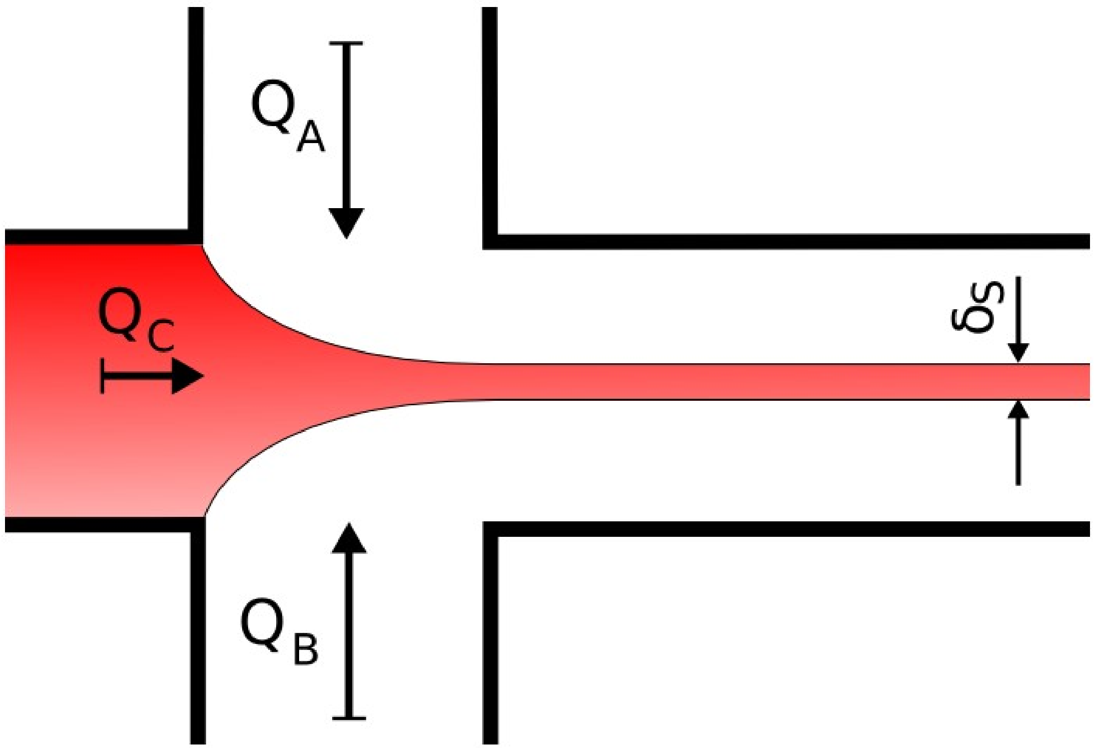
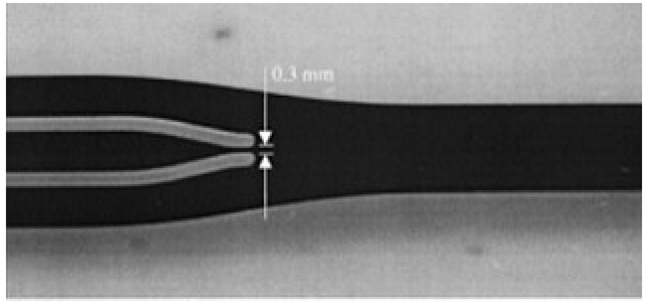
HYDRODYNAMIC FOCUSING INSIDE RECTANGULAR CHANNELS

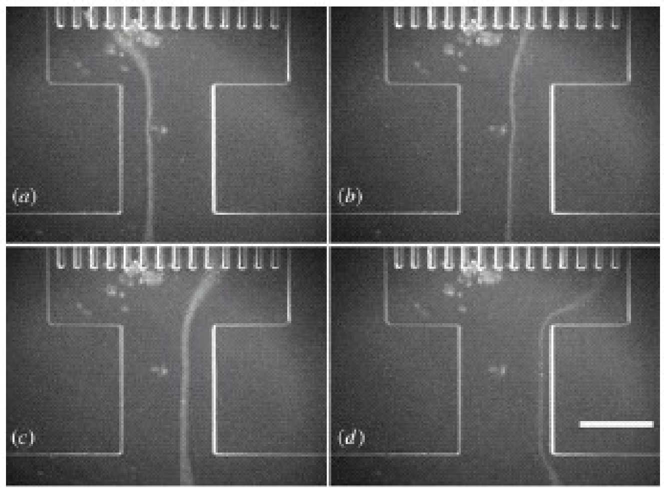
Piotr Domagalski
Technical University of Lodz, Poland



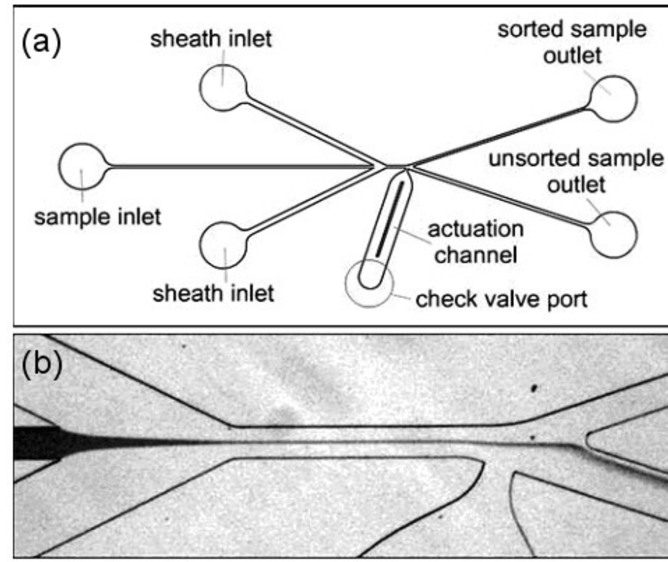
Schematic view of hydrodynamic focusing.
Index C refers to central inlet, A and B respectively to side streams. Focused stream width is marked δ_s.



