Micro-
&
Nano-fluidics
challenges of fluid mechanics

Part 1

Why, what, how and where we need it?

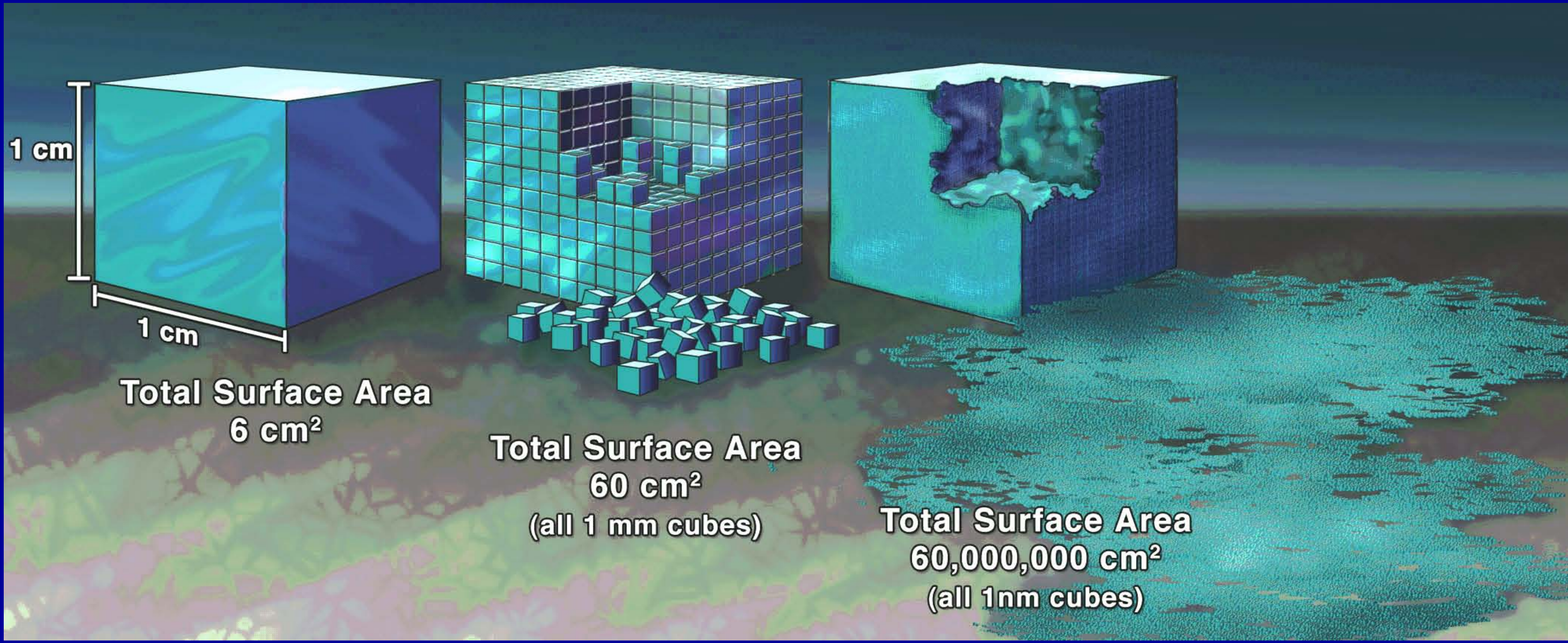
Tomasz A. Kowalewski
Department of Mechanics and Physics of Fluids
IPPT PAN, Warszawa
http://fluid.ippt.gov.pl/nano/

Small is beautiful!

- There's Plenty of Room at the Bottom! *R.P. Feynman 1959*
- All bio-systems are driven by nano-scale mechanism – typical mechanics barriers broken: gecko, ant, bee, blood cell, bacteria and virus – minimum energy and large mechanical /chemical outcome
- Integration and multifunctionality!
- New functions due to the scaling effects, new materials
- Faster (parallel work), cheaper (by massive production), low energy consumption, lighter (flying robo-labs)
- By moving individual molecules - can we make them to do any work we wish (!?)

…after 50 years billions of devices like inkjet, conductive polymers, fuel injection, ABS, airbag, blood analysis, DNA chips, drug testing and delivery, high definition screen, micro heat exchangers, scanning microscope, AFM ...

Scale effect



At the nanoscale, fundamental mechanical, electronic, optical, chemical, biological, and other properties may differ significantly from properties of micrometer-sized particles or bulk materials. One reason is surface area. Surface area counts because most chemical reactions involving solids happen at the surfaces, where chemical bonds are incomplete.

http://fluid.ippt.gov.pl/nano/

Nano technology 21st Century revolution!

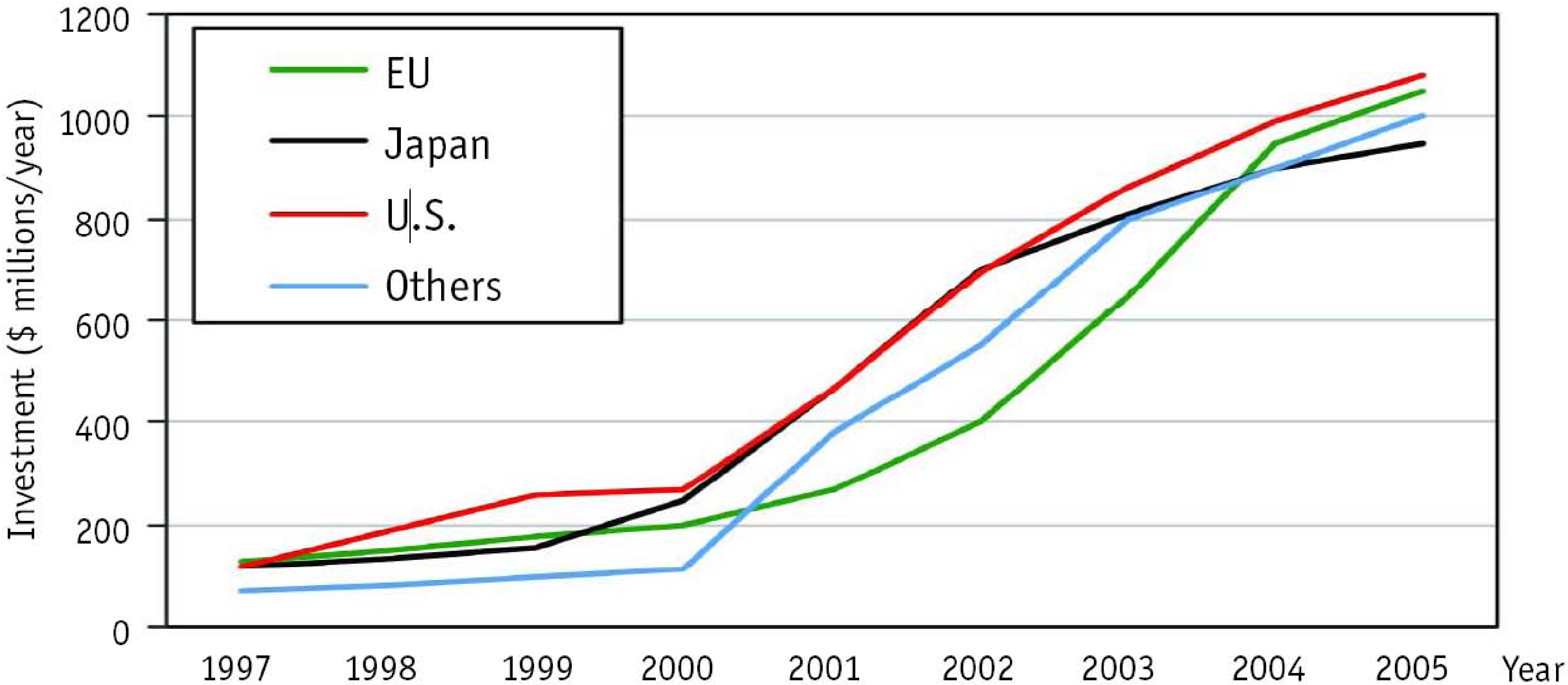
- **2001** National Nanotechnology Initiative (USA) http://www.nano.gov ~ $1.3mld/year

- **2003** NMP priority: Nano-technologies and Nano-science: http://cordis.europa.eu/nanotechnology/ ~ 1.4mld € / 4 years – direct EU funding

Nanotechnology - the science, engineering, and technology related to the understanding and control of matter at the length scale of approximately 1 to 100 nanometers. It is not just working with matter at the nanoscale! <u>It is mainly research and development</u> of materials, devices, and systems that have novel properties and functions due to their nanoscale dimensions or components, and has the associated goal of understanding and gaining control over them.

Nano technology 21st Century revolution!

