European COMSOL Conference 2009

Milan, 15.10.2009

Particle Flow Control by Magnetically Induced Dynamics of Particle Interactions

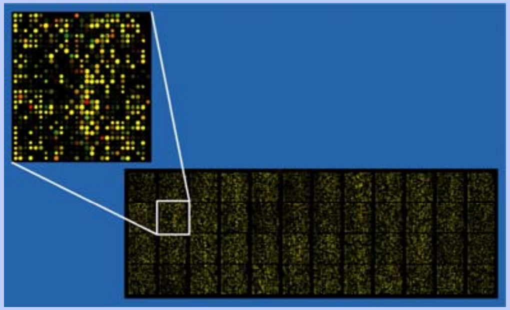
F. Wittbracht, A. Weddemann, A. Auge, A. Hütten

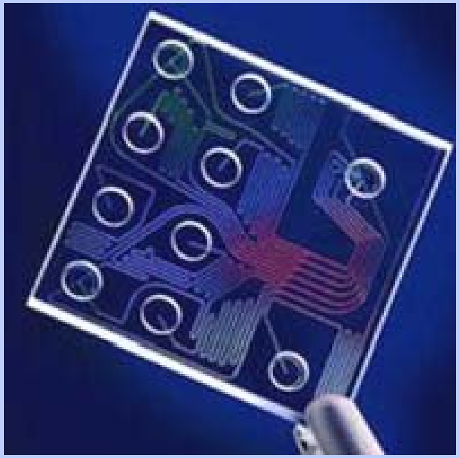
D2

Bielefeld University

Motivation

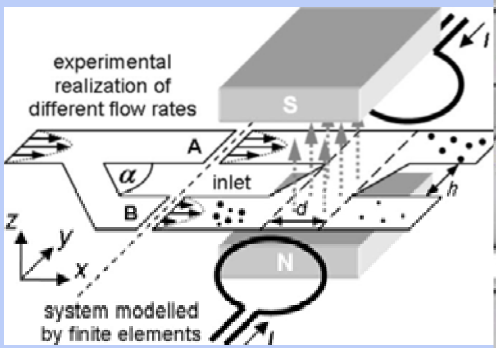
- Lab on a Chip (LOAC)
- Scaling down of single or multiple lab processes to a chip-format
- Application examples:
  - DNA sequencing
  - Electrophoresis
  - Blood sample preparation
- Two different types:
  - Microarrays
  - Microfluidics

