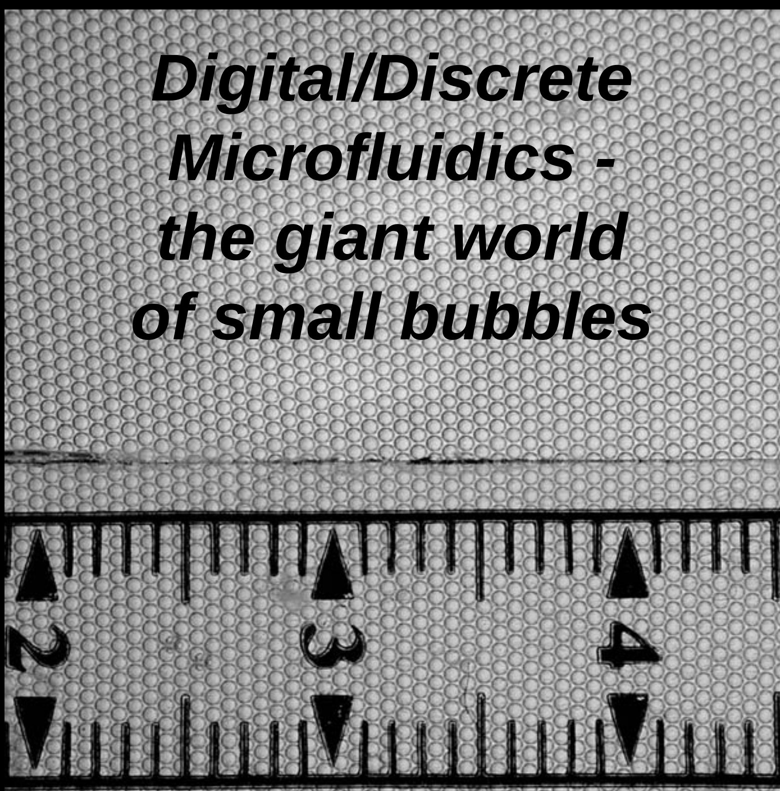
Shared lecture:

1. Microfluidics - (me)
2. Fluid dynamic simulations of foams with FEMLAB (COMSOL) - Anthony Saugey



WIEBKE **Drenckhan**

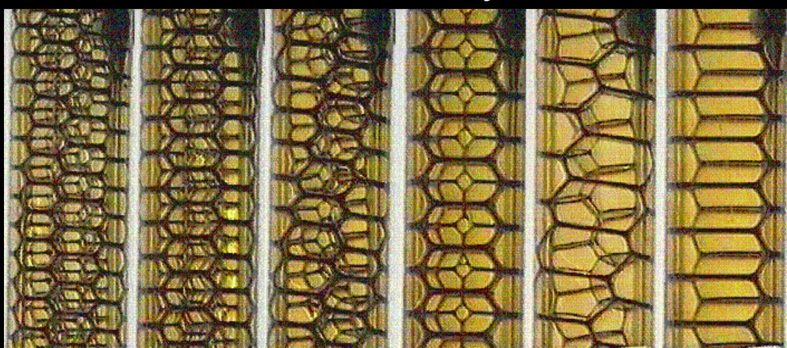
BUBBLES
FOAMS

→

DROPLETS
EMULSIONS

[= SAMPLES]

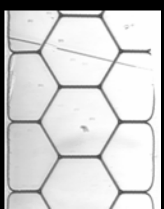
Ordered foam structures in cylindrical tubes