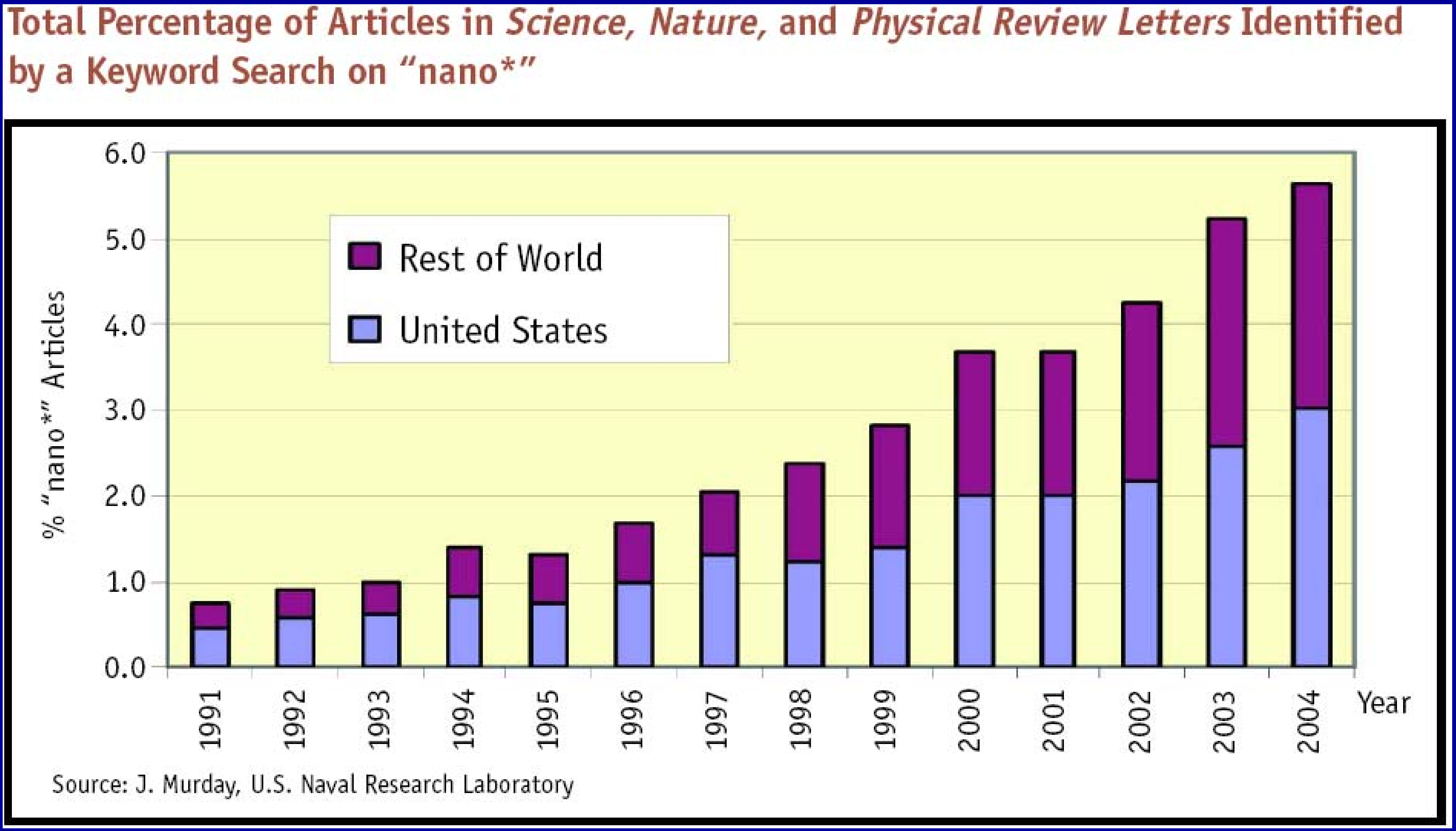
Government Nanotechnology R&D Investments in 1997-2004



Source: M. Roco, National Science Foundation

http://fluid.ippt.gov.pl/nano/

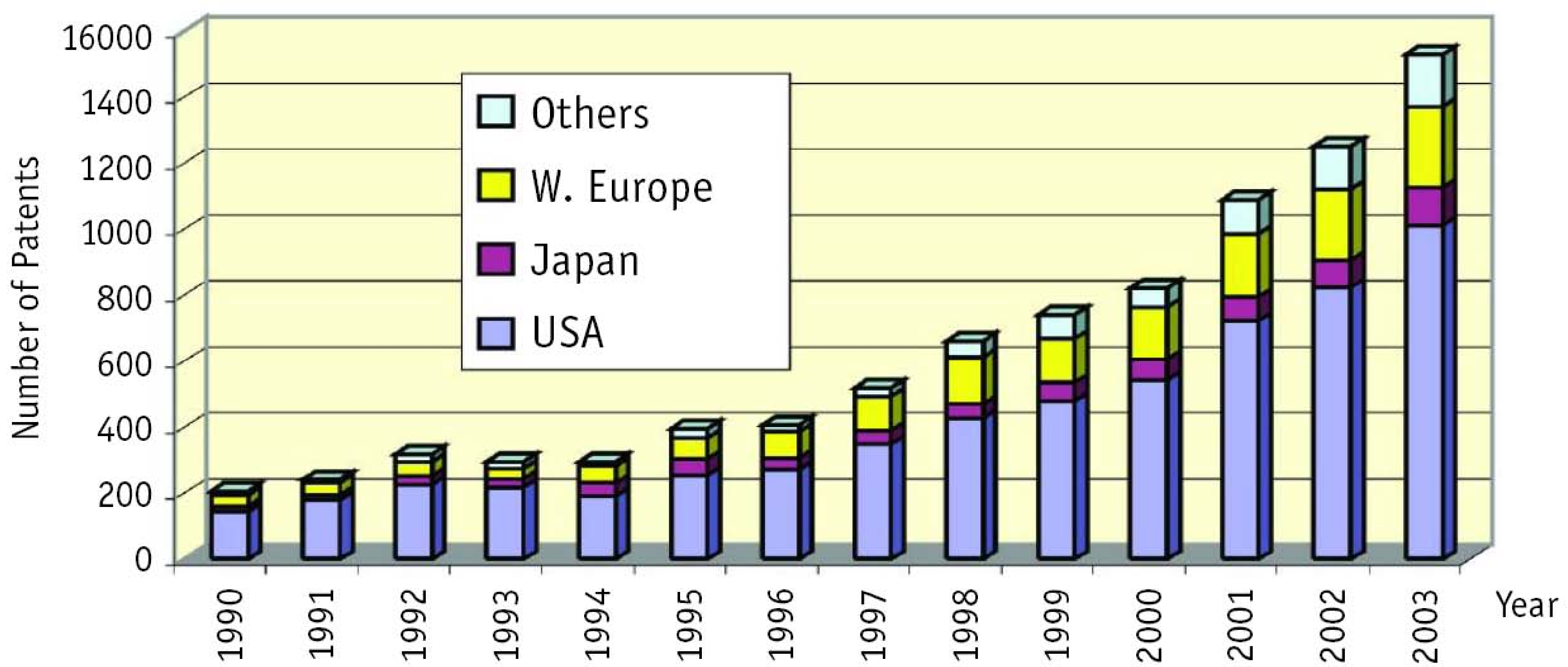
Nano technology 21st Century revolution!



http://fluid.ippt.gov.pl/nano/

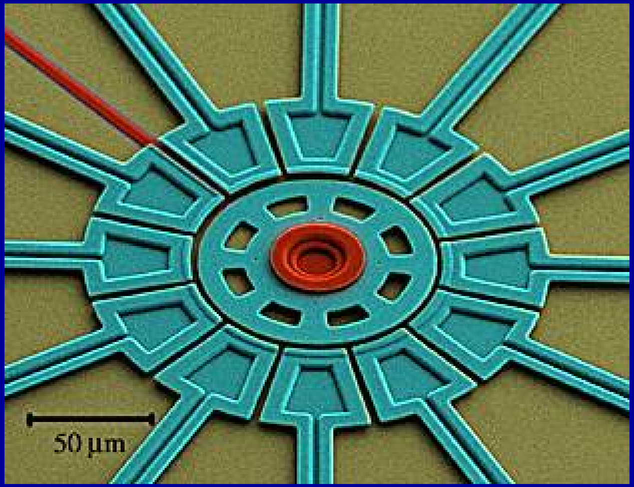
Nano technology 21st Century revolution!

Number of Nanotechnology-related Patents Identified by a Search of Titles and Claims of Patents in the USPTO Database



Source: Huang, Z., H. Chen, Z.-K. Chen, and M. Roco. 2004. *International Nanotechnology Development in 2003: Country, Institution, and Technology Field Analysis based on USPTO Patent Database. Journal of Nanoparticle Research*, 6:325-354.

MEMS
Micro-Electro-Mechanical-devices



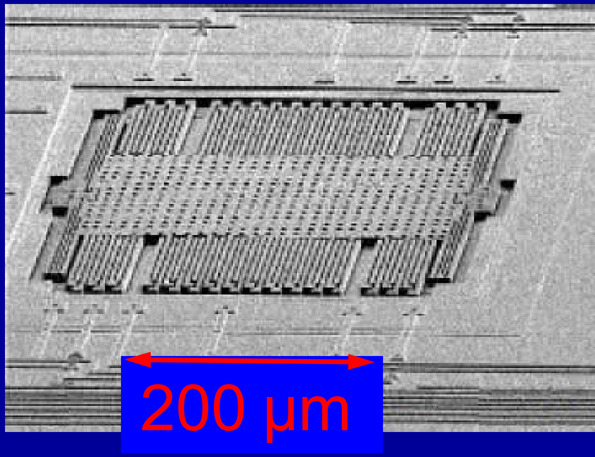
Electrostatically actuated micromotor made from polycrystalline silicon using surface micromachining techniques

Leg movements effected by heating pulses to polyimide joints. The size of the silicon legs is 1000x600x30 microns, and the overall chip size of the robot is 15x5x0.5 mm. The robot can carry 50 times its own weight with speed of 6mm/s.

http://fluid.ippt.gov.pl/nano/

Sensors

- **ISE – Ion Selective Electrodes** miniaturized analytical devices, which can deliver real-time and on-line information on the presence of specific compounds or ions in complex samples
- **Micro Total Analysis Systems (μTAS)** - integration of the whole analytical process on one chip - applications in biology and medicine during DNA, genome, and clinical measurement (lab-on-chip)
- **Electronic Nose (ETongue, ENose) -** micro systems for automatic analysis and recognition (classification) of liquids or gases, including arrays of non-specific sensors, data collectors and data analysis tools.
- **Acceleration sensors (airbag)**



Microfluidics
Fluid physics at the nanoliter scale

- **Microfluidics** refers to the research and development of micro-scale devices that handle small volumes of fluids, down to nano-, pico- and femtoliter volumes

- **Microfluidic devices** require construction and design differ from macro-scale devices. The dominant physical quantities change in the micro-world (scaling effect): the liquid flow tends to be laminar, surface forces and surface tension start to dominate, and therefore, phenomena that are not seen in the macro-scale become significant.

- **Microfluidic systems** have diverse and widespread applications, like inkjet printers, portable blood analysers, DNA and proteomic chips, Lab-On-a-Chip systems, and micro Total Analysis Systems.

