Inertial manipulation of bubbles in rectangular microfluidic channels

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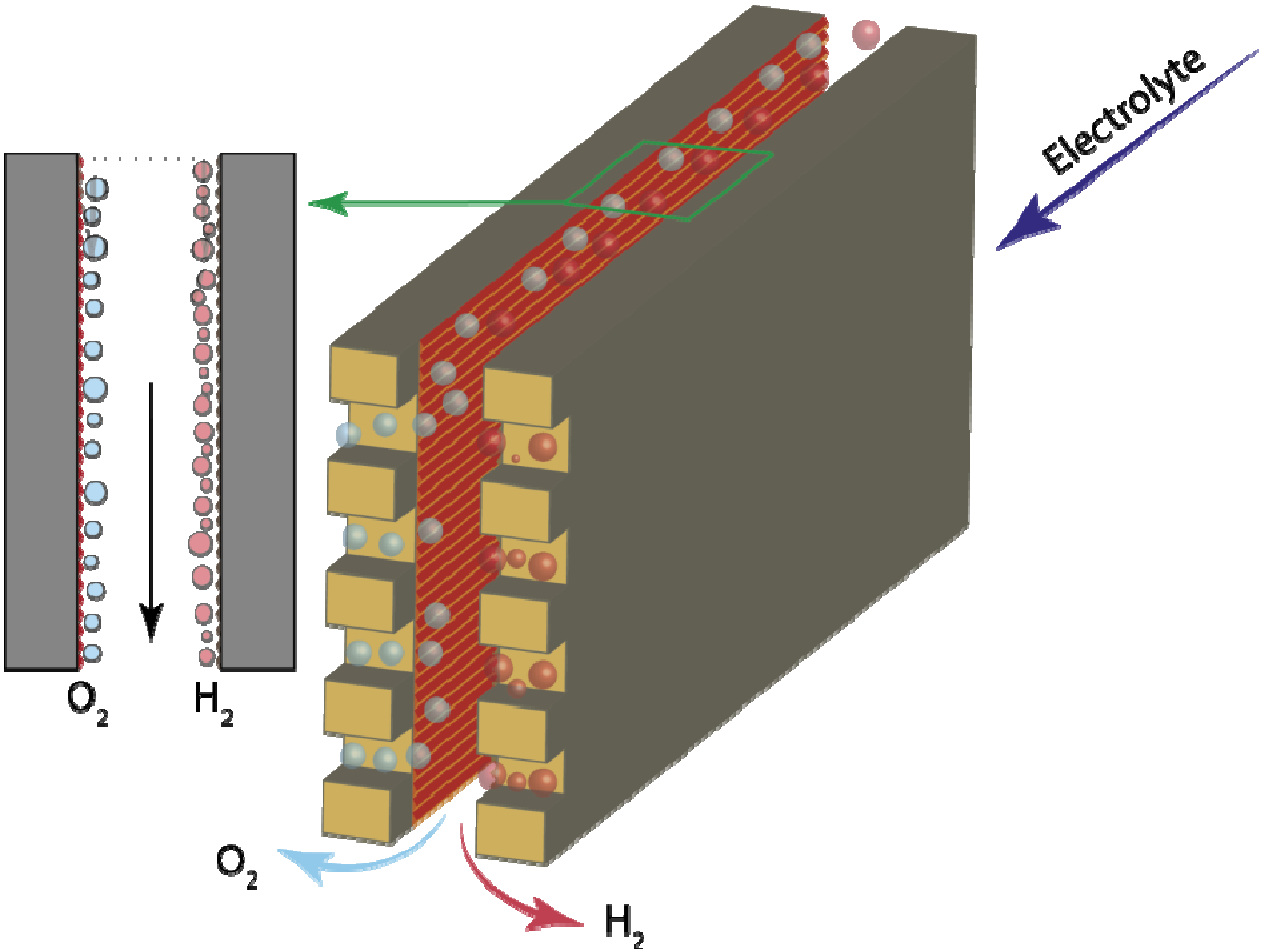
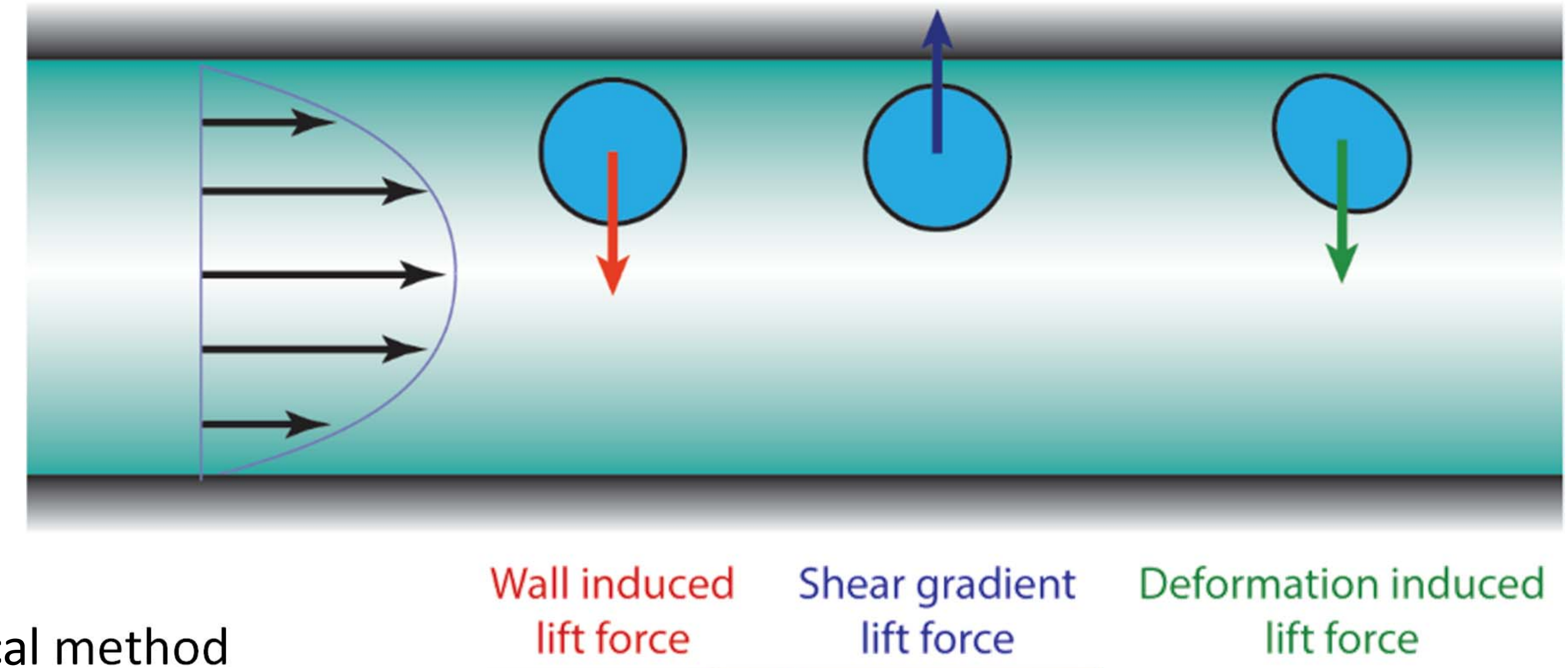
Motivation