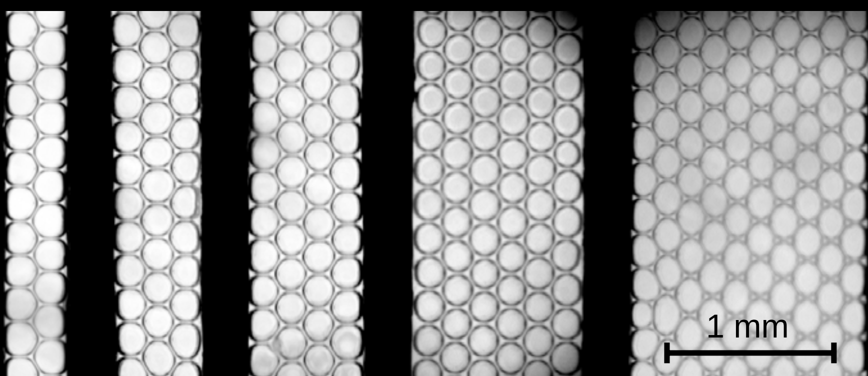


Creative Foams Tutorial

Ordered foam structures in flat channels

200 μm





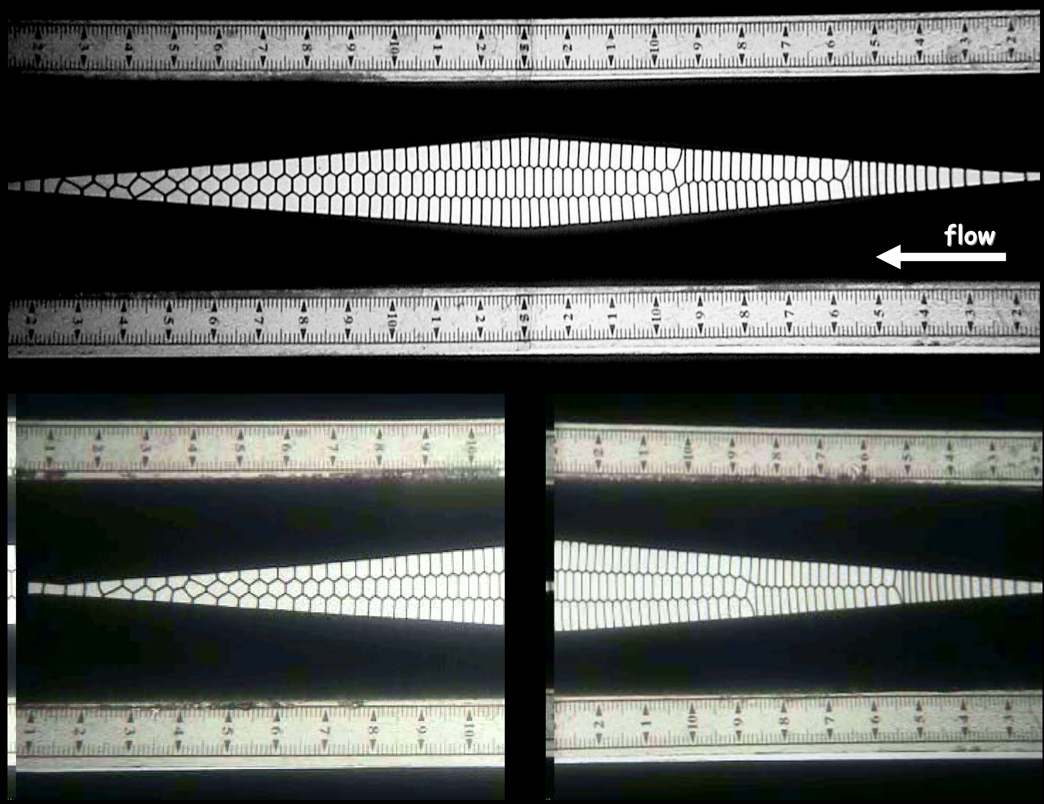
J.-P. Raven,
P. Marmottant

dry

