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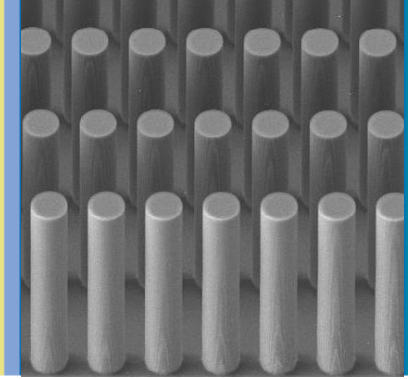

Deterministic ratchet technology for large-scale separation of partice suspensions

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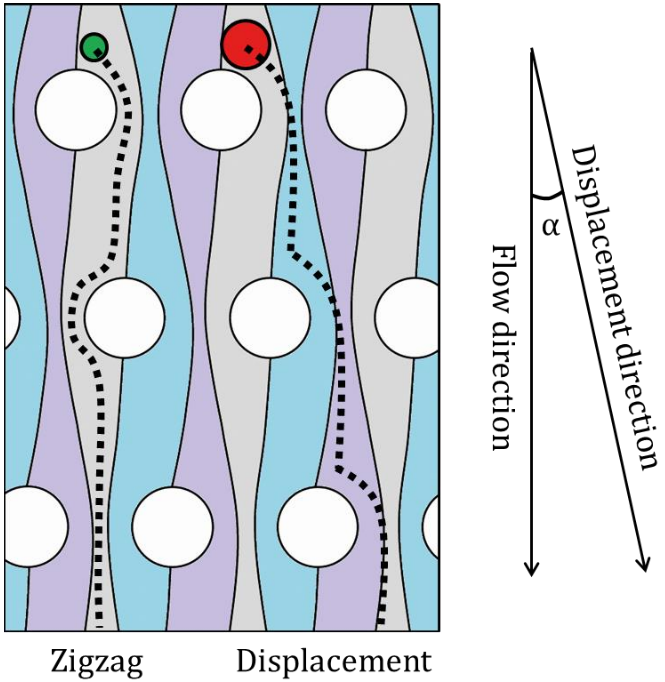
Wetsus, European Centre of Excellence for Sustainable Water Technology

combining scientific excellence with commercial relevance

Deterministic ratchets – what and how?

- **Gaps > particles**
- Obstacle columns placed in an angle (α)
- Structure fluid into flow lanes
- $D_{particle} > 2{*}D_{fc}$ (red) obstacles can push particles laterally
- $D_{particle} < 2{*}D_{fc}$ (green) particles follow the flow direction



