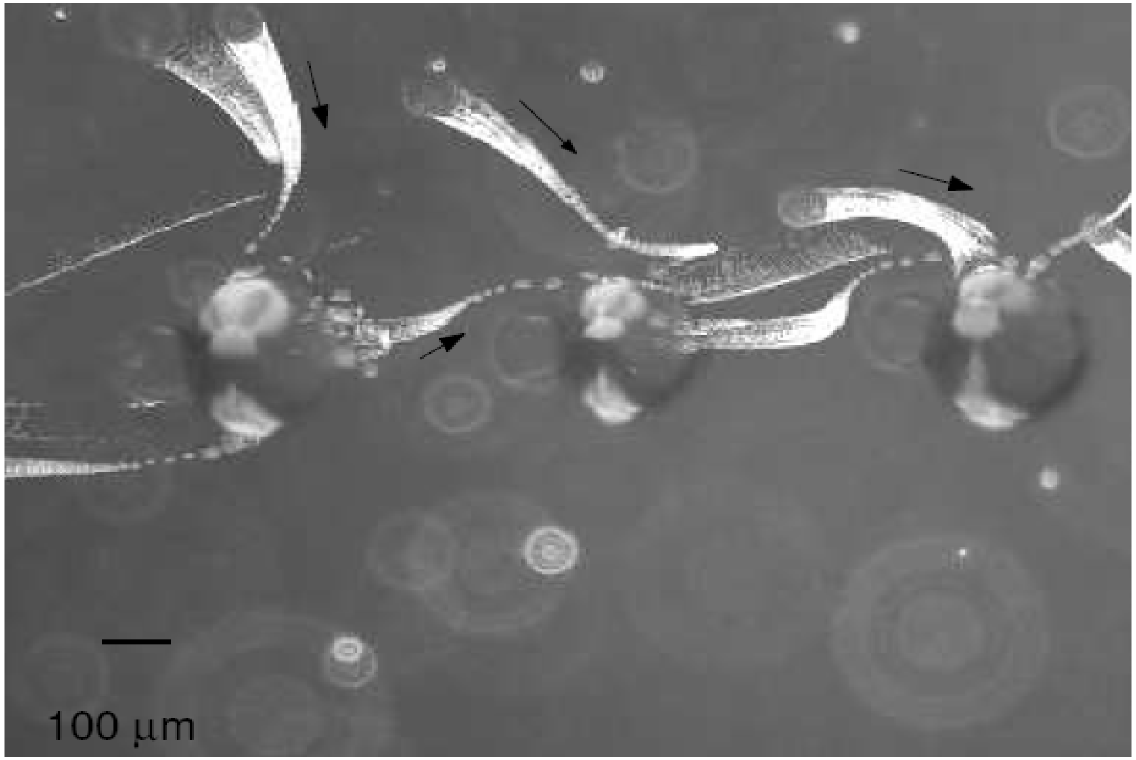
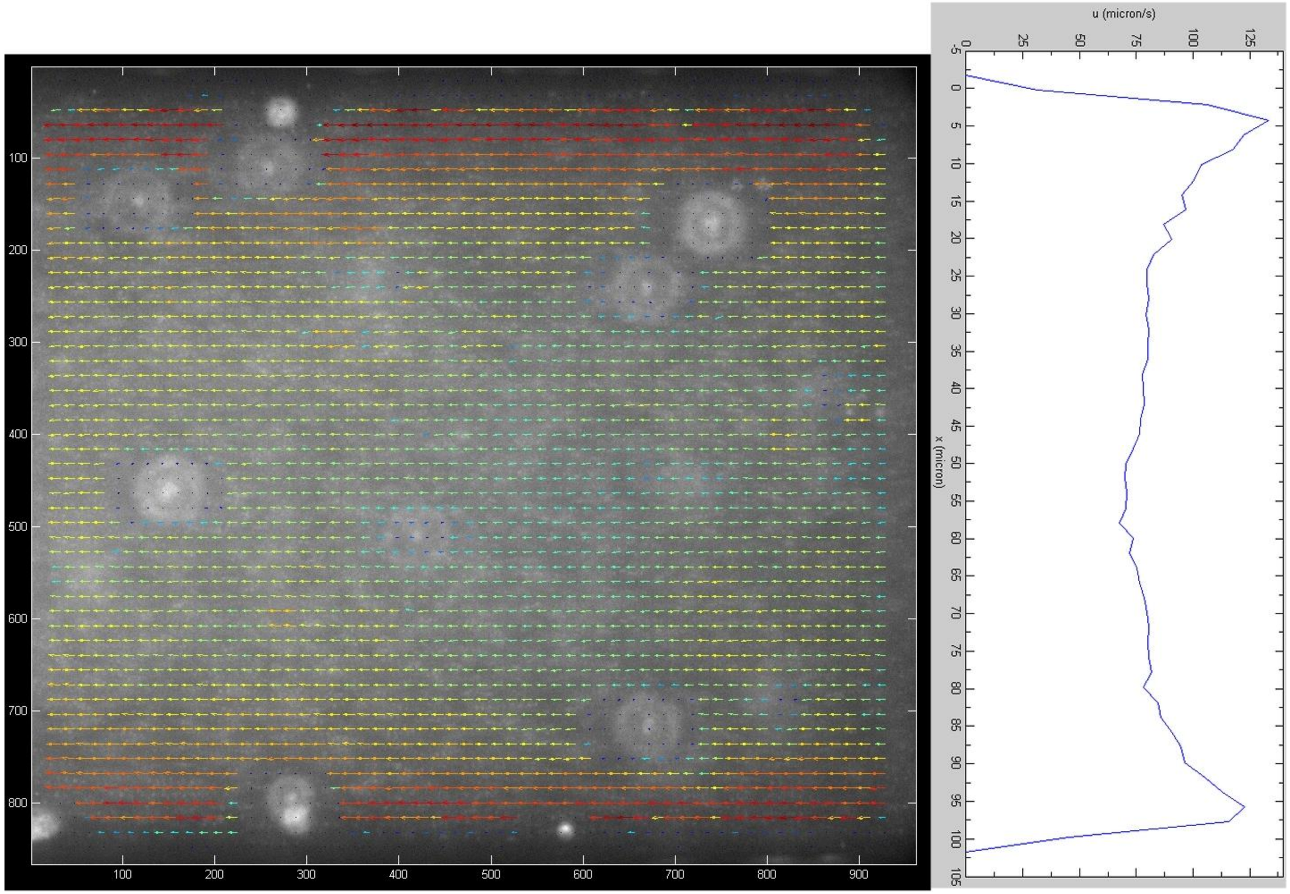
MESA-fluidics



Han Gardeniers
MESA+ Institute
for Nanotechnology
University of Twente

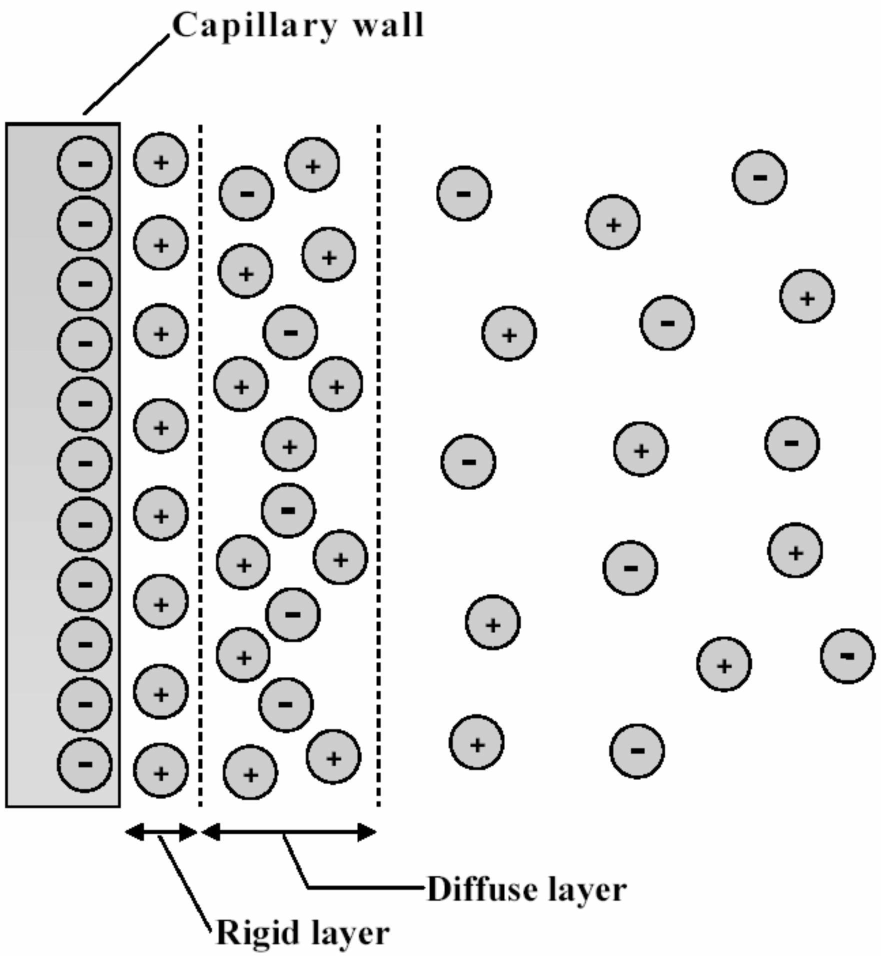
Summer School in Nanofluidics
ICTP, Trieste, Italy

Field-effect control of electro-osmotic flow

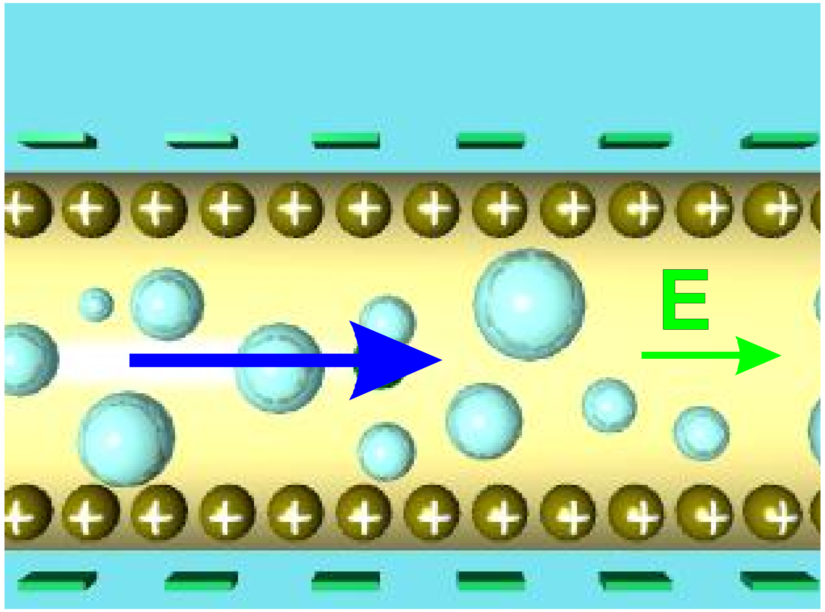


E.J. van der Wouden e.a. Colloids and Surf. A 267, 2005, 110
D.C. Hermes e.a. Microsystem Technol. 12, 2006, 436
E.J. van der Wouden e.a., Lab Chip 6, 2006, 1300

Electro osmotic flow (EOF)



Stern's model of the double-layer charge distribution at a negatively charged capillary wall leading to the generation of a zeta potential and EOF



$$v_{EOF} = \frac{-ez}{h} E$$

η = viscosity
ε = dielectric permittivity
ζ = "Zeta-potential" ~ wall charge
E = electric field strength
v = linear velocity