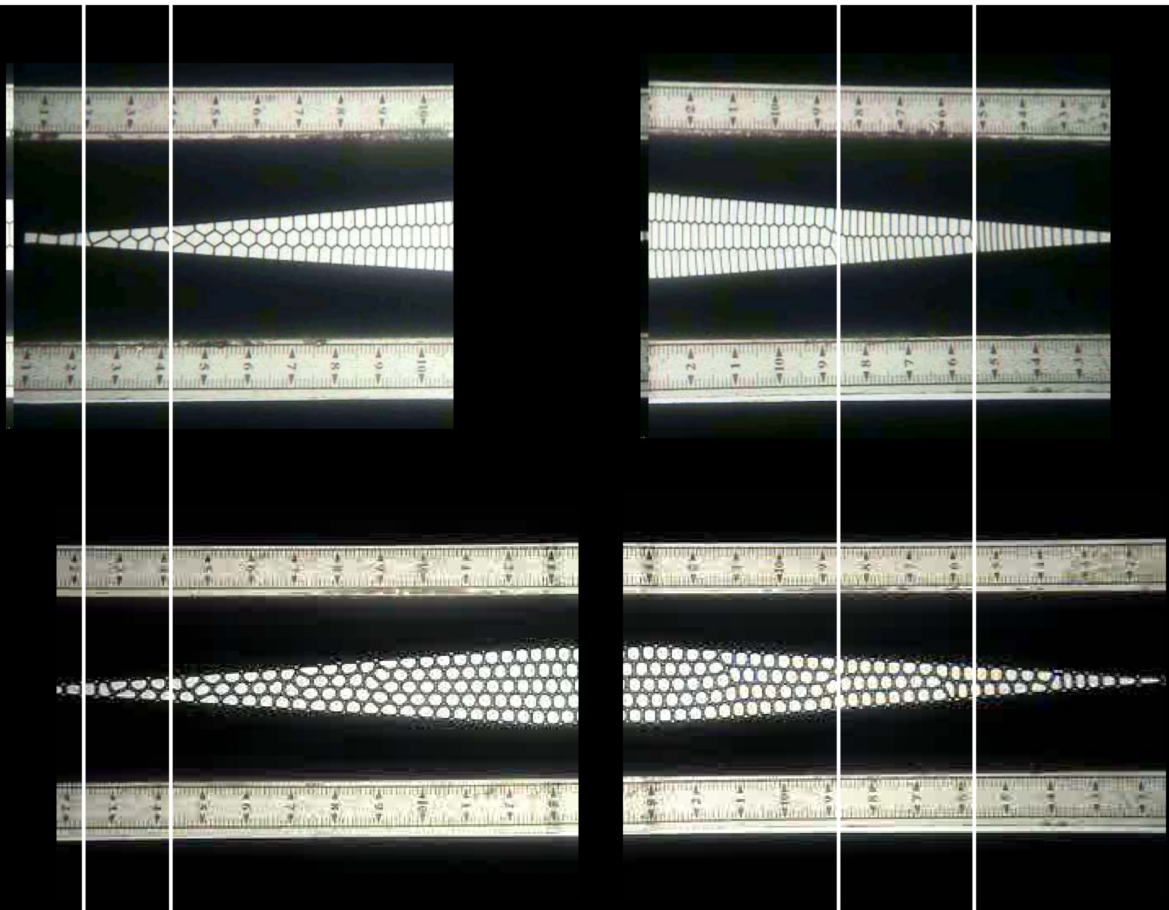
wet

200 μm depth

Quasi-2D foam flow through a wedge



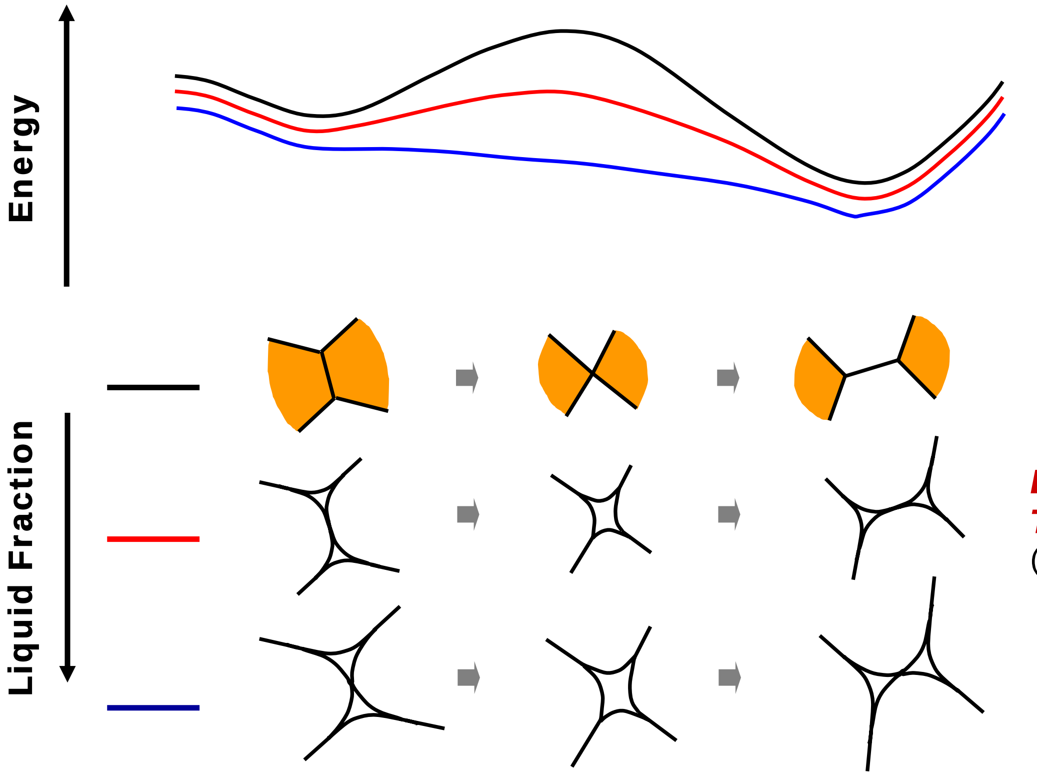
Coupling of channel size & bubble size + strong hysteresis