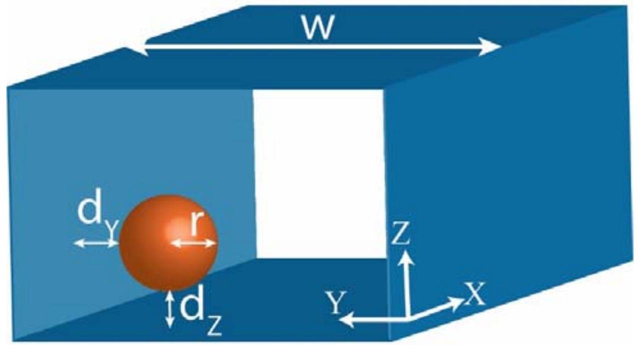
"A membrane-less electrolyzer for hydrogen production across the pH scale." *Energy & Environmental Science* 8.7 (2015).

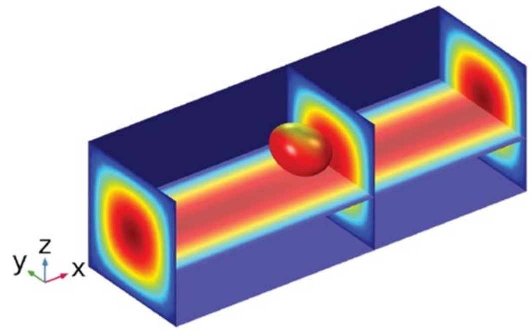
Forces



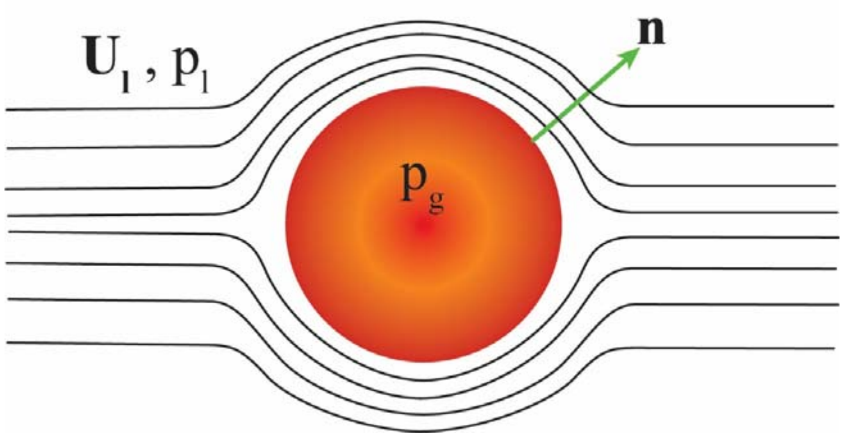
Outline

- Numerical method
- Experimental device
- Relevant parameters
- Bubbles vs. Solid particles
- Conclusion





