Disputation i Teknisk Mekanik

Fredag 2020-03-27, kl 10.00

Respondent:	Zhouyang Ge
Titel:	Droppinteraktioner och suspensionsflöden
Handledare:	Prof. Luca Brandt
	Asso. Prof. Outi Tammisola
Fakultetsopponent:	Asso. Prof. François Gallaire, École polytechnique fédérale de Lausanne, Schweiz
Betygsnämnd:	Dr. Elisabeth Lemaire, Institut de Physique de Nice, Frankrike
	Dr. Martin Trulsson, Lund Universitet, Sverige
	Dr. Gustaf Mårtensson, Mycronic AB, Sverige
Ordförande:	Prof. Fredrik Lundell
Sponsorer:	EU Horizon 2020 (MICROFLUSA), VR

Procedure

- **The respondent will present the thesis**
- **The opponent will discuss the thesis**
- **The grading committee will ask questions**
- **The audience may ask questions**
- **The public part of the defence will be closed**
- **The result will be announced at Osquars Backe 18, floor 6**

On Droplet Interactions and Suspension Flow

Zhouyang Ge

Department of Engineering Mechanics,
KTH Royal Institute of Technology, Stockholm, Sweden

But what are *droplets*?

Droplets are micron to millemetre sized liquid balls formed under surface tension.*

*Photo by Martin Brechtl on Unsplash.
†Source: `https://youtu.be/P1ww1IXRfTA`.

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Let's have some fun!

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Background, motivation and challenge

Photonic crystals (PhC) are materials patterned with a periodicity in dielectric constant and show great potential for building sophisticated optical circuitry that can route, filter, store or suppress optical signals.

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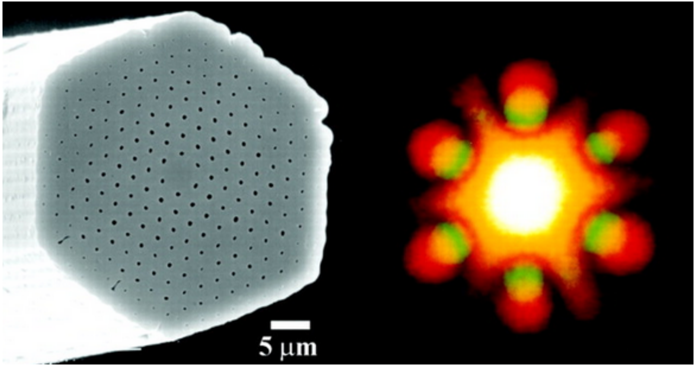
(a) 

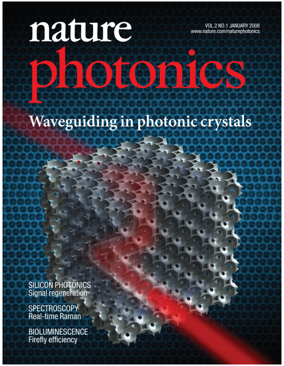
(b) 

Figure 1: (a) A scanning electron micrograph of a solid-core photonic crystal fibre and its far-field optical pattern.* © AAAS Science. (b) Cover photo of the January 2008 issue of Nature Photonics, showing an artistic rendering of a light beam passing through a 3D photonic crystal. © Springer Nature.

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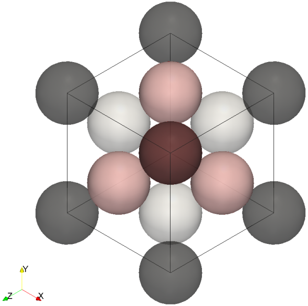

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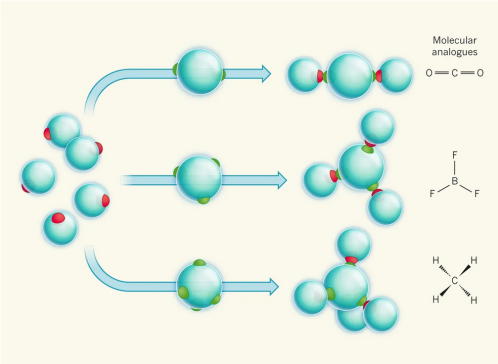

(b)

Figure 2: (a) A diamond cubic (view angle 111). (b) Self-assembly of micron-sized patchy particles, using single-stranded DNAs as selective "glues" to bind to nearby colloids.* The directional bindings mimic the arrangements of bonds around atoms, and the obtained cluster may serve as basic building blocks for more complex structures. However, the process relies on Brownian motion to bring complementary partilces into their range of attraction. Therefore, even if they can self-assemble into a diamond lattice, the rate of production will be too slow to meet practical needs. © Springer Nature.

