COMSOL CONFERENCE
2015 GRENOBLE

EMPIRe Laboratory

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

# Simulation of Constant-Volume Droplet Generators for Parallelization Purposes

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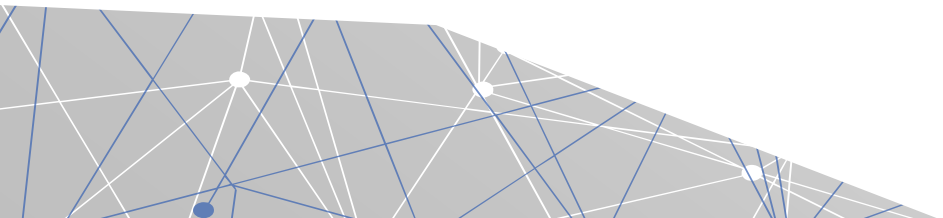
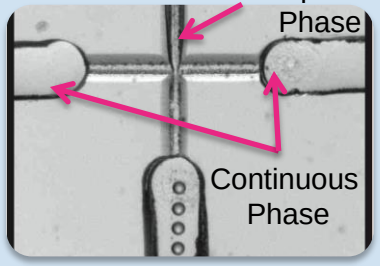
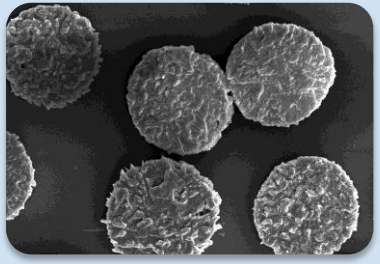
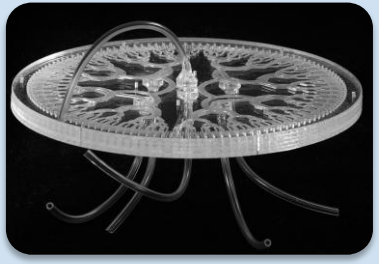


# Introduction







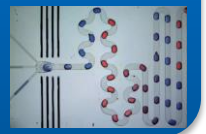
## Micro Droplets

- Droplets as micro-Reactors
- Droplets as detection systems
- Greater Surface: Volume

(ESPCI LBC)

## Applications for this technology

- Quantum dots
- Micro & nano particles
- Active Pharmaceutical Ingredients
- Nano crystals



(Garsteski)

## Scaling up

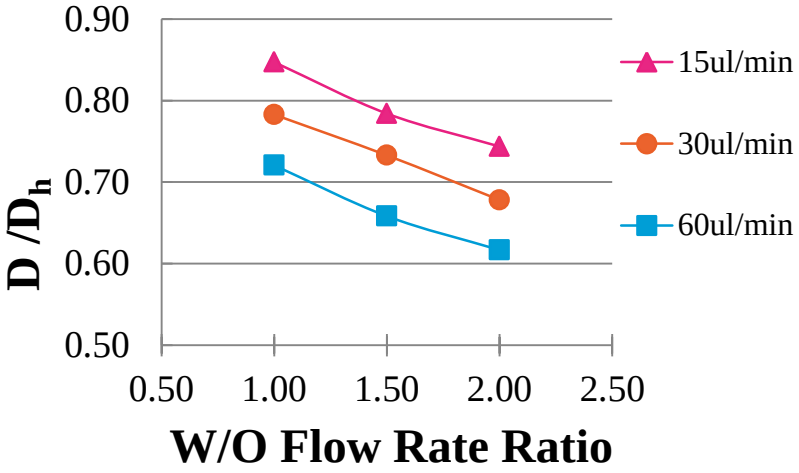
- Parallelization
- Flow are highly coupled
- Must to retain uniformity in hundreds of generators