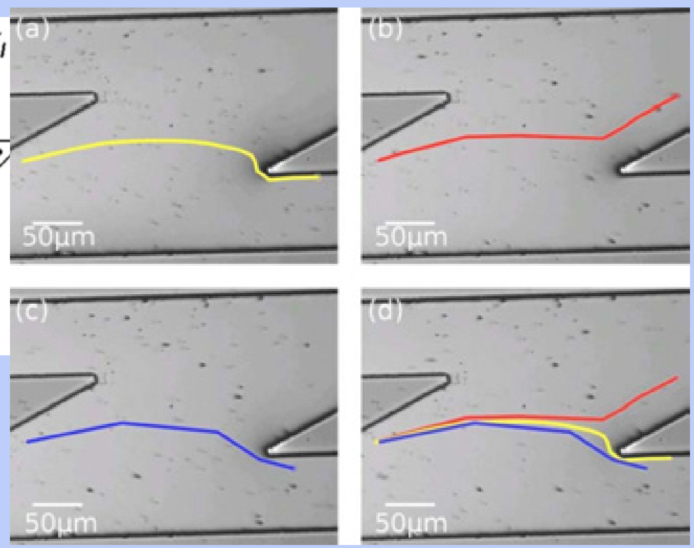


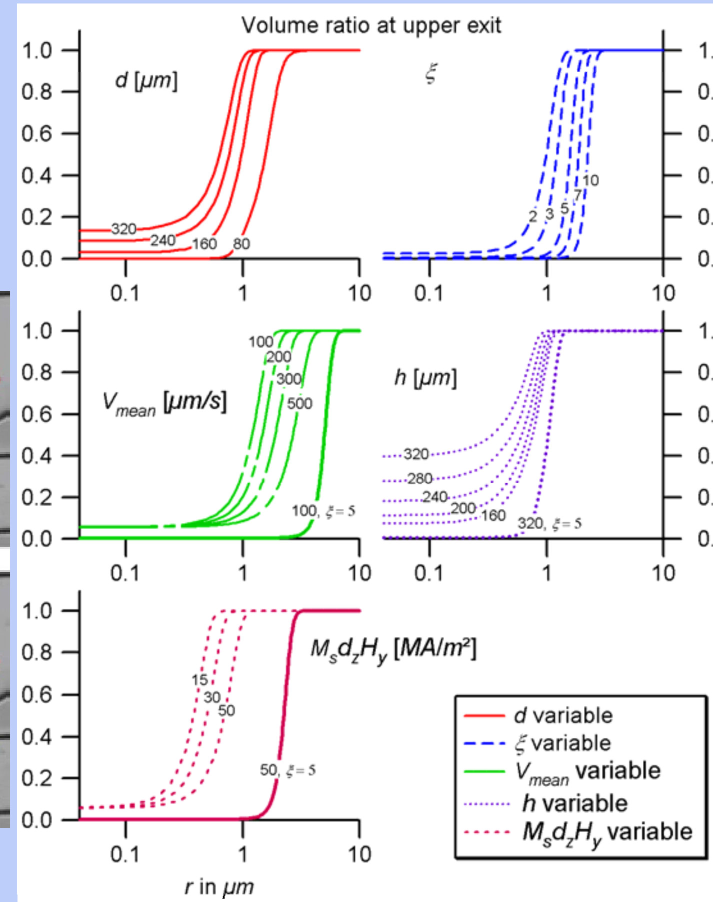


LOAC + Magnetism

- Separation of magnetic beads in microfluidic systems



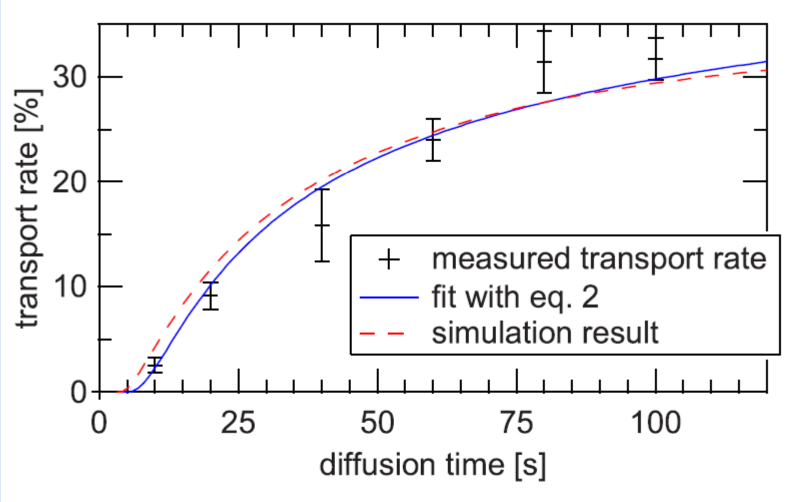


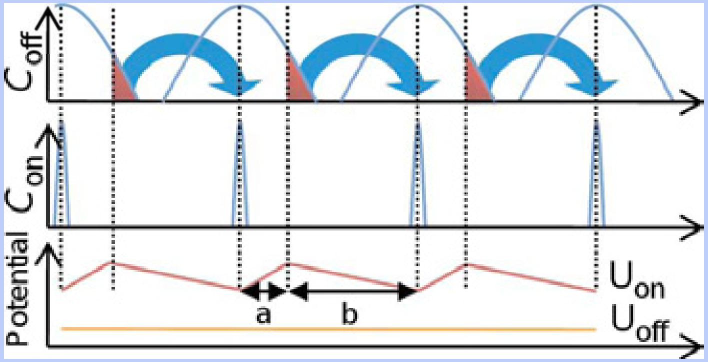


A. Weddemann et al., Appl. Phys. Lett. **94**, **173501** (2009)

LOAC + Magnetism

- Magnetic ratchet





A. Auge et al., Appl. Phys. Lett. **94, 183507 (2009)**

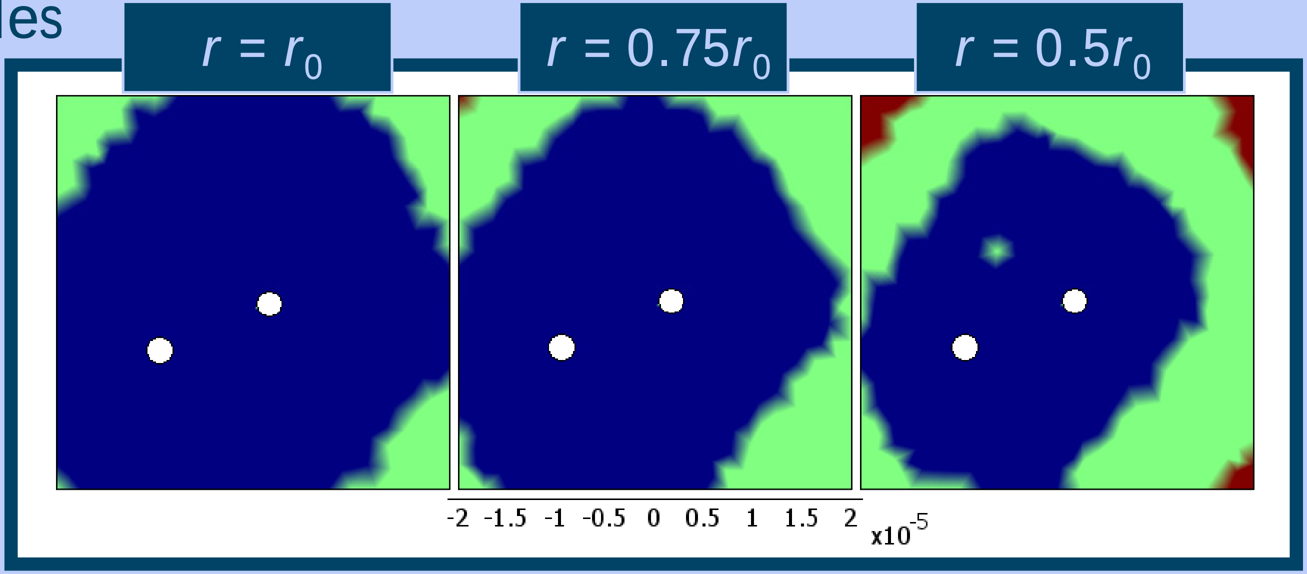
So far:

→ Interaction of particles omitted

→ Low-concentration limit

Particle interactions

- Important for high throughput methods
- Interacting particles can behave in a different way than single particles