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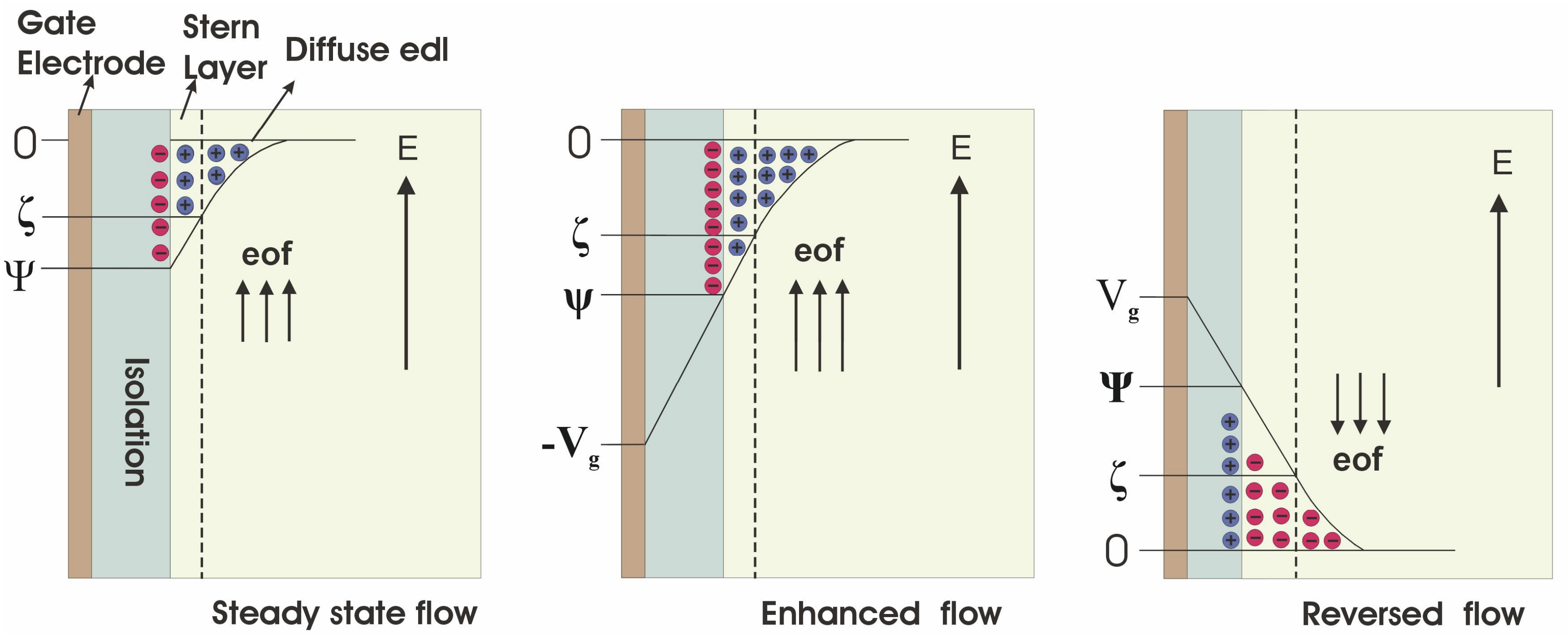
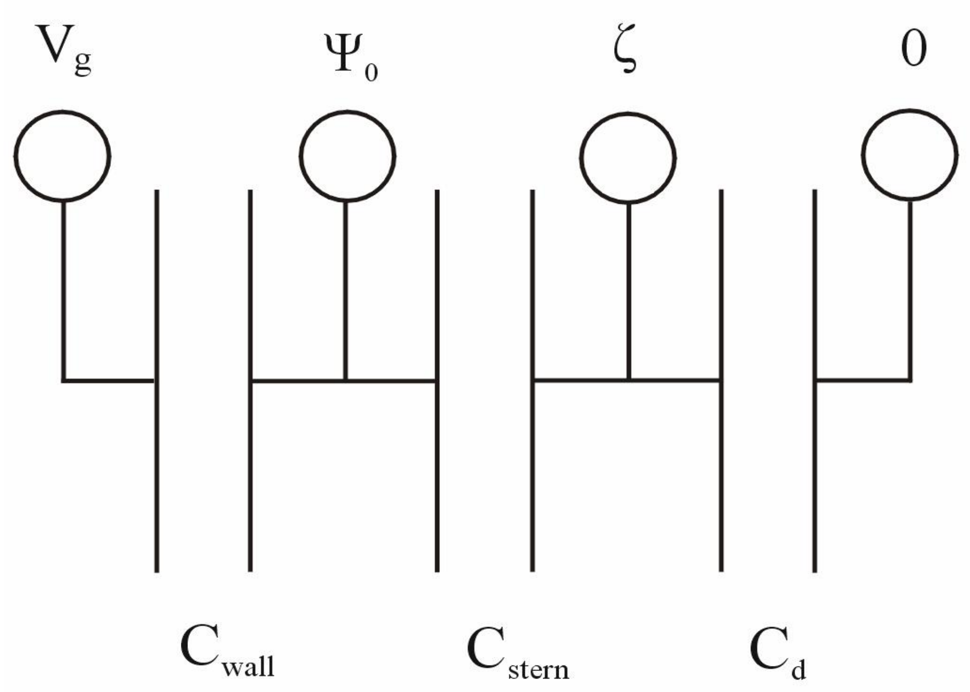
EOF control by radial voltage



Electrical model



$$C_{wall} = \frac{e\mathrm{A}}{d}$$

$$C_d = \frac{e\mathrm{A}}{l_d}$$

$$\Delta z = \frac{C_{wall}}{C_{dl}} V_g$$

$$l_d = \left(\frac{e \cdot R \cdot T}{F^2 \cdot \frac{1}{2} \Sigma c_i z_i} \right)^{\frac{1}{2}}$$

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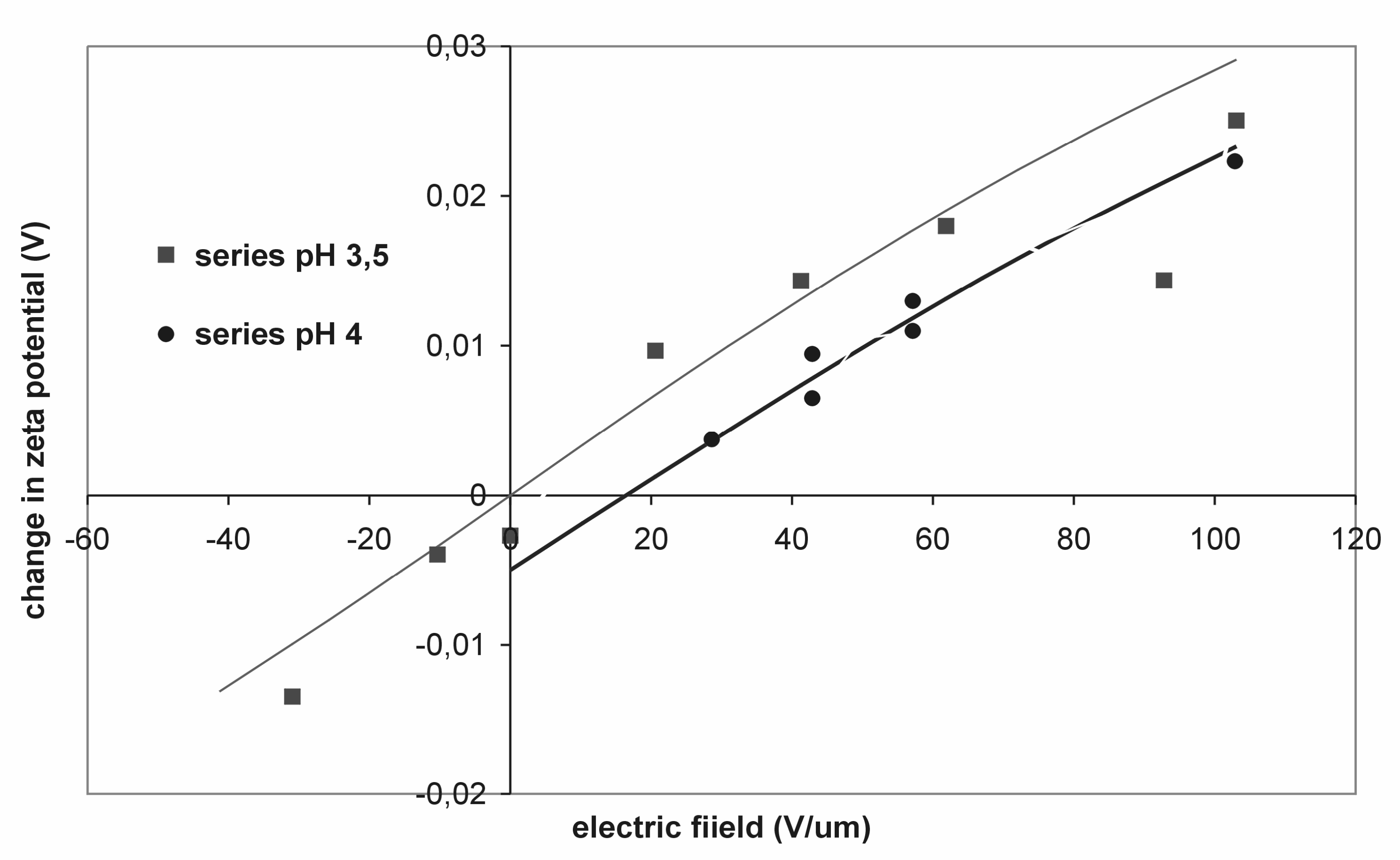
Influence gate potential on local zeta potential



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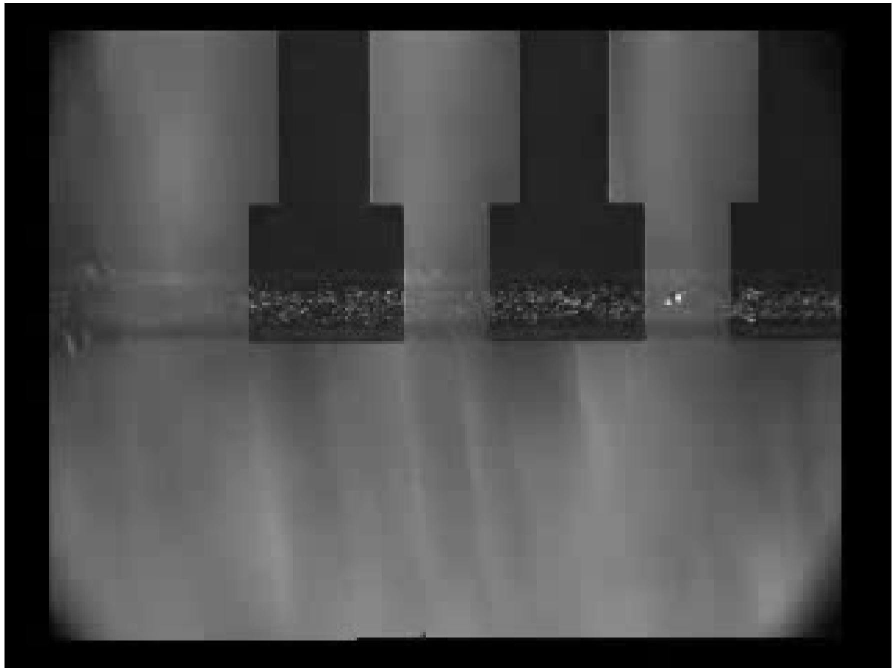
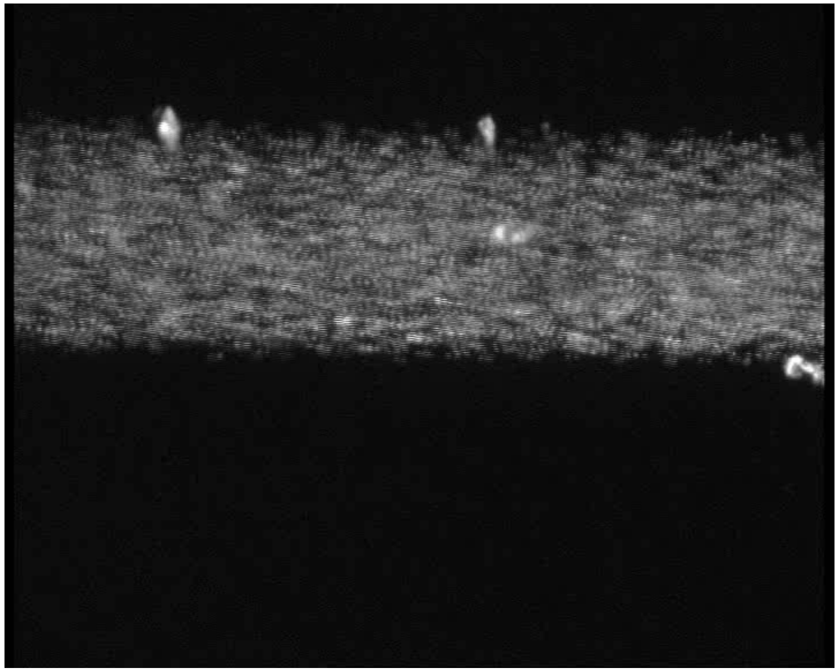
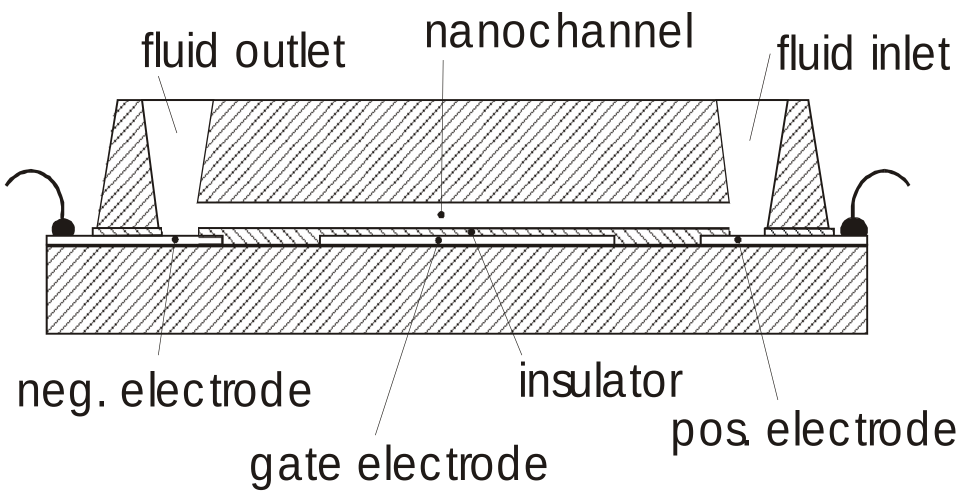