- **Applications** in medical, biological and environmental sectors, in-vitro diagnostics, genetic analysis and functional genomics, chemical synthesis, drug screening, drug delivery, defence against biological and chemical weapons, environmental analysis, but include also information technology (DNA computer) and automotive industry.

Microfluidics
Fluid physics at the nanoliter scale

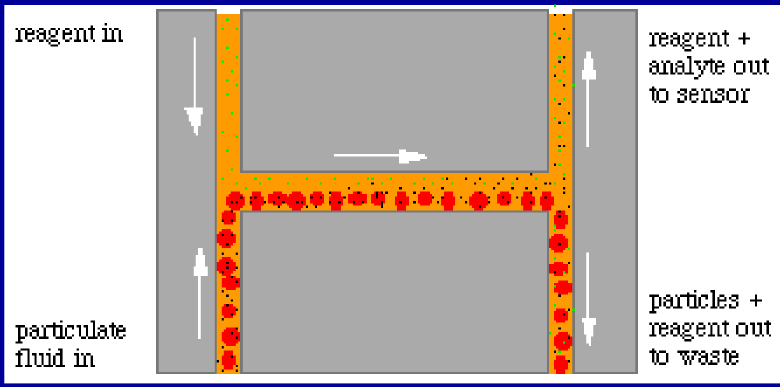
Important Dimensionless numbers

Re	Reynolds	inertial/viscous
Pe	Péclet	convection/diffusion
Ca	capillary	viscous/interfacial
Wi	Weissenberg	polymer relaxation time /shear rate time
De	Deborah	polymer relaxation time /flow time
El	elasticity	elastic effects /inertial effects
Gr	Grashof	Re for buoyant flow
Ra	Rayleigh	Pe for buoyant flow
Kn	Knudsen	slip length /macroscopic length

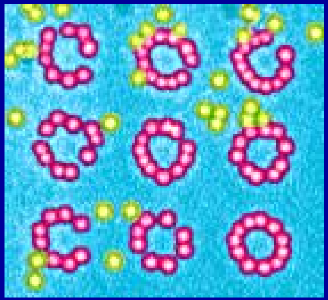
… and challenging computational methods (CFD for nano-scales)

Micro-Fluidics

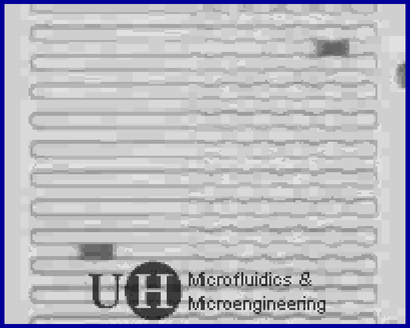
- H-filter - allows *continuous extraction of molecular analytes* from fluids containing interfering particles (e.g., blood cells, bacteria, microorganisms, dust, and viruses).



- Micro-mixer – 1um polystyrene spheres, trapped by nine helical rings of laser beam. The particles rotate at hundreds of rpm and entrain rapid flows from the surrounding fluid, acting as a micrometer-scale mixer.



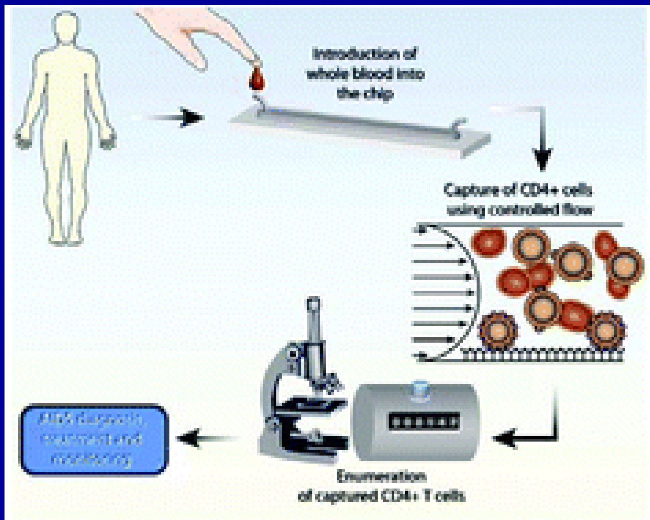
- Precision control of erythrocytes through silicon flow whose channels width varies sinusoidally The real time data processing allows infrastructural investigation of erythrocyte samples by precisely measuring both velocity and a volume index for each erythrocyte.



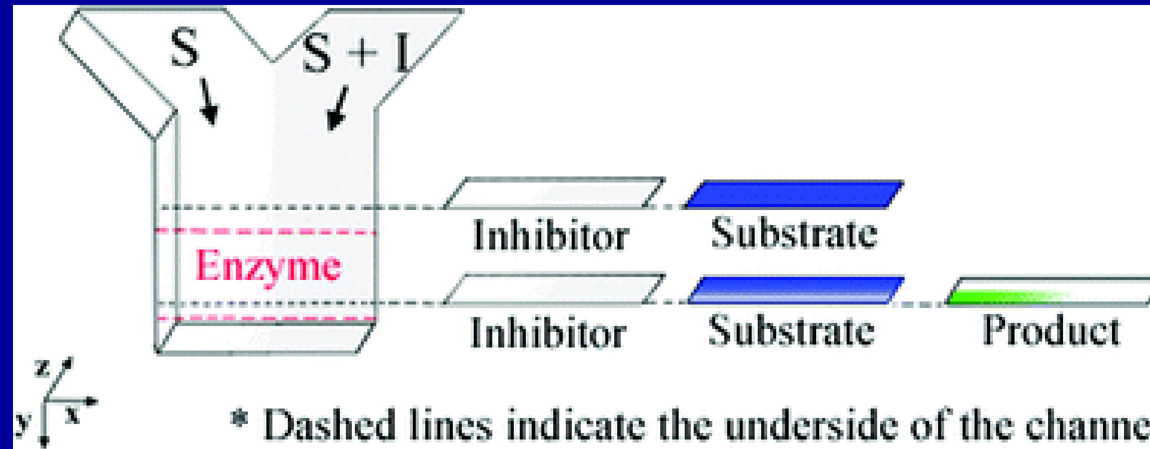
http://fluid.ippt.gov.pl/nano/

Lab on a Chip

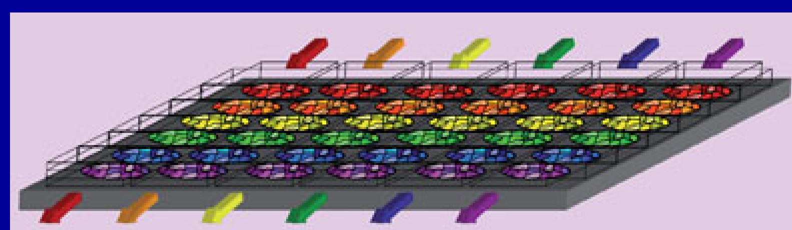
Google: 5210000 hits



Counting HIV with a chip. … ***A chip that allows rapid and easy detection of HIV infected cells in blood*** … **. , *Lab Chip*, 2007**



High-throughput screening of enzyme inhibition using an inhibitor gradient generated in a microchannel Elena Garcia, Melissa S. Hasenbank, Bruce Finlayson and Paul Yager, ***Lab Chip*, 2007**

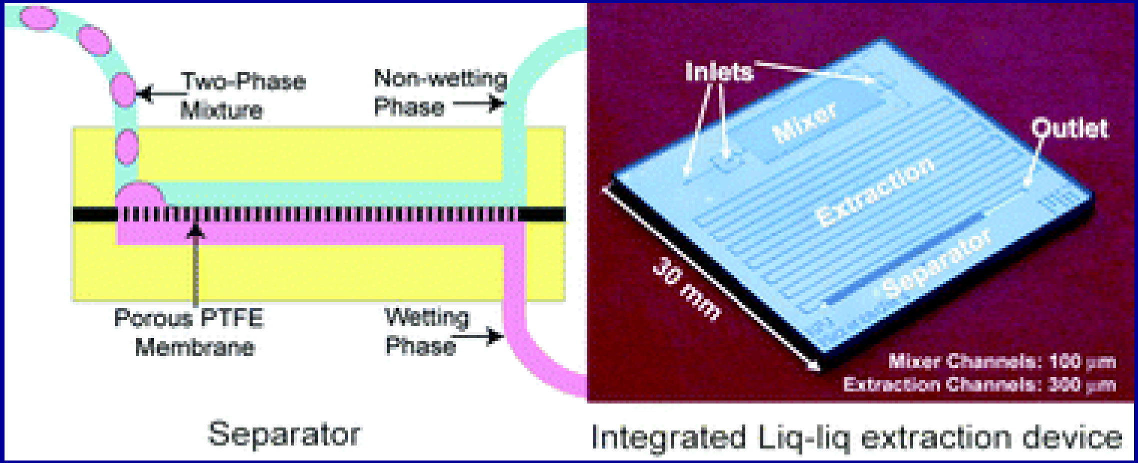


Microfluidic system to monitor gene expression continually, a so-called dynamic study. By altering the genes to express fluorescent proteins and exposing the cells to different conditions it can measure the effects on gene expression as a change in fluorescence

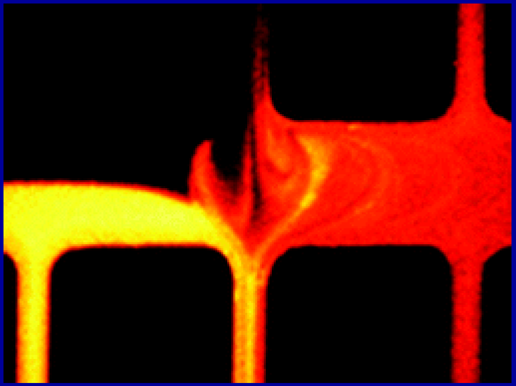
***Lab Chip*, 2007, 7, 77 - 85**

http://fluid.ippt.gov.pl/nano/

Lab on a Chip



Integrated continuous microfluidic liquid–liquid extraction
Jason G. Kralj, Hemantkumar R. Sahoo and Klavs F. Jensen, *Lab Chip*, 2007