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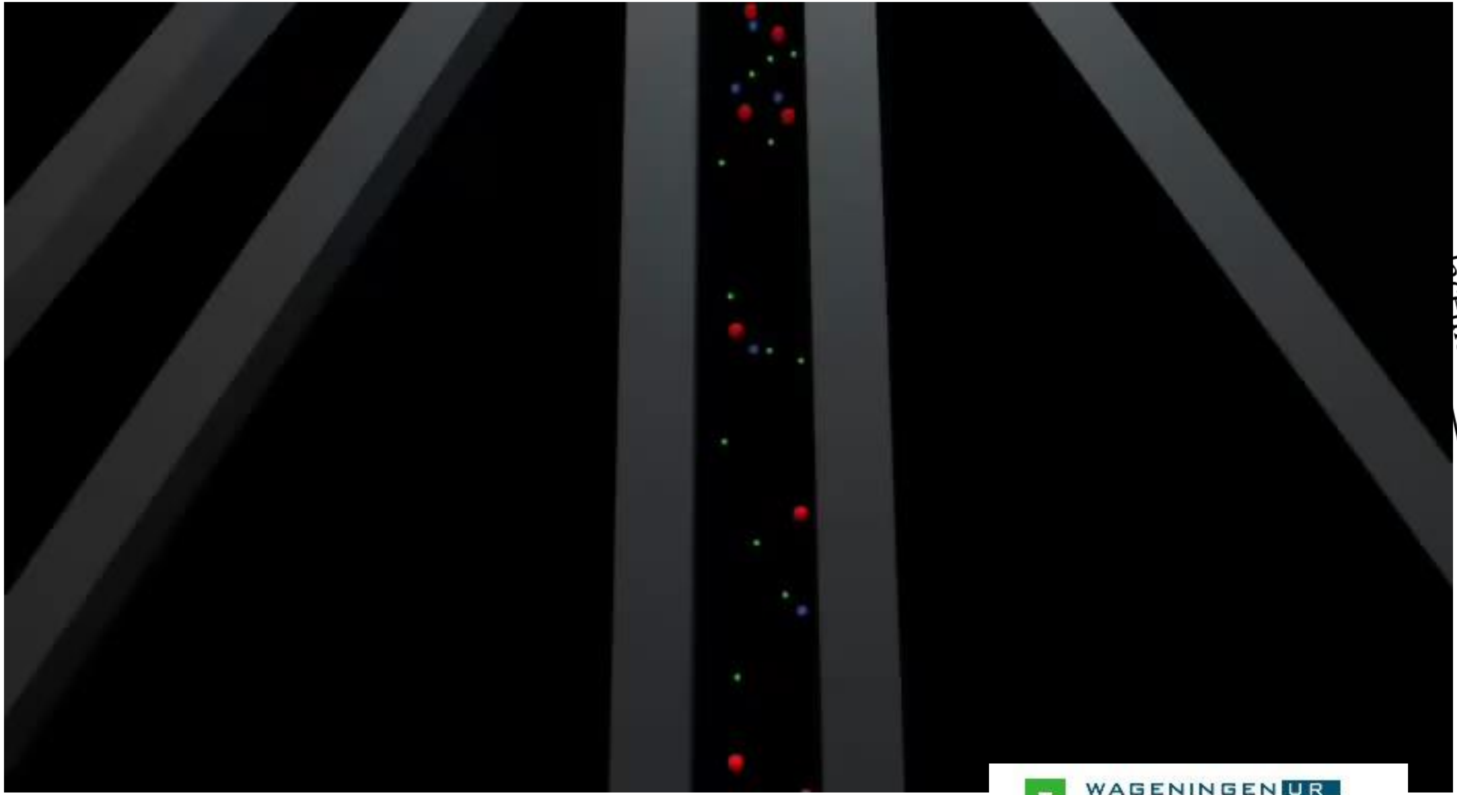
Deterministic ratchets – what and how?



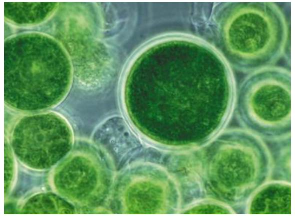
Youtube: jshholm

Applications

Suspension separation and fractionation

- Original: biomedical diagnostics (e.g. tissue, blood)

- Other interesting industries
  - Food: filtration beer/wine
  - Biotechnology: concentration of algae
  - Laundry: removal of detergent and dirt (a.o. emulsions)
  - Water treatment: flocs


The main challenge

Microfluidic device with a throughput of ~1 ml/min

The objective:

Investigate deterministic ratchet technology for large-scale application

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Y.S. Lubbersen, 2015

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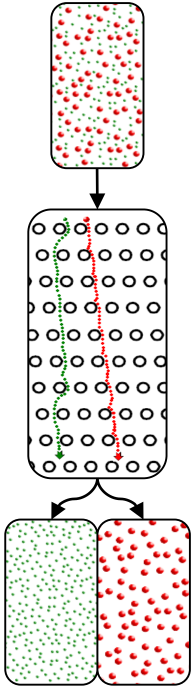
Suspension separation at moderate Reynolds numbers



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Lubbersen et al., *Chemical Engineering Science* (2012)

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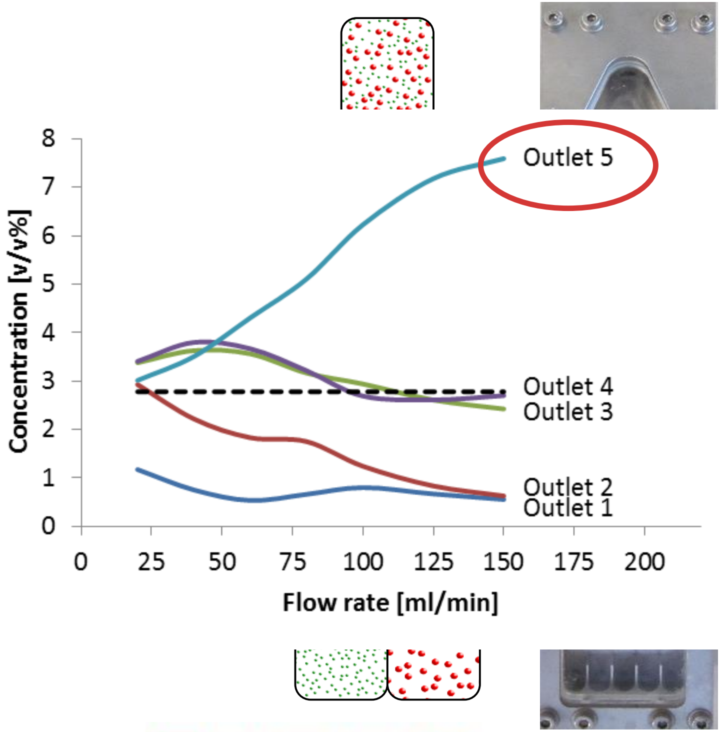
Suspension separation at moderate Reynolds numbers