Numerical Setup



Liquid	Gas	$\frac{\mu_g}{\mu_l}$
Isopropanol	Nitrogen	0.00838
Ethanol	Nitrogen	0.0154
Water	Nitrogen	0.0174

Boundary condition at bubble interface:

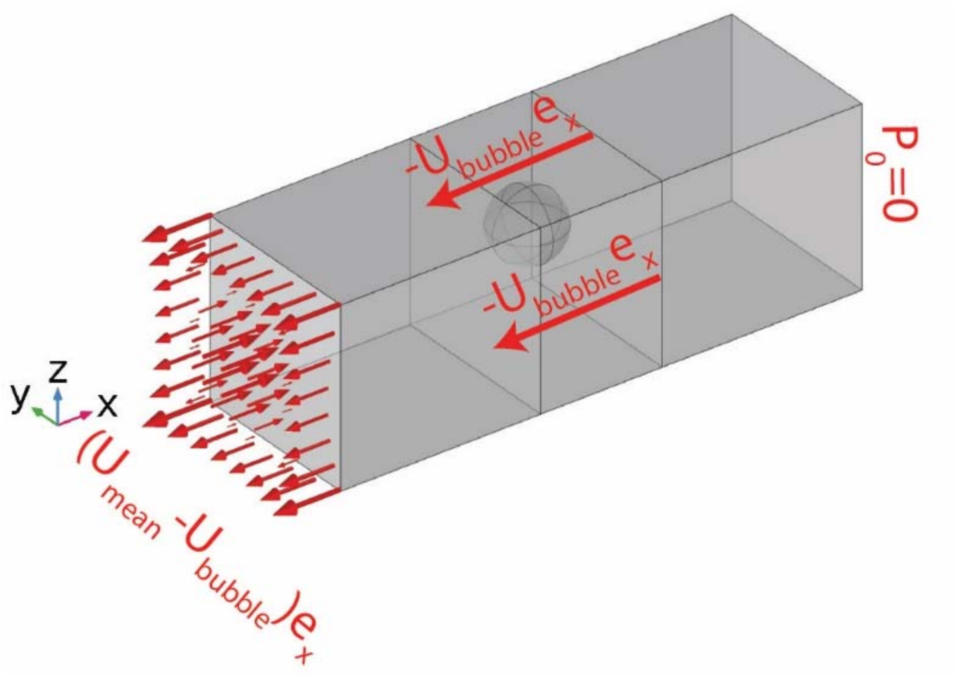
$$\boldsymbol{n}.\left[-p_l\boldsymbol{I} + p_g\boldsymbol{I} + (\nabla\boldsymbol{U} + (\nabla\boldsymbol{U})^T)_l - \frac{\mu_g}{\mu_l}(\nabla\boldsymbol{U} + (\nabla\boldsymbol{U})^T)_g\right] = \frac{1}{Ca}\boldsymbol{n}(\nabla.\boldsymbol{n})$$

Assuming $\frac{\mu_g}{\mu_l} = 0$

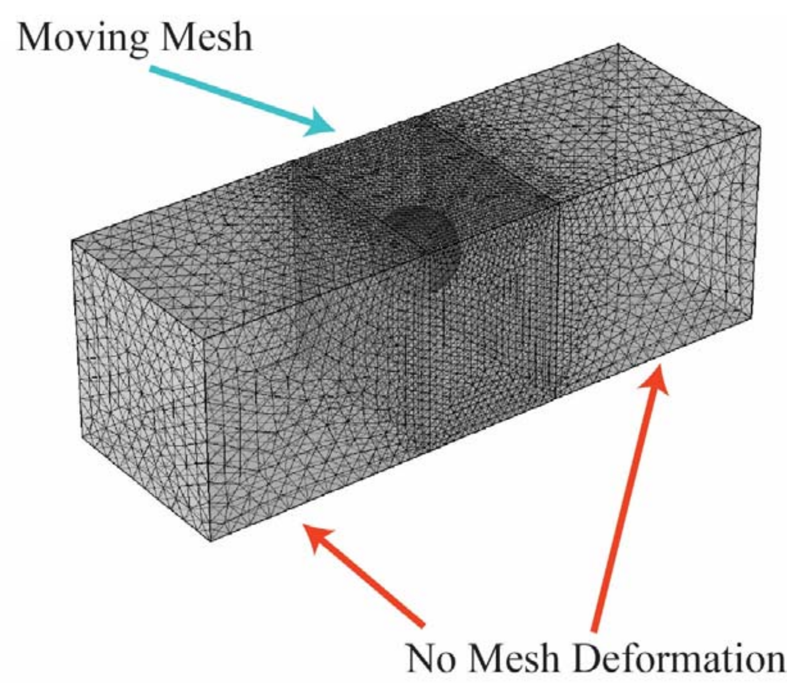
$$\boldsymbol{n}\cdot\left[-p_l\boldsymbol{I} + p_g\boldsymbol{I} + (\nabla\boldsymbol{U} + (\nabla\boldsymbol{U})^T)_l\right] = \frac{1}{Ca}\boldsymbol{n}(\nabla\cdot\boldsymbol{n})$$