A. Weddemann, A. Auge, F. Wittbracht, S. Herth, A. Hütten, Proc. Europ. COMSOL Conf. Hannover 2008, ISBN 978-0-9766792-8-8

→ New strategies for manipulation and guidance of magnetic particles

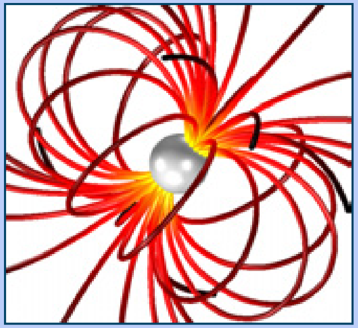
Governing equations

- Particle motion

$$m\frac{dv}{dt} = F_{mag} + F_{hyd}$$

- Magnetic field *H* created by a magnetic moment *m*

$$H^1_{\text{part}}(r) = \frac{1}{4\pi}\left(\frac{3\langle m^1_{part}, r\rangle r}{|r|^5} - \frac{m^1_{part}}{|r|^3}\right)$$



- Force on a second magnetic *m* moment close by

$$F^{21}_{mag} = \mu_0 (m^2_{part} \cdot \nabla) H^1_{part}$$

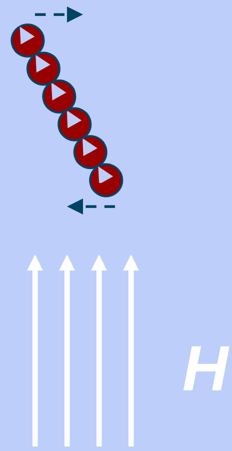
  - Susceptibility of the surrounding medium omitted