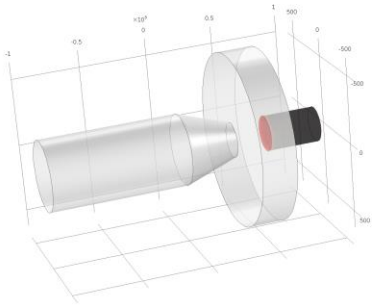
## Improving Droplet Generators

- Minimization of flow variations between adjacent devices
- Designing Constant Volume Generators that do not depend on flow rates

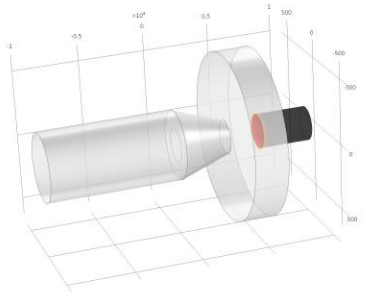
# Introduction





Oil Flow Rate (Red) = 15μL/min
Water Flow Rate = 15μL/min

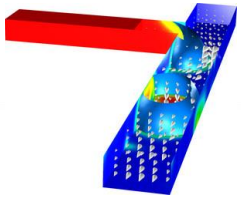


Oil Flow Rate (Red) = 20μL/min
Water Flow Rate = 40μL/min

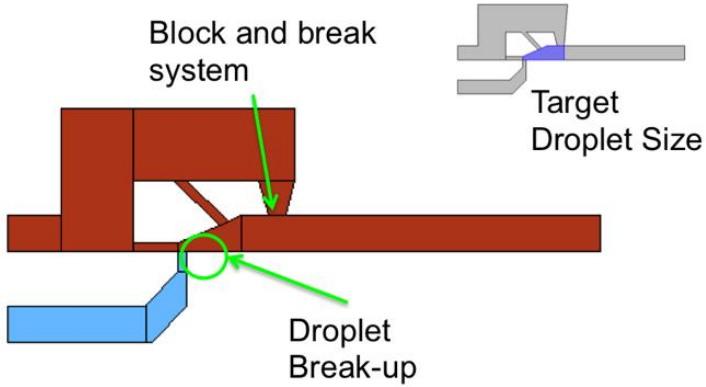
# Device Description



- Constant volume Droplet Generation
- Similar to a classic T-junction generator with bypass channels
- Block-Break Mechanism Proposed by (Van Steijn, 2013)
- Size of the droplets is dependent on the geometrical dimensions and not on the flowing rates



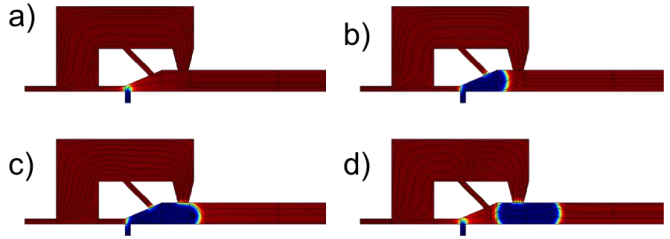
(COMSOL App Library)



# Device Description



a) The disperse phase meets the continuous phase at a junction.
b) The drop grows gradually protected by the cavity. The bypass allows free flow of the continuous phase
c) The bypass systems gets blocked
d) Droplet break-up



# Use of COMSOL Multiphysics



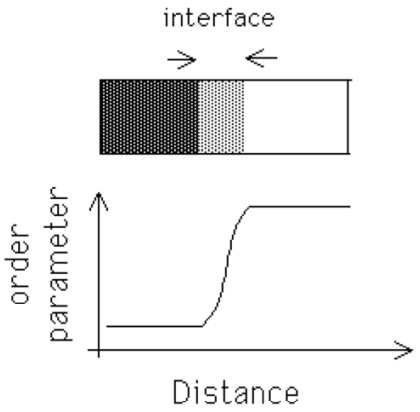
- Conservation of Momentum and Mass
- The multiphase flow is described by the **parameter $\phi$**. The interface between them (phase field) is the set of values $1 < \phi < 0$.