Pressure inside bubble p_g can be obtained by considering constant bubble volume

Numerical Setup



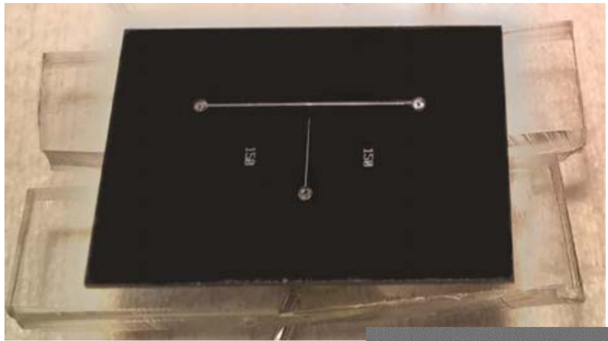
Comsol Computational setup



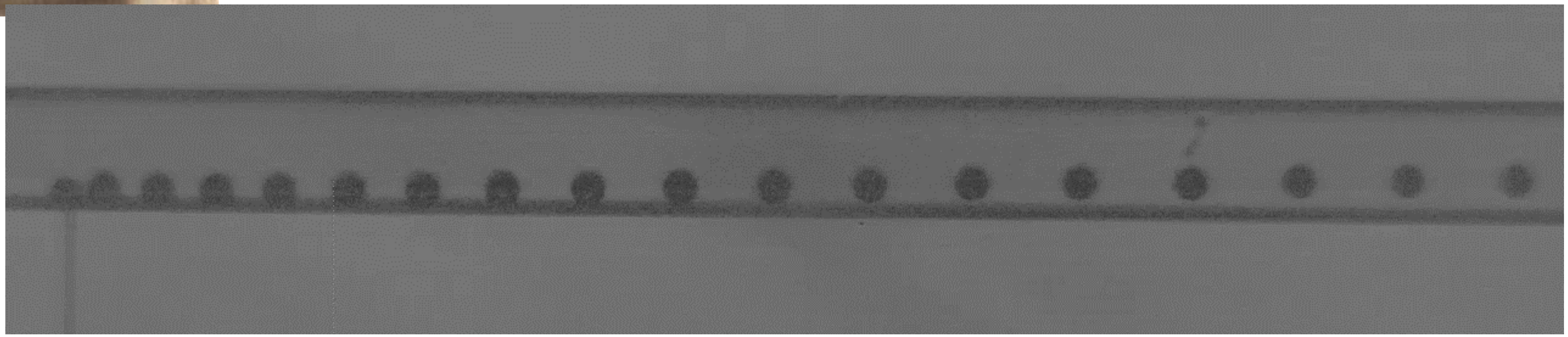
Computational Mesh

Laminar Two-Phase Flow, Moving Mesh Module

Experiment



Bubble formation at the T-junction

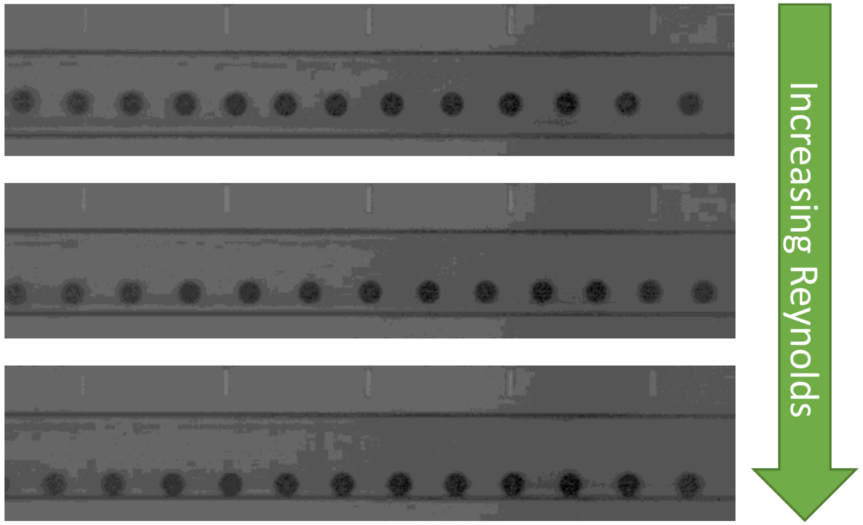