Lee G.B., Trans ASME I, 2001

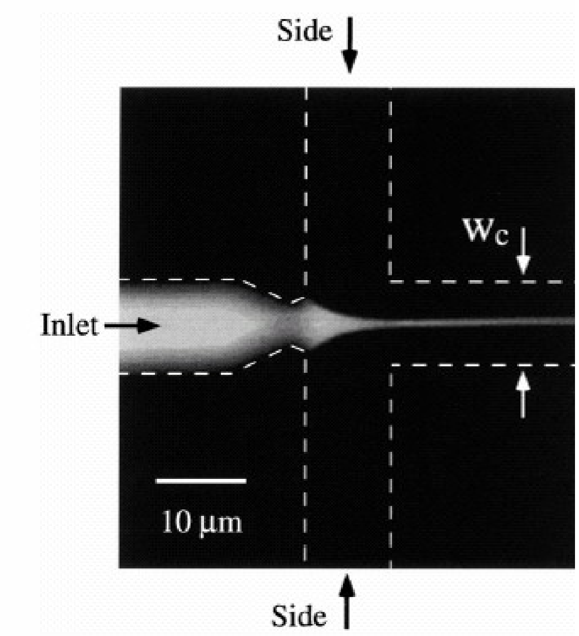


Vestad T., J. Micromech. Microeng., 2004

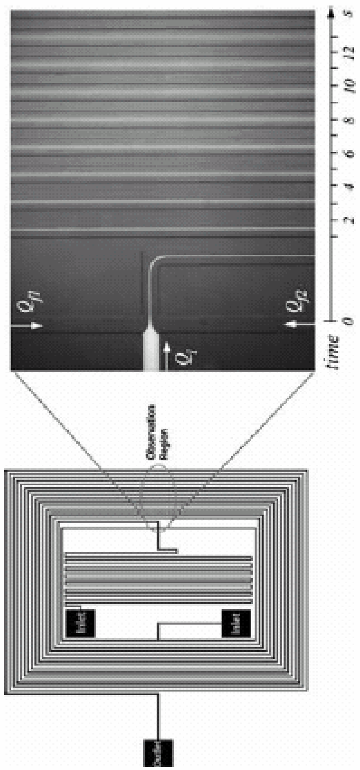


Lee G.B., J. Micromech. Microeng., 2005

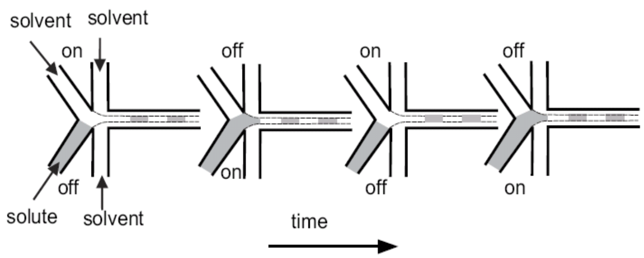
Cytometry, flow adressing in Lab-On-a-Chip systems