An ultrashort mixing length micromixer: The shear superposition micromixer,
Frédéric Bottausci, Caroline Cardonne, Carl Meinhart and Igor Mezi, …
***complete mixing in under 10 ms within a length of 200 μm*. *Lab Chip*, 2007**

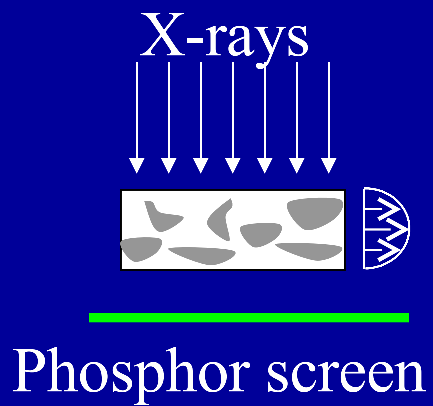
Specific Diagnostics Methods

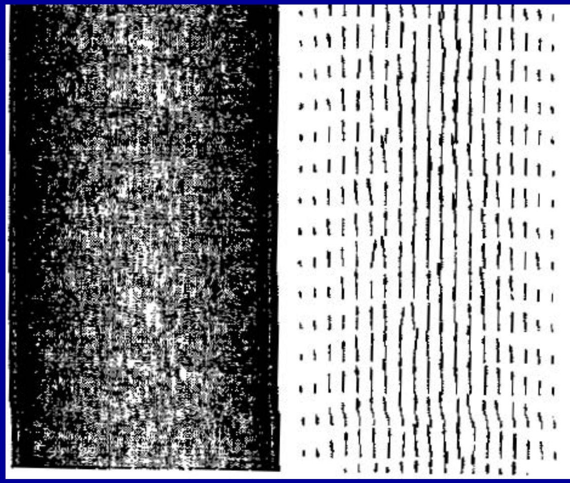
- Electrons
- X-Rays
- Visible Light
  - Dyes
    - Molecular Tagging Velocimetry
  - Particles
    - Micro Particle Image Velocimetry (μPIV)

X-ray Microimaging

Lanzillotto, et al., *Proc. ASME*, 1996, AD52, 789-795.

- Positives
  - Can image inside normally opaque devices
- Negatives
  - low resolution ~20-40μm
  - depth averaged (2-D)
  - requires slurry to scatter x-rays
  - requires collimated x-rays



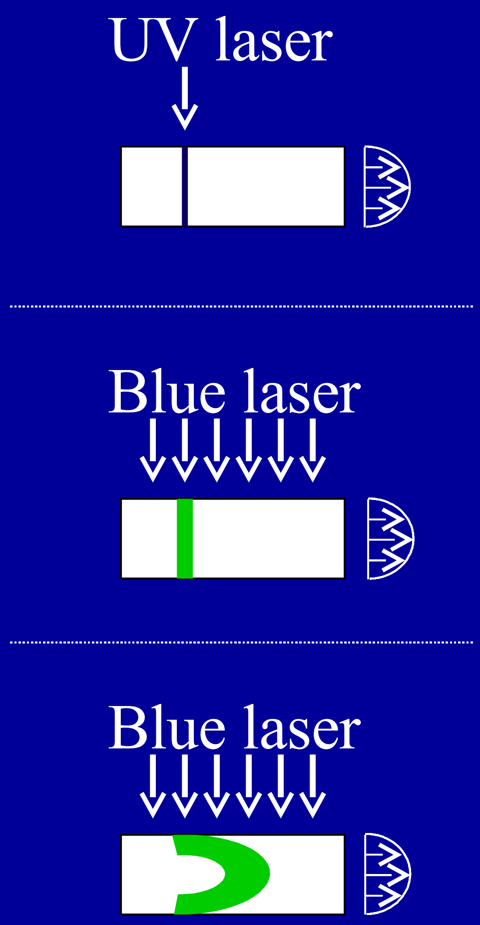


Raw Image & Calculated Velocity

Molecular-Tagging Velocimetry

Paul, et al., *Anal. Chem.*, 1998, **70**, 2459-2467.

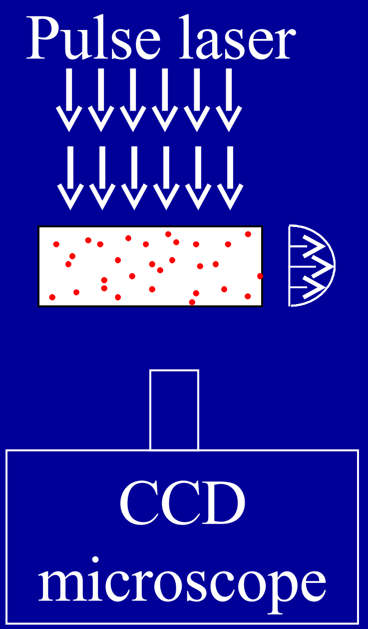
- Positives
  - minimally intrusive
  - better with electrically-driven flows
  - works with gas or liquid flows
- Negatives
  - low resolution ~20-40μm
  - depth averaged (2-D)
  - greatly affected by diffusion
  - must invert convection eq.



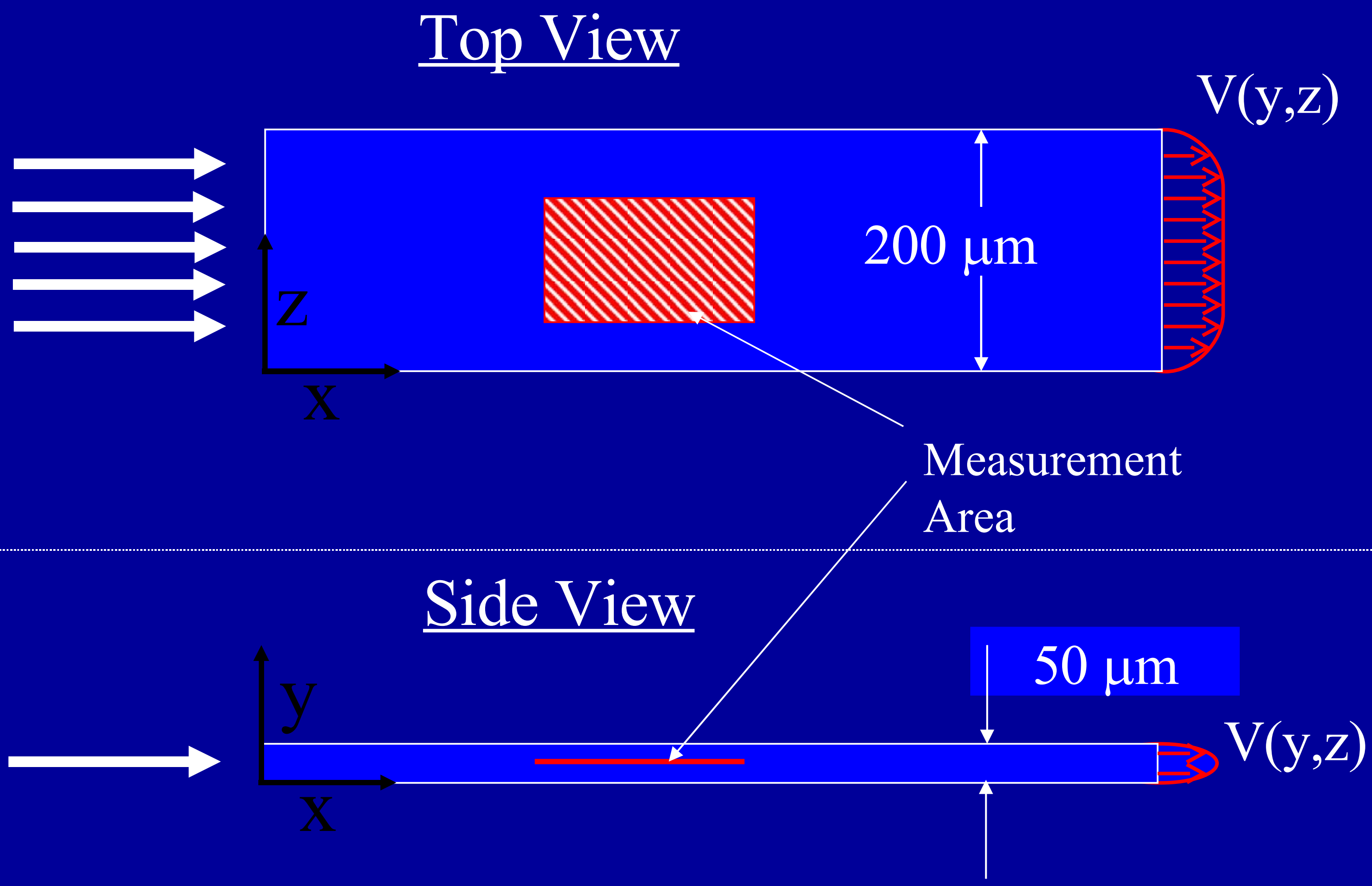
Micro-Particle Image Velocimetry(m-PIV)

Santiago, et al., *Exp. Fluids*, 1998, **25**(4), 316-319.

- Positives
  - high resolution ~1 μm
  - small depth average ~2-10 μm
  - minimally intrusive
- Negatives
  - requires seeding flow
  - particles can become charged



µPIV Velocity Field Measurements



Differences between μPIV and conventional PIV

- Brownian motion of nm-scale tracers

$$\varepsilon_B = \frac{\langle s^2 \rangle^{1/2}}{\Delta x} = \frac{1}{u}\sqrt{\frac{2D}{\Delta t}}$$ where $$D = \frac{\kappa T}{3\pi\mu d_p}$$

  Zero-mean noise source

  <u>Large sample number reduces effect</u>

- Typically minimal optical access

  volume illumination and wavelength filtering

  low particle concentrations

- Miniscule signal reflected from tracer particles

  Rayleigh scattering range ($d_p \leq \lambda$)

  very inefficient scattering

  use fluorescent particles to eliminate background

An Essential Ingredient:
Correlation Averaging

Three techniques involve the same operations

- 1. Acquire image fields
  - *ensemble average*
- 2. Correlate image fields
  - *ensemble average*

$$R_{AB} = \int A(X)B(X+s)dX$$

- 3. Determining velocity vector from peak in correlation
  - *ensemble average*

Operations (2) and (3) are nonlinear and don't commute.