Governing equations

- Magnetic moment *m* in a field *H* feels a torque

$$\tau = \mu_0 m \times H$$

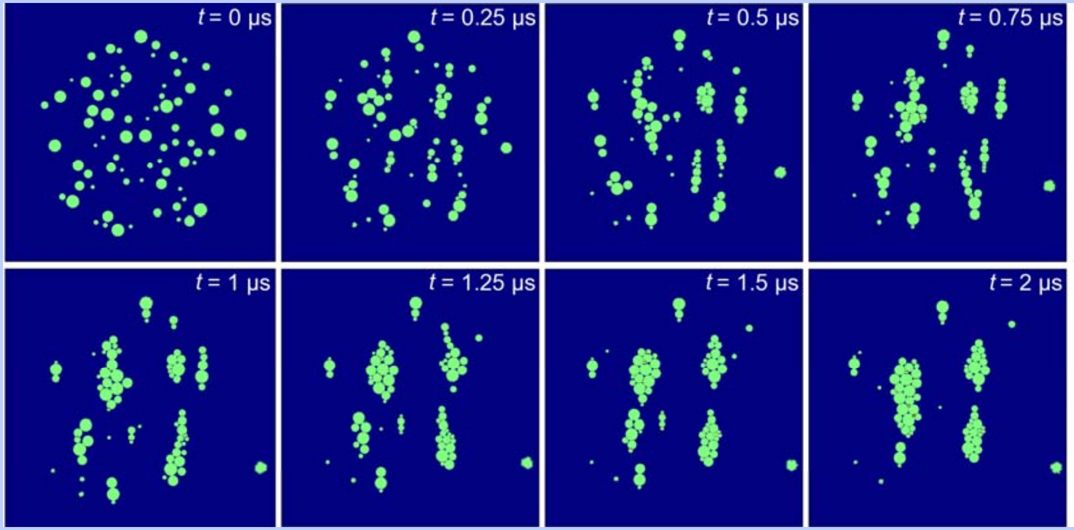
  - strong external fields: *m* II H_{ex}
  - remagnetization processes on nanosecond time scale: perfect alignment with H_{ex} even for time dependent external fields



- Stokes equation $$\eta \Delta u = -\nabla p$$

Simulation results

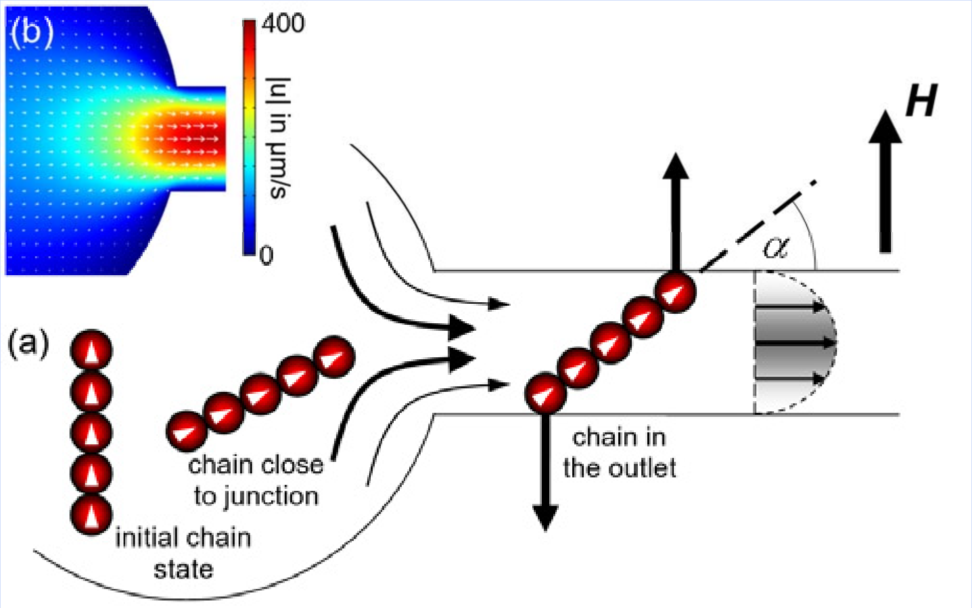
- Spatial particle distribution
  - particle sizes: 0.5-1 *µm*
  - saturation magnetization: 1000 *kA/m*