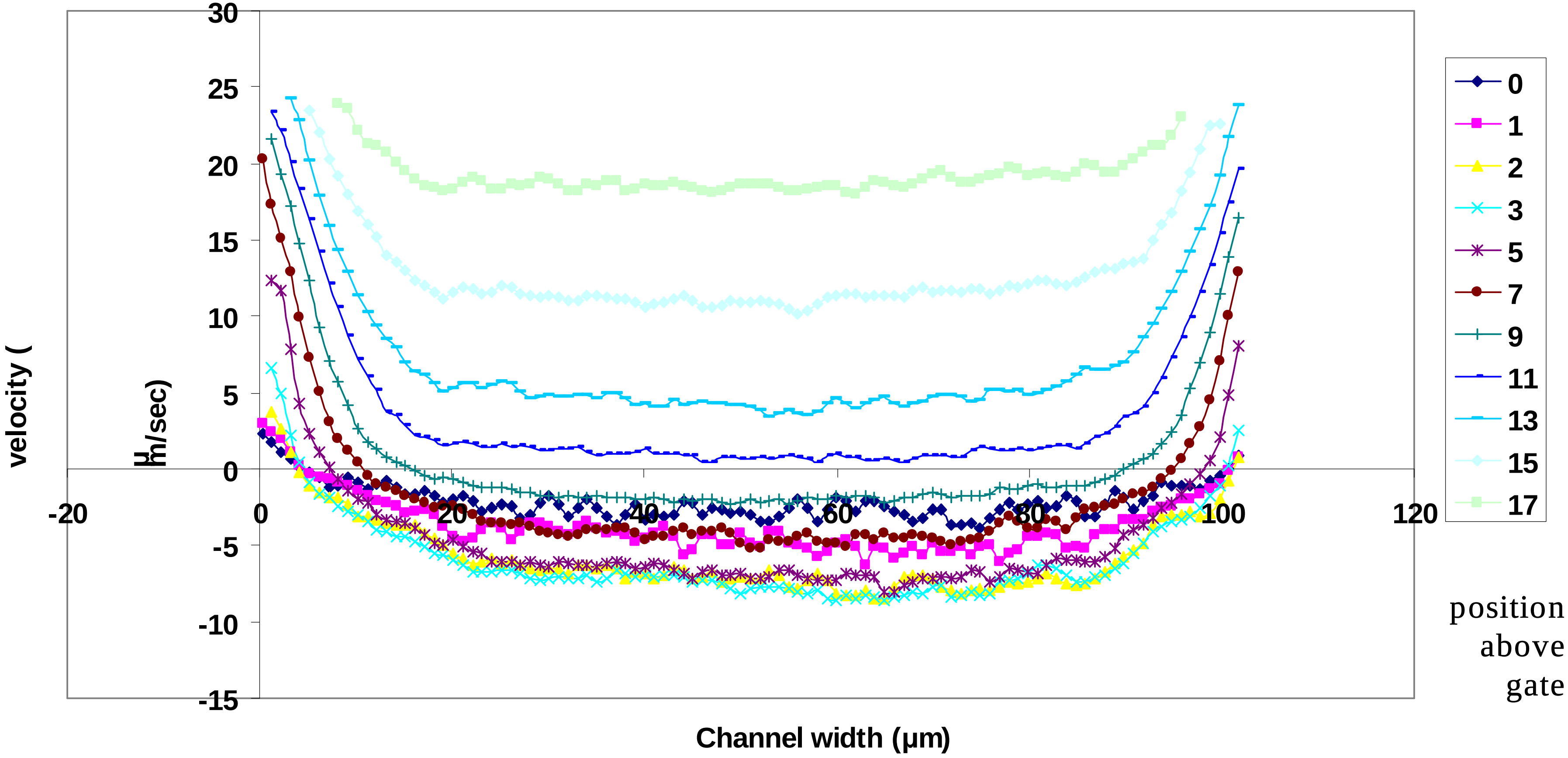
Gate DC voltage on-off



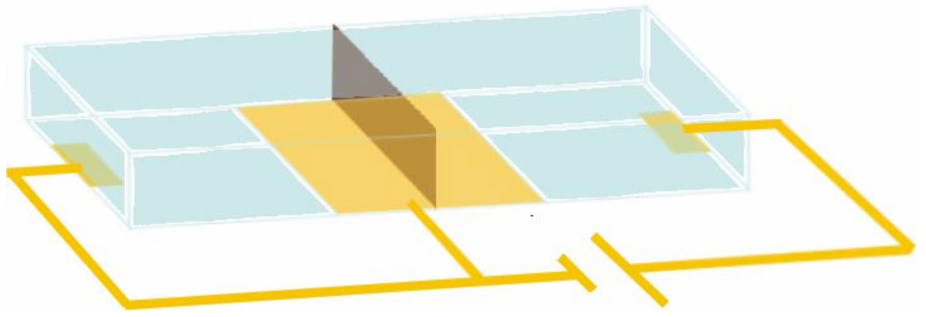
Gate AC voltage



Particle image velocimetry



position above gate



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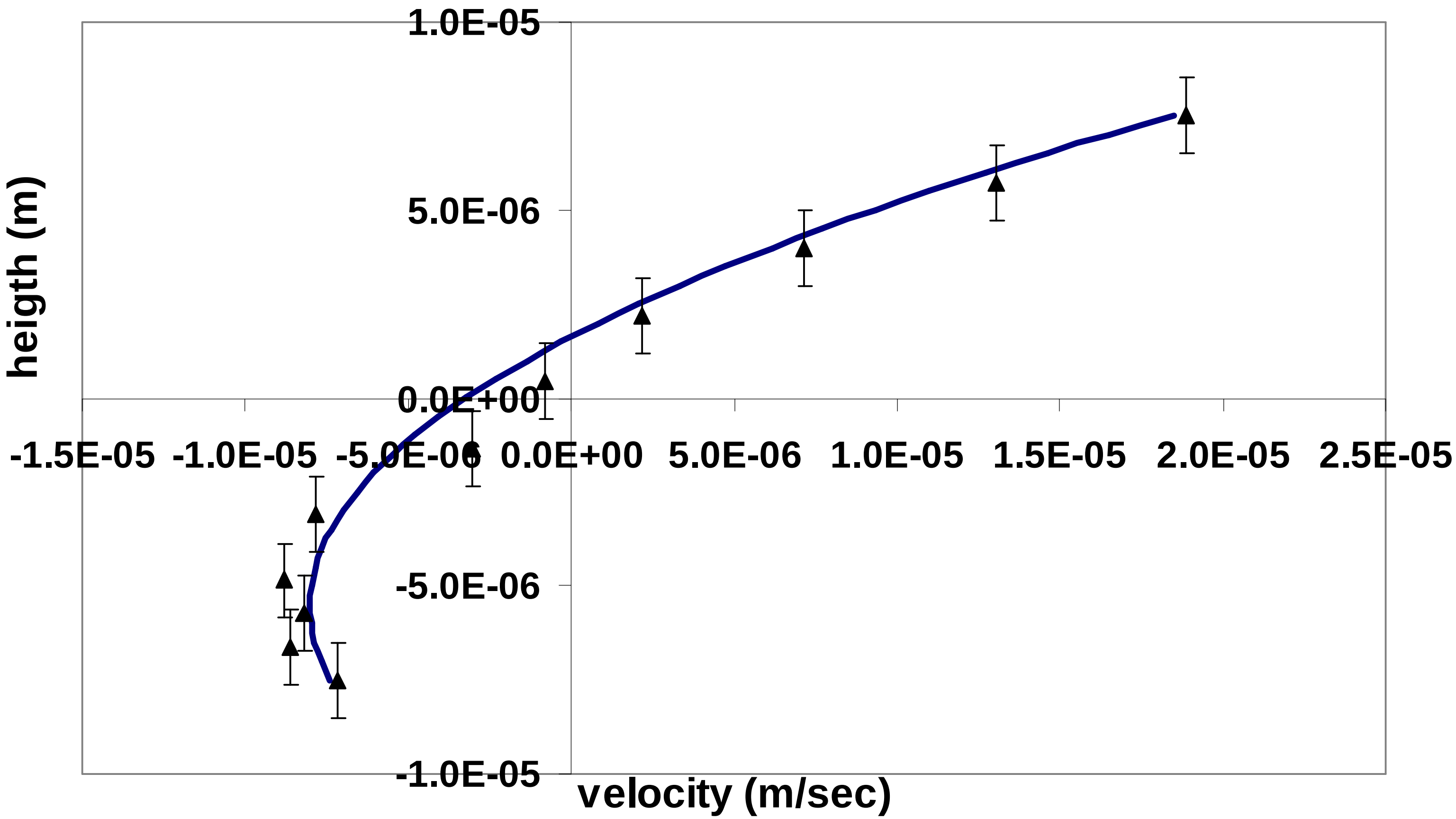
C. Pirat and E. van der Wouden, 2007, unpublished

University of Twente The Netherlands

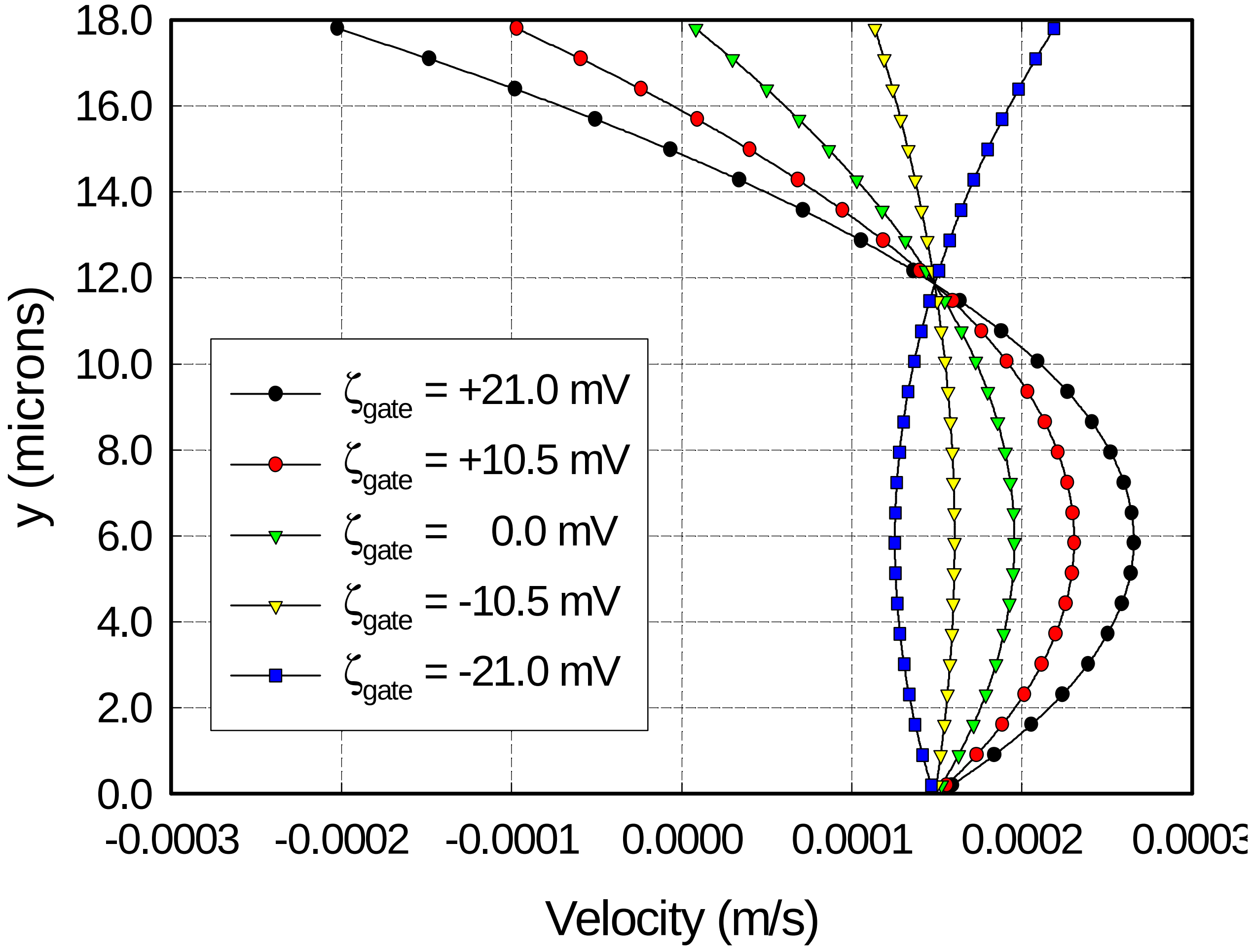
PIV summary



Velocity as a function of the channel height at the channel center width for a gate potential of 300 V, which corresponds with ζ = -0.4 mV

C. Pirat and E. van der Wouden, 2007, unpublished

FEM simulated velocity profiles under gate electrode for different zeta potentials



Robert Barber
and David Emerson

Centre for Microfluidics and Microsystems Modelling (C3M)

Warrington

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The Netherlands

Microfluidic NMR

NMR: how does it work?

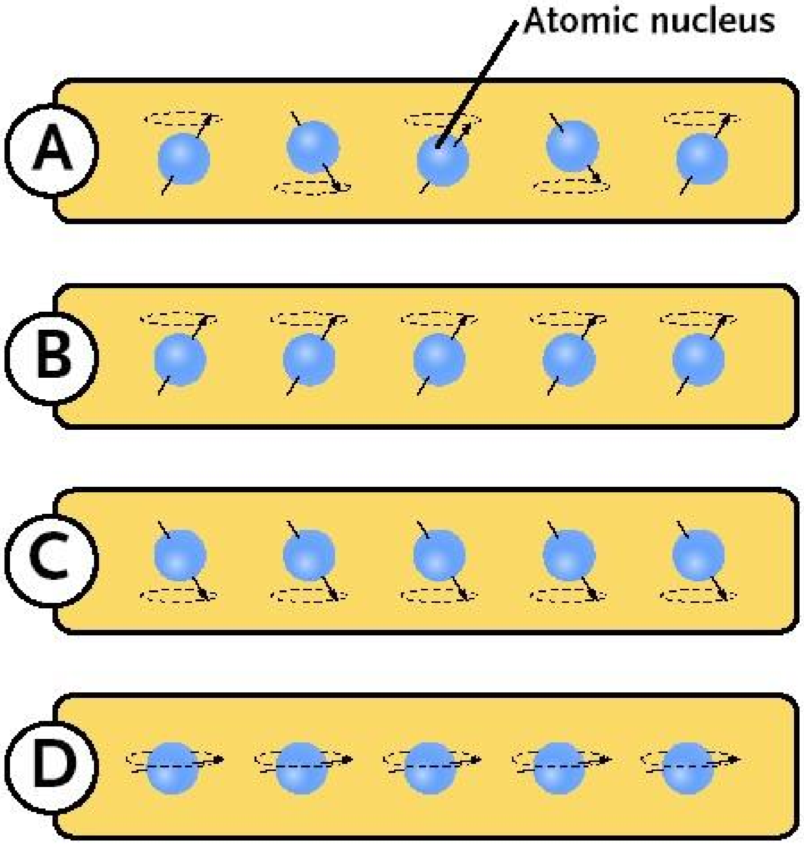
NMR = Nuclear Magnetic Resonance

Without magnetic field
spins are randomly oriented (A)

In a magnetic field spins align
parallel (B) or anti-parallel (C)

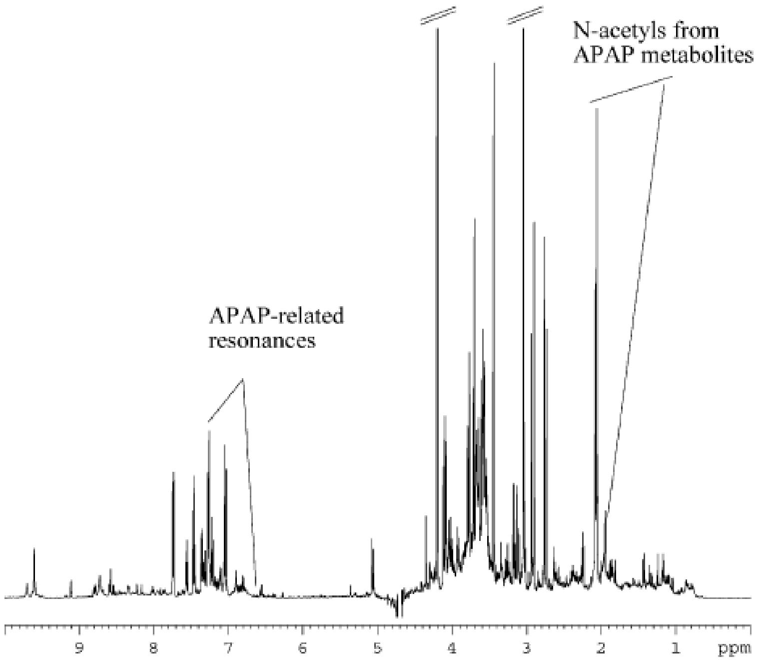
A matching r.f. signal will switch
the spins from state B to C

When r.f. is turned off, the spins
relax to low-energy state B in a
precession process



NMR: what is it used for?