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Experiments, strategy and questions

Six years ago, a series of experiments performed at ESPCI, Paris suggested an alternative approach...

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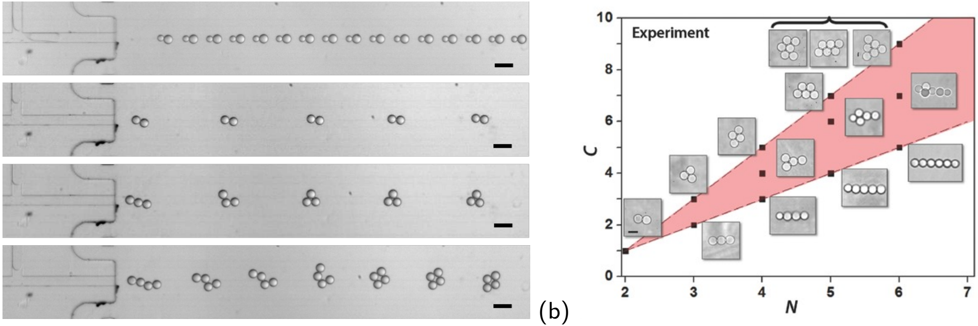

Figure 3: (a) Self-assembly of two to four droplets in a microfluidic chip; scale bars, 100 μm. (b) Observed cluster morphologies mapped on a $C - N$ diagram, where C represents the number of droplet-droplet contacts and N is the number of droplets per cluster.* Scale bar is 5 μm. Images courtesy of Dr. Bingqing Shen.

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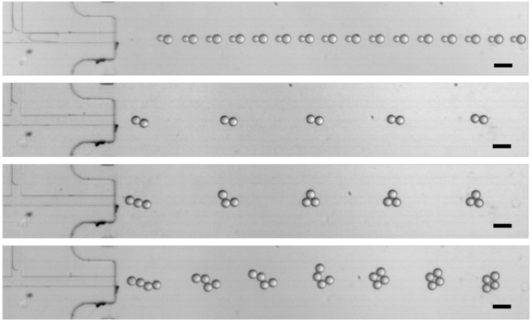
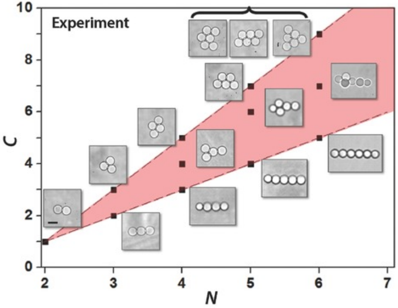
(a) 

(b) 

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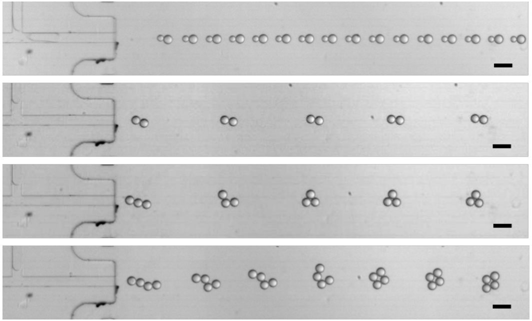
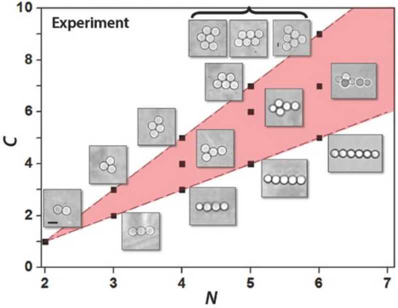
(a) 

(b) 

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The questions are, why do they organize into such patterns? What is the hydrodynamic mechanism? Can we further optimize it?