Hysteresis depends on liquid fraction – relationship with yield stress

T1-process in WET foams

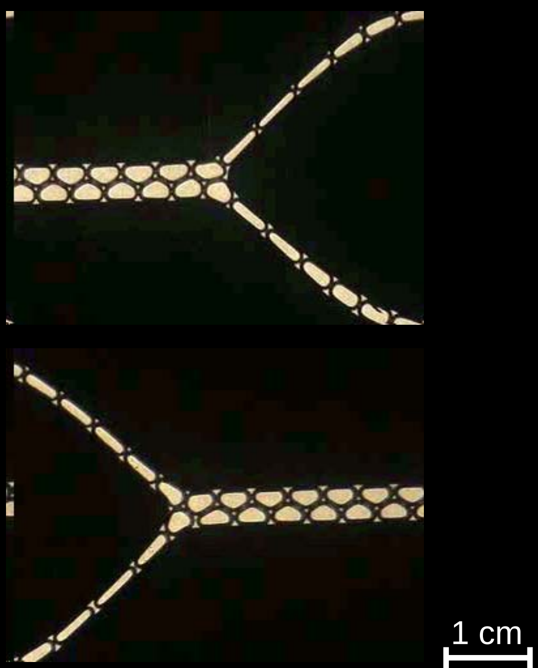
Francois
Sylvie
Simon



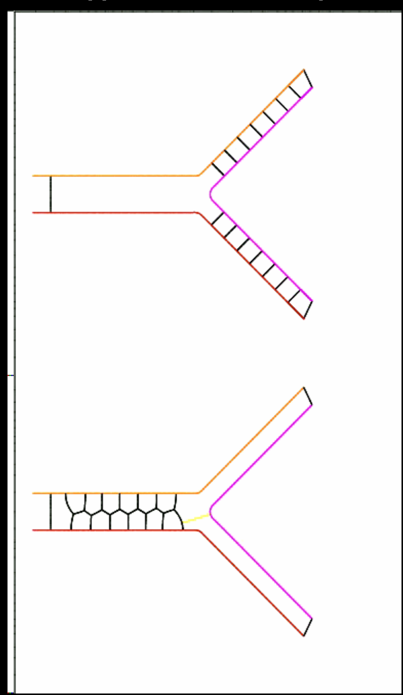
Decoration Theorem
(Weaire)

Make things more interesting:
For example FANCY Y-FRONTS

EXPERIMENT



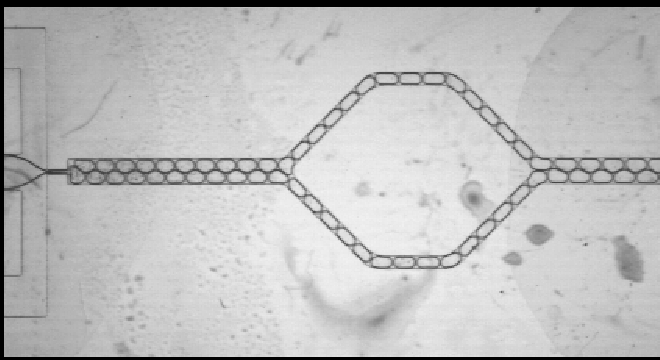
SIMULATION
(quasistatic, Simon)



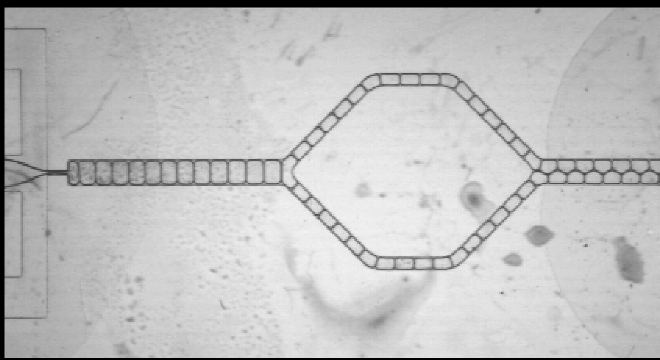
Antje’s & Jan- Paul’s Tutorial

Finally: Downscaling

Micro-foams

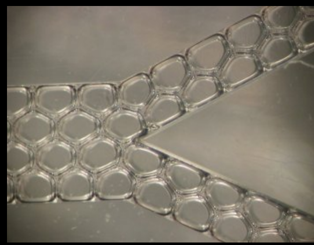


200 μm



(J.-P. Raven, P. Marmottant, Grenoble)

Micro-emulsions



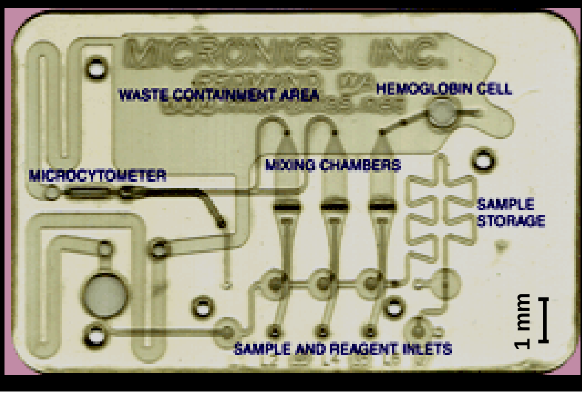
(R. Seemann, S. Herminghaus, Max Planck Inst. Goettingen)

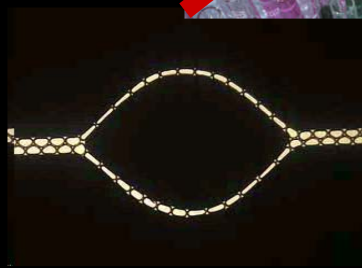
These systems are great for two very good reasons:

1. Strong applied interest

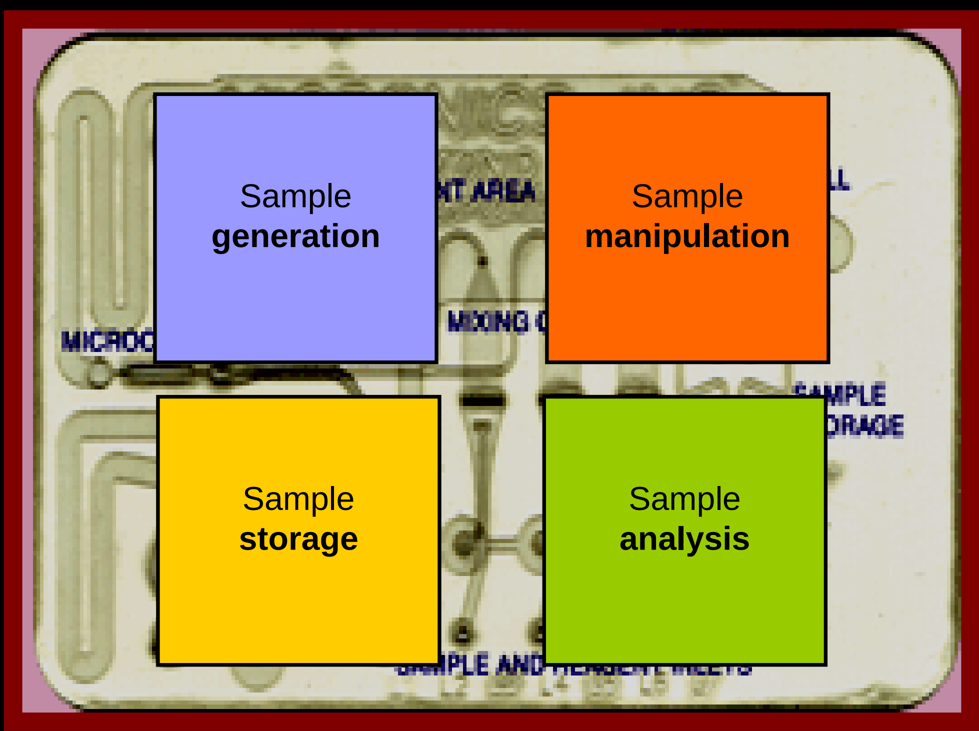
2. Improve understanding of foam and emulsion rheology on the scale of a few bubbles (simulations doable etc., also the case for non-micro systems)

DISCRETE/DIGITAL MICROFLUIDICS
for LAB-ON-A-CHIP TECHNOLOGIES





DISCRETE/DIGITAL MICROFLUIDICS



SOME FUNDAMENTAL INGREDIENTS
to fluid dynamics (of foams) on small length-scales *L*

- $$\mathrm{Re} = \frac{\rho U L}{\eta}$$ small

  Reynolds number (ratio of inertial forces to viscous forces)

➡ Laminar flow (can be a real nuisance) [see Caroline]

- $$l_c = \sqrt{\frac{\gamma}{\rho g}} \approx 1.7\ \mathrm{mm}$$

  Capillary length (ratio of gravity force and surface tension force)

➡ $l < l_c$ surface tension dominates gravity [see Antje and Yann]

- $$\frac{\mathrm{SurfaceArea}}{\mathrm{Volume}} \sim \frac{L^2}{L^3} = \frac{1}{L}$$

➡ Surface effects become increasingly important [Jan-Paul's banana foams]

- $$F_{viscous} \sim \frac{1}{L}$$

➡ Viscous dissipation becomes increasingly important

- $$\Delta p \sim \kappa \sim \frac{1}{L}$$

➡ Small curvatures entail large pressures

No NEW physics ☹ - but shifted relative weight of physical ingredients, providing new insight (for instance micro-gravity scenario, study viscous effects etc.)

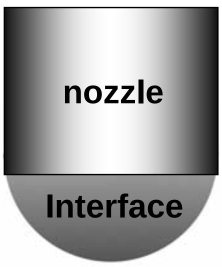
Sample generation

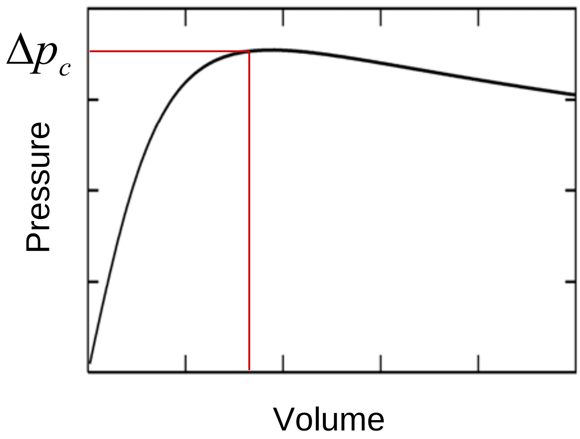
Small things under large pressures

example: nozzle design

quasistatic

Traditionally droplets and bubbles formed from small nozzles





$$\Delta p = \frac{2\gamma}{\mathrm{r}} \qquad \text{(Laplace law)}$$

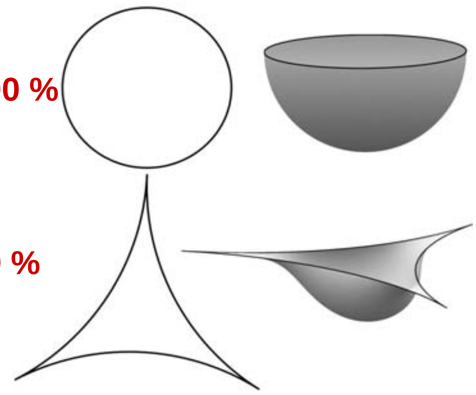
$$\rightarrow \Delta p \sim (\text{length})^{-1}$$

$$\Delta p = \gamma \kappa$$

κ - mean curvature

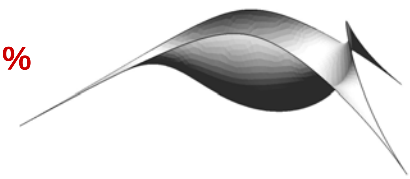
Δp_c = 100 %

Δp_c = 89 %



The Winner is:

Δp_c = 77 %

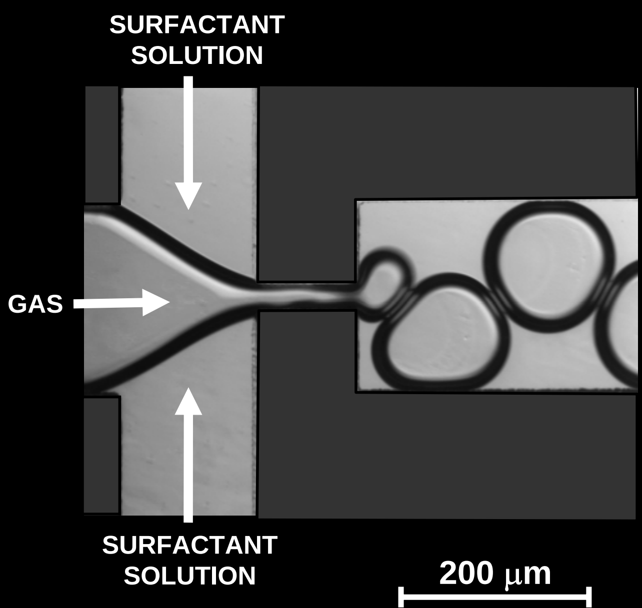


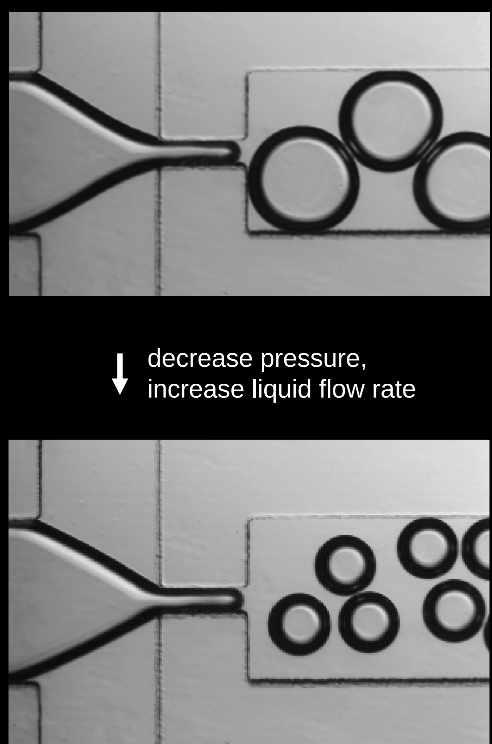
Gravity negligible – need different detachment mechanism

P. McGuinness *et al* J. of Phys. D (2005)

H. H. Chen and M. P. Brenner, *Phys. Rev. Lett.* 92 (16), (2004)

The challenge of making small bubbles and droplets



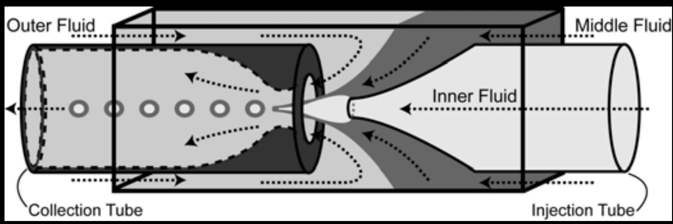


Soft lithography

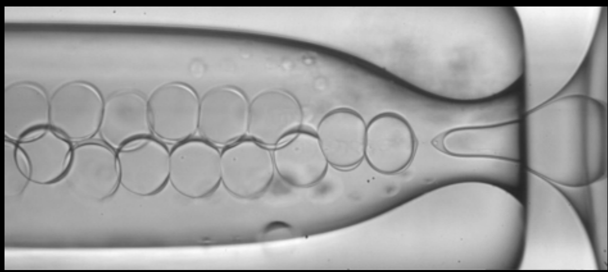
(J.-P. Raven, P. Marmottant, Grenoble)

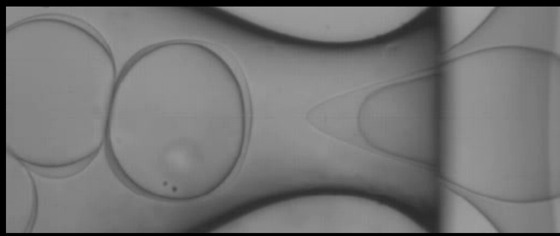
P. Garstecki, I. Gitlin, et al, APP. PHYS. LETT. **85(13)**, Sept. 2004