- usually no chain breaking due to flow induced shear stress
- Changing the field direction → chain rotation low frequencies

  → Clusters travel as confined objects

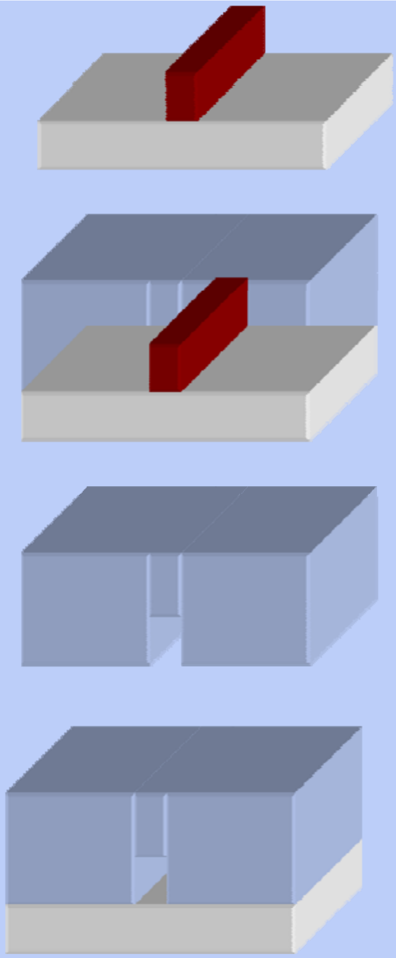
Simulation results



- for inhomogeneous velocity fields, the chain orientation can differ from the field direction

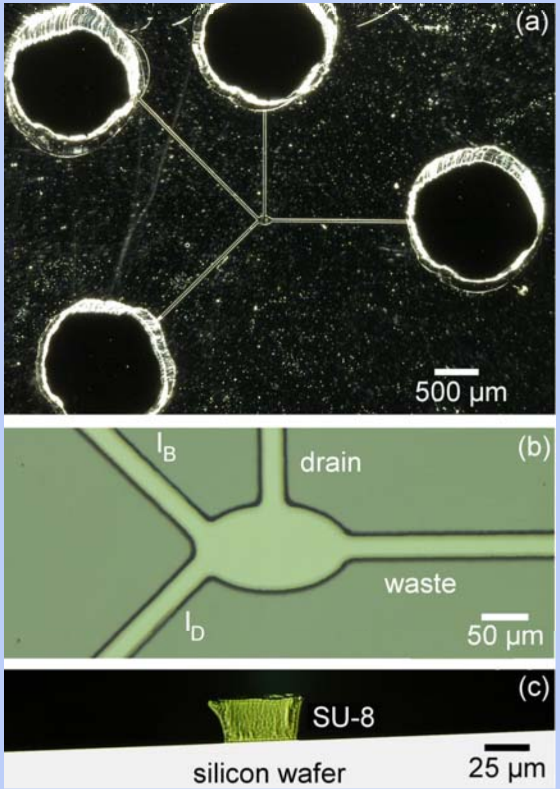
Experimental realization

- Sample preparation:
  - Optical lithography
  - Soft lithography
- Oxygen plasma treatment to ensure proper sealing