Knight J.B., Phys. Rev. Lett., 1998

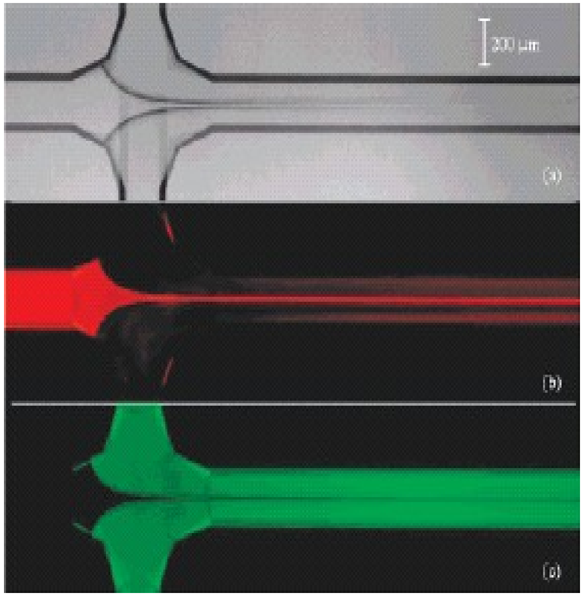


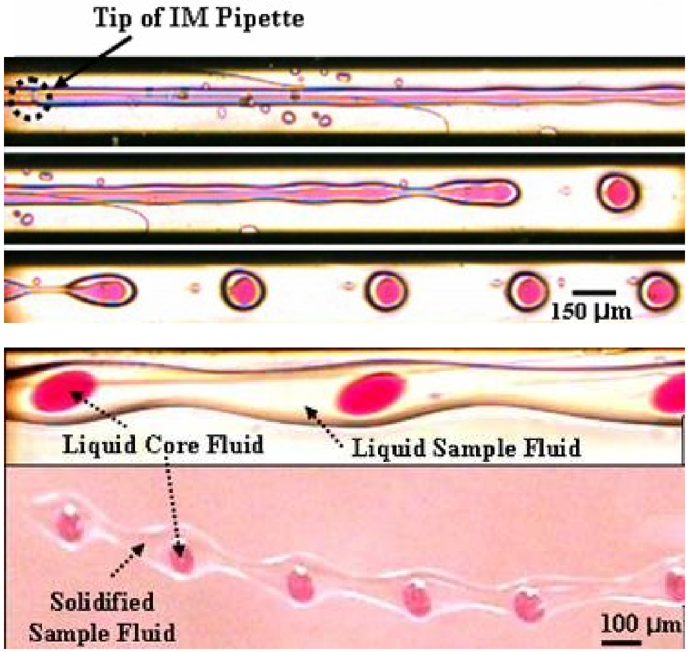
Stiles T., Microfluid Nanofluid, 2006



Nguyen NT., Proc. of SPIE, 2005

Micromixing

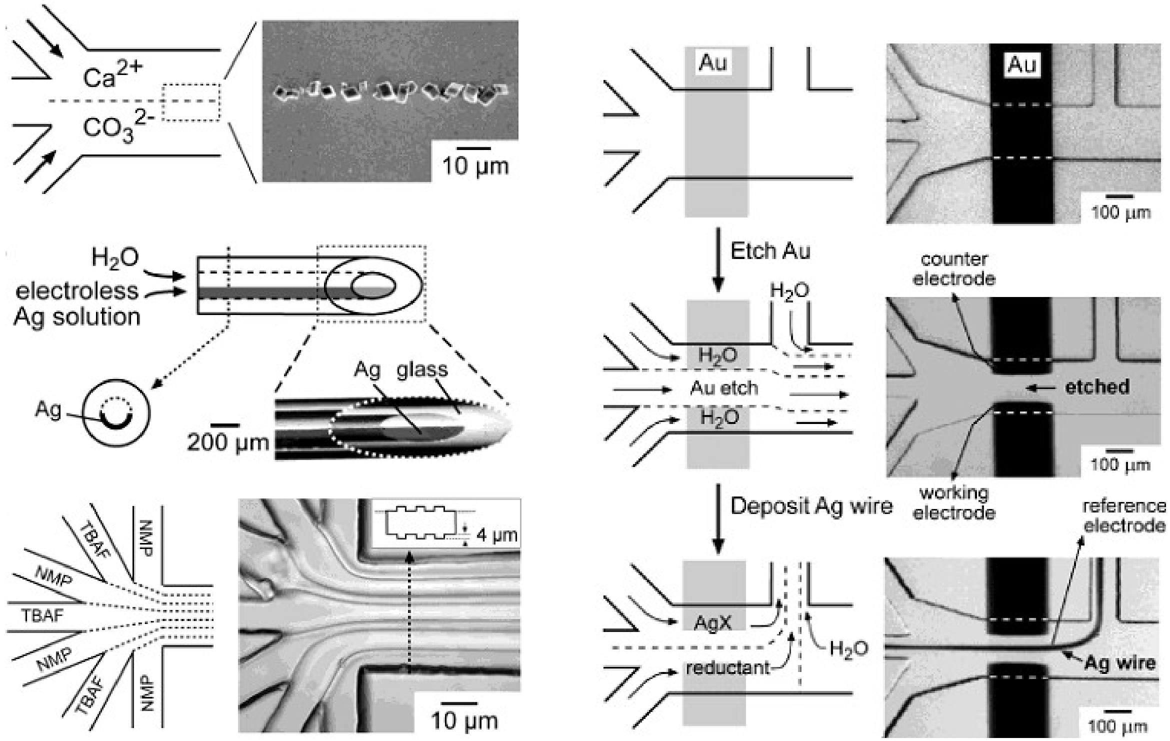




Jahn A., J. Am. Chem. Soc., 2004

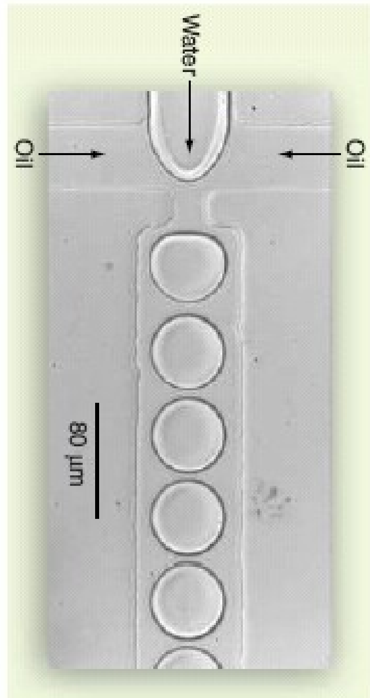
Hyun J-O., J. Micromech. Microeng, 2006

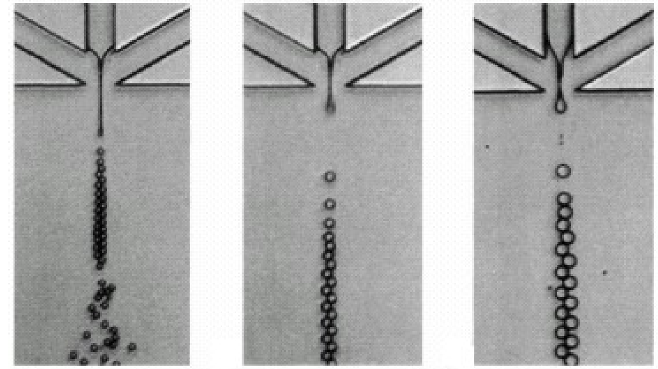
Reactors

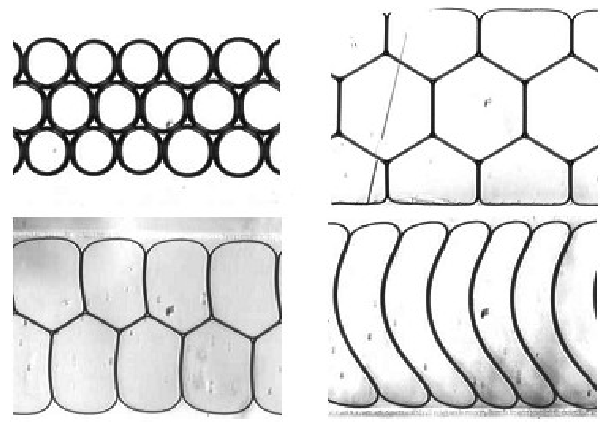


Kenis P.J., Science, 1999

Microfabrication







Utada A.S., Science, 2005,
Raven J.P., The European Physical Journal, 2006,
Xu Q., Appl. Phys. Lett., 2004

Two-phase systems generation

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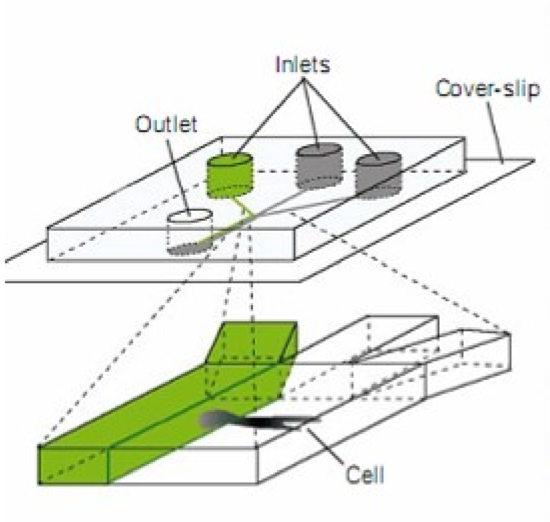
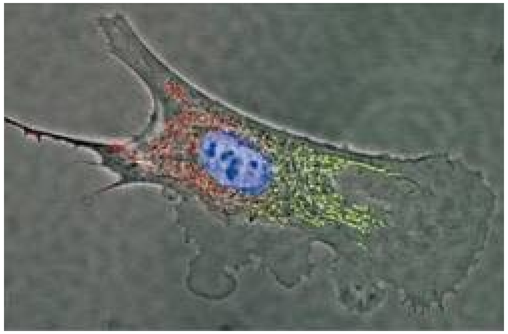
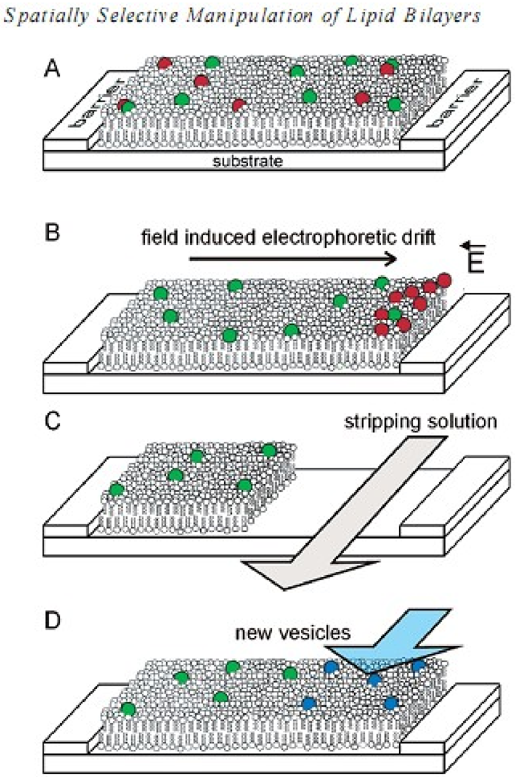
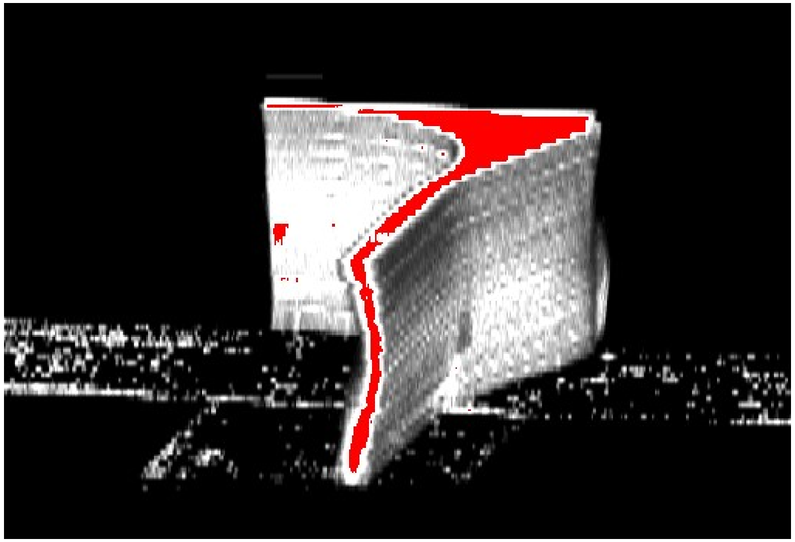