Chemical structure information



500-MHz ^{1}H NMR spectrum of untreated urine obtained 4 h after a 500-mg APAP dose
M. Spraul e.a. Anal. Chem. 75, 2003, 1546

Imaging

J.P.Hornak, http://www.cis.rit.edu/htbooks/mri/

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NMR for micro & nano fluidics

Water confinement in nanopores

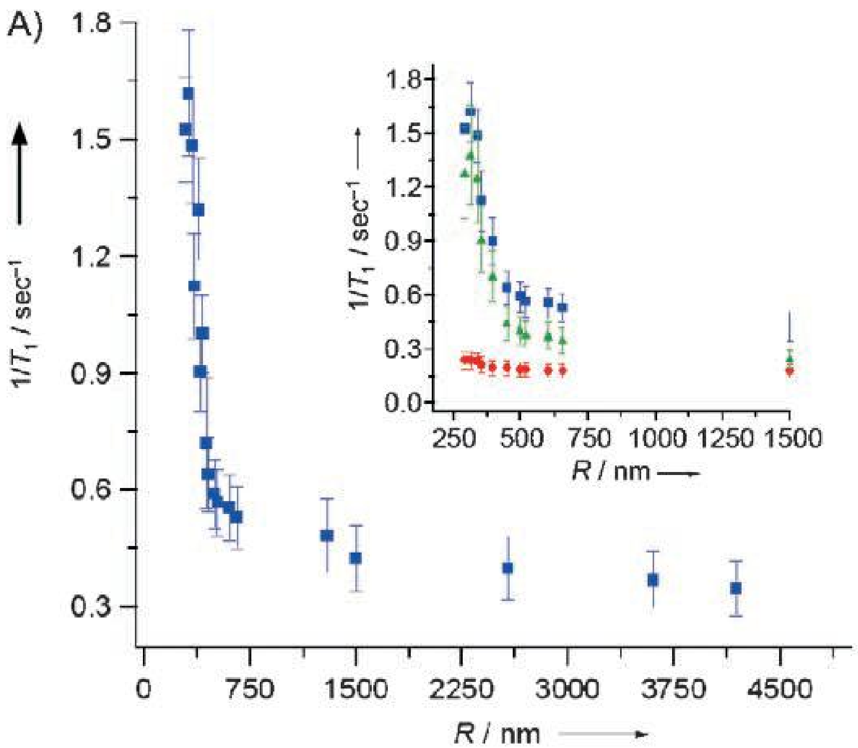
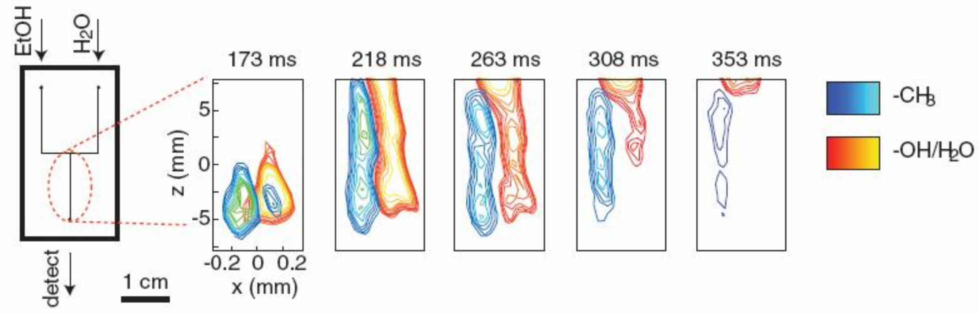


Figure 1. A) The size dependence of [1]H $1/T_1$ values (■) of water confined in micro- and nanospaces at 300 MHz and 22°C. The inset shows the size dependence of intermolecular translational (▲) and intramolecular rotational motions (●) obtained from experimental [1]H $1/T_1$ (■) values of water in the channel range of 295 to 1500 nm.

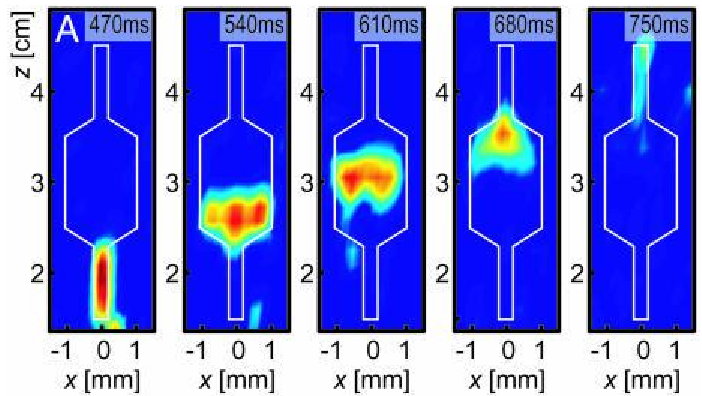
T. Tsukahara e.a. Angew. Chem. Int. Ed. 46, 2007, 1180

Flow imaging



High-resolution time-resolved images of mixing inside microfluidic chip. Contour plots of ethyl alcohol and water inside the outlet channel of the microfluidic chip. Resolution along x is 75 µm and 2.5 mm along z.

E. Harel e.a. Phys. Rev. Lett. 98, 2007, 01760



Microfluidic gas-flow profiling using remote-detection NMR
C. Hilty e.a. Proc. Natl. Acad. Sci. 102, 2005, 14960

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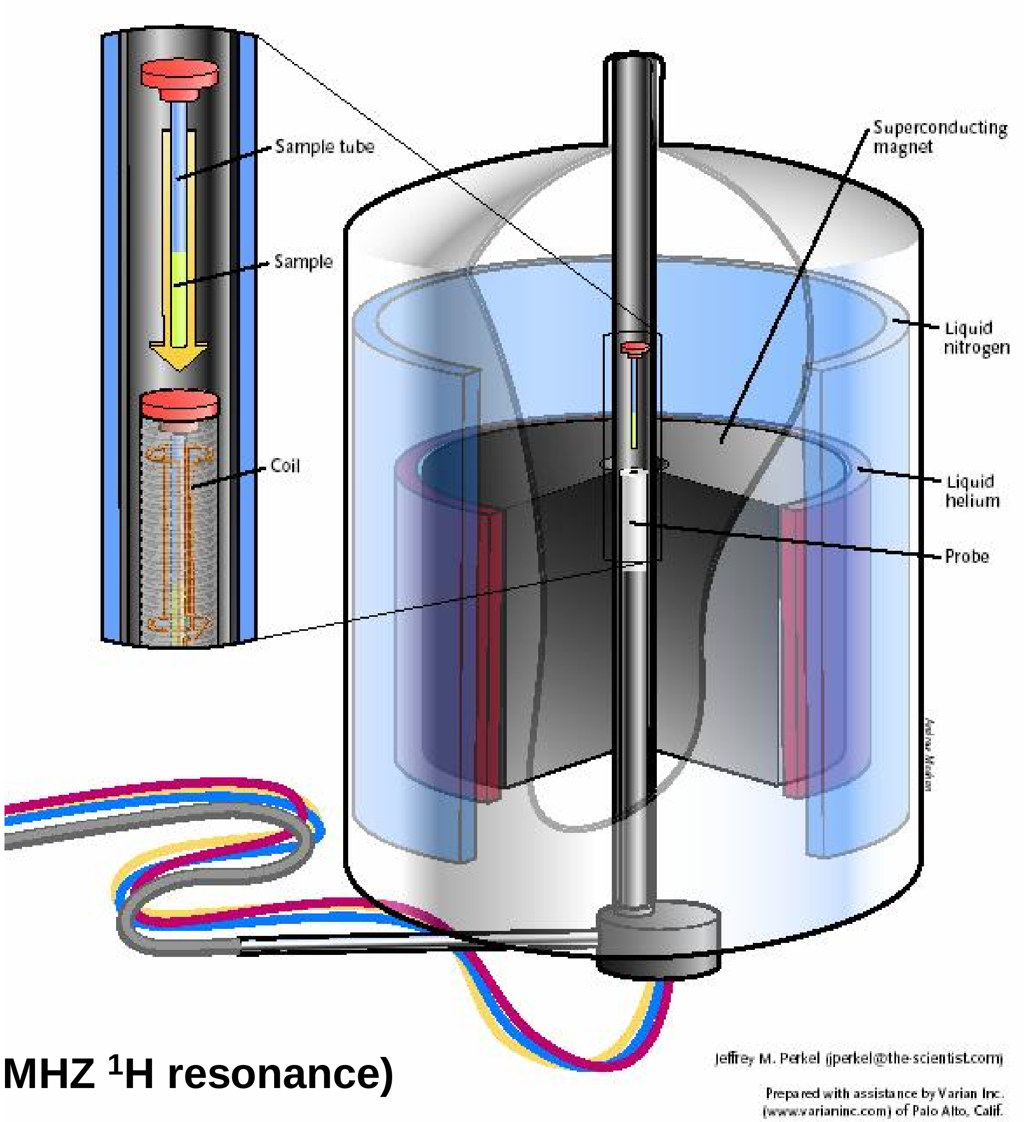
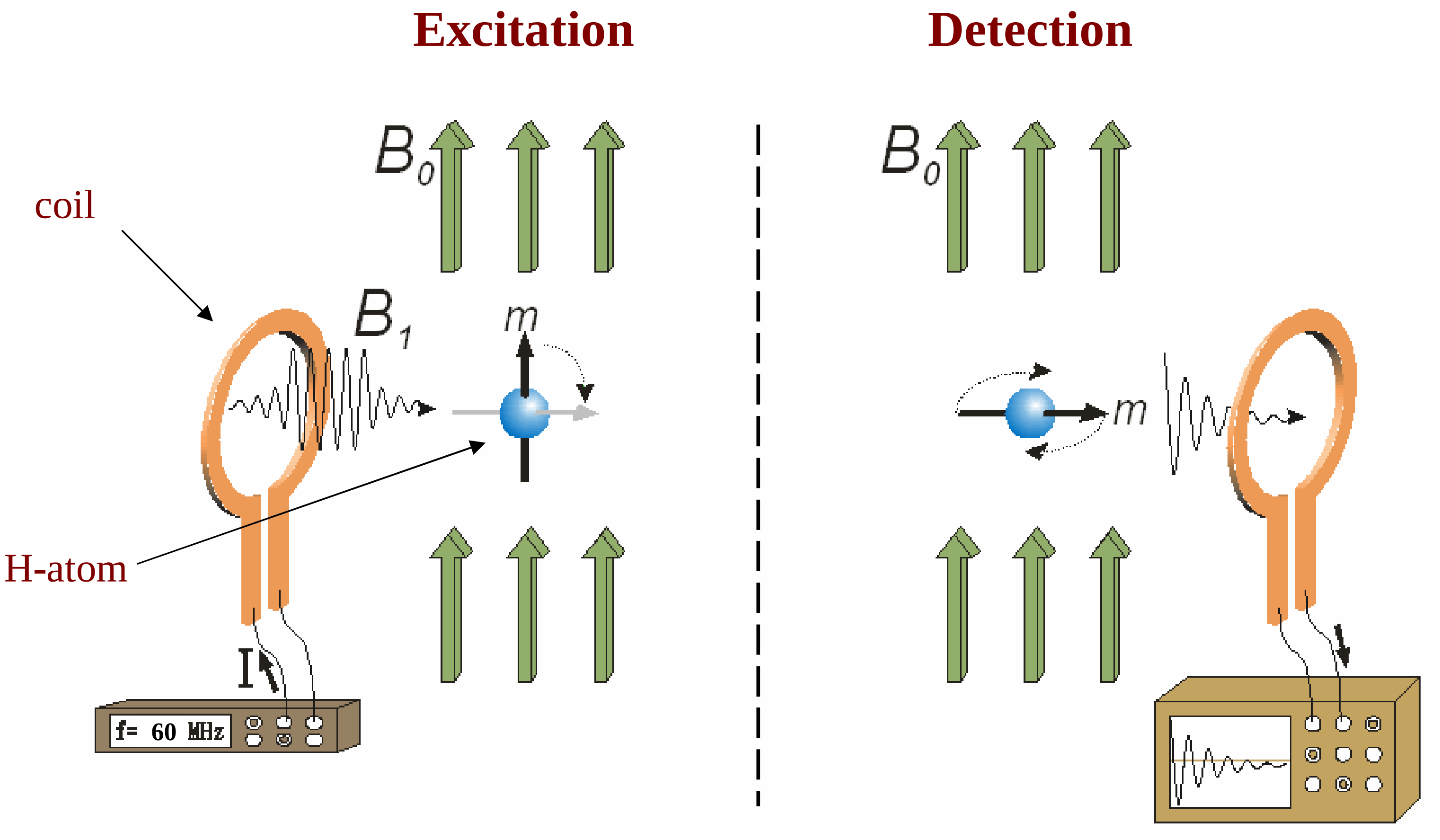
NMR: How is it done?