Navier-Stokes:

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u}\cdot\nabla)\mathbf{u} = -\frac{1}{\rho}\nabla p + \gamma\nabla^2\mathbf{u} + \frac{1}{\rho}\mathbf{F}$$

Continuity Equation for incompresible flow:

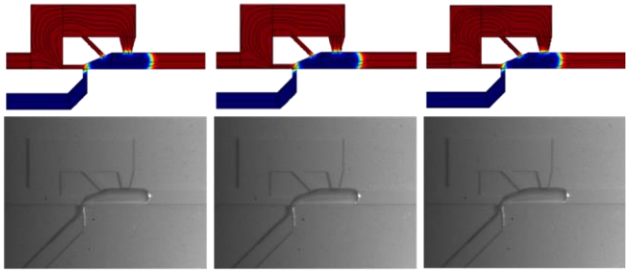
$$\nabla\cdot\mathbf{u} = 0$$



# Simulation Results & Discussion

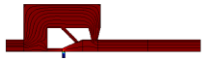


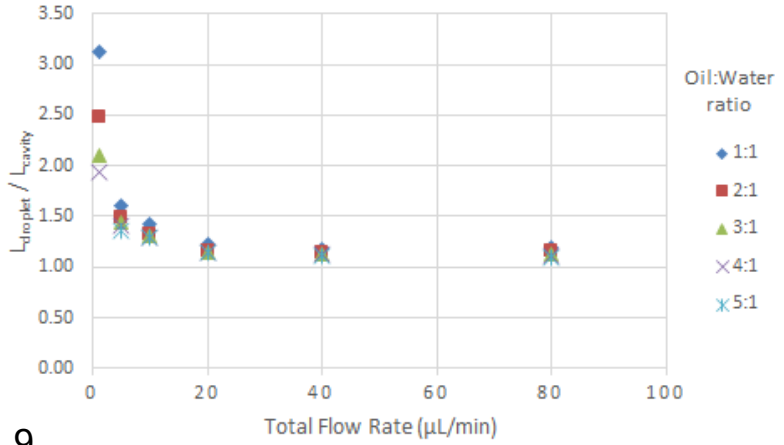
- Simulations were validated with experimental results
- Devices were manufactured using soft-lithography and tested at different flow rates
- Flow study was performed to evaluate the robustness of the geometry



# Simulation Results & Discussion



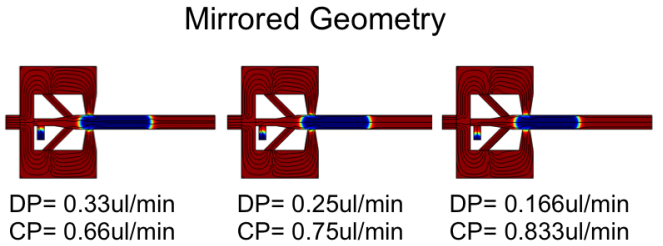
| @20ul/min | OWR 1:1 | OWR 2:1 | OWR 3:1 | OWR 4:1 | OWR 5:1 |
|---|---|---|---|---|---|
| TVF |  |  |  |  |  |



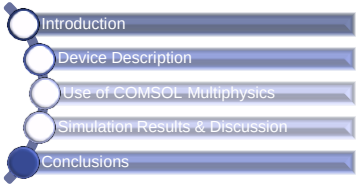
# Simulation Results & Discussion



- The model helped us to design a mirrored geometry of similar robustness to flow variations
- This geometry may reduced the probability of device failing for undesirable wetting
- The fabrication process is more challenging because it requires vertical addition of the disperse phase



# Conclusions




- Simulation of a geometrically set generator was presented
- The device showed great robustness to flow changes
- Simulations were validated with experimental results
- The simulation allowed us to quickly develop a new mirrored geometry with similar characteristics
- Future work includes the fabrication of a parallel device with hundreds of constant-volume  droplet generators.

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Merci Beaucoup!!
Happy to take any questions.