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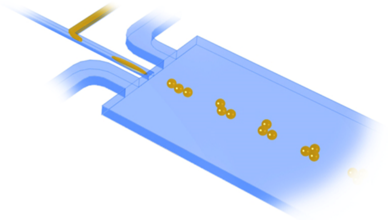
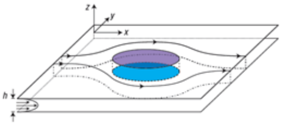
A simple q2D dipolar model

Noticing the strong geometric confinement of the microfluidic channel, physicists at ESPCI proposed the following *dipolar model*.





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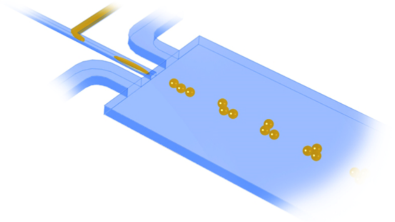

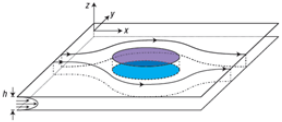

Obersvations & hypotheses

- Droplets are in quasi-two-dimensional (q2D) space.
- Depletion force attracts nearby drops.
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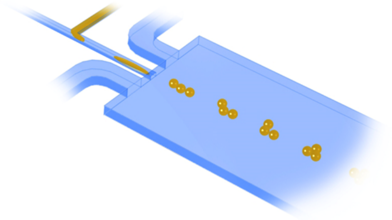

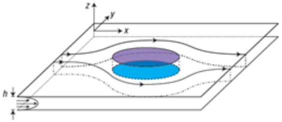

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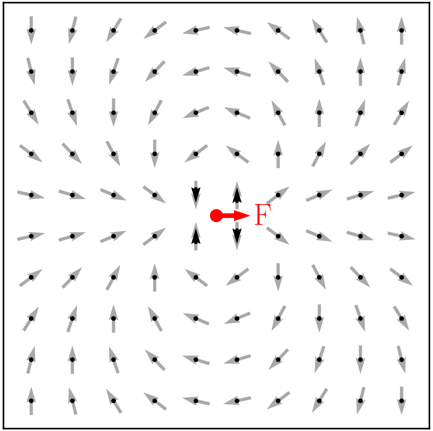

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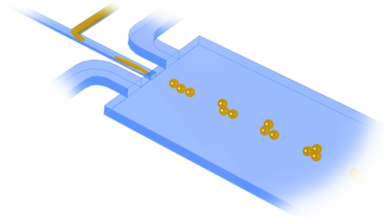

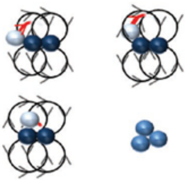

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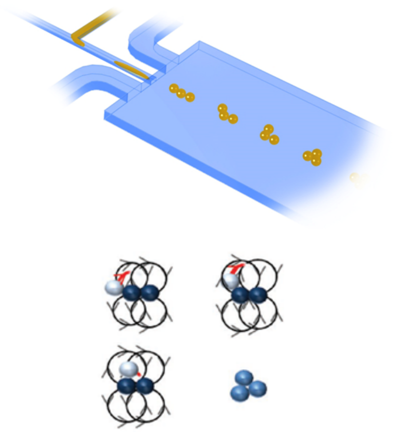

Is this picture really correct?

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$$\rho\left(\frac{\partial \boldsymbol{u}}{\partial t} + \boldsymbol{u} \cdot \nabla \boldsymbol{u}\right) = \nabla \cdot \boldsymbol{\sigma} + \boldsymbol{f}, \tag{1b}$$

where $\boldsymbol{\sigma}$ is the viscous stress tensor, given as

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In developing the numerical solver, no such assumptions are made.

ICLS/GFM

Hypotheses for cascade directions

- In Batchelor we believe.
- Yes we still do.

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Thank you for your attention.