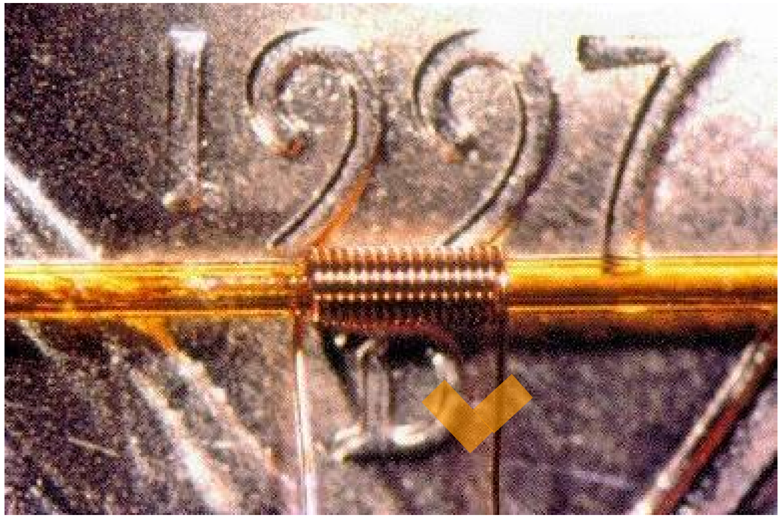


State of the art NMR: 21.1 Tesla (or 900 MHZ ^{1}H resonance)

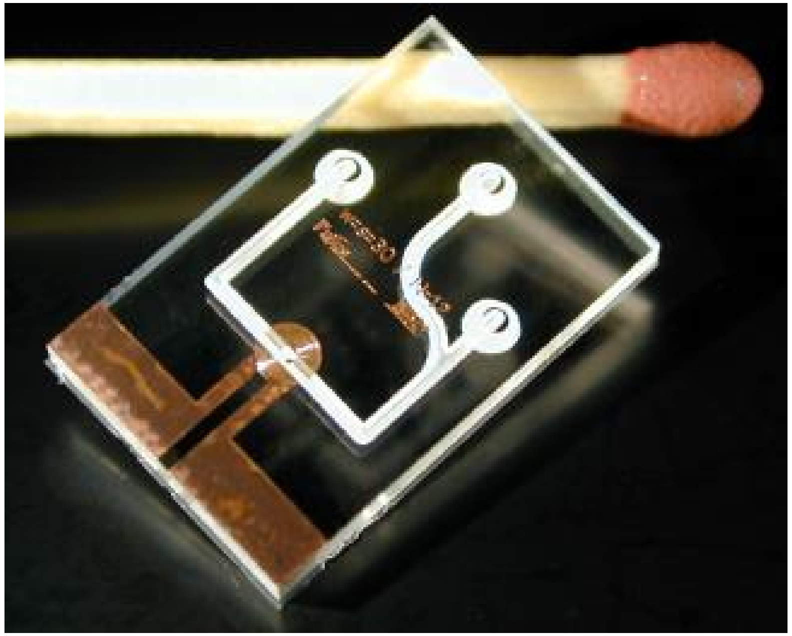
Pulsed NMR measurement



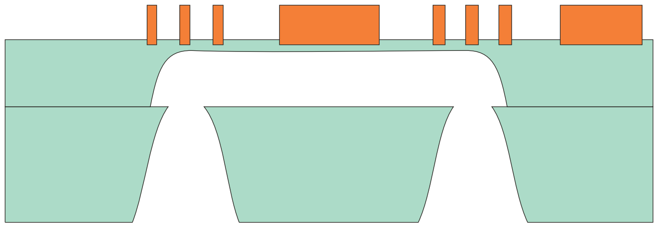
Micro NMR



Solenoidal NMR microcoil wound around capillary
http://www.protasis.com/



Microcoil on microfluidic glass chip
H. Wensink e.a. Lab Chip 5, 3005, 280



Reaction chamber volume: 570 nl

Detection volume: 56 nl

Minimum time from mixer to coil: 0.9 sec

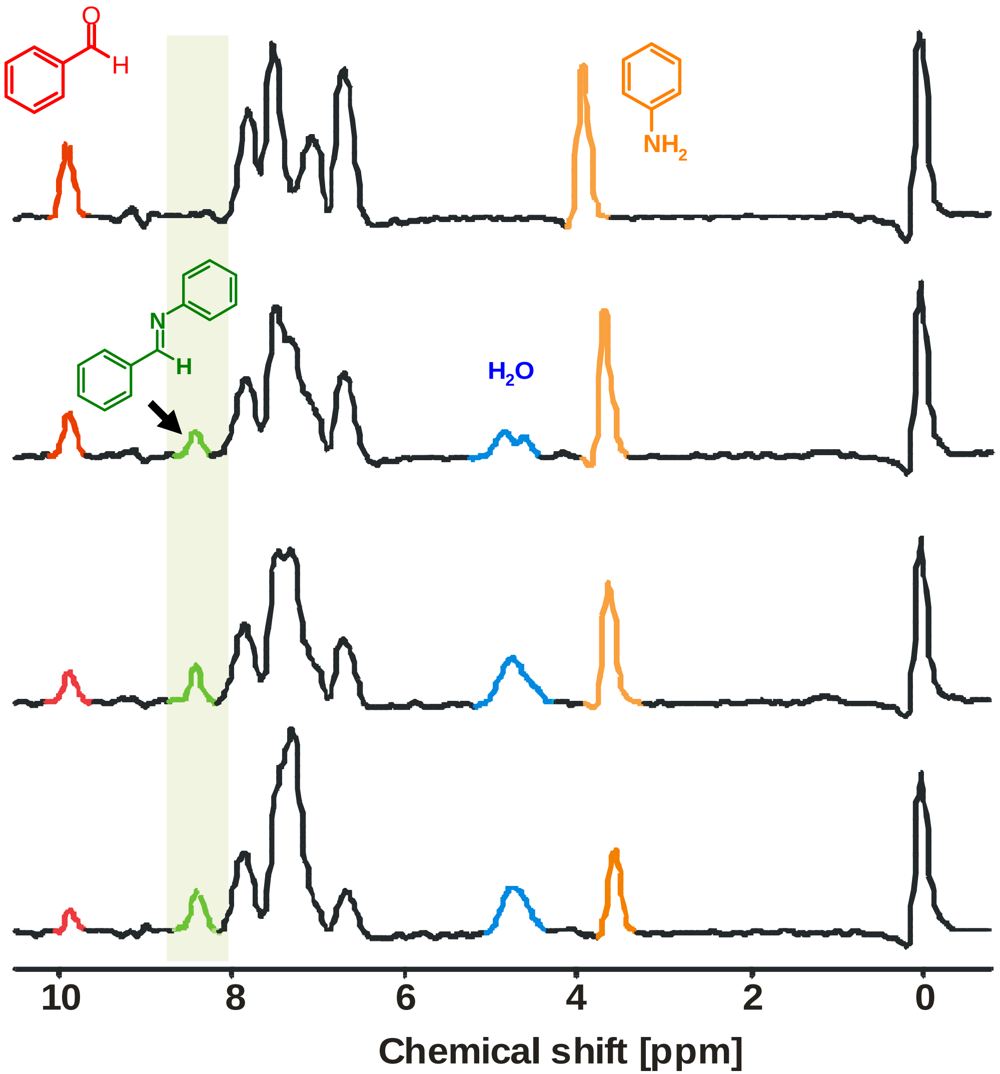
Reaction monitoring

4.00 mL/min (8.6 s)

0.44 mL/min (77 s)

0.22 mL/min (156 s)

0.10 mL /min (342 s)



H. Wensink e.a., submitted to Lab Chip

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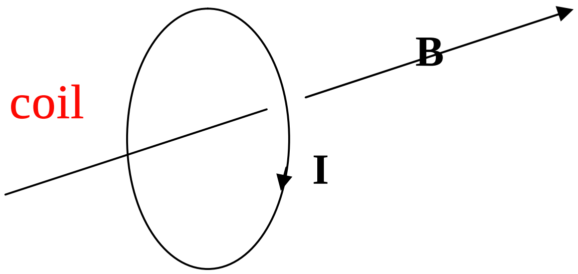
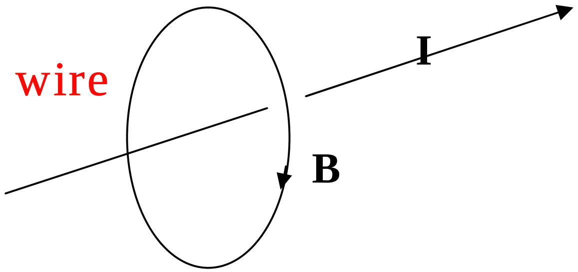
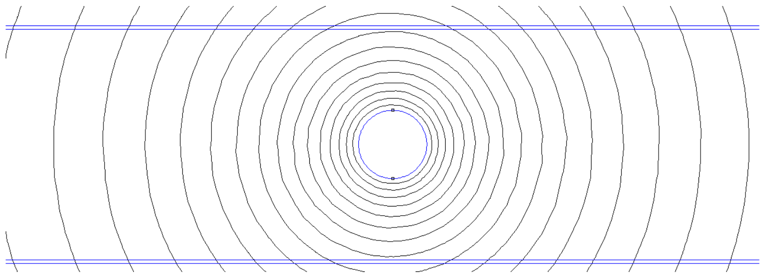
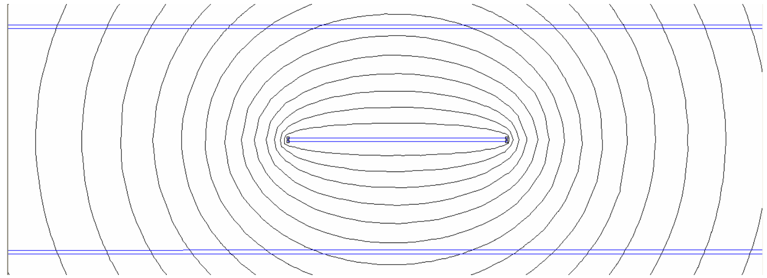
New concept: "wire" instead of coil







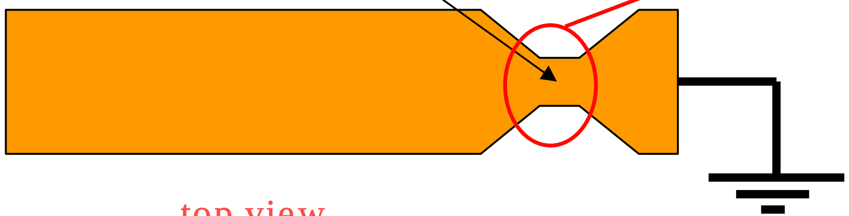
flatten the wire



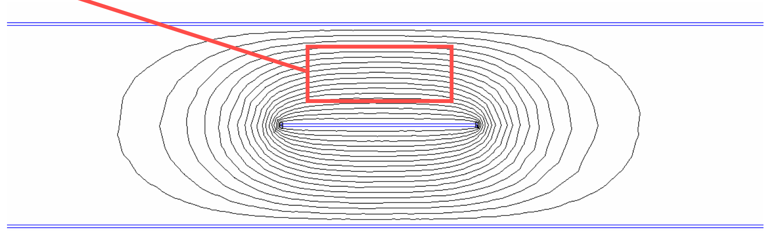
confine field by mirrors

High current density:
high local B-field

Sample area



top view



cross-sectional view

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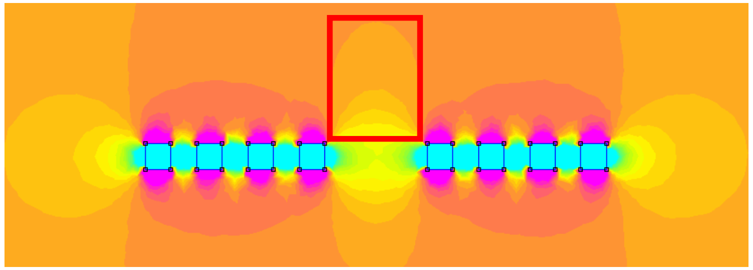
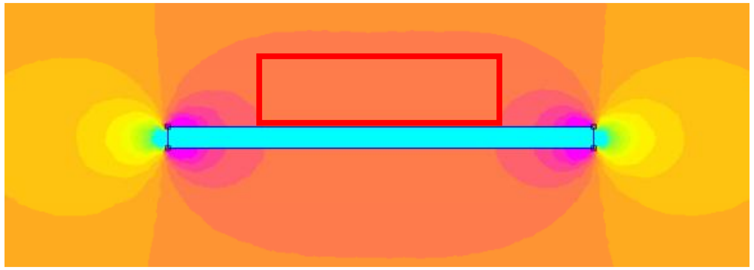
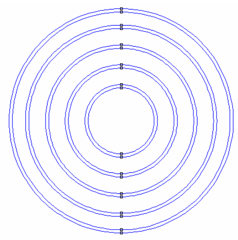
J. van Bentum e.a. The Analyst 129 (2004) 793-803

University of Twente
The Netherlands

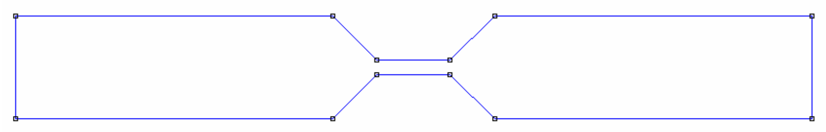
Spectral resolution: coil vs. r.f. stripline