Separation and recovery improves with increasing flow rate

Particles go to outlet 5



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Lubbersen et al., *Chemical Engineering Science* (2012)

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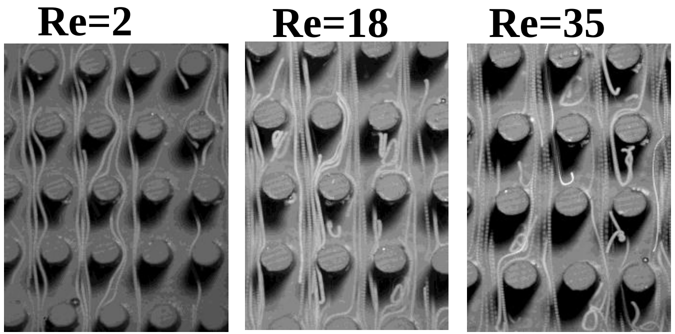
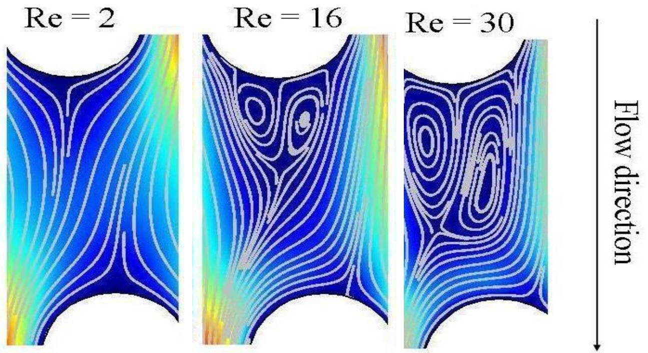
Visualization of fluid flow

Vortex formation



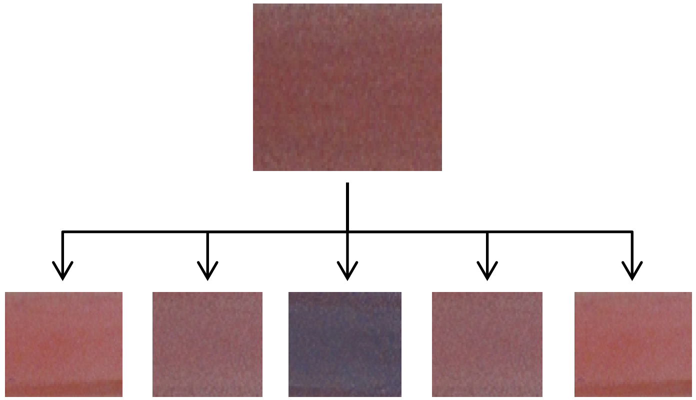
Forced particles in displacement direction, improving the separation efficiency