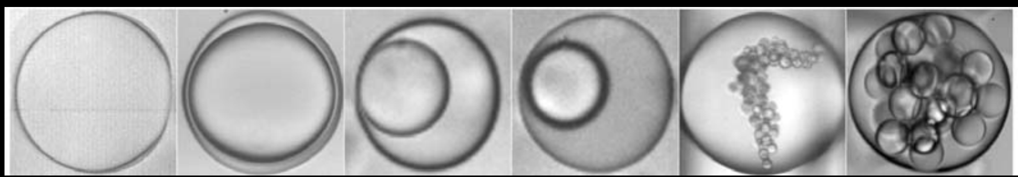
Double Emulsions



5 mm

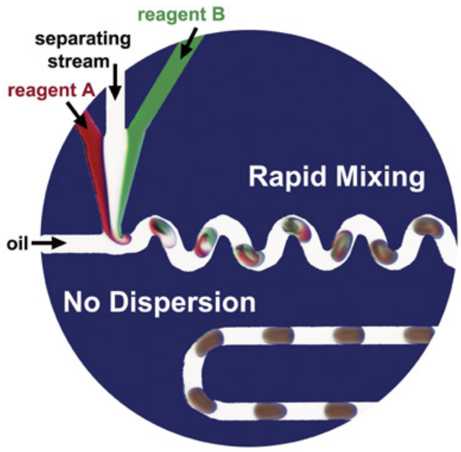


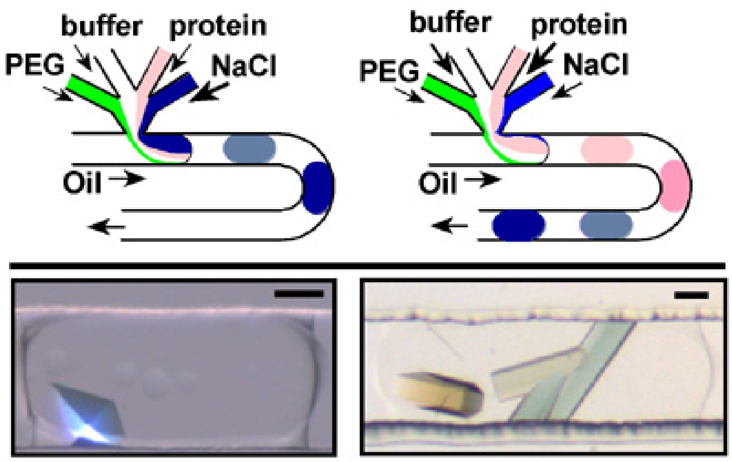




Weitz lab, Harvard University   Elise Laurenceau, Sang Yann Yip Cheung

Example: micro-mixers & micro-reactors for the analysis of proteins





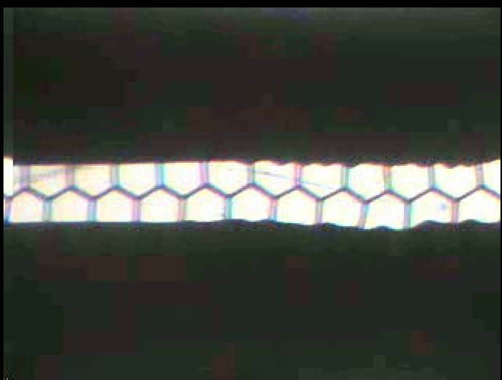
Thaumatin   Catalase

[Caroline again ☺]

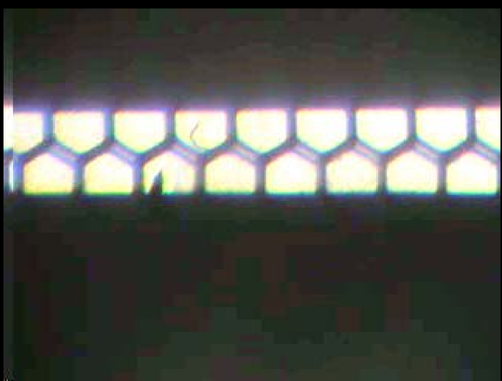
Ismagilov Group
at Chicago University

Sample manipulation

Sample manipulation

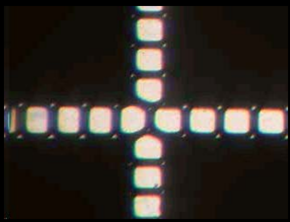


Plug flow guaranteed!