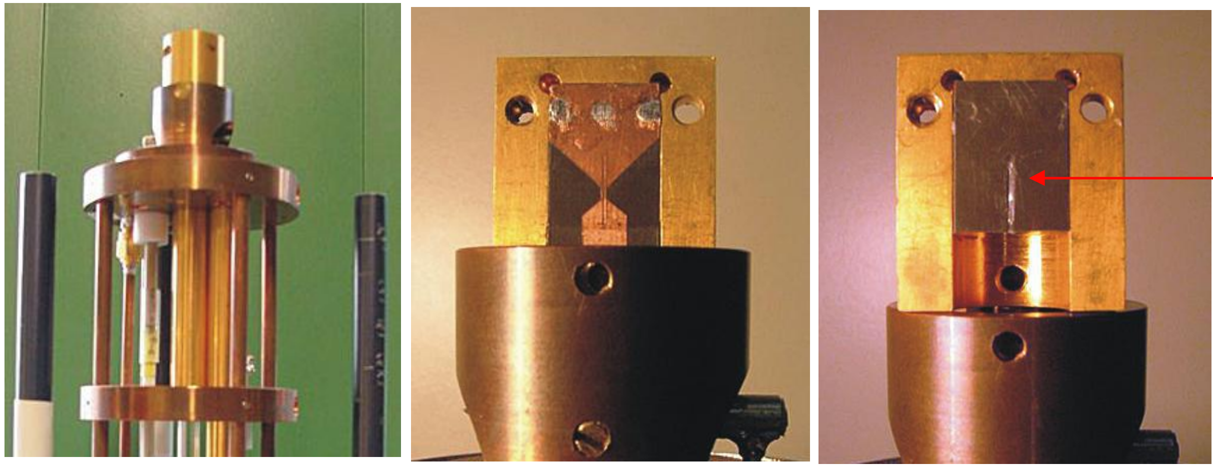
microcoil



r.f. stripline

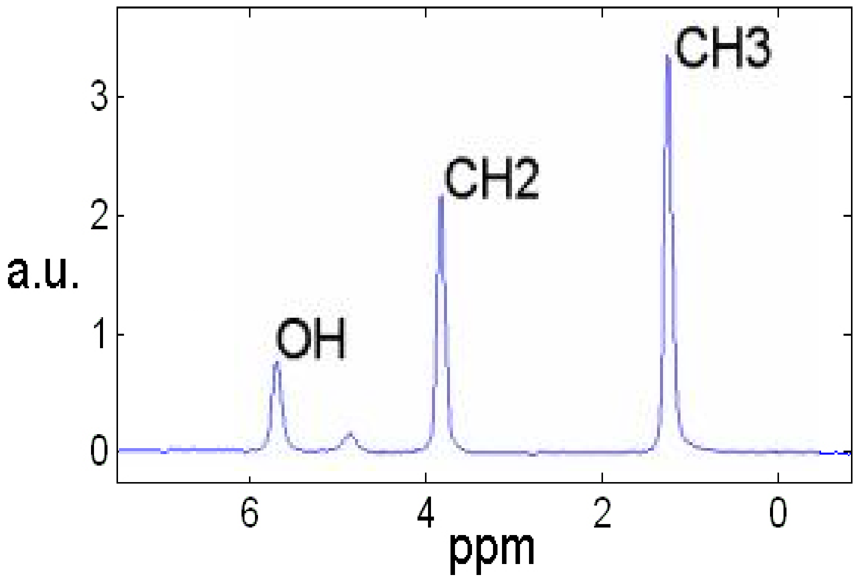
B_0-field distortion is lower —> higher resolution

Prototype on PCB for liquid NMR



capillary on metal line

Sample: ethanol (VLSI-grade)
Volume: 10 nl
SNR: ~ 785
Power: 5 W
FWHM: 0.07 ppm(40 Hz)
LOD: $2 \cdot 10^{13}$ spins/√Hz
Single scan !



J. van Bentum e.a. J. Magn. Reson. (minor rev.)

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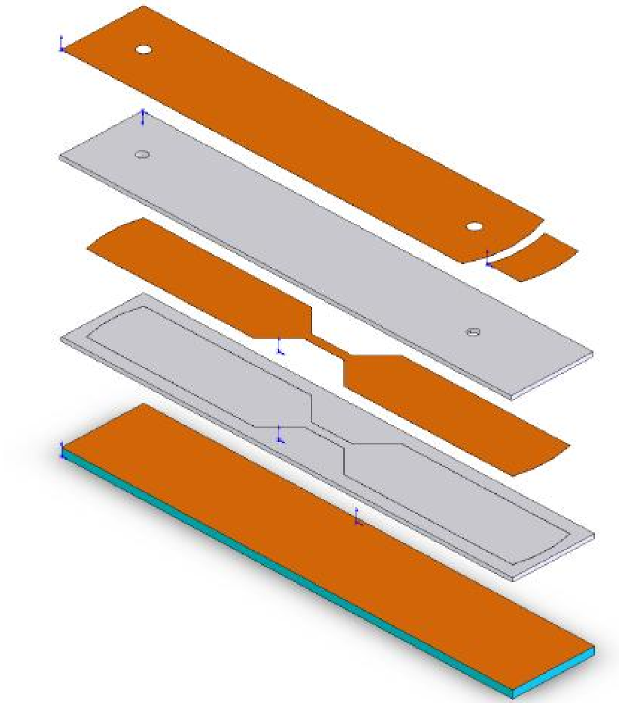
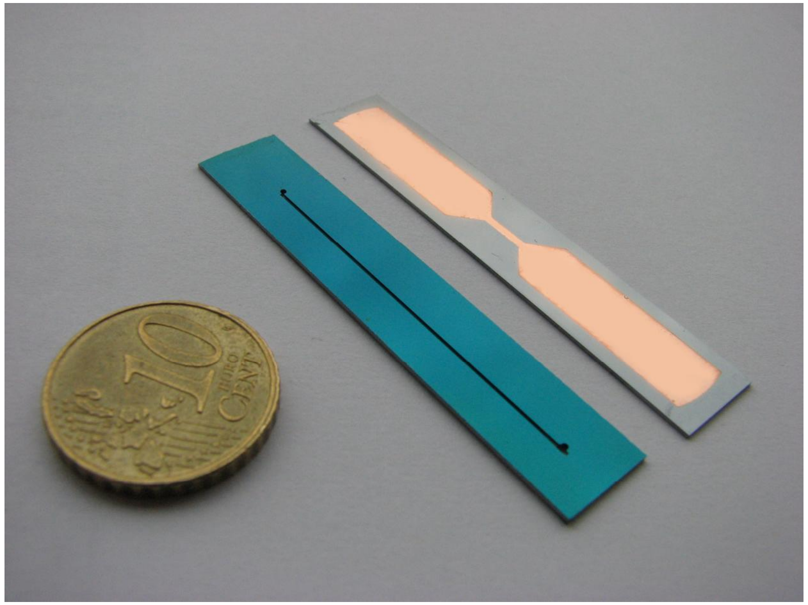
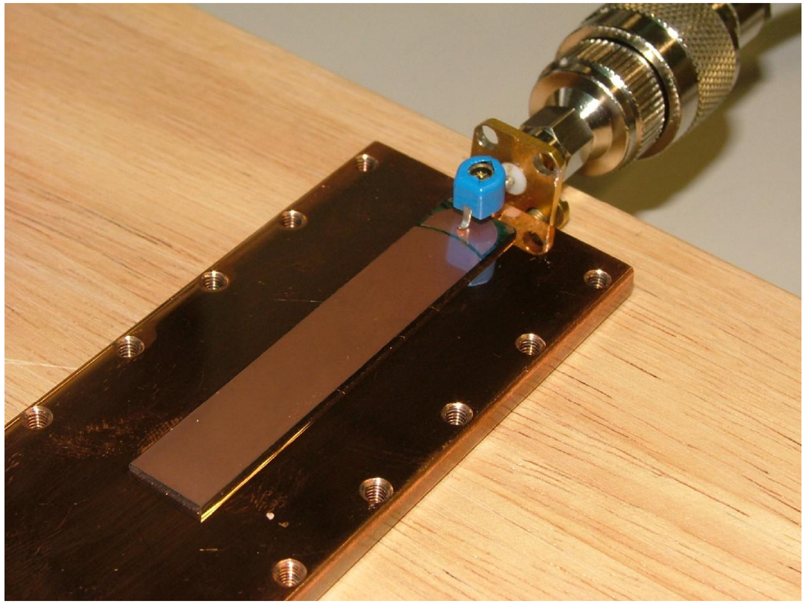
Si stripline chip with microfluidic channel







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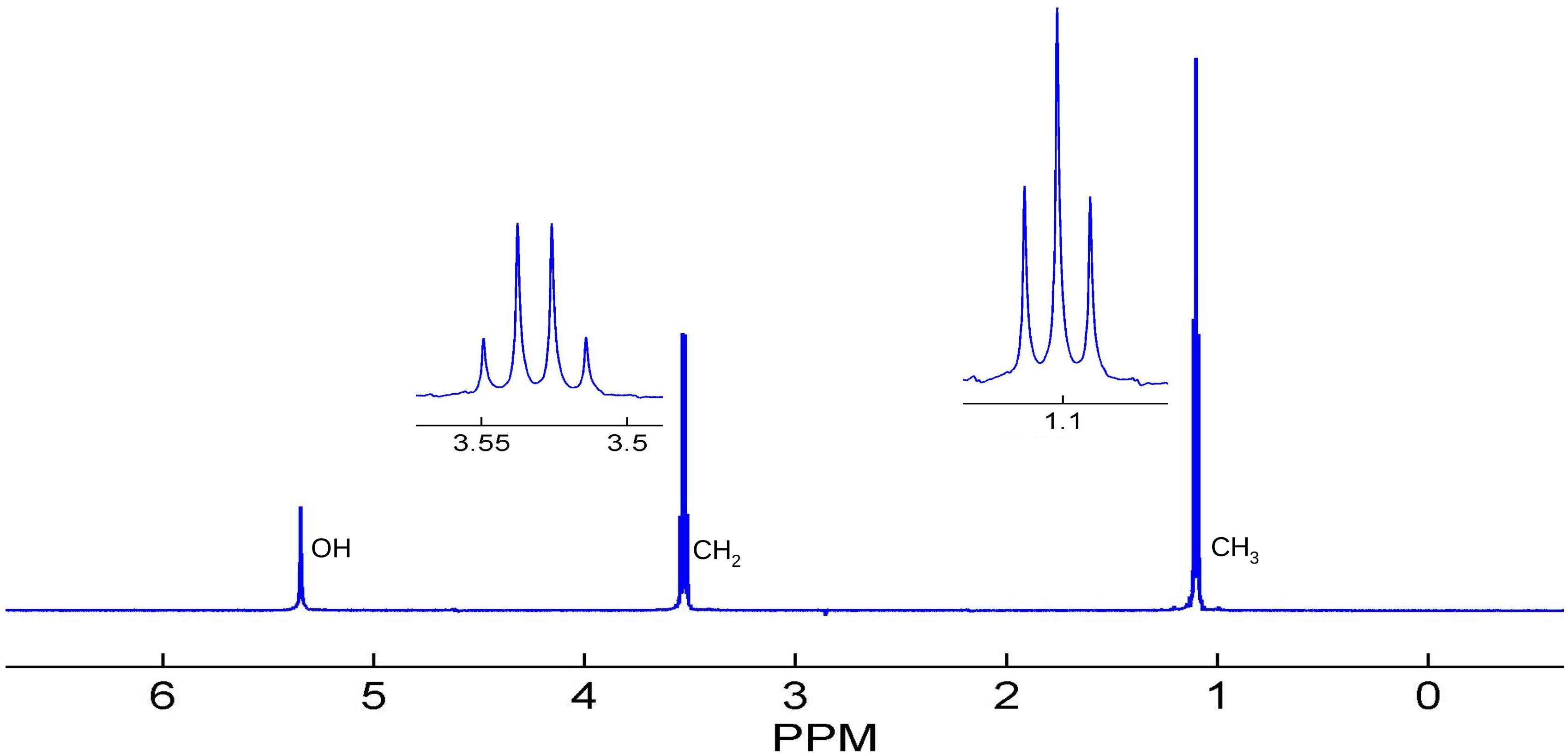
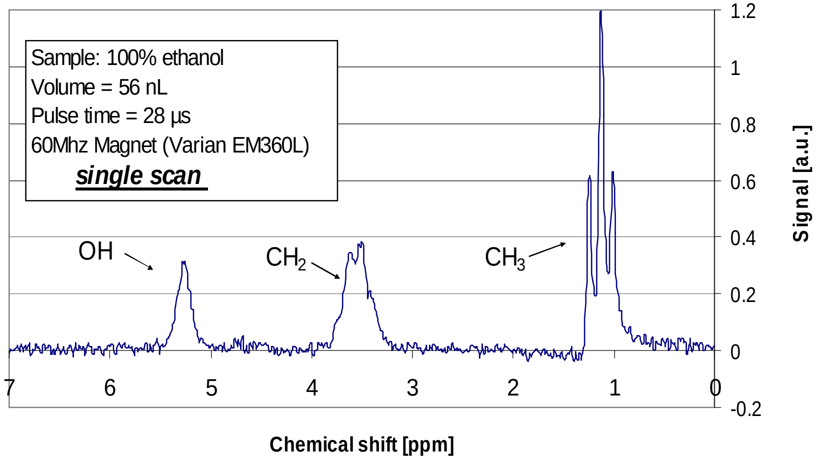
NMR stripline spectrum of ethanol