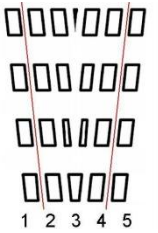


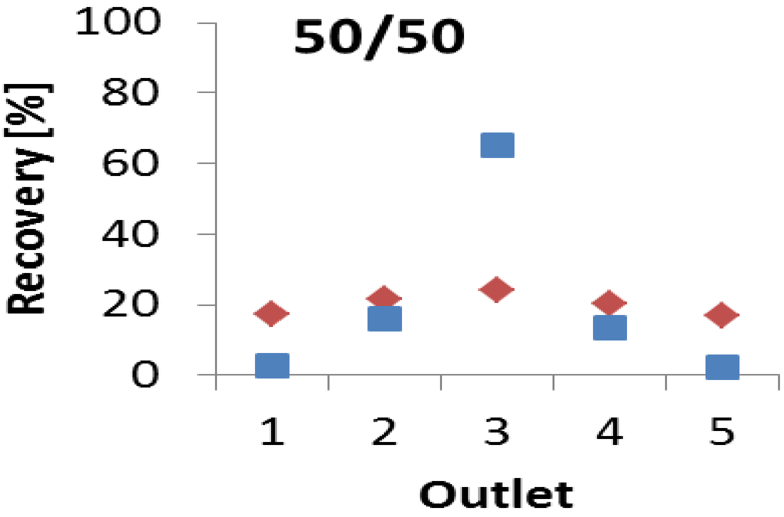
Lubbersen et al., *SEPPUR* (2013)

Investigate deterministic ratchet technology for large-scale application

- Fractionation of 32-38 µm (red) and 90-106 µm particles (blue)
- In: $V_{red}=V_{blue}$







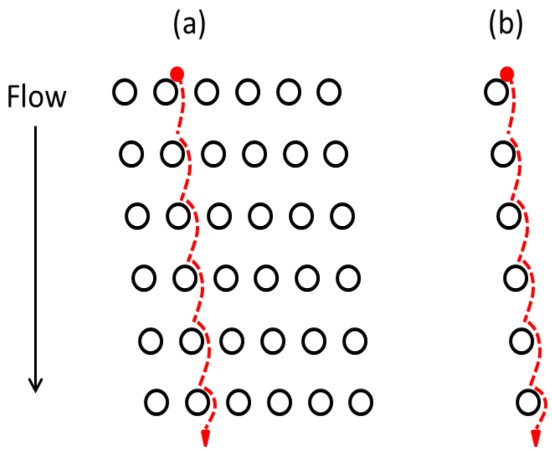
Lubbersen et al., Chem. Eng. Process (2014)

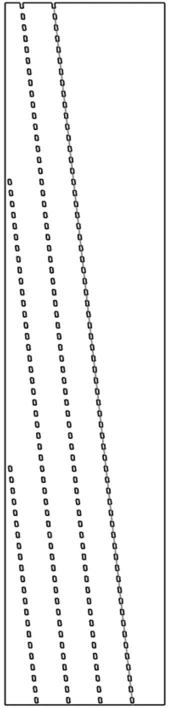
Investigate deterministic ratchet technology for large-scale application

Sparse deterministic ratchet:

– Lower risk of particle accumulation
– Reduced pressure drop
– Improved manufacturability

