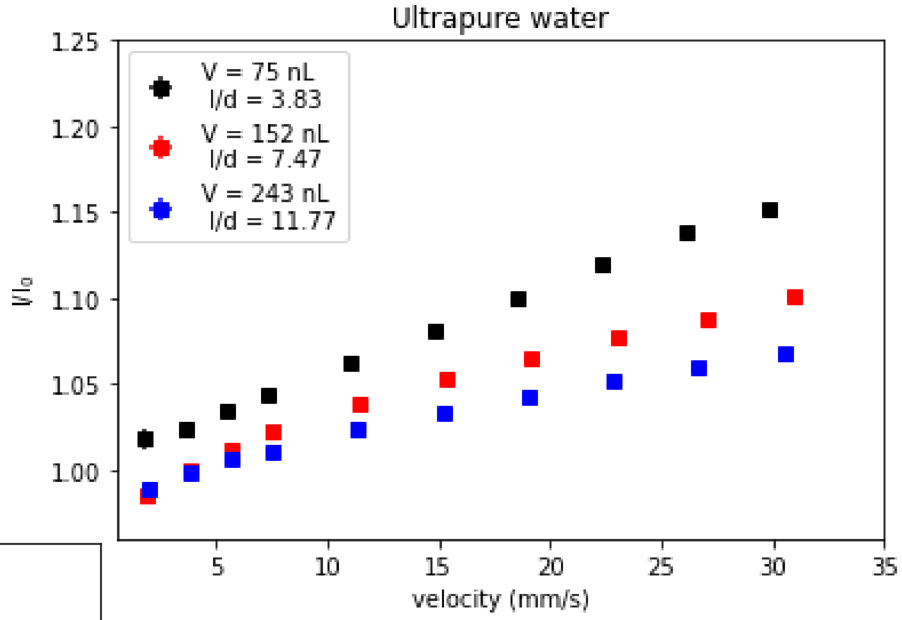




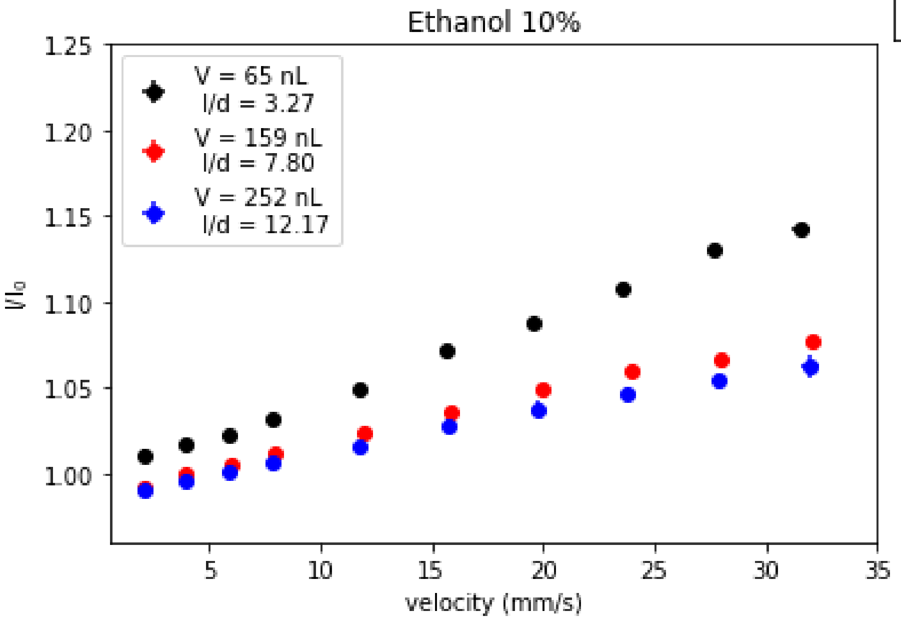
51.2 mN/m



Data Analysis

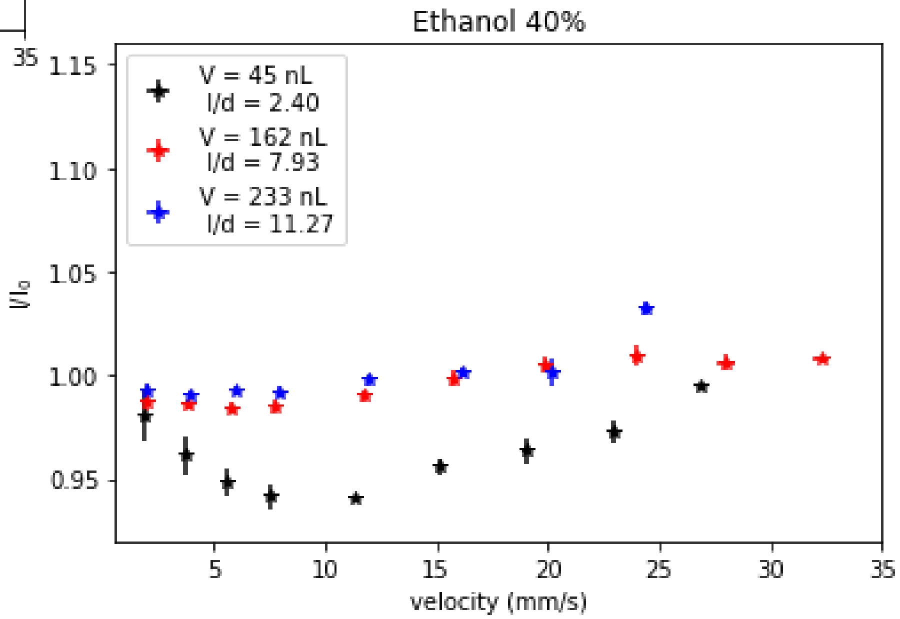


32.1 mN/m



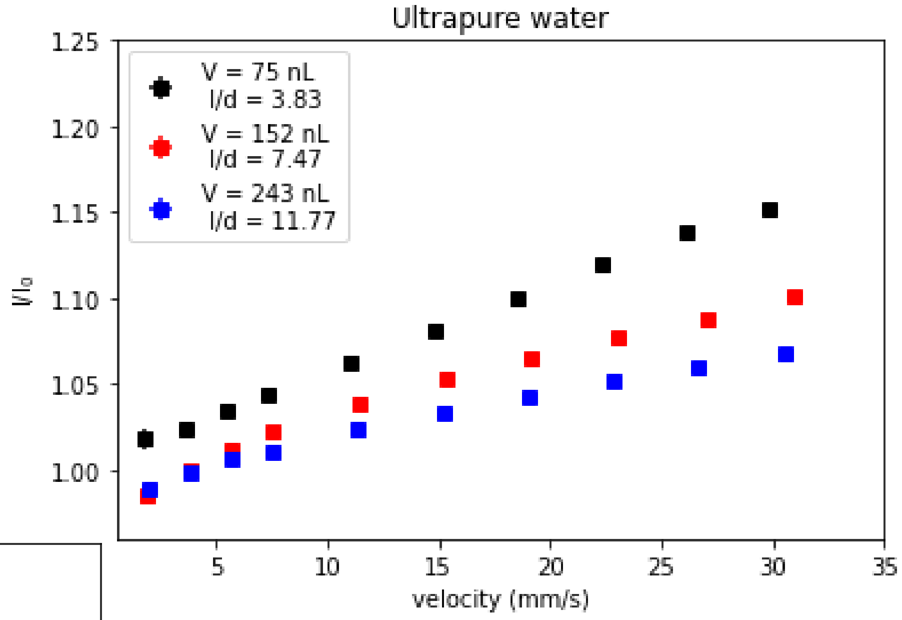
51.2 mN/m

14.7 mN/m

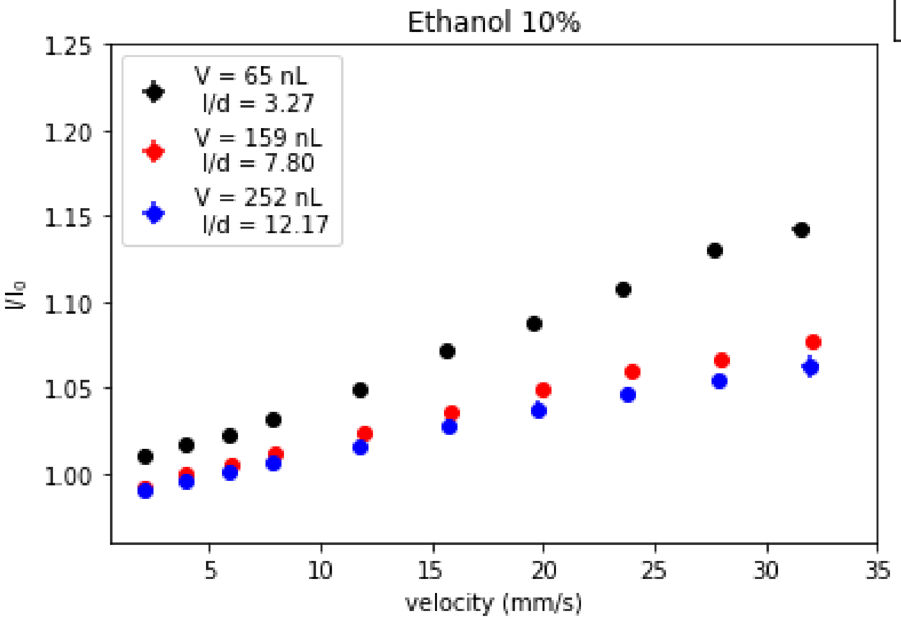


Data Analysis

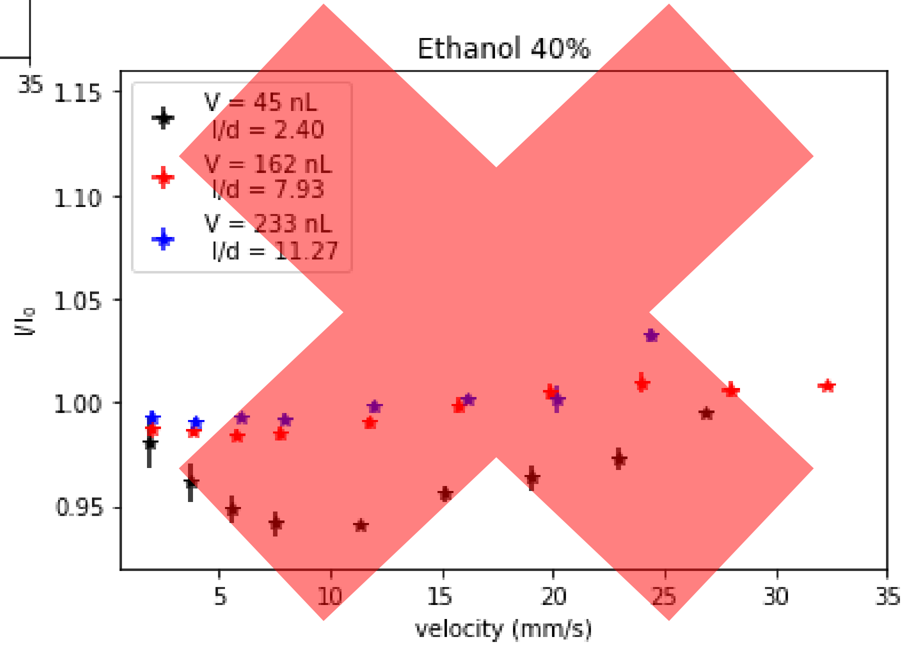
32.1 mN/m



14.7 mN/m

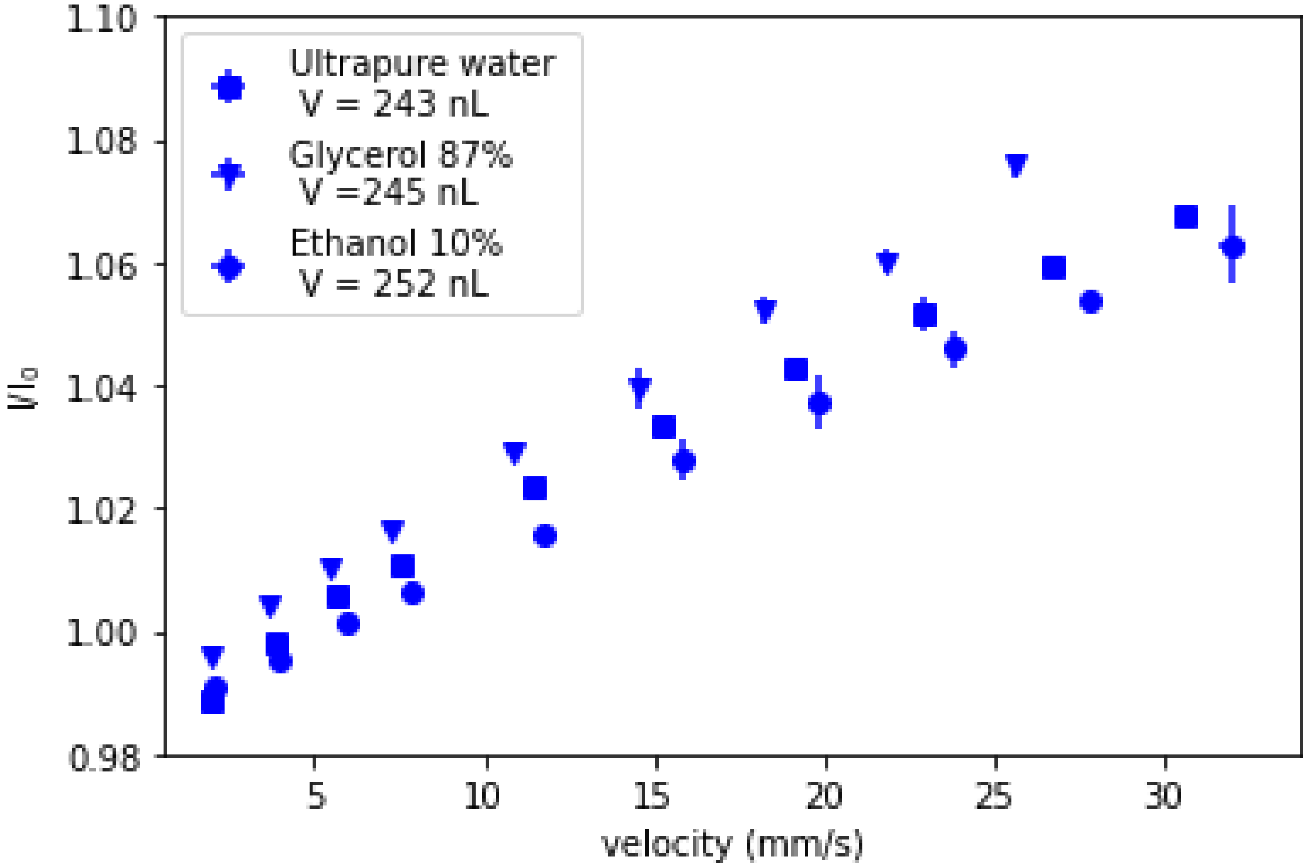


51.2 mN/m



Data Analysis

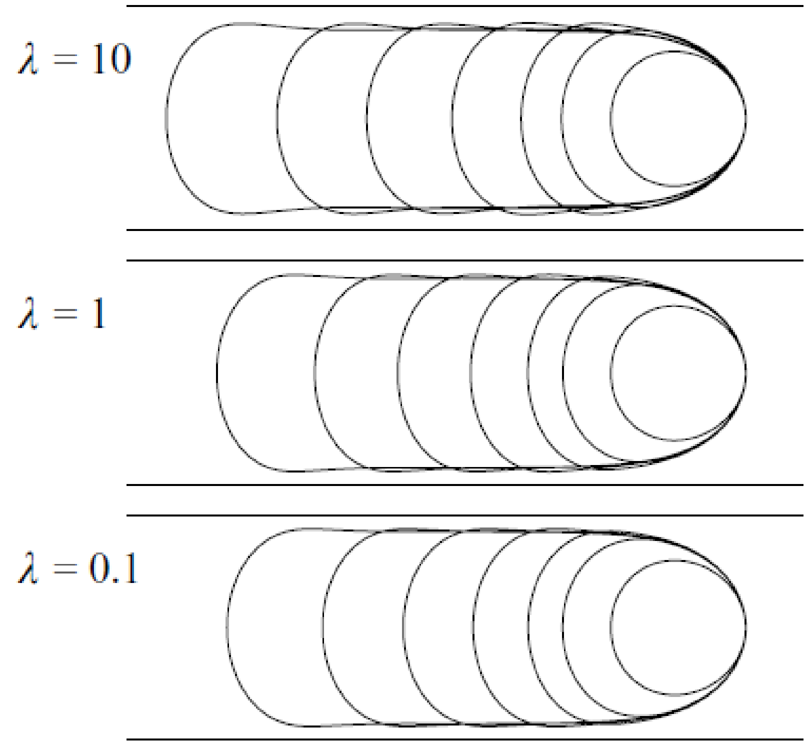
❖ Comparison between drops of similar size for different dispersed phases.