(Delnoij, et al., 1999; Meinhart, et al., 2000)

Comparison of Averaging Techniques

(Meinhart, Wereley, Santiago, JFE, 2000)

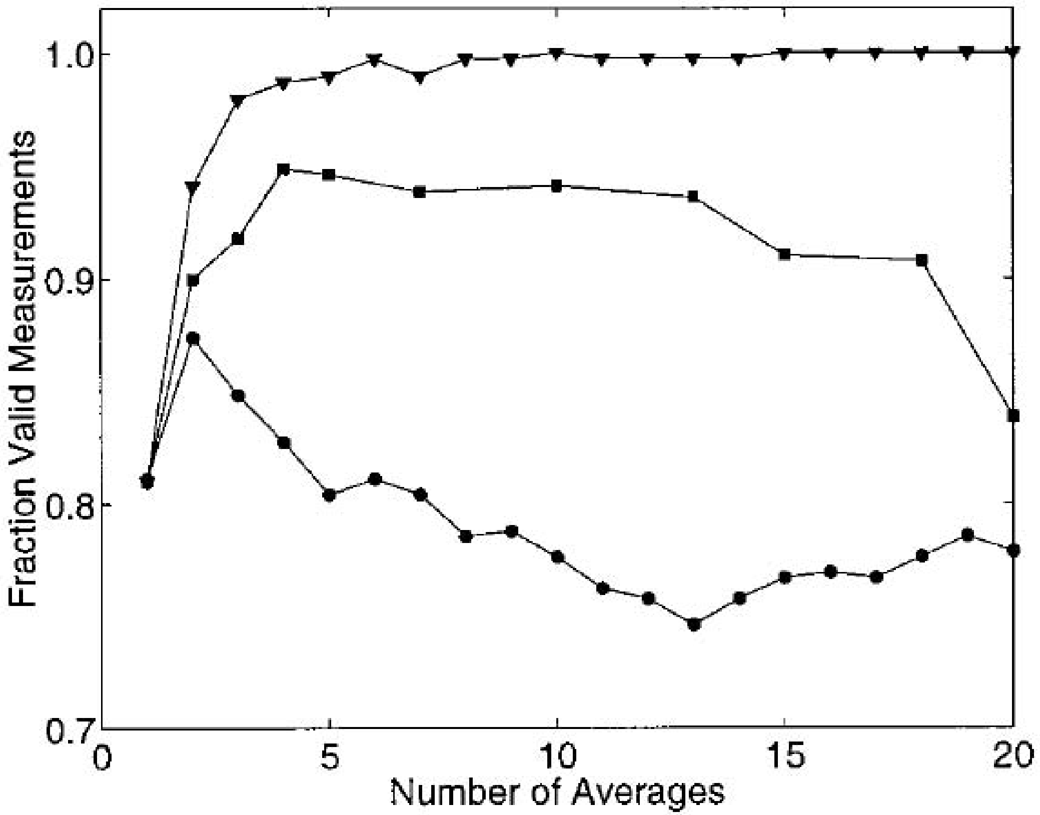


Fig. 4 Comparison of the performance of the three averaging techniques: average velocity ●, average image ■, and average correlation ▼

- Average velocity (●) can't work really well
- Average image (■) improves results for moderate numbers of images, then degrades
- Average correlation (▼) saturates for large sample numbers

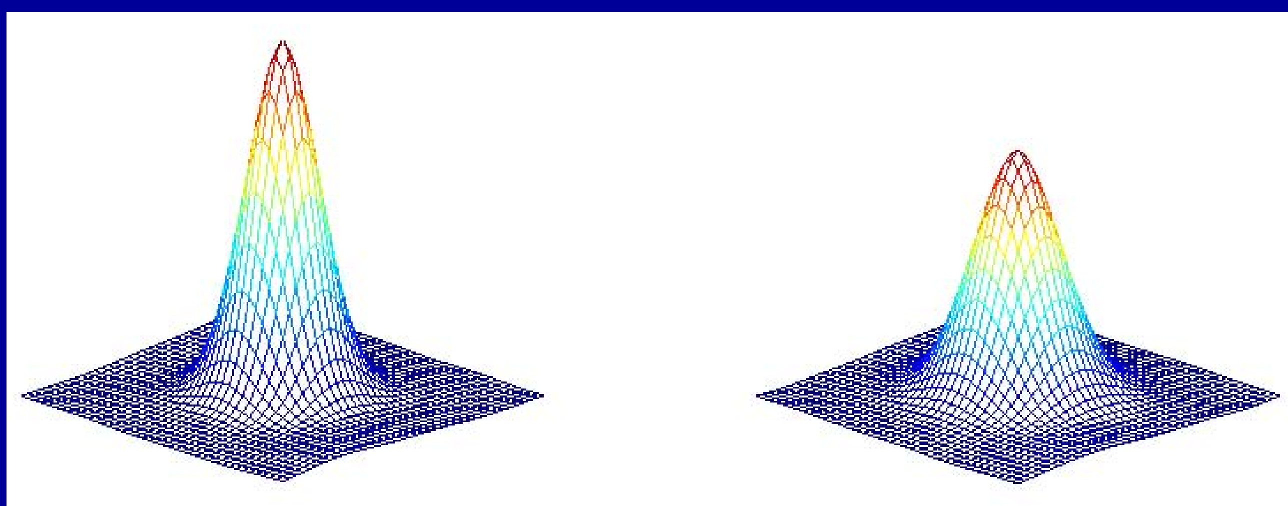
Other things you can do with μPIV

- Based on diffusion of tracers can assess
  - Temperature of fluid
  - Particle Size
  - Turbulence intensity
- Using linearity of Stokes flow can
  - Extract wall details
- Working with infrared can see through some materials
- Reduce correlation window to single pixel
  - Submicron spatial resolution

Relating Temperature to Peak Area Change

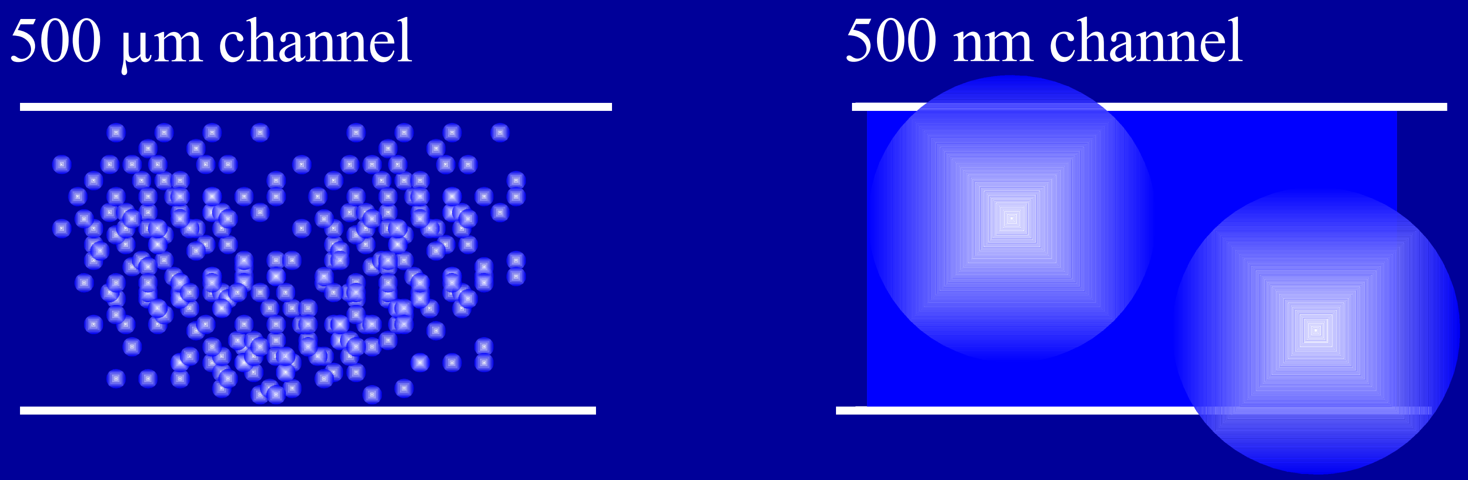
- Based on Brownian motion of tracers broadening correlation peak
- Einstein (1905) developed formula for diffusion coefficient

$$\left\langle s^2 \right\rangle = 2DDt \quad \text{where} \quad D = \frac{kT}{3pmd_p}$$



Beating Diffraction Effects: nano-PIV

- For circular aperture diffraction unbiased blurring of particle image
- Microscope spot size ~λ
- Places some limitations on analysis but does not eliminate light as a tool for nanoscale measurements



Nano-PIV Tracers

- Molecular tracers – 50nm
- Bacterial tracers
- Quantum dots – semiconductor crystals of 2 -16nm (10-50 atoms)!