- Challenge = Pressure distribution

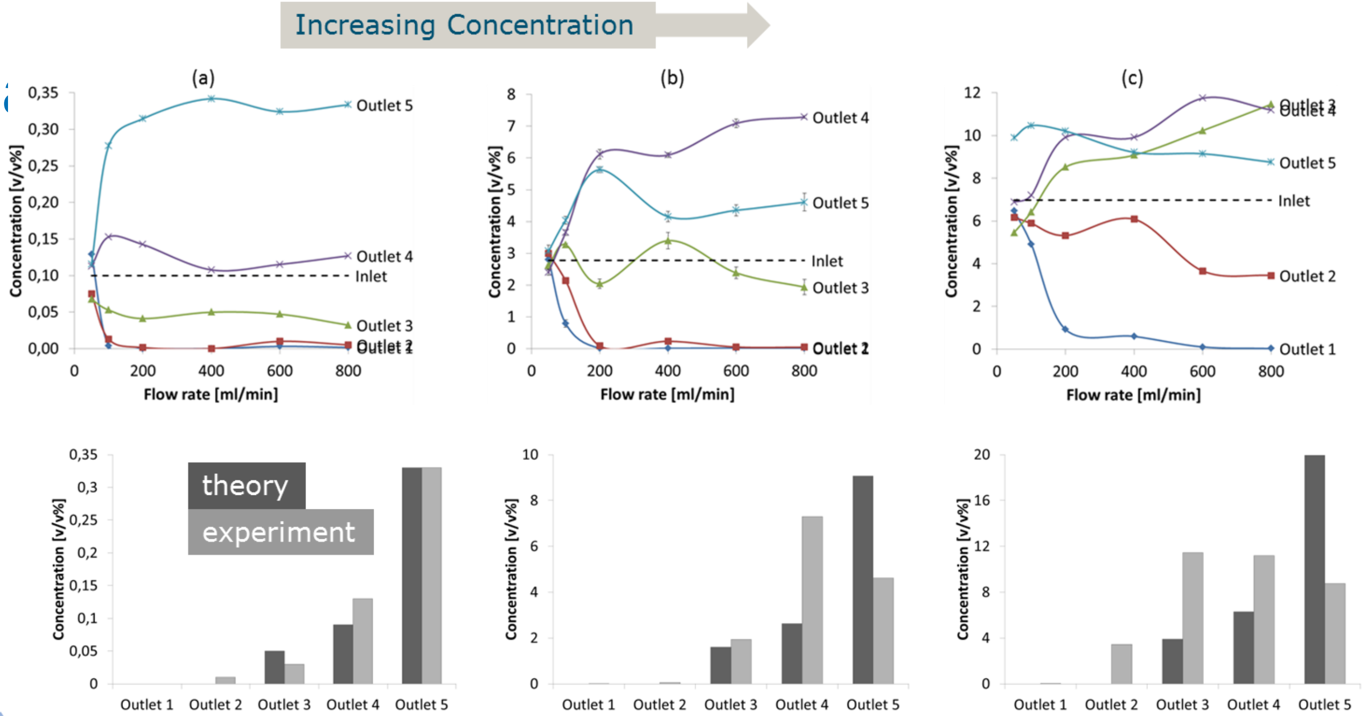


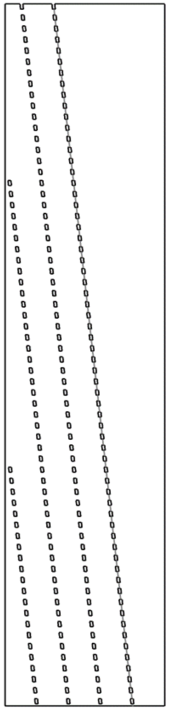


Lubbersen et al., Chem. Eng. Process (2015)

Investigate deterministic ratchet technology for large-scale application

Spa





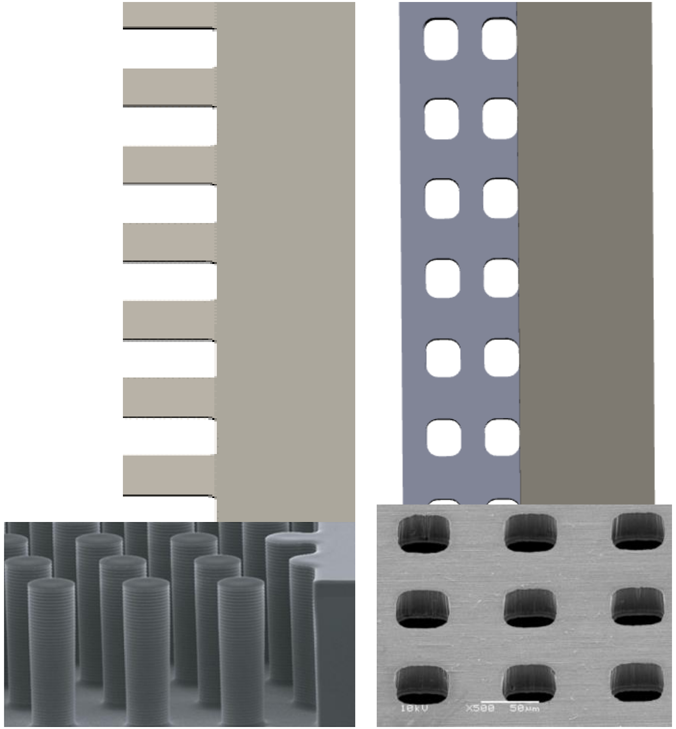
Lubbersen et al., Chem. Eng. Process (2015)