Takayama at al. Nature 2001



Kam at al. Langmuir 2003



3D CLSM projection of hydrodynamic focussing

Increasing accuracy

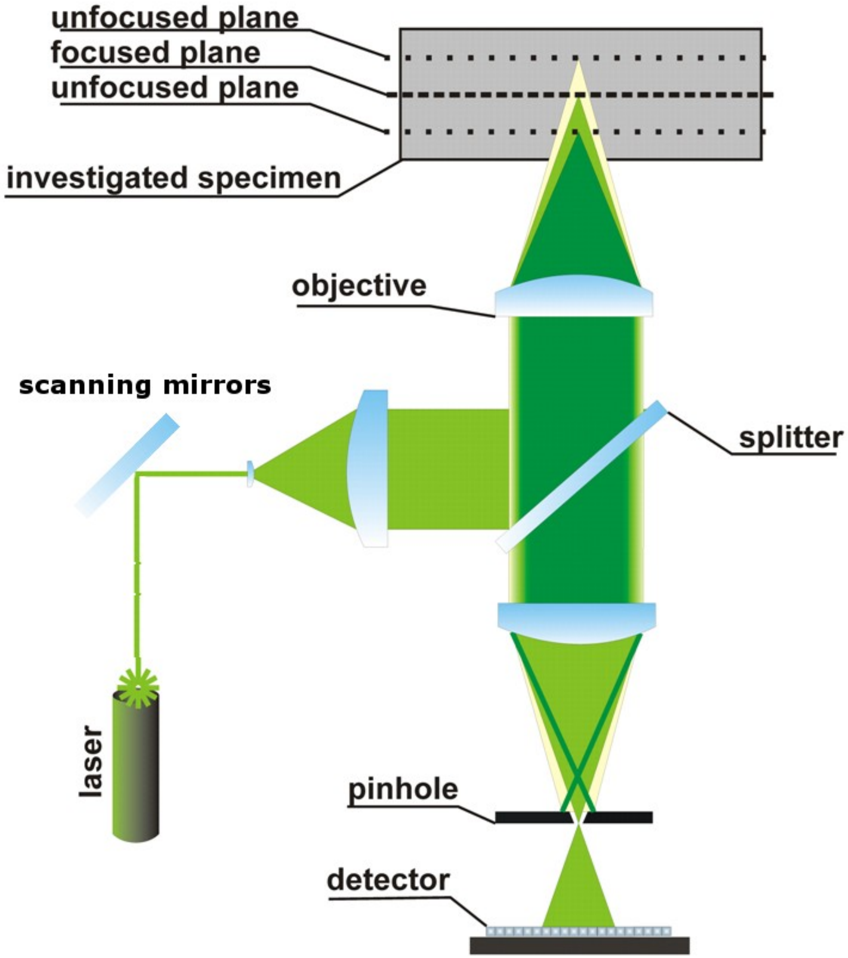
↓

Compilcated three-dimensional phenomenon

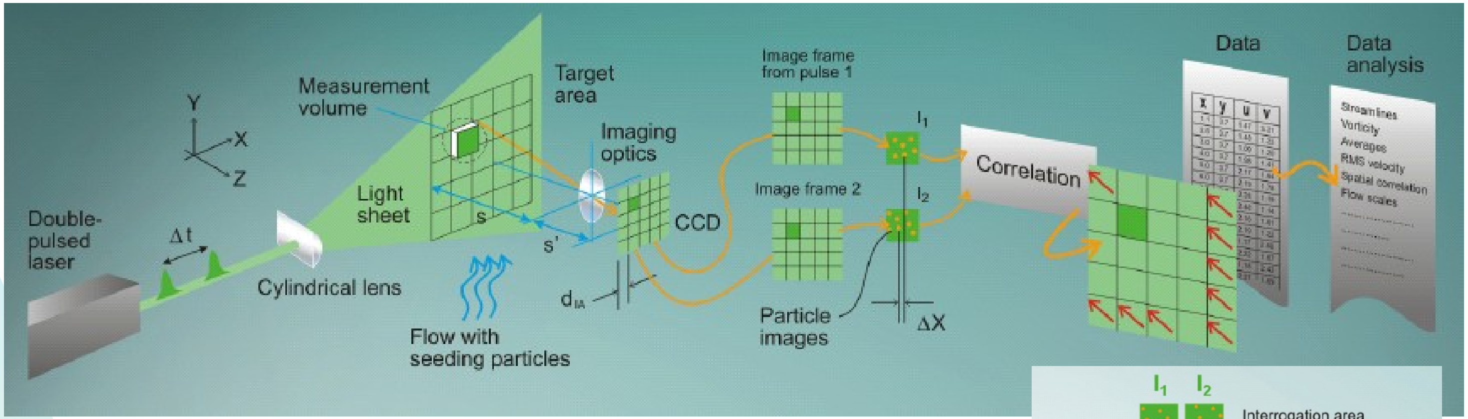
AIM: full description of 3D aspect

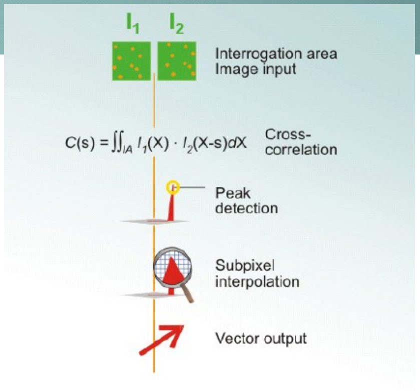
Confocal Laser Scanning Microscopy

- Carl Zeiss Axiovert 100 M +LSM 510 Meta
- Plan-Neofluar 20x/0.51, 10x/0.3
- C-Apochromat 10x/0,45
- Laser HeNe 543 nm Argon 488 nm from LASOS lasertechnik
- Alexa Fluor 546, FTIC
- Carl Zeiss LSM software



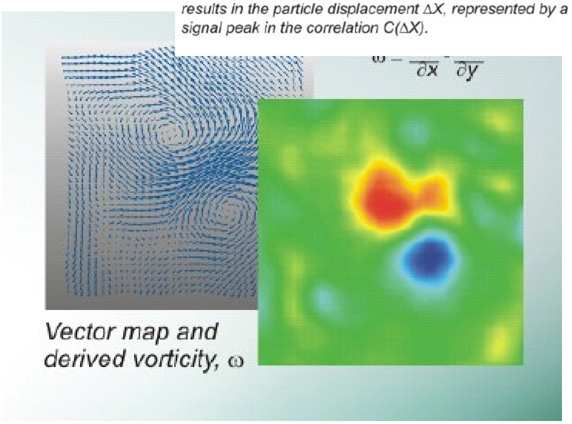
PIV Particle Image Velocimetry





The correlation of the two interrogation areas, I_1 and I_2, results in the particle displacement ΔX, represented by a signal peak in the correlation C(ΔX).

- Olympus BX51
- Plan-Neofluar 20x/0.51, 10x/0.3
- Laser Nd-YAG 543 nm (MiniLite PIV from Continuum)
- Kodak MEGAPLUS ES1.0/10bit CCD
- 1 µm 540/560 polystyrene beads from Molecular Probes Inc.