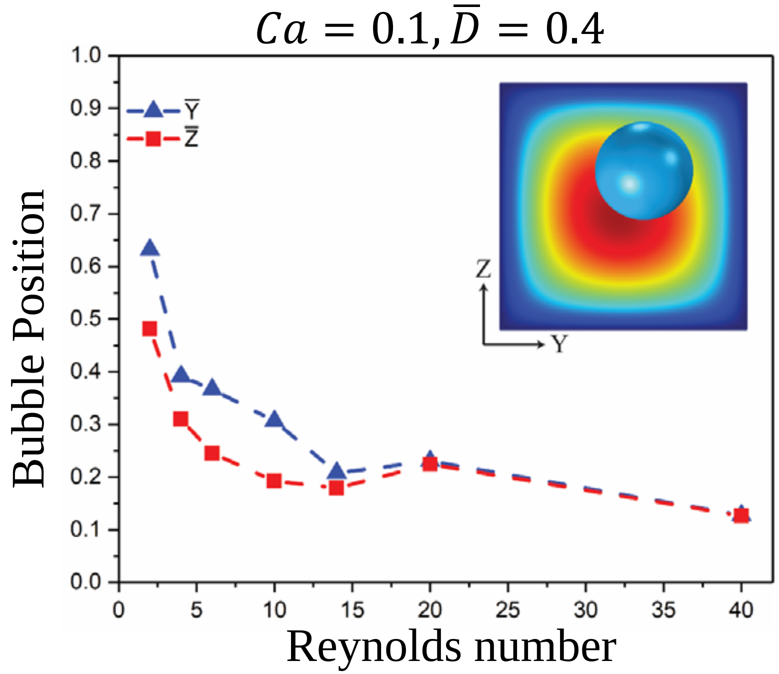
$$\textit{bubble position}: \begin{cases} \bar{Y} = 0 \rightarrow \textit{Wall} \\ \bar{Y} = 1 \rightarrow \textit{Center} \end{cases}$$

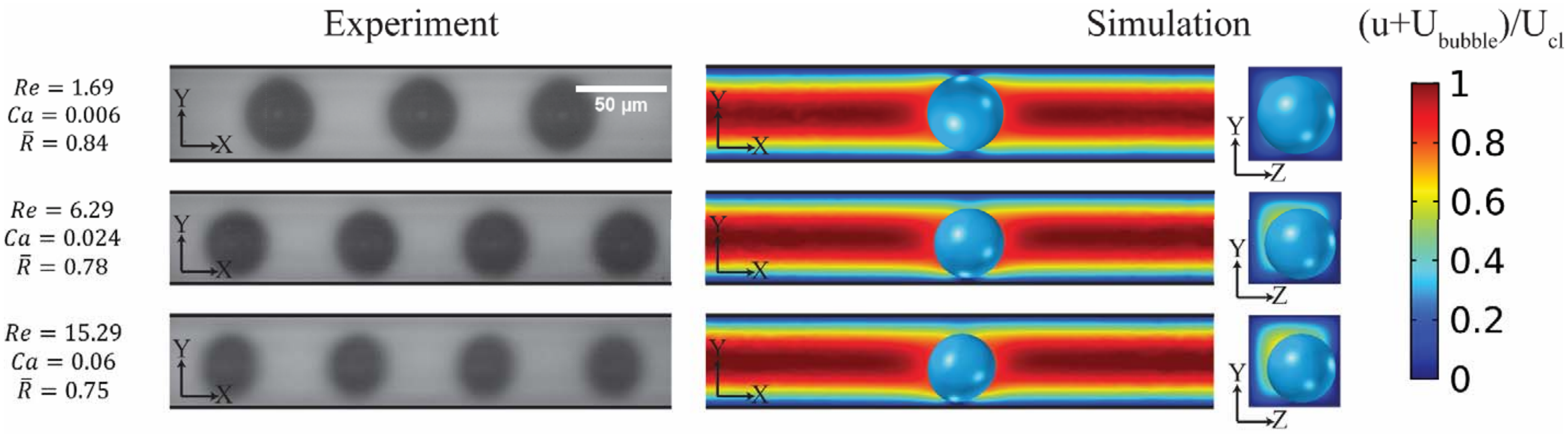
Re	0.48	0.51	2.11	2.60	2.66	7.37	9.48	10.60
$\bar{Y}_{experiment}$	1.00	1.00	0.52	1.01	0.52	0.36	0.48	0.77
$\bar{Y}_{simulation}$	0.80	0.95	0.53	0.96	0.48	0.36	0.50	0.80