Investigate deterministic ratchet technology for large-scale application

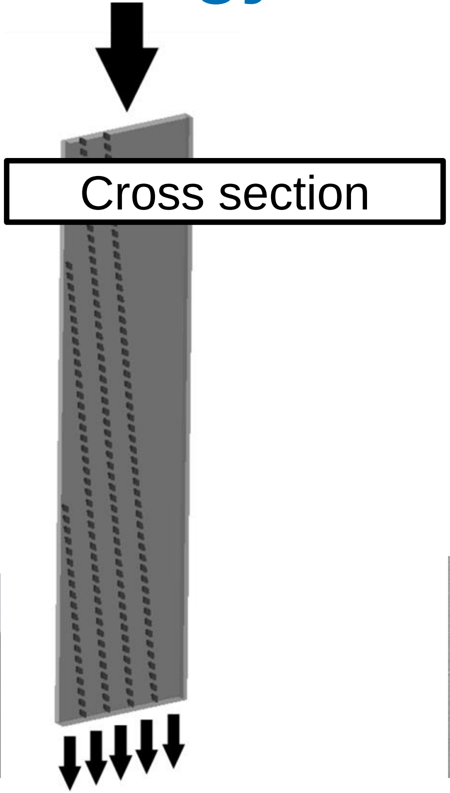
Sieves to mimic obstacle structures

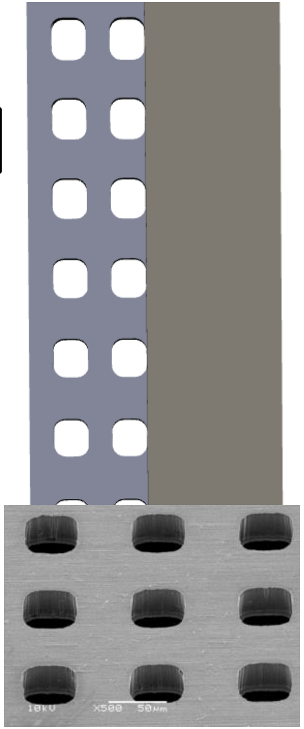
- Allows increased aspect ratio obstacles and therefore throughput

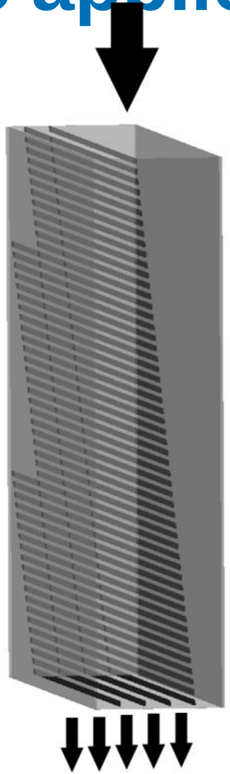
- Improves manufacturability:



Investigate deterministic ratchet technology for large-scale application



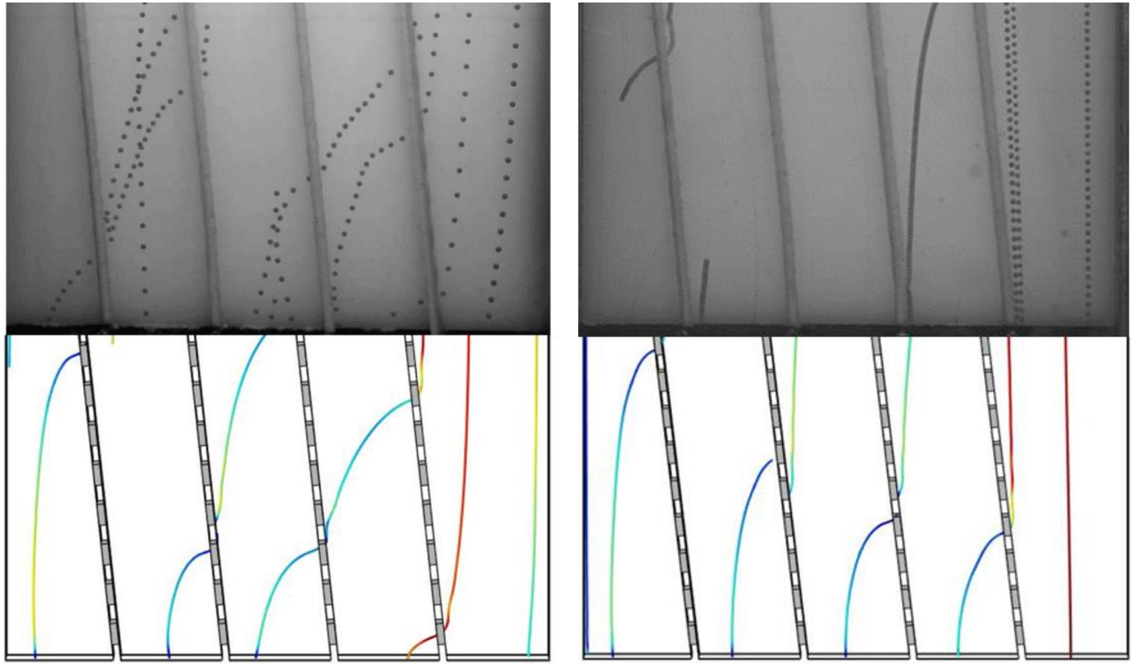




Cross section

Investigate deterministic ratchet technology for large-scale application

- Sieve-based particle separation
- Pressure distribution impaires separation



Improving pressure distribution by changing outflow conditions

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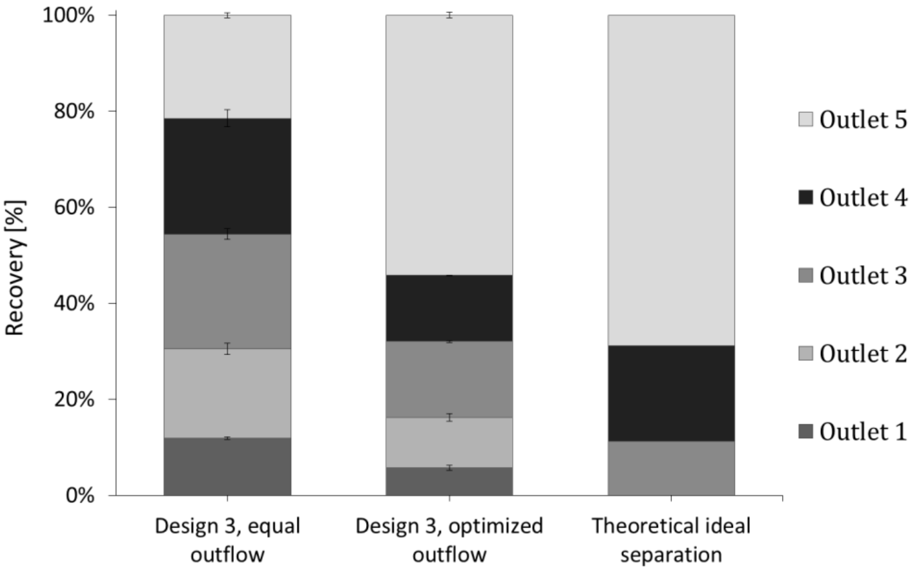