DANTEC materials

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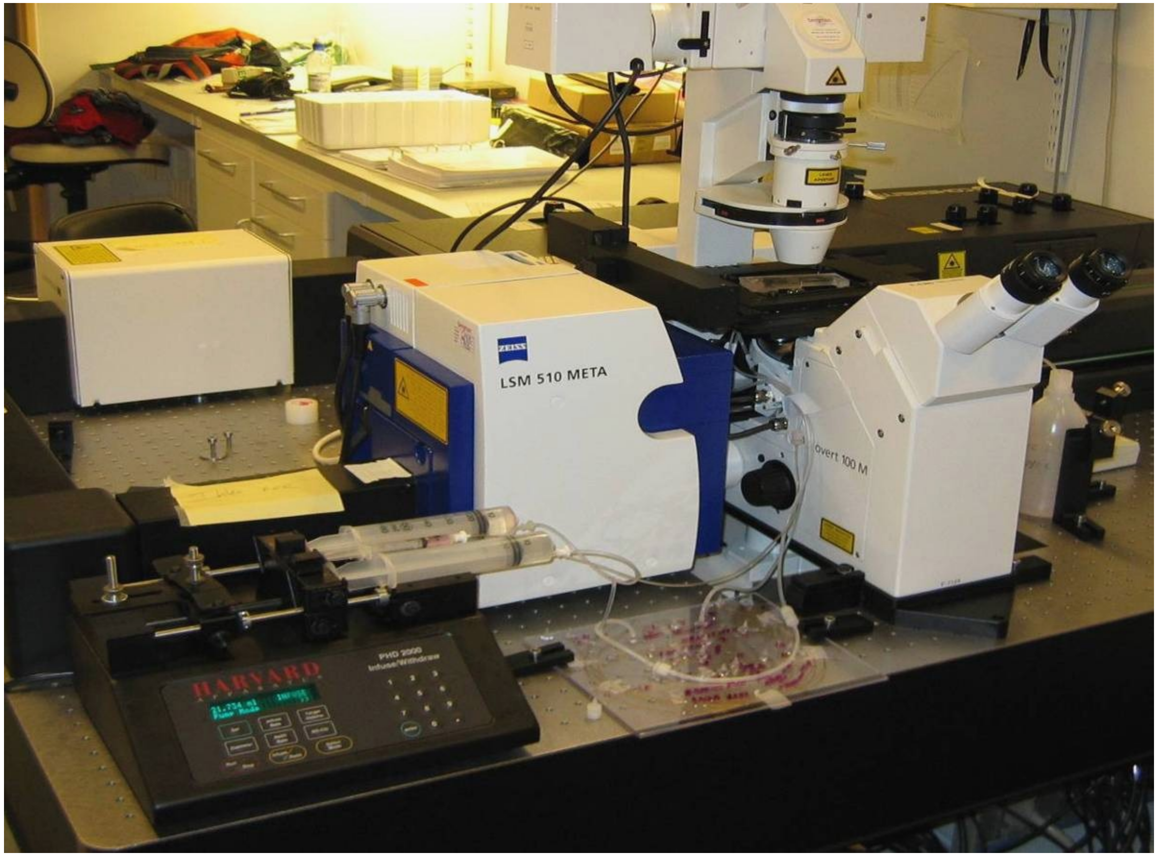
CFD

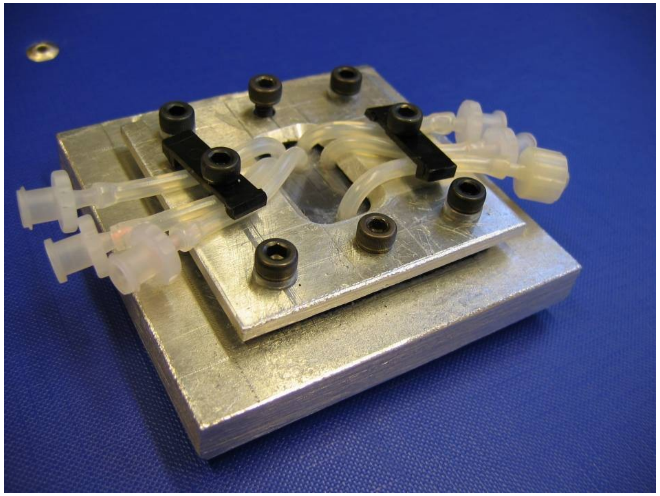
ANSYS CFX10 software

- Unstructured tetragonal mesh 265k-460k nodes (1499k–2624k elements)
- Boundary conditions:
  - inlet mass flowrates
  - outlet pressure
  - Newtonian fluid, noncompressible fow with no-slip condition
- Coupled algebraic multigrid method
- Bounded second oder upwind scheme
- Pentium 4 (3,2 -3,6 GHz), 2 GB RAM, Linux/Windows XP



Laboratory setup
(Confocal Laser Scanning Microscopy)

- milled, thermally bonded PMMA microchannels
- Silicon/elastomer/glass microchannels
- Cross-sections
  260x200 µm
  800x1040 µm