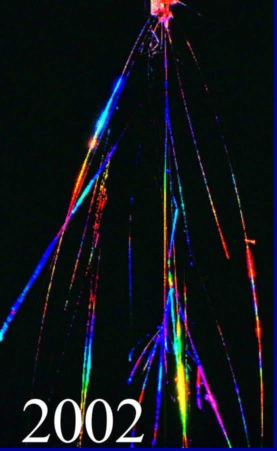
Exp. Fluids 2006, Kenneth Breuer, Brown University

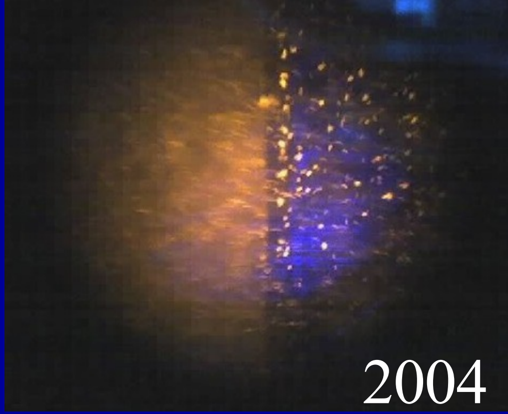
Fluorescence of CdSe quantum dots

D. Talapin, University Hamburg

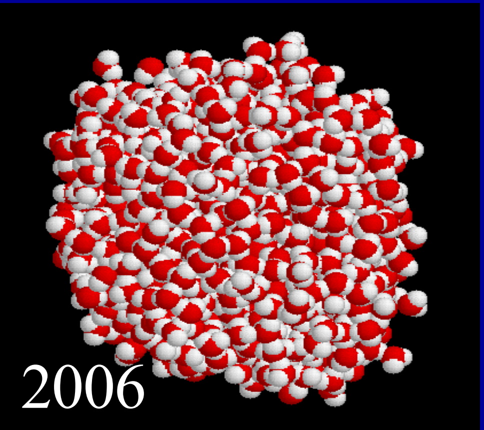
μFlow measurement

- Variety of techniques available for spatially-resolved view of flow
  - X-Ray Microimaging
  - Molecular Tagging Velocimetry
  - Micro Particle Image Velocimetry
- With μPIV many quantities available
  - Velocity
  - Temperature
  - Particle size
  - Turbulence intensity
  - Boundary location
- Possible with μPIV to work below the diffraction limit



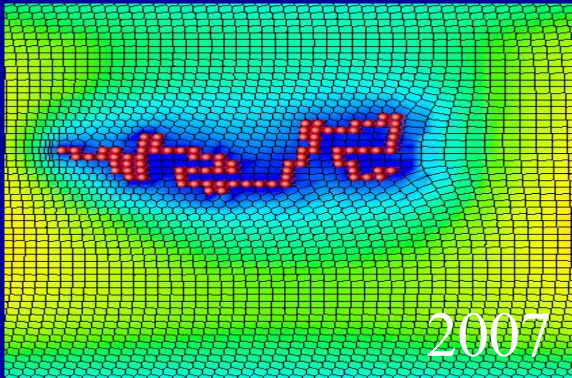


Micro-
&
Nano-fluidics



Where we are?

ZMiFP – 2007



Experimental labs

Equipment

- **Full Field Measurements:**
- High Speed Camera (up to 40 000 frames per second)
- 2D & 3D high resolution PIV system (1.2 K x 1K)
- PIV systems with 3 CCD colour and B&w cameras
- High speed PIV, microPIV system.
- Laser CW Ar 3W
- Double Pulse Laser Nd-YAG (2 x 30 mJ), 10ns

- **Point Measurements:**
- 3 components hotwire sensors (100kHz)
- High accuracy temperature recording (±0.01K)
- Precise pressure transducers

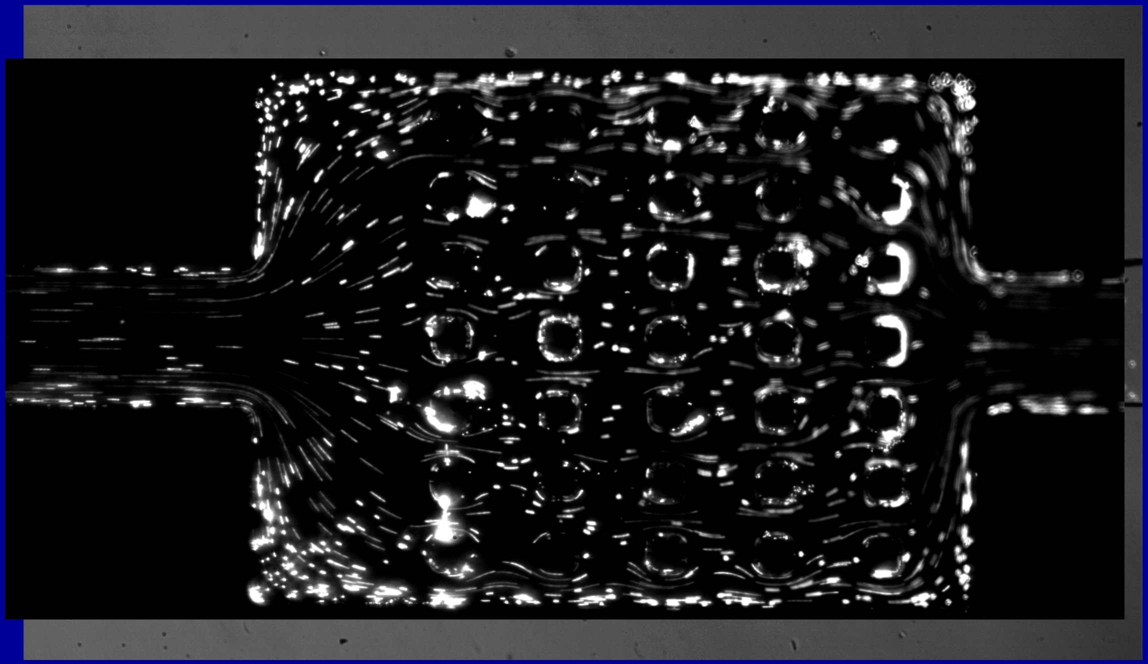
Experimental labs

Equipment -> expected soon for our new lab

- High speed laser for micro-PIV
- Atomic Force Microscope
- Environmental Scanning Electron Microscope
- Laser scanning microscope
- Nano-manipulator System
- Clean room for nano- and bio- experimentation
- Nanotomograph

Lab-on-Chip, manipulating molecules, DNA in pore, gene expressio

Micro-PIV application for flow visualization



20fps

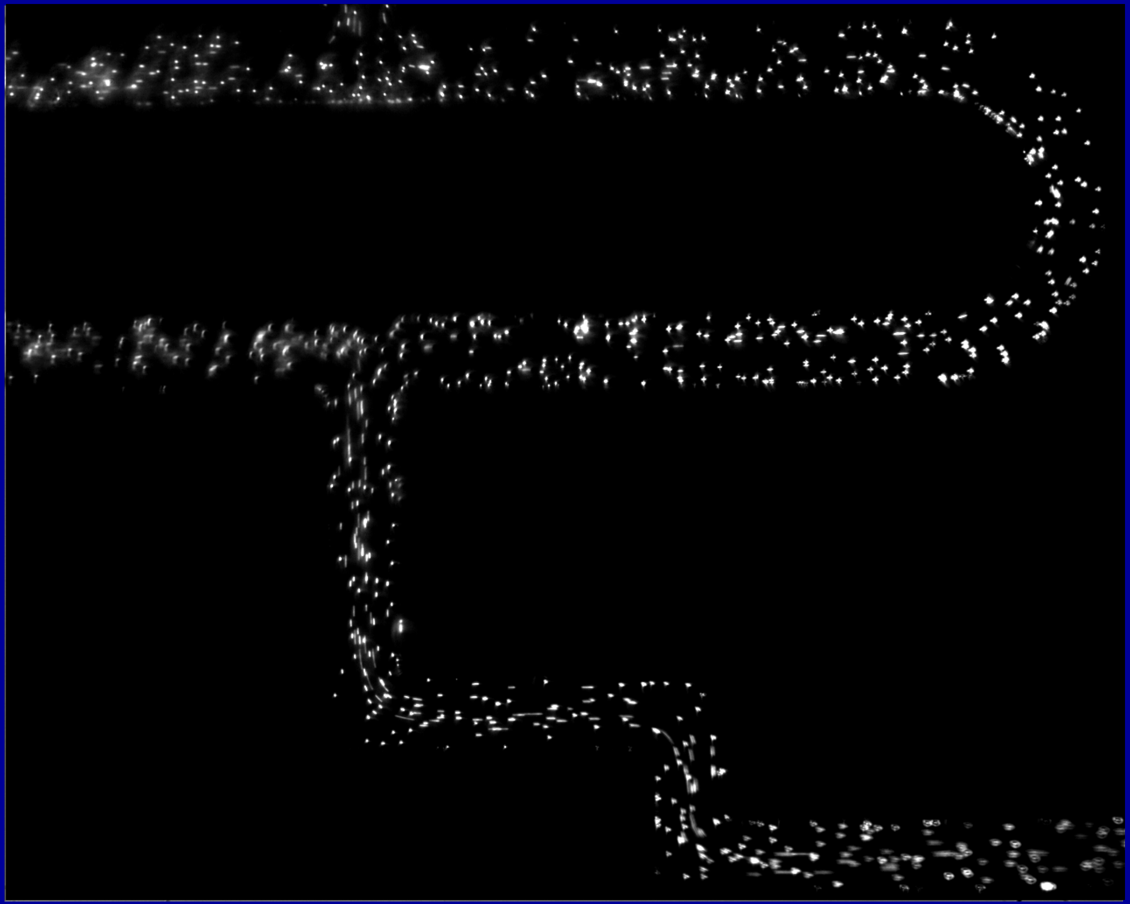
Laser Ar CW 5W

1536 µm

Flow passing micro-palisade

Channel width : 200µm, fluorescent tracers 2µm

Micro-PIV application for flow visualization



40fps

Laser Ar CW 5W

Flow in micro-mixer

Channel width : 100μm, fluorescent tracers 2μm

Micro-PIV application for drop production control

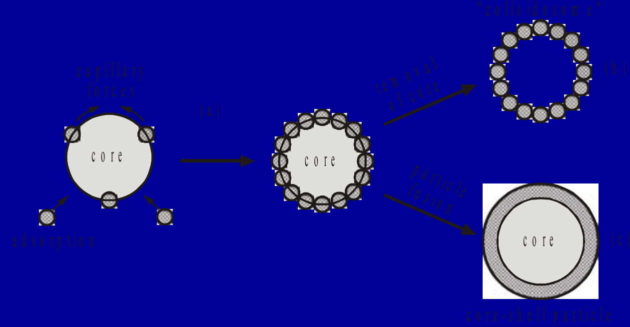
Micro and nano-droplets or bubbles - tool for:

- chemistry: massive chemical tests in micro-reactors
- medicine: drugs delivery (lungs, brain etc)
- biotechnology
- biology: cell response
- optics
- material science: matrix for new material fabrication

Controlled production of uniform droplets:

- drop on demand devices
- micro-fluidic devices
- shear/turbulent drops break-up in micro-channel

massive production

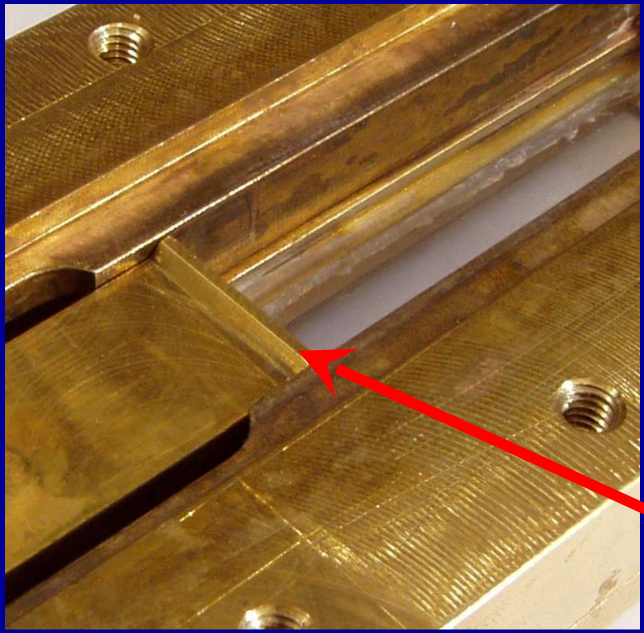


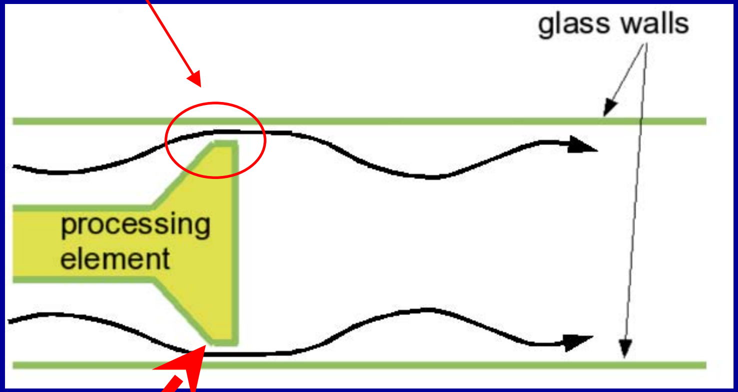
CONEX Project

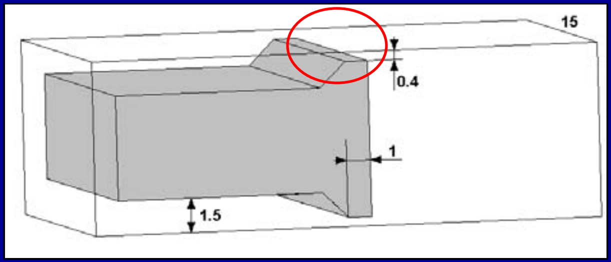
Production of droplets emulsion in turbulent flow

Emulsifier with optical access for flow investigation

micro-channel



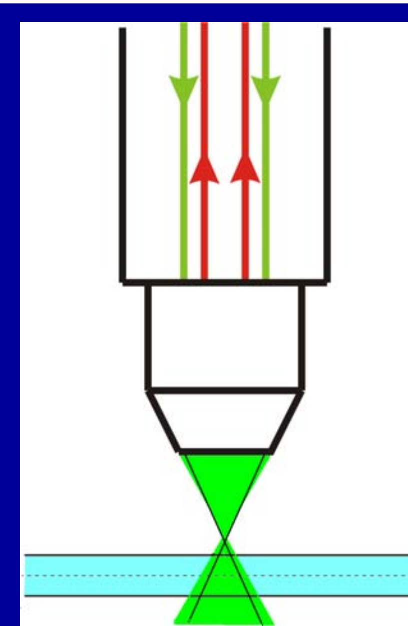




High speed imaging and velocity measurements

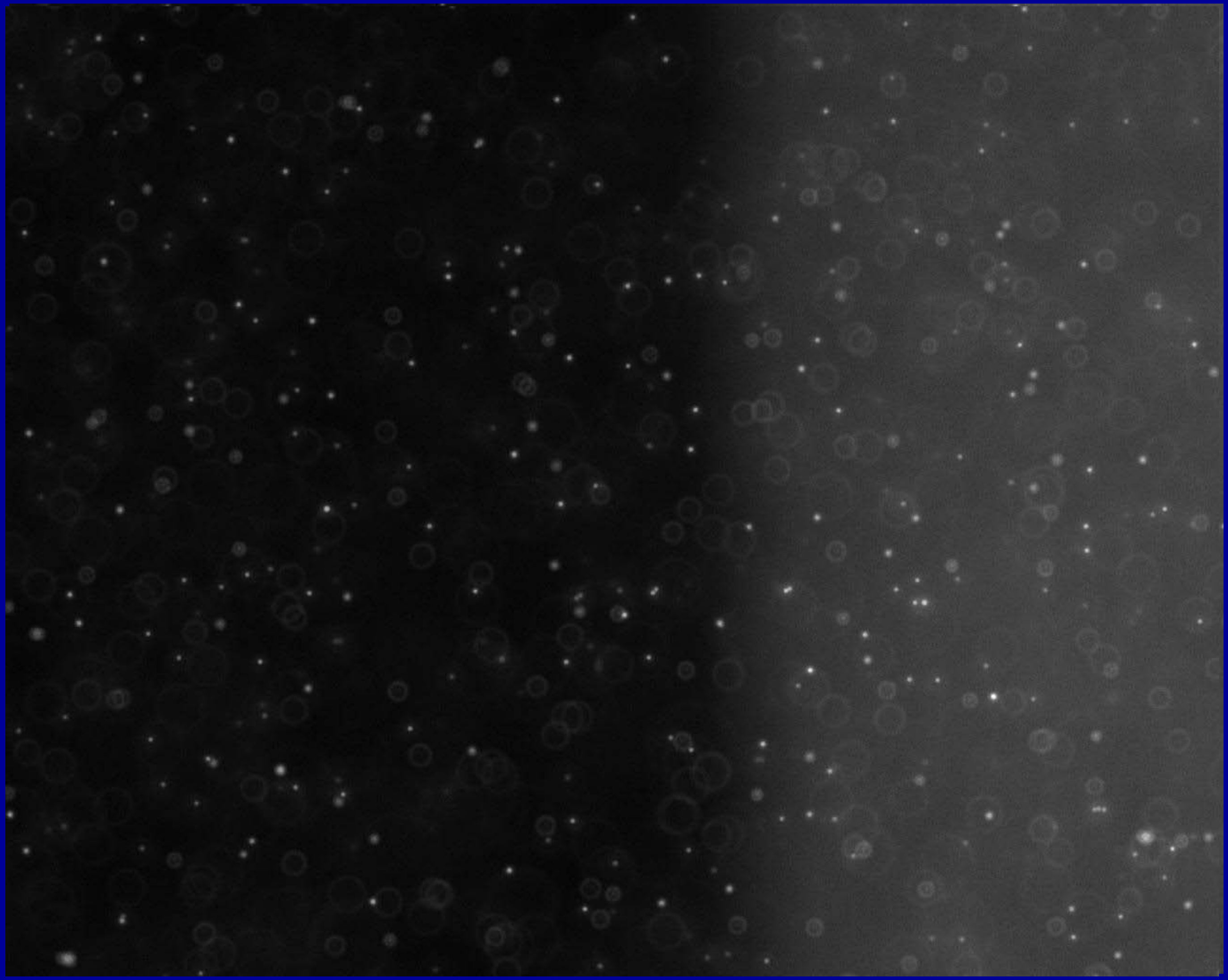
gap: 0.4mm x 15mm, flow rate: up to 0.204 *dm³/s*,
Characteristics Reynolds Number Re=8000