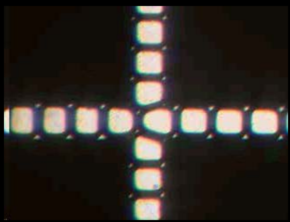


detectors

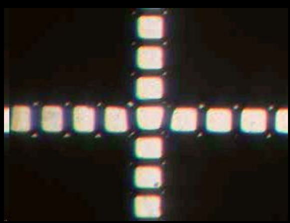
The magic cross



bubble
injection

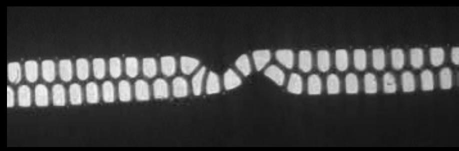


bubble
removal

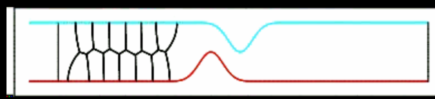


bubble
swapping

Changing places



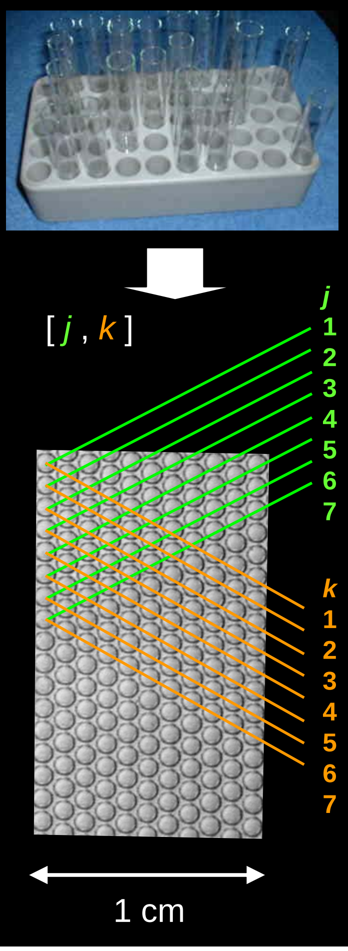
experiment

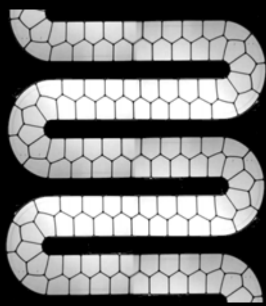


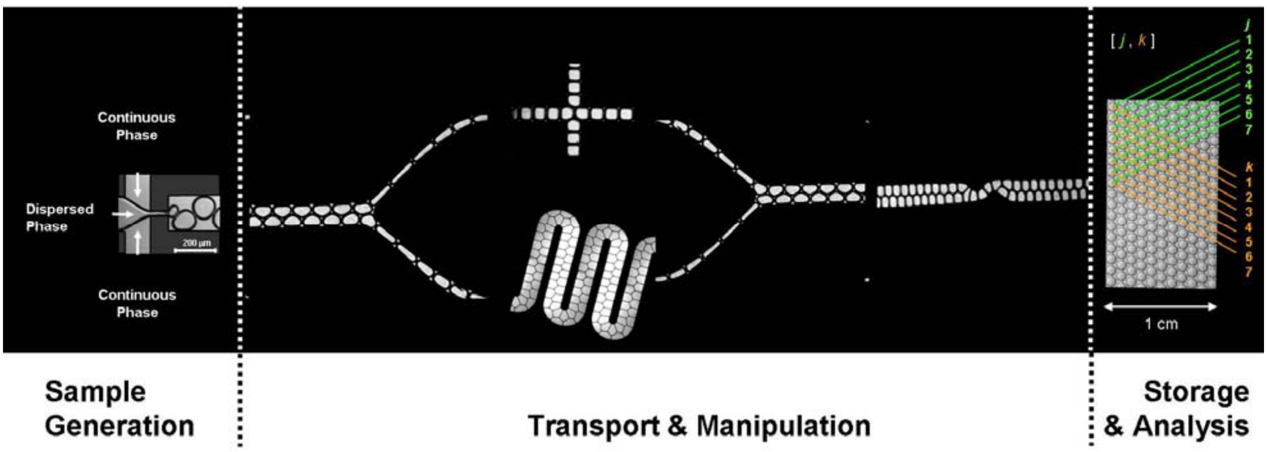
simulation

Sample storage & analysis

Storage &
Analysis in one

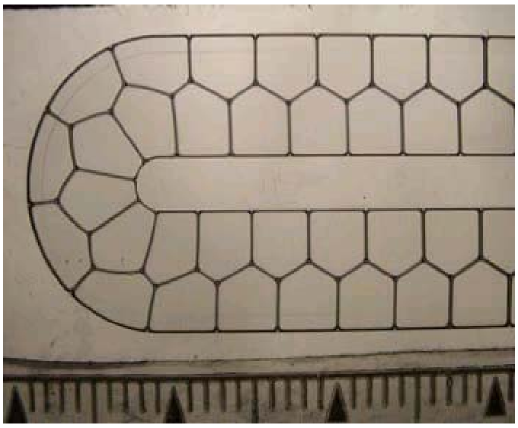


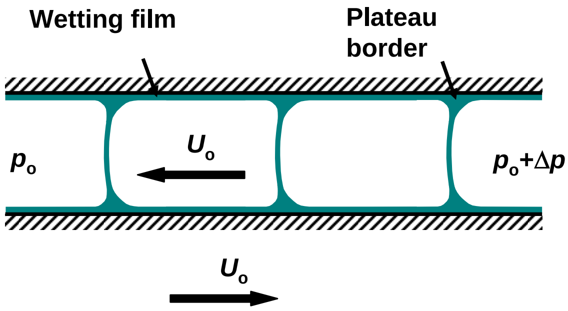




Transition to Anthony ….

Small length scales – large dissipation etc….





Bretherton, Denkov, Cantat