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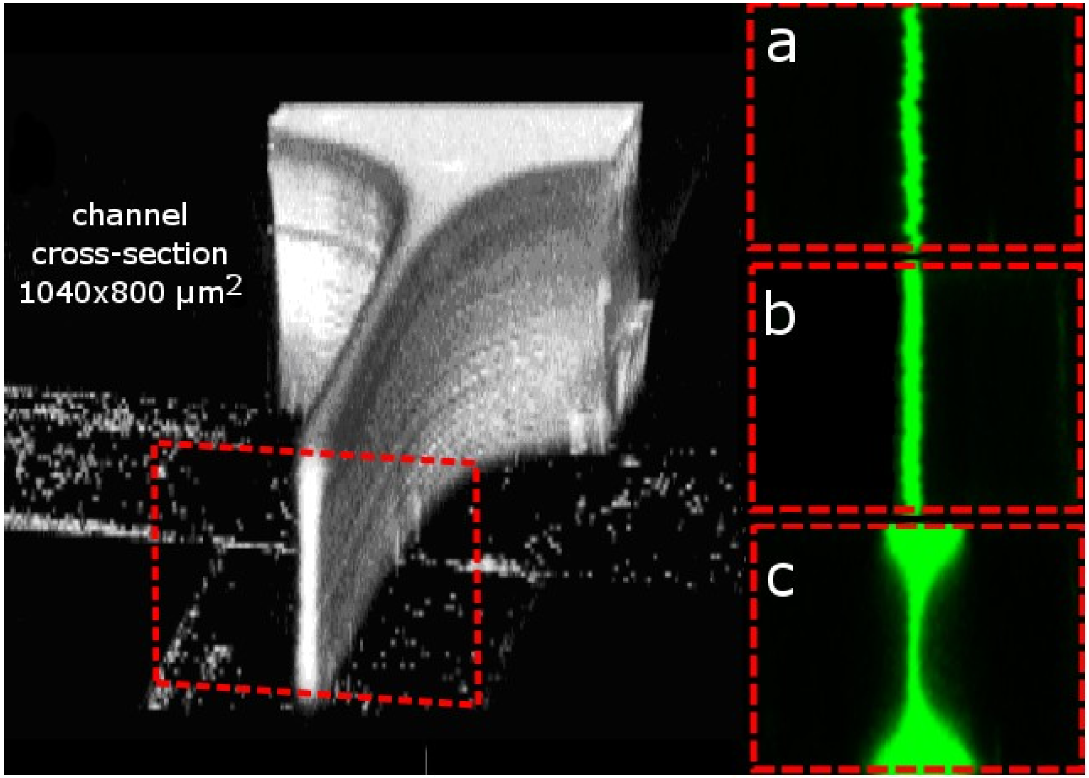
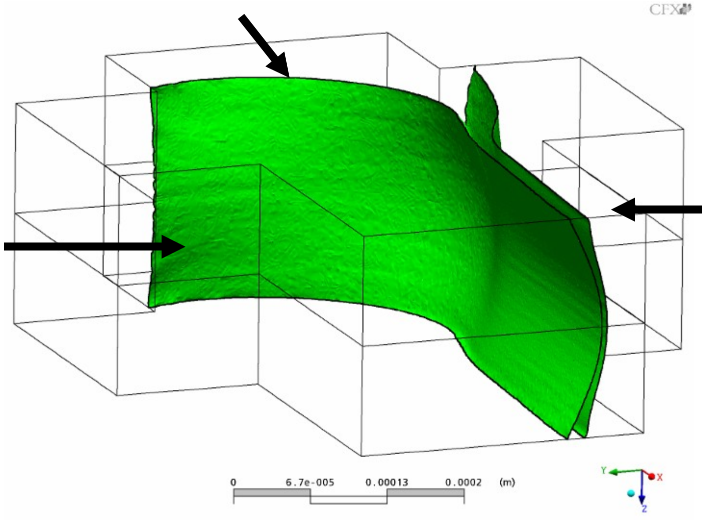
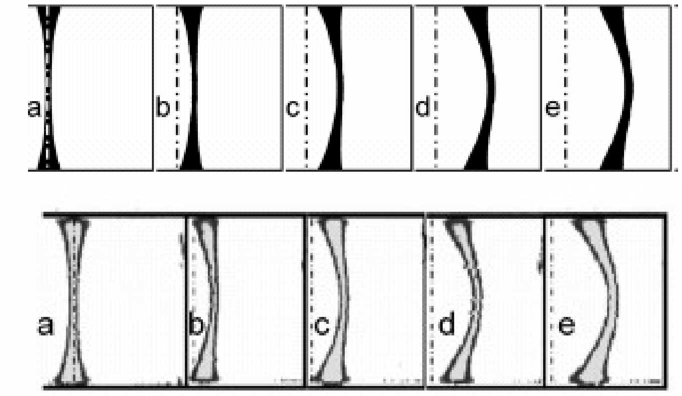


3D confocal projection of hydrodynamic focussing visible cross-sections of outlet channel.

Mean flow velocity

a) 1,66 cm/s; b) 3,32 cm/s; c) 6,65 cm/s, corresponding Reynolds number 3,23 6,46 and 12,92

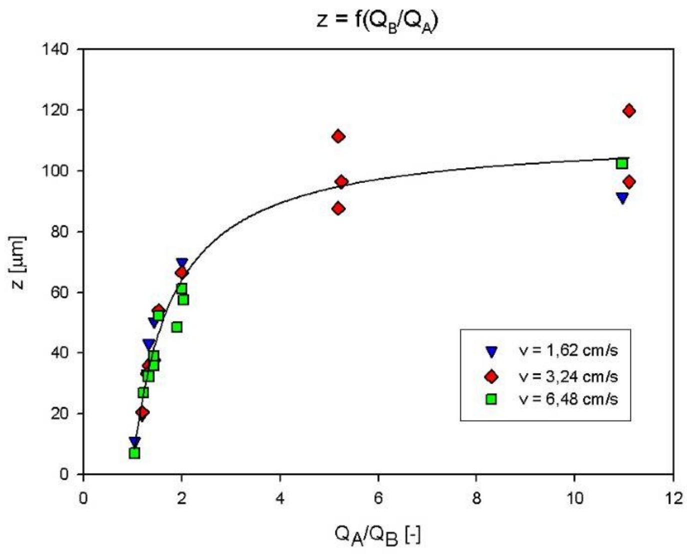


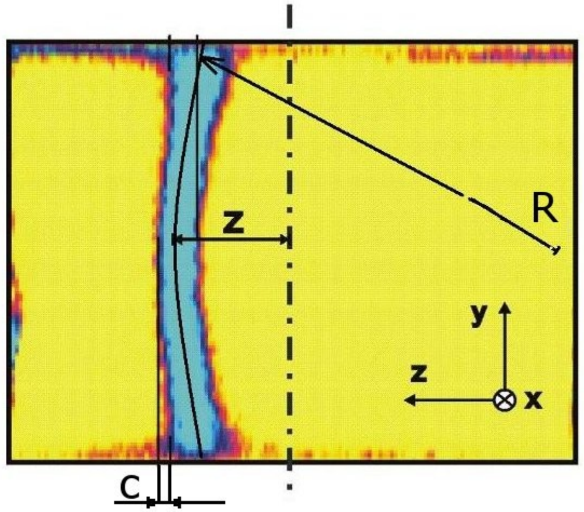


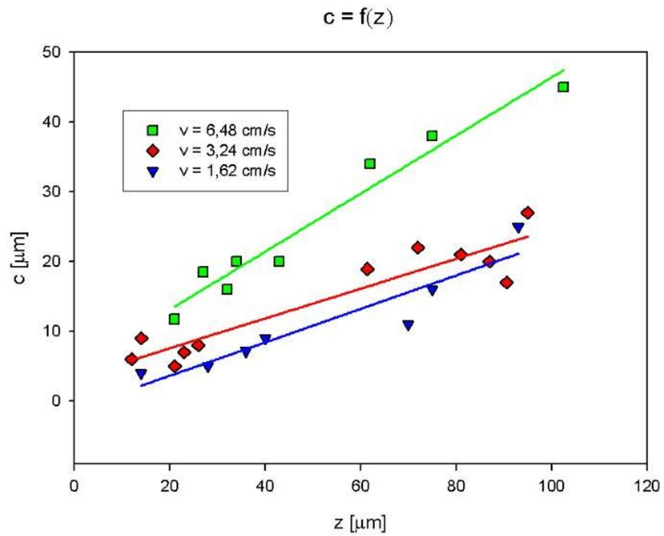
Non symmetrical aspect of hydrodynamic focussing
Comparison against CFD* (top)
Side stream ratio (QA/QB):