❖ We have the biggest deformation from the drop with the highest viscosity.

Data Analysis

- A similar result was observed in the numerical simulations of Lac and Sherwood [4], they showed that drops with higher viscosity ratios exhibit greater deformation when the other parameters were fixed.



$$\lambda = \frac{\mu_d}{\mu_c}$$

$$Ca = \frac{\mu_d}{\gamma} V$$

Conclusions

- In this preliminary study the deformations of droplets in microchannels were analyzed with varying physical parameters such as composition, speed, surface tension and viscosity.
- The results obtained suggest that the deformation of the drop is particularly influenced by the viscosity, however this is only a preliminary result that needs to be confirmed by a more accurate analysis.

Perspective

- Investigate deeper the effects of viscosity and surface tension by taking systematic measurements with different percentages of glycerol and ethanol.

- For a more complete analysis, the effect of surfactants should be studied.

Bibliography

1. D. Ferraro, P. Sartori, N. Akhtar, A. Zaltron, M. Pierno, G. Mistura, The role of surfactants on the shape of confined droplets moving in circular microchannel, 2020.
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3. C. N. Baroud, F. Gallaire and R. Dangla, Dynamics of microfluidics droplets, Lab Chip, 2010, 10, 2032.
4. LAC, E., & SHERWOOD, J. (2009). Motion of a drop along the centreline of a capillary in a pressure-driven flow. Journal of Fluid Mechanics, 640, 27-54.
5. Makuch, Karol, Gorce, Jean-Baptiste, Garstecki, Piotr 2019. Non-wetting droplets in capillaries of circular cross-section: Scaling function. Physics of Fluids, Vol. 31,