Top: 600 MHz, single scan; J. Bart 2007

Bottom: 60 MHz, single scan; H. Wensink 2004



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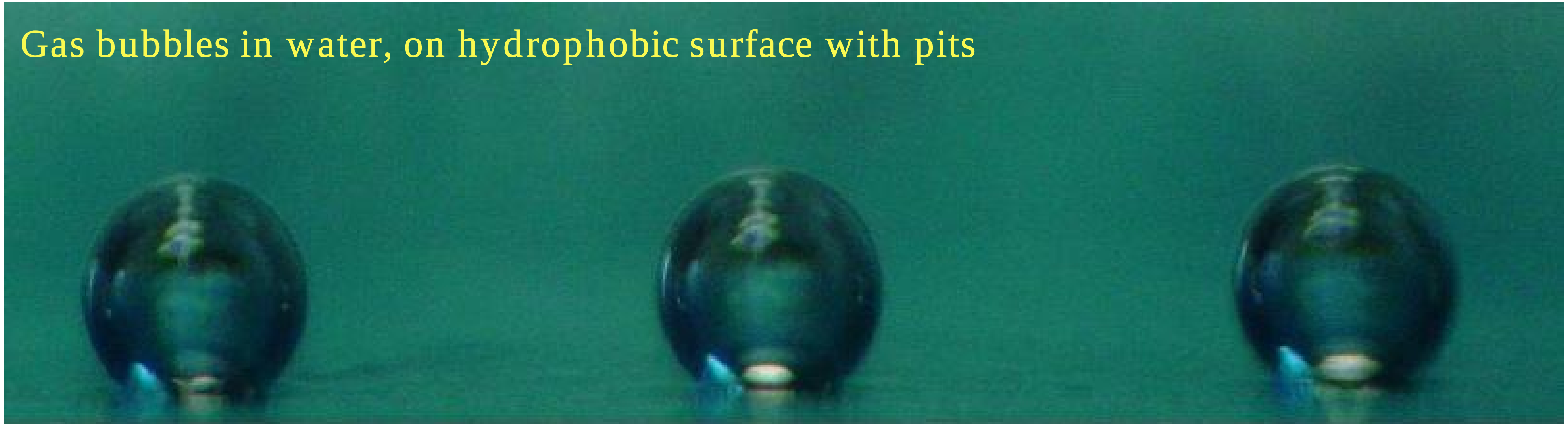
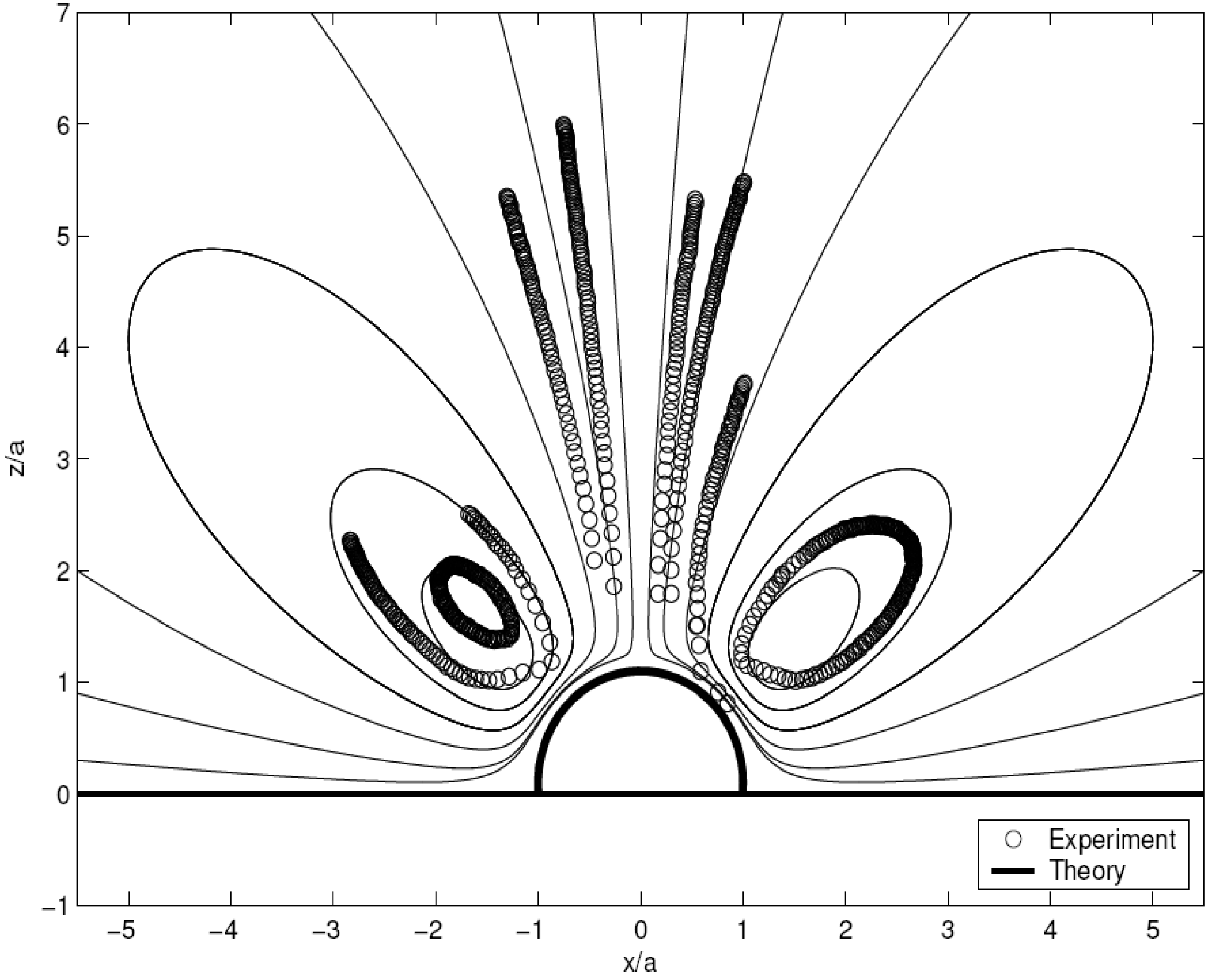
Microfluidics under sound control



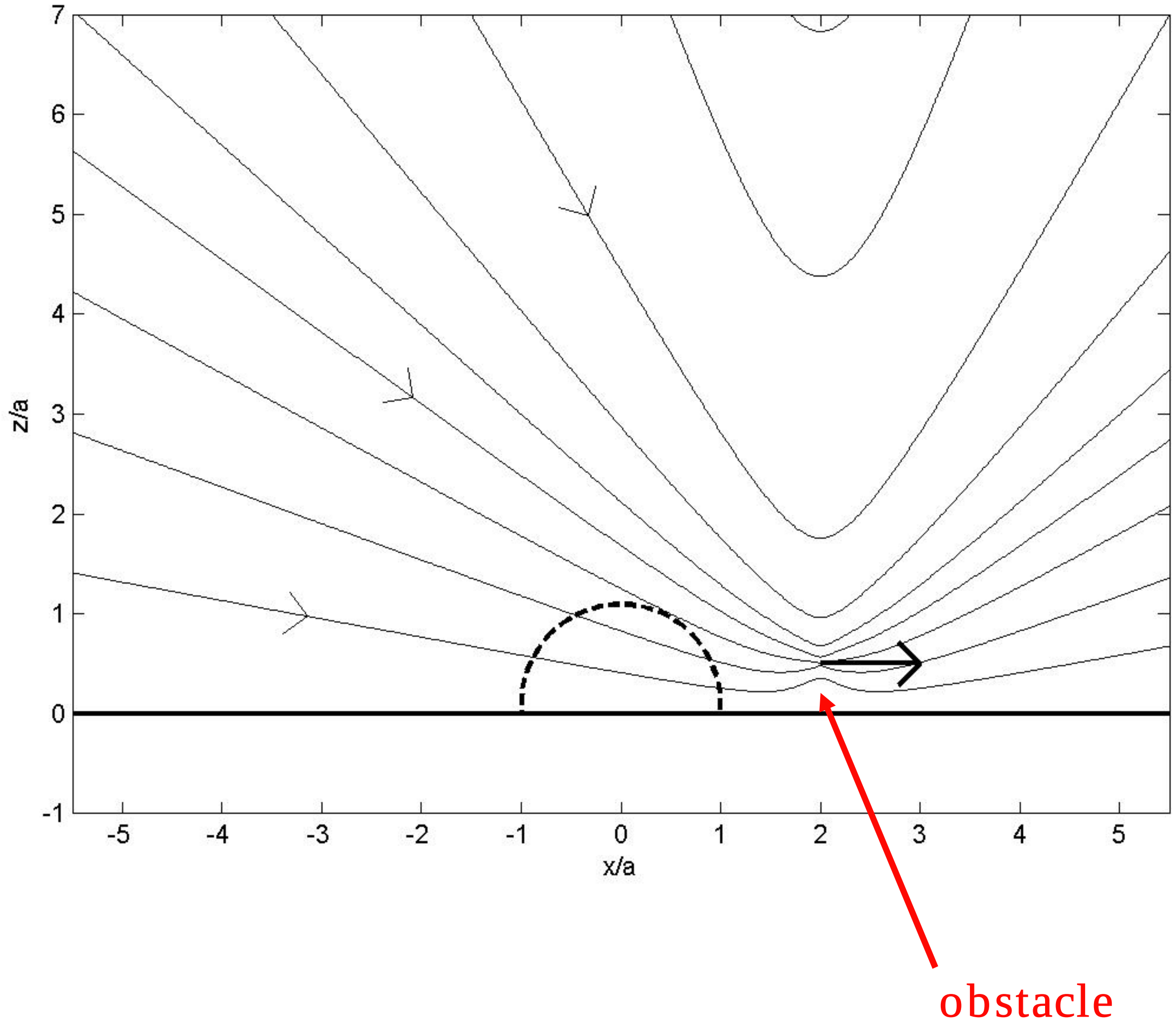
P. Marmottant & S. Hilgenfeldt, Nature 423, 2003, 153 and PNAS 101, 2004, 9523
P. Marmottant e.a. J. Fluid Mech. 568, 2006, 109

Oscillating gas bubble in liquid

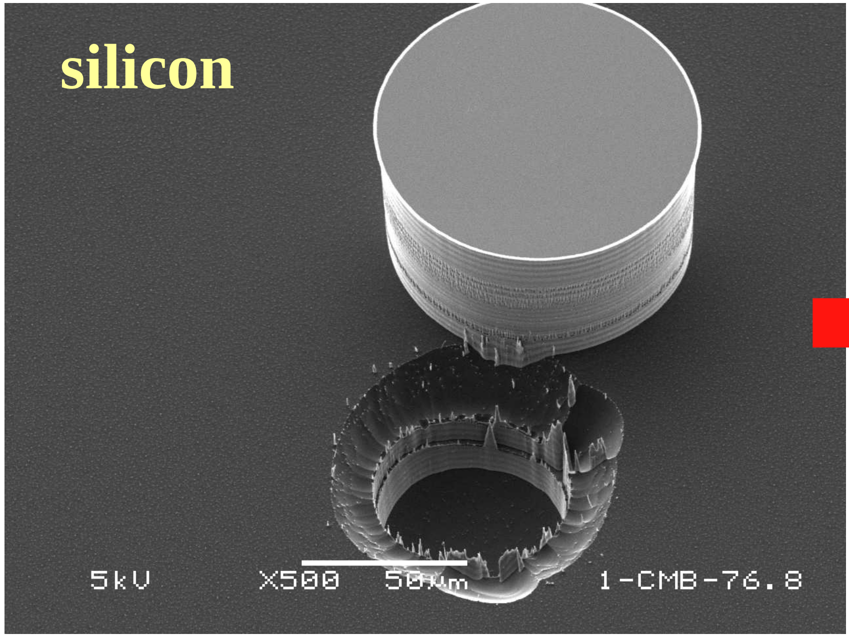


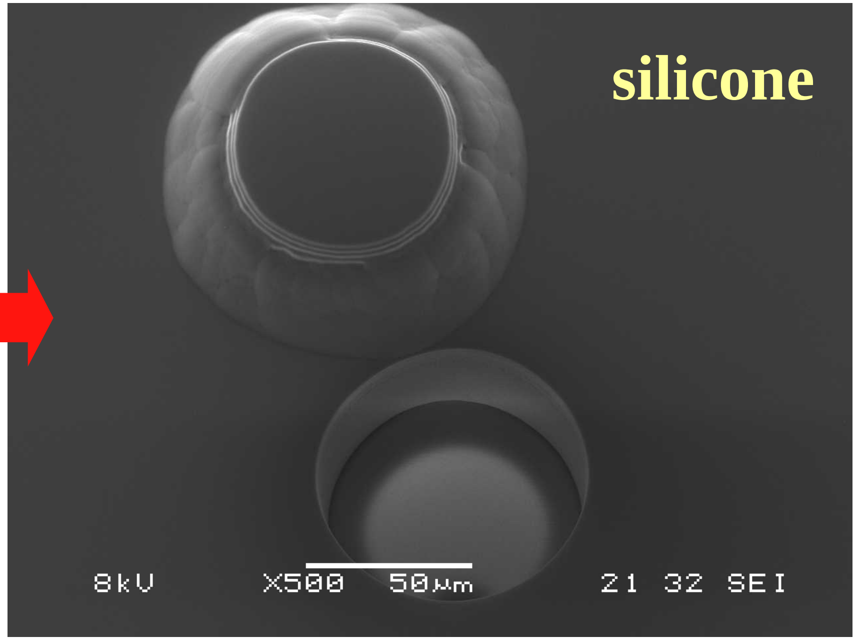
P. Marmottant & S. Hilgenfeldt, Nature 423, 2003, 153 and PNAS 101, 2004, 9523