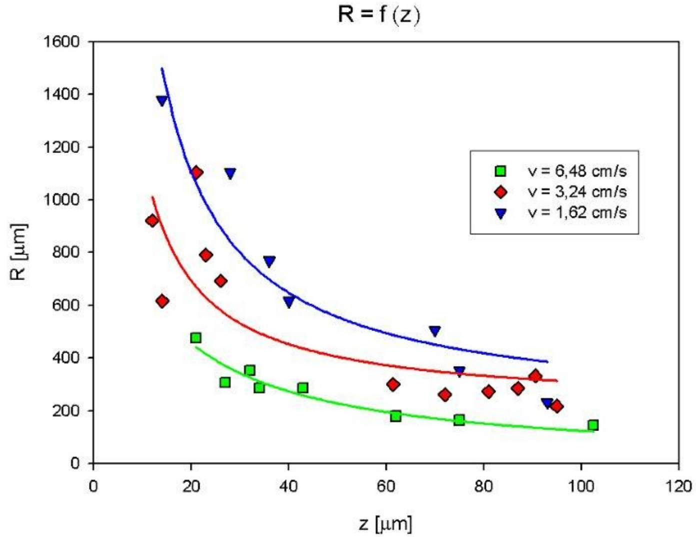
a) 1; b) 1,73; c) 2; d) 3; e) 7,57

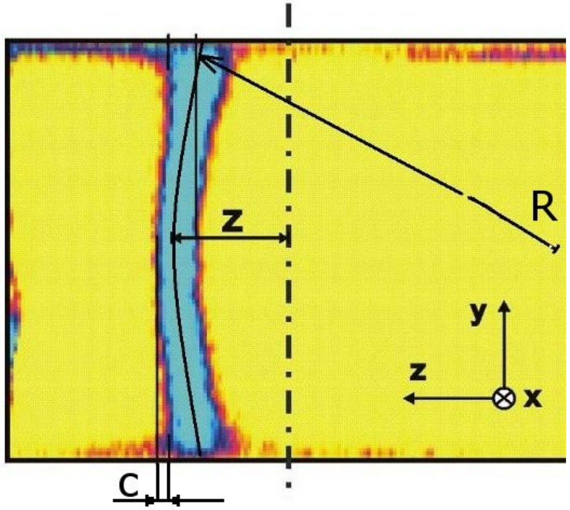
*Solli L., Mielnik M.M., Saetran L.R., Proc. of 2nd International Conf. On Transport Phenomena in Micro and Nanodevices, Barga, Italy 2006

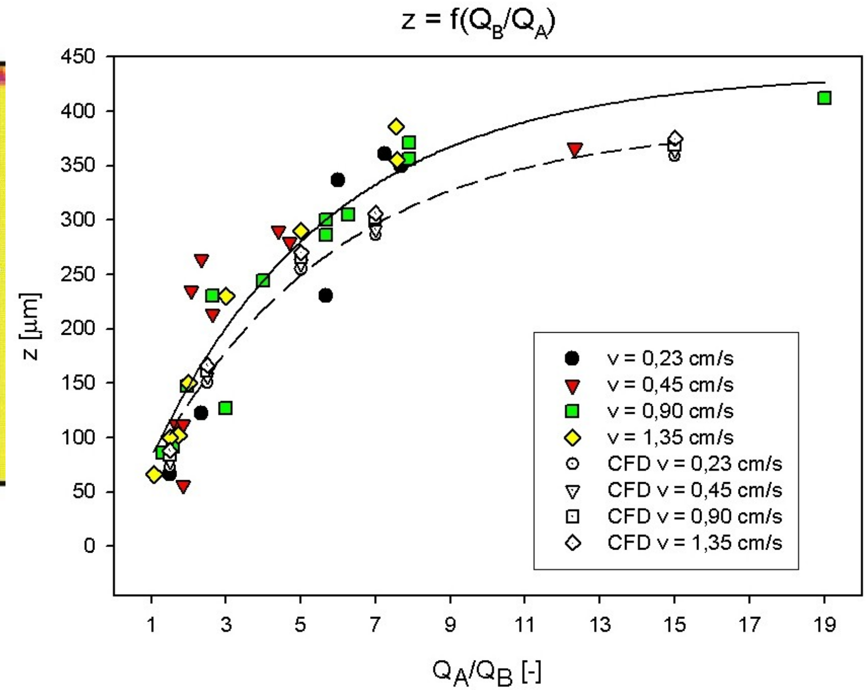

z = f(QB/QA)
z [µm]
QA/QB [-]
v = 1,62 cm/s
v = 3,24 cm/s
v = 6,48 cm/s

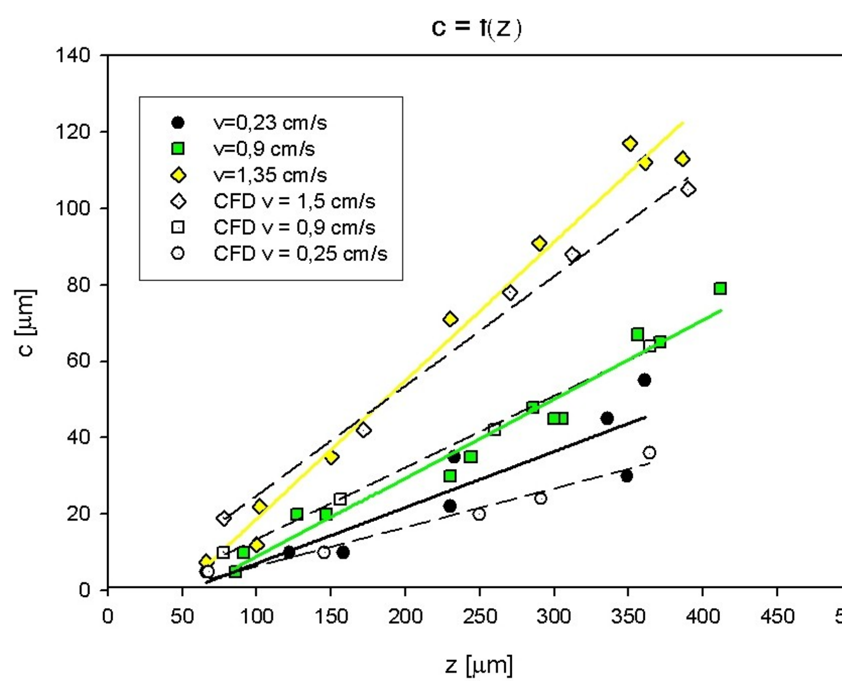

R
z
y
z
x
C


c = f(z)
c [µm]
z [µm]
v = 6,48 cm/s
v = 3,24 cm/s
v = 1,62 cm/s


R = f (z)
R [µm]
z [µm]
v = 6,48 cm/s
v = 3,24 cm/s
v = 1,62 cm/s







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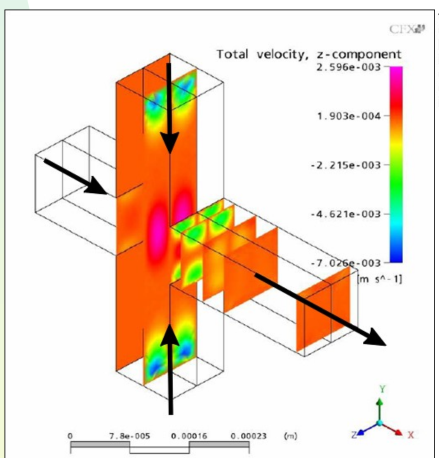
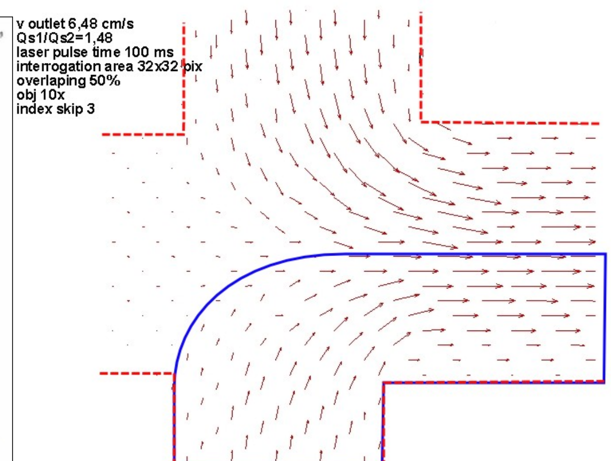
Responsible mechanisms:

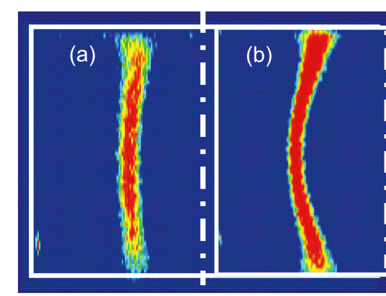
- Forehead collision of two laminar profiles
- Diffusion, surface tension (wetting angle)
  - Secondary flow pattern
  - Boundary layer separation
  - Moffatt vortices



CFD – z component of velocity



PIV flowfield of hydrodynamic focusing



CLSM cross-section of outlet channel
Mean flow velocity
v= 0,023 cm/s (a),
v=0,9cm/s (b).

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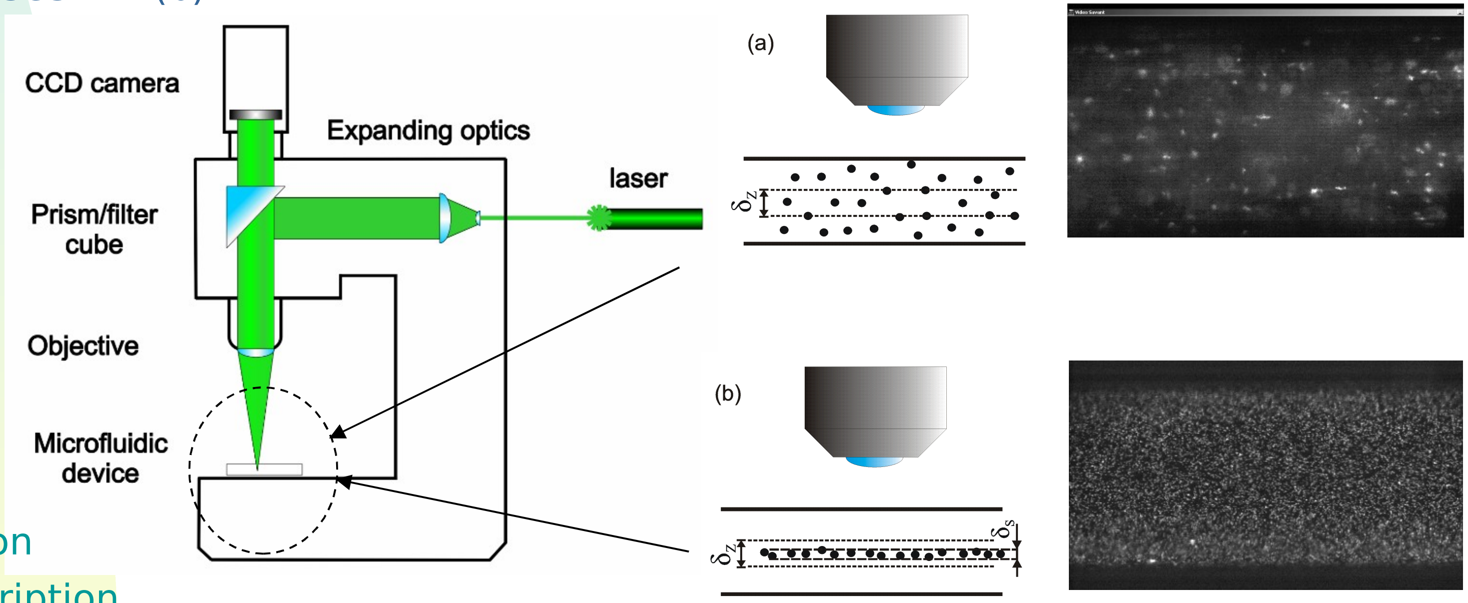
Summary:

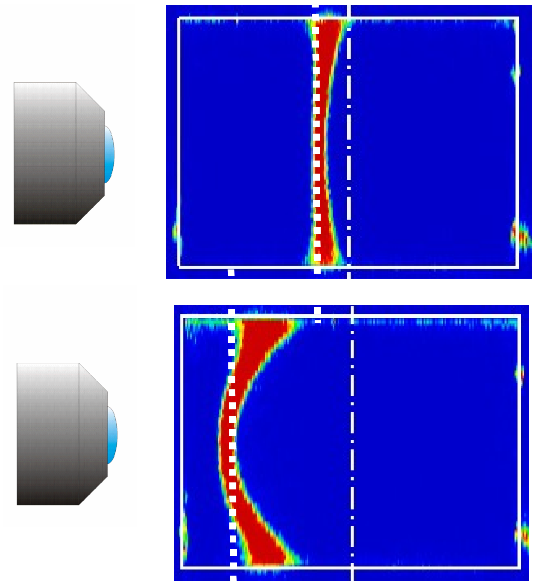
- Two kinds of focused stream deformations
- Basic relations between parameters
- Mechanisms explained

Aplication: flow visualisation (SeSPIV)*

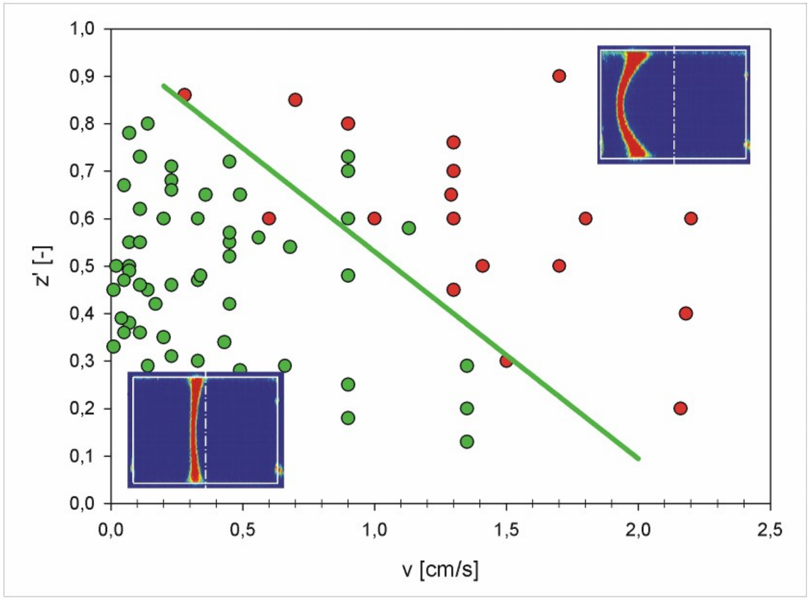
bulk illumination – depth of focus problems (a)
solution: SeS PIV (b)



Influence of flow pattern on Selective Seeding PIV (SeSPIV)



Flowfield visusalisation problem in SeS PIV



SeS PIV limit of applicability

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New applications

Acknolegewments

- Marek Dziubiński, Technical University of Lodz, Poland
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- Ingrid Lunde, currently Safetec Inc., Norway
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Thank you for attention