Numerical vs. Experiments

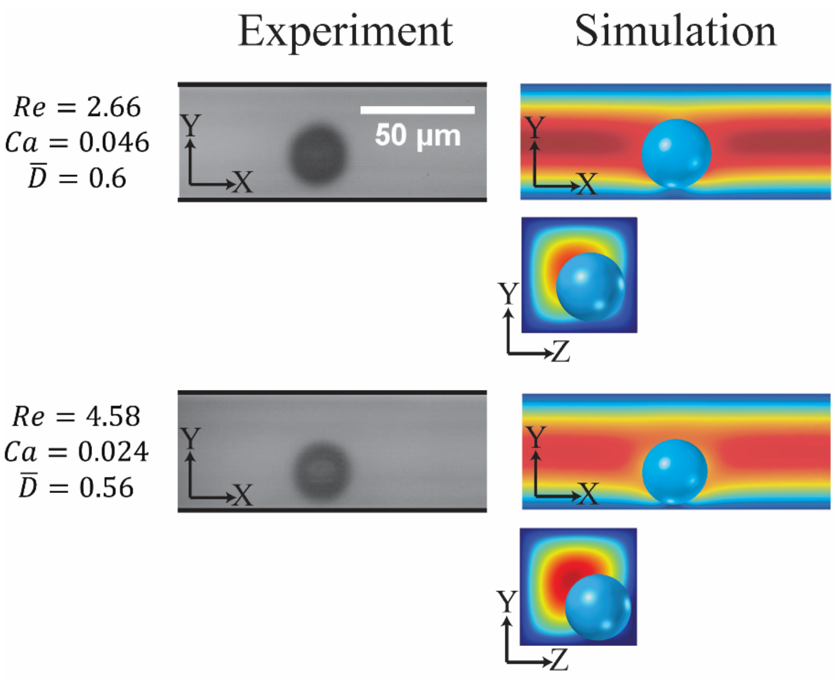
Effect of Reynolds Number

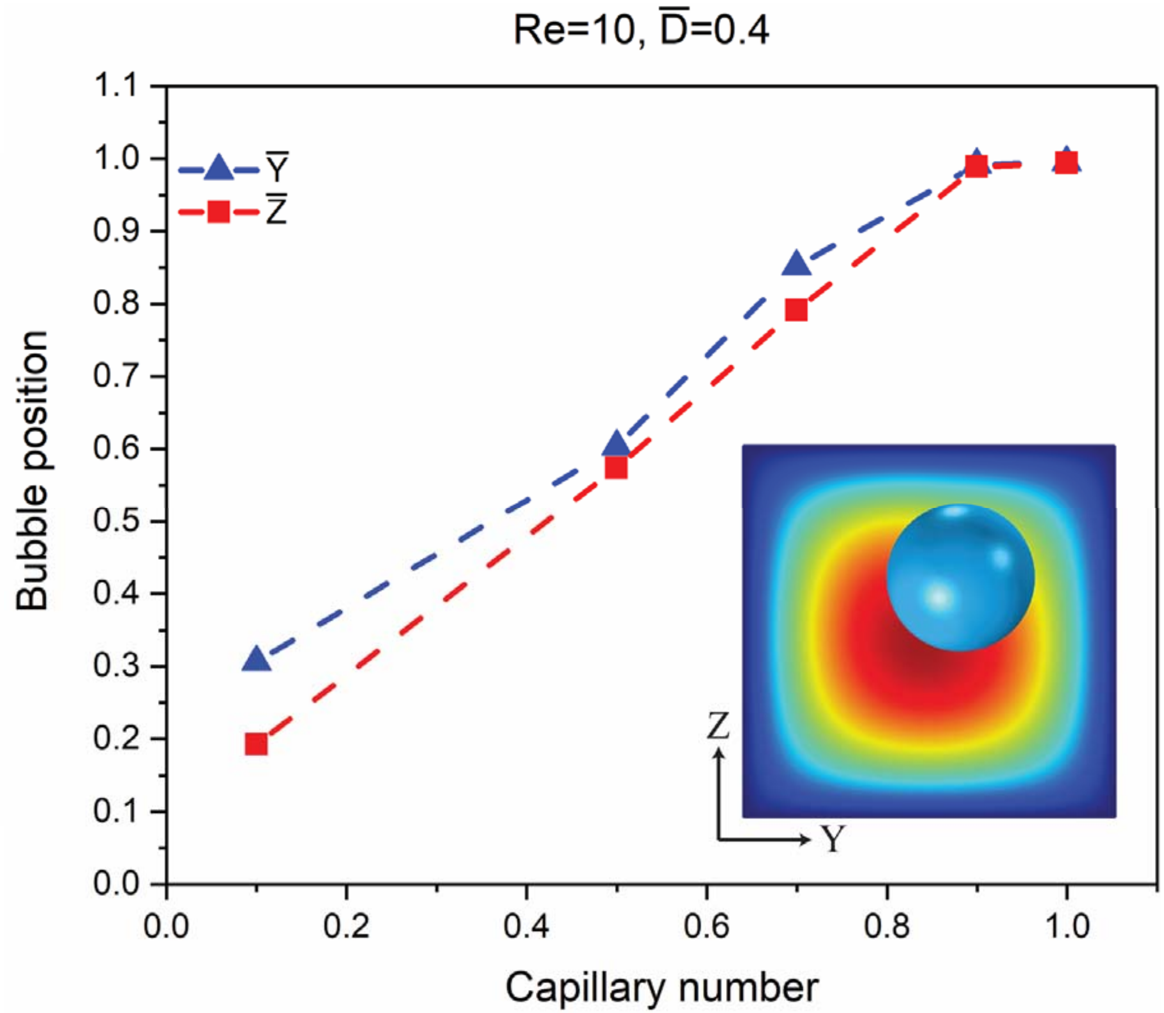




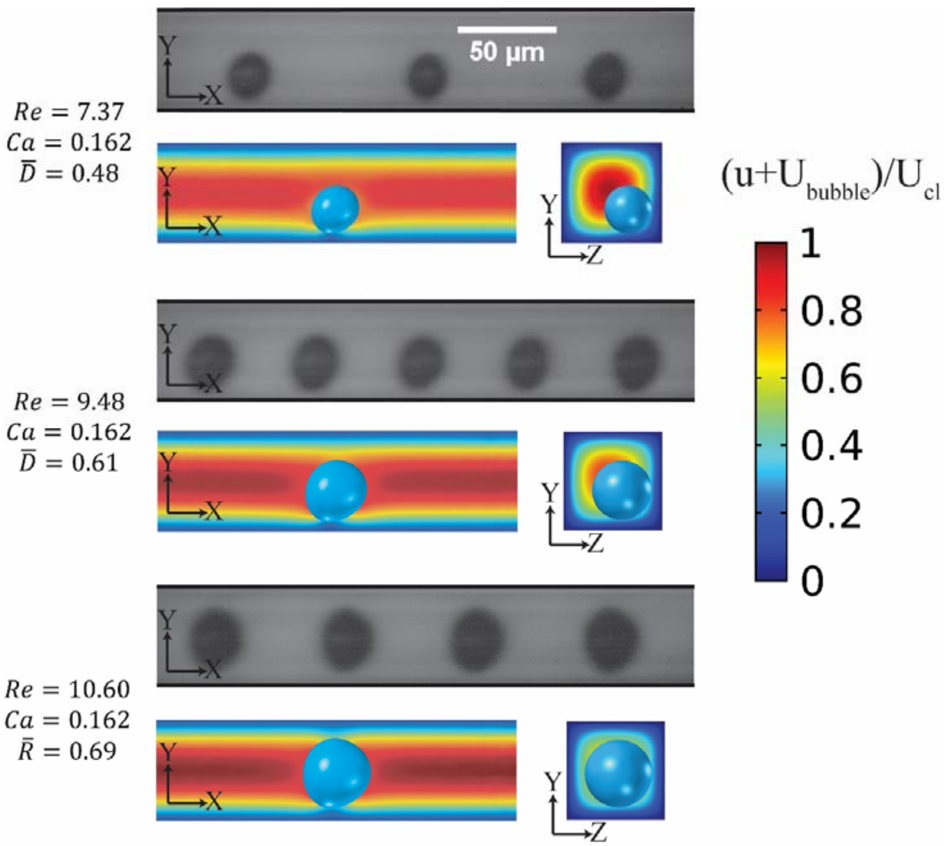


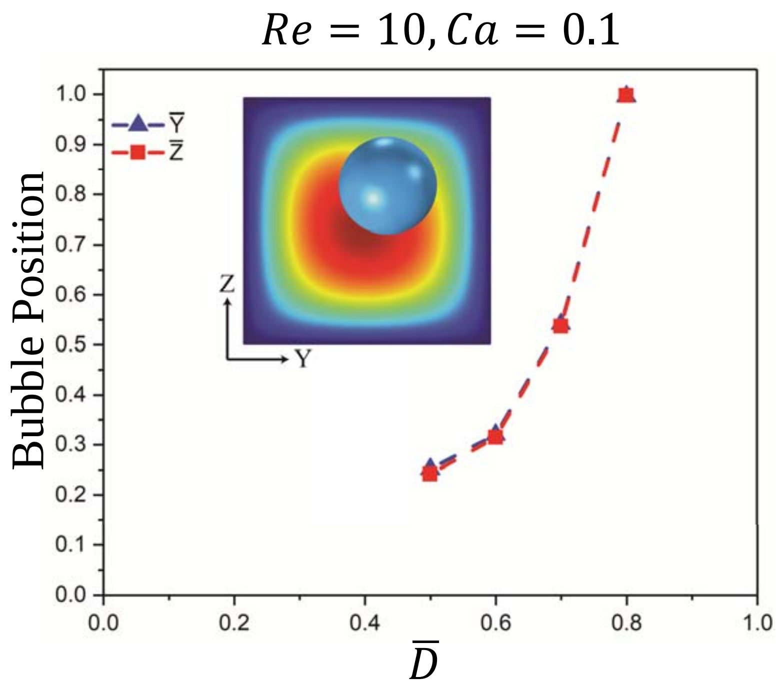
Effect of Capillary Number



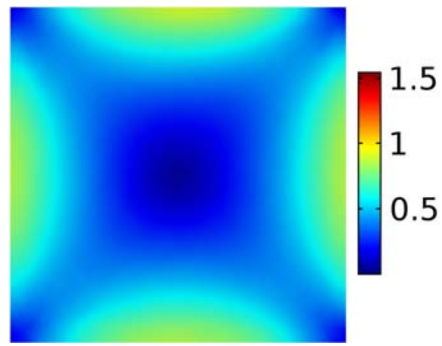