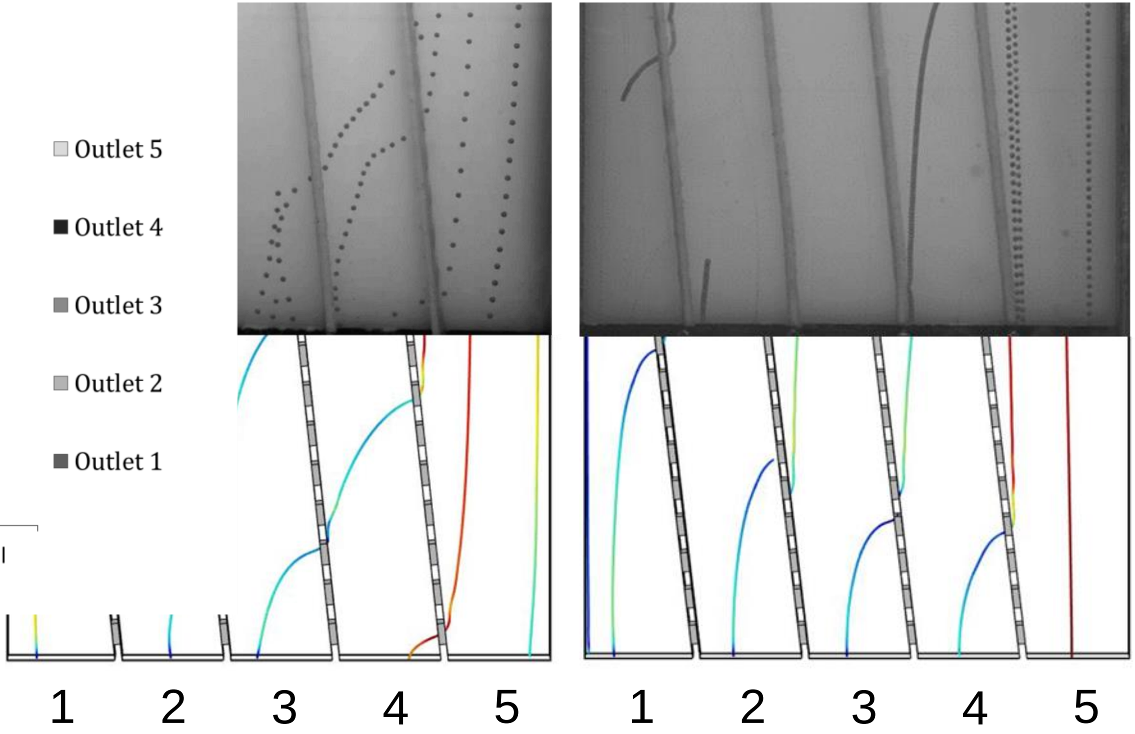

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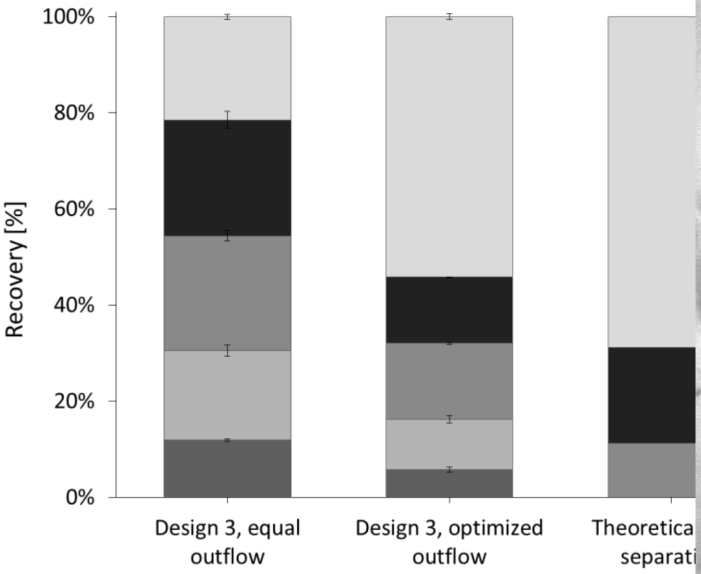

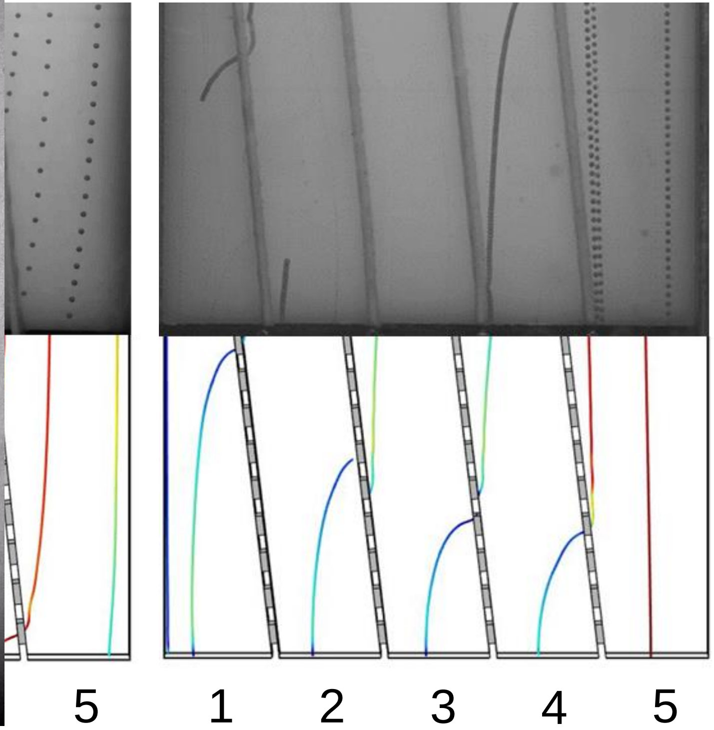

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Conclusions

- Increased flowrates improves separation
  - At moderate Re, vortices assist separation
- Separation using sparse obstacle arrays
  - Lower pressure drop
  - Reduced risk of particle accumualtion
  - Easier/cheaper to manufacture
- Use sieves mimic obstacles
  - Allows larger cross section (=larger single unit throughput)
  - Easier/cheaper to manufacture compared to obstacles

Future plans

Establish design rules

- Create fundamental understanding

Design of bench-scale system

- Practical systems

Evaluation & Conceptual design of complete process