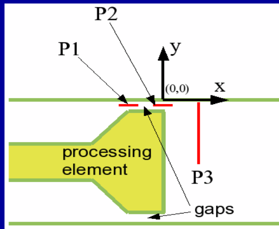
EXPERIMENTAL SETUP



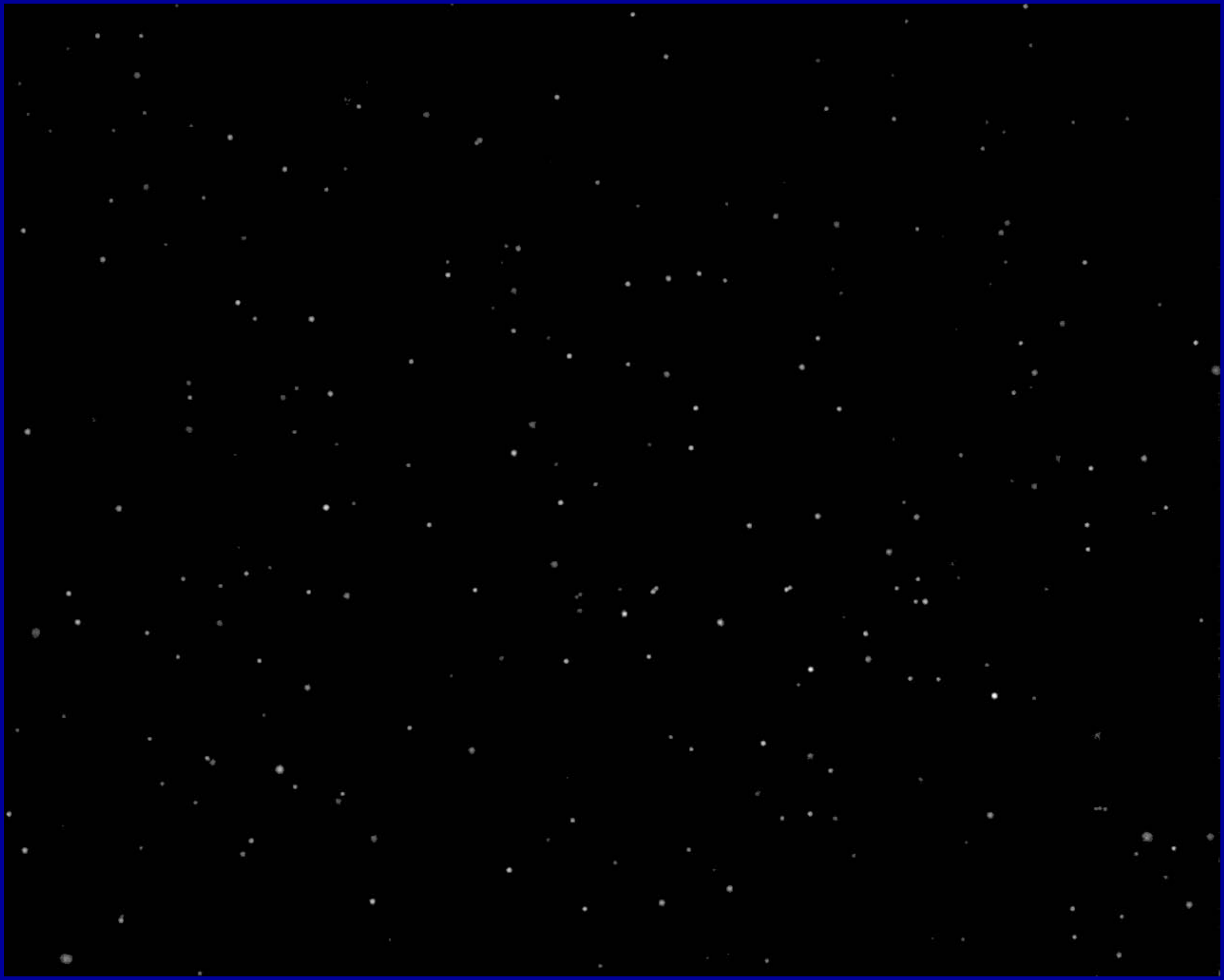
- PIV Camera – *PCO SensiCam* (resolution 1280x1024)
- High Speed CMOS Camera – *PCO 1200.hs* (up to 40720 fps)
- Double Pulse Laser Nd-YAG - *SoloPIV NewWave* (30mJ per pulse)
- Laser CW Ar 5W

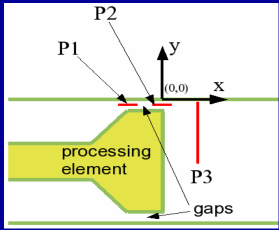
Double shot of tracers





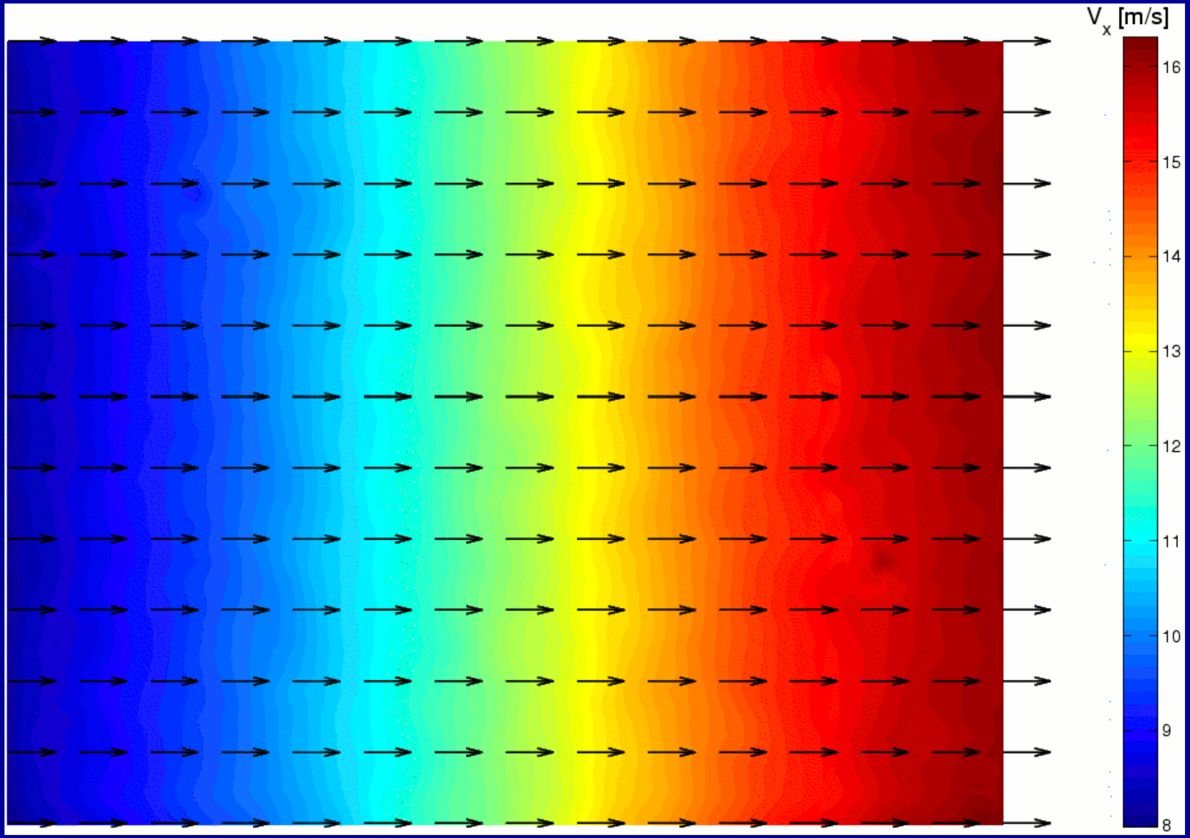
Filtering

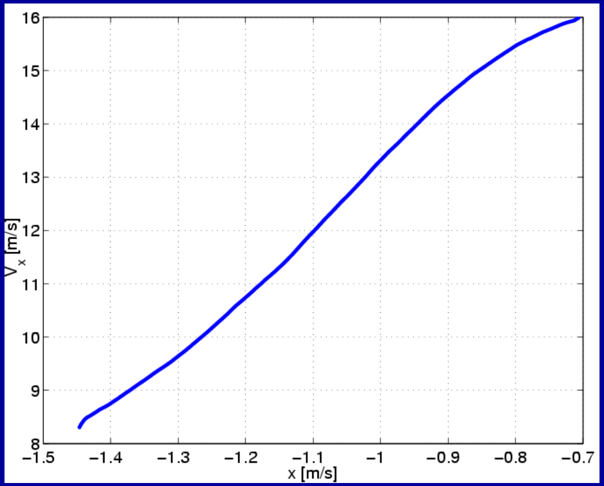


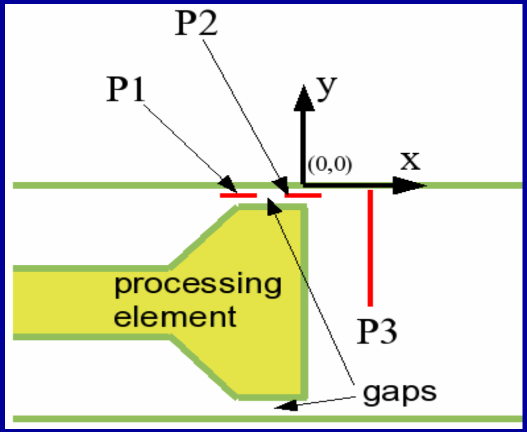


Micro-PIV RESULTS

Average velocity field





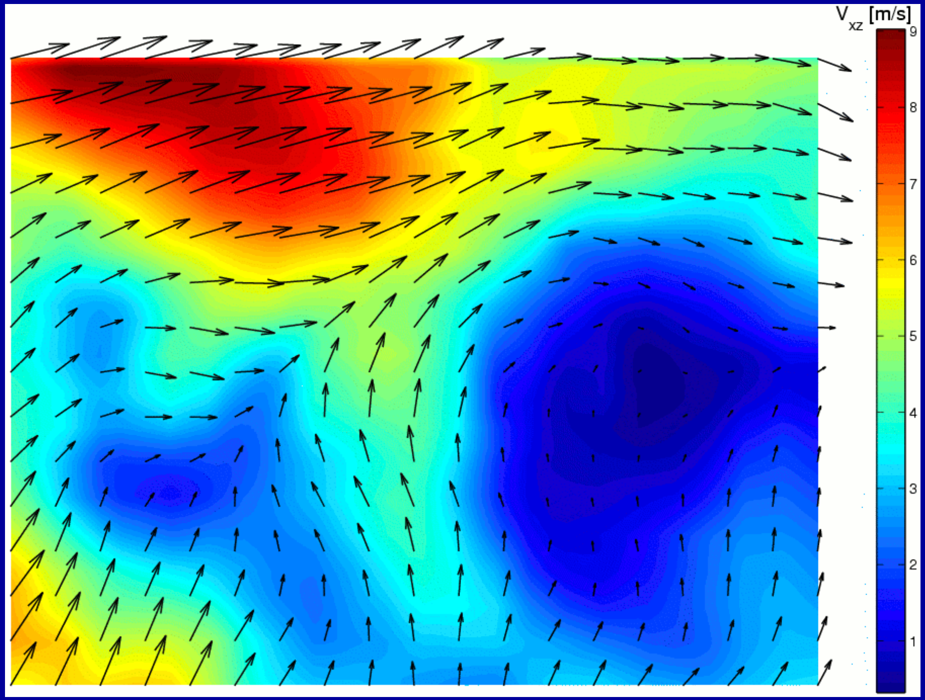


Position P1