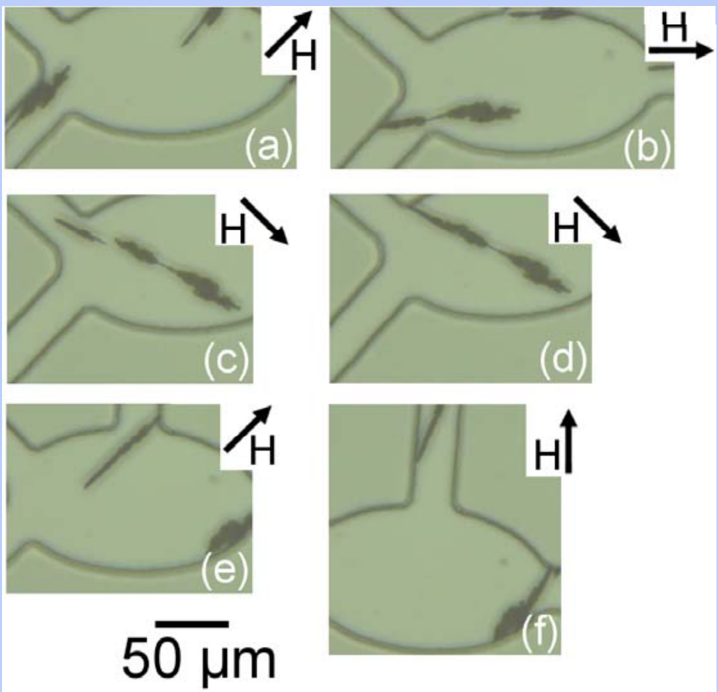
Experimental realization

- coils for generation of in-plane homogeneous magnetic field (macroscale)
- pivotable sample holder
- digital optical microscope
- Dynabeads MyOne (d = 1.05 μm) and M-280 (d = 2.8 μm)

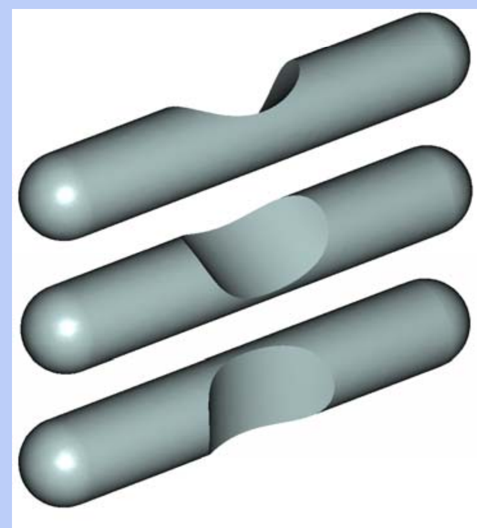


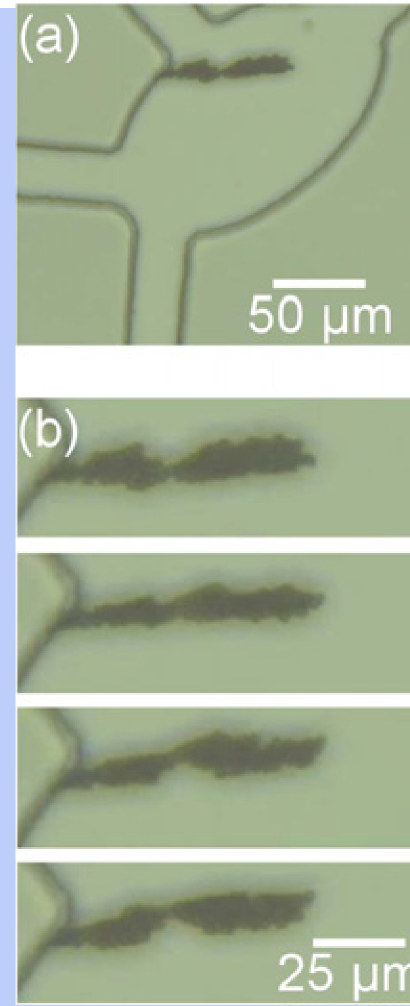
Experimental results

- direction of the magnetic field controls particle flow



- Self-ordering due to magnetic and hydrodynamic forces





Conclusion & Outlook

Conclusion

- Deduce guidelines from FEM simulations
- Experimental realization of flow guidance using particle-particle interactions
- No electromagnetic components on the microscale needed

Outlook

- New microfluidic devices using particle interactions
- GMR/TMR sensor intergration
  - "Detection of magnetic particles by magnetoresistive sensors" by A. Weddemann

    Electromagnetics and Optics I,

    4:45 pm