Asymmetric flow pattern

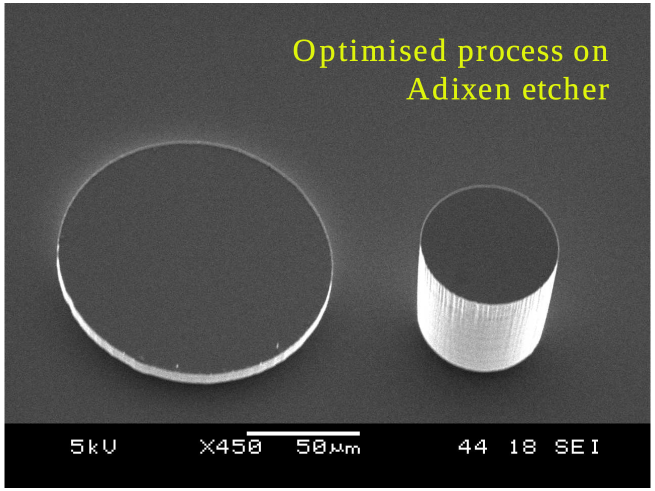


From silicon to silicone





P.S. silicone = PDMS



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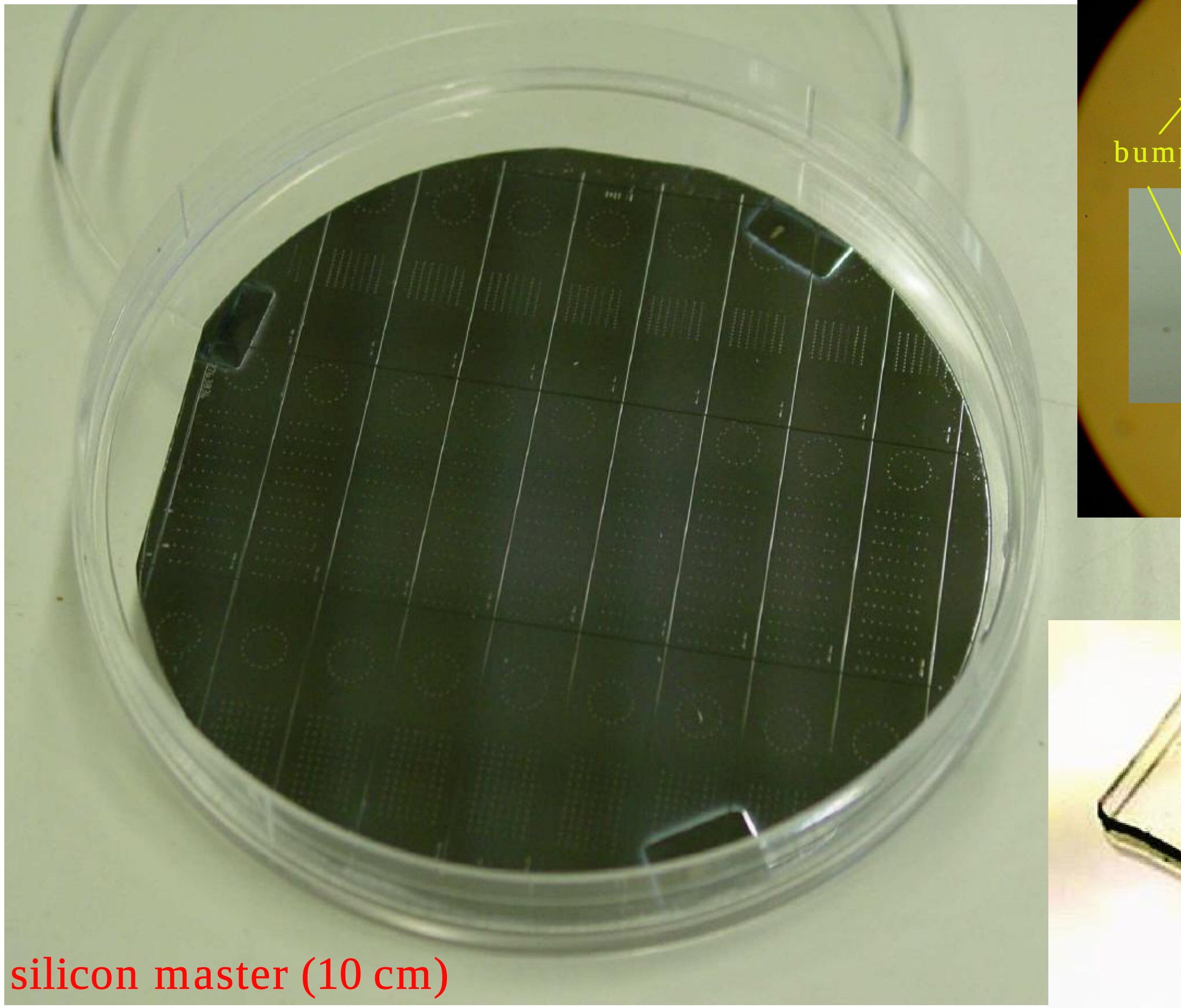
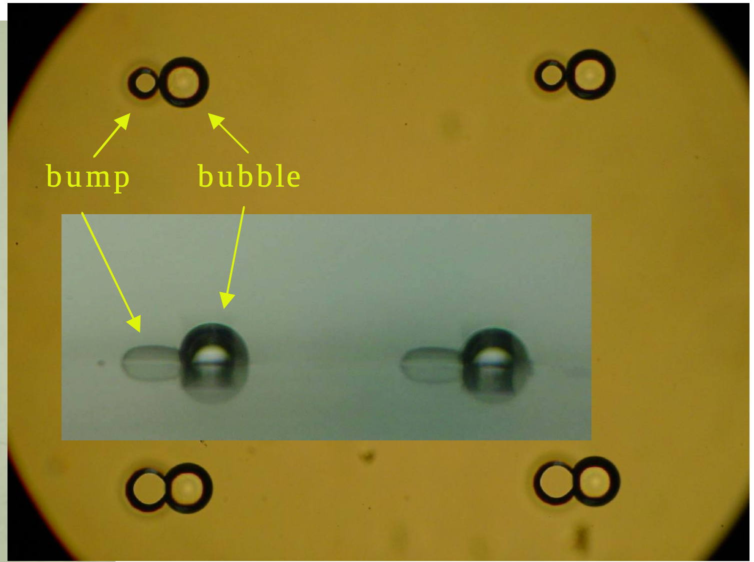
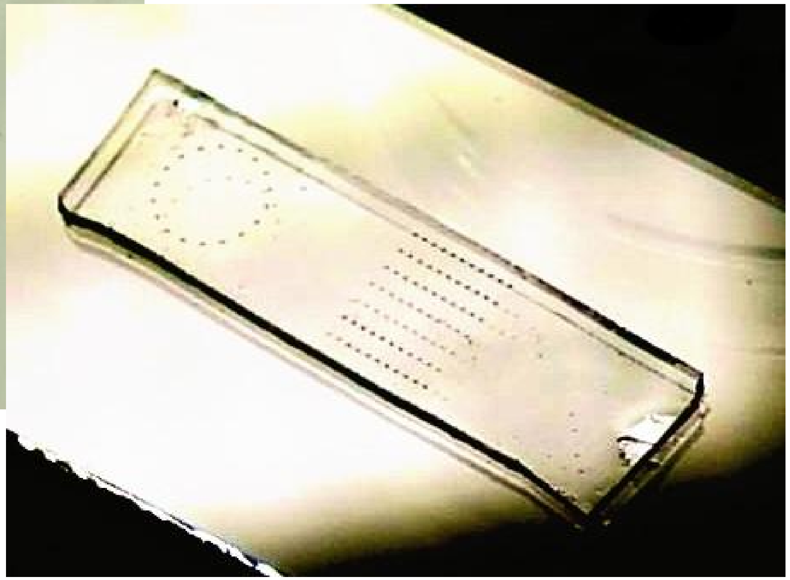
Microfabricated pit-bump combi's





PDMS replica



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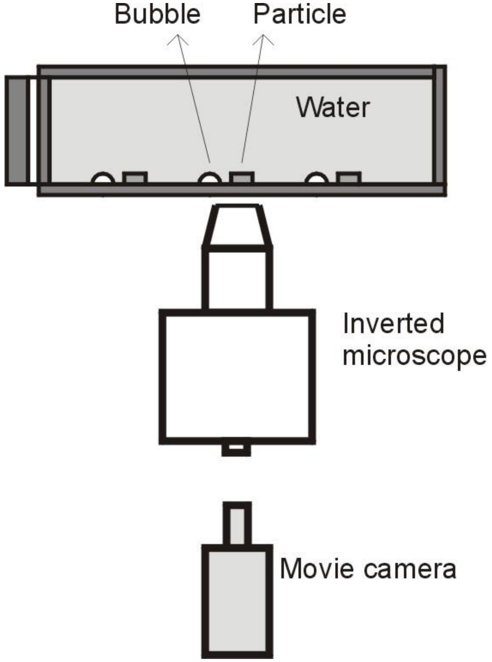
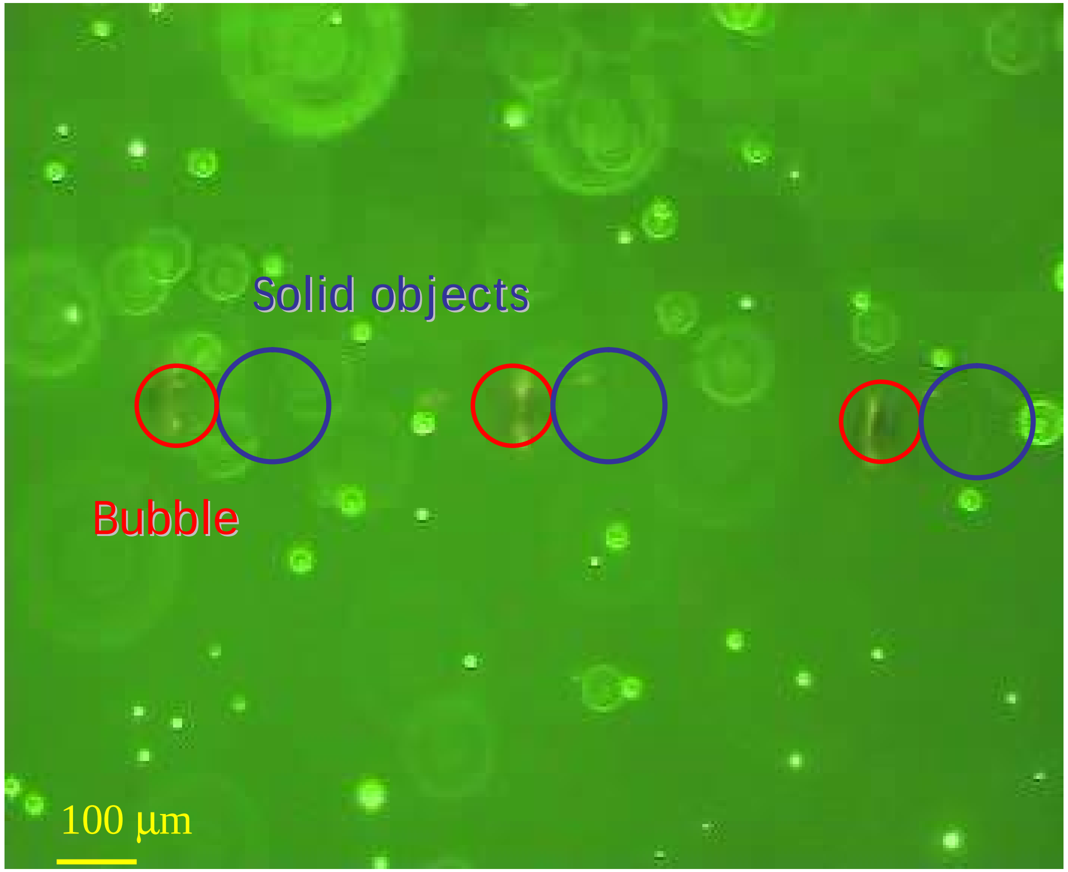
Bubble-powered transport



Bottom view

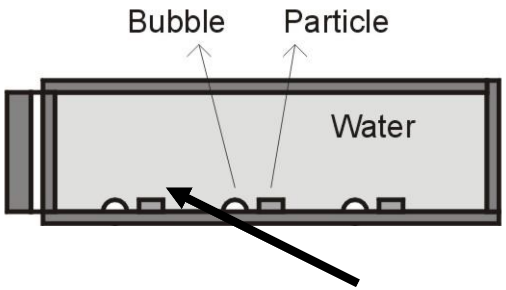


Transported material:

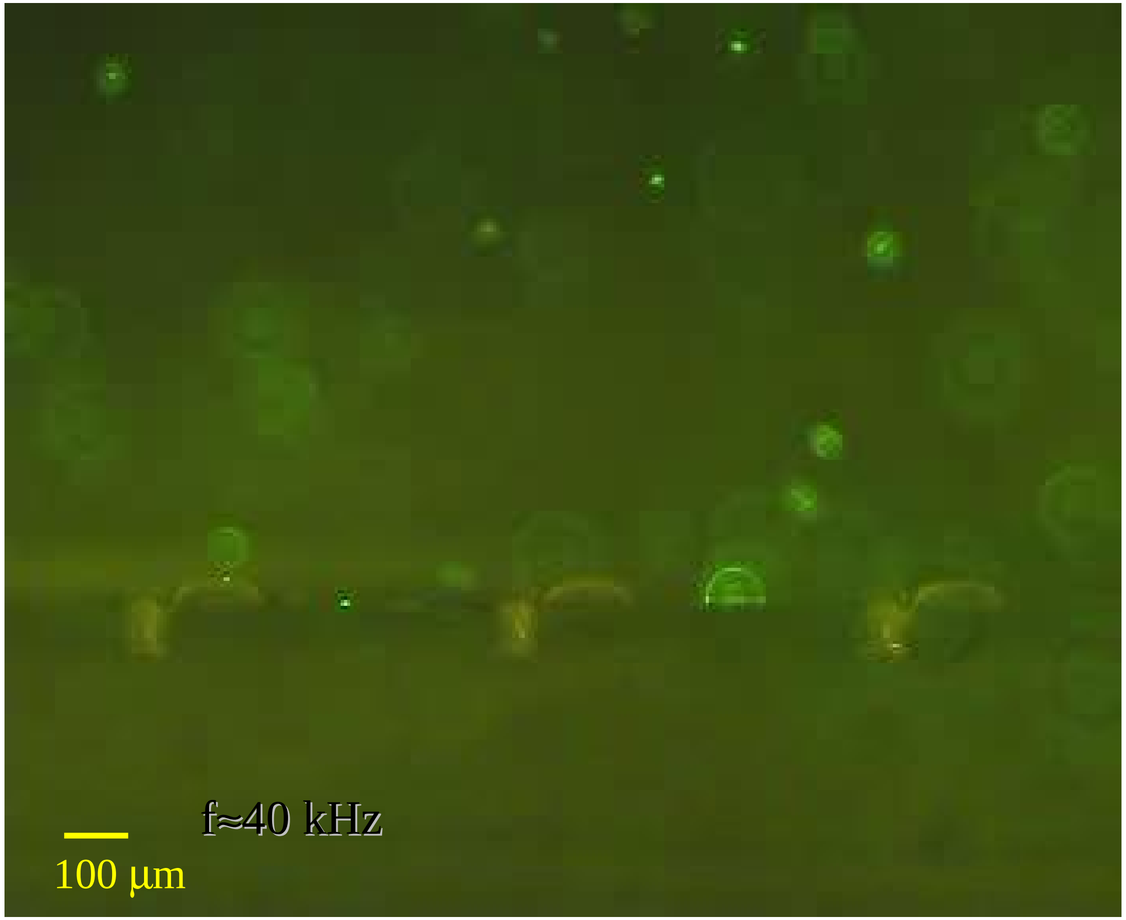
r = 1μm tracer particles

f≈40 kHz

Bubble-powered transport



Side view



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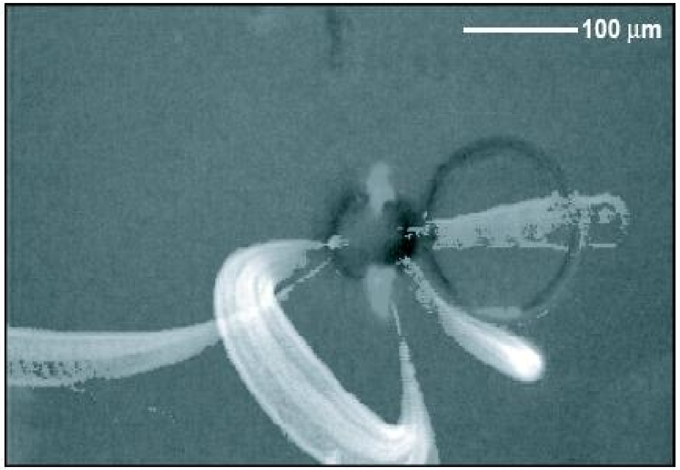
Particle and cell treatment

A



Fluorescent bead transport

B