Effect of Bubble Diameter



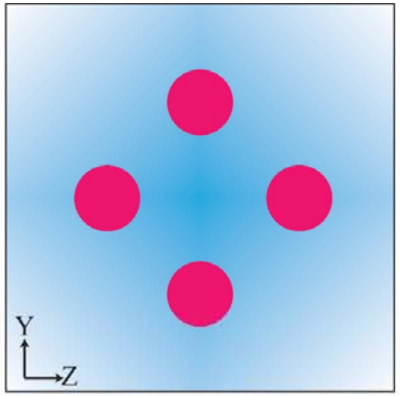


Shear rate at the channel cross-section



Bubbles vs. Solid particles

Solid particle

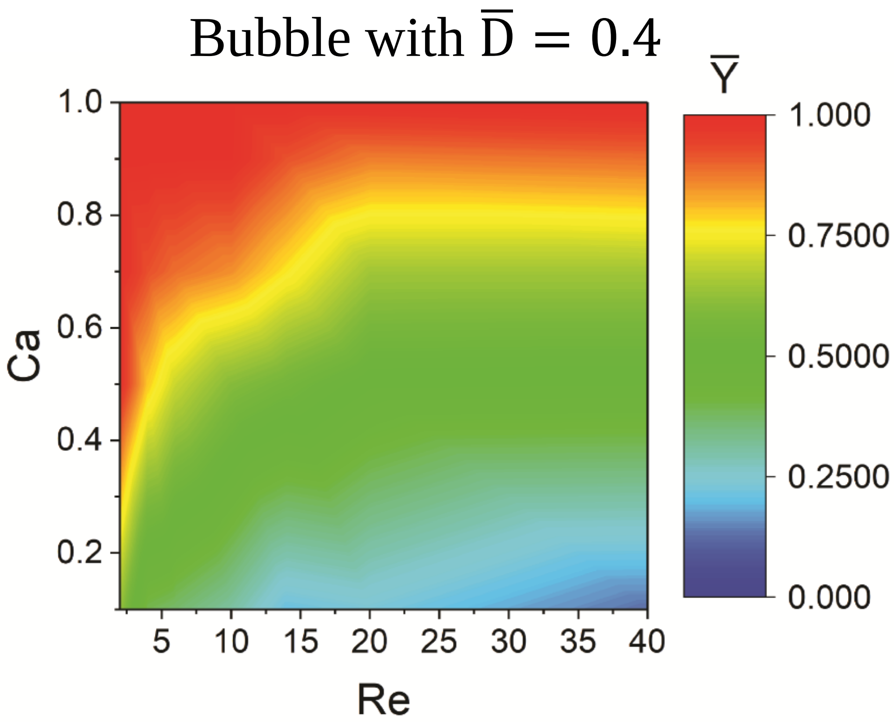


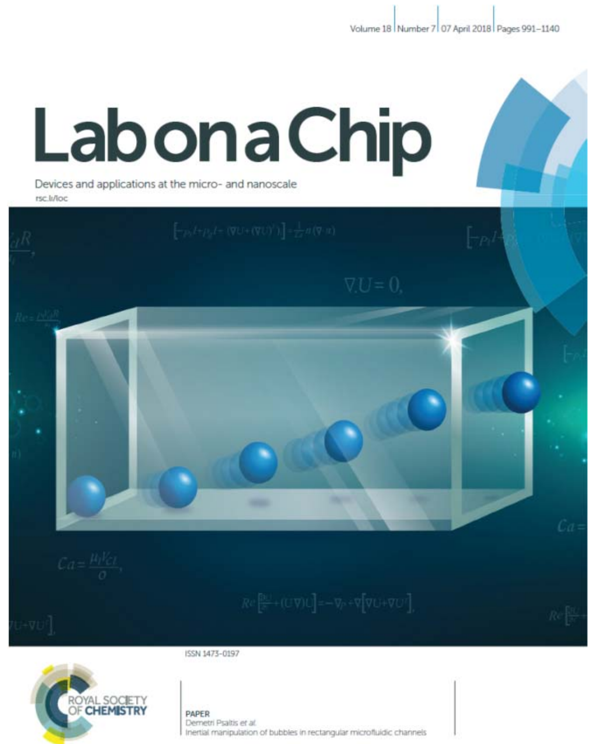
Amini, Hamed, Wonhee Lee, and Dino Di Carlo. "Inertial microfluidic physics." Lab on a Chip 14.15 (2014): 2739-2761.

Conclusion

Effective parameters

- Reynolds number
- Capillary number
- Bubble diameter
- Bubble vs. Solid particle





"Inertial manipulation of bubbles in rectangular microfluidic channels." *Lab on a Chip* 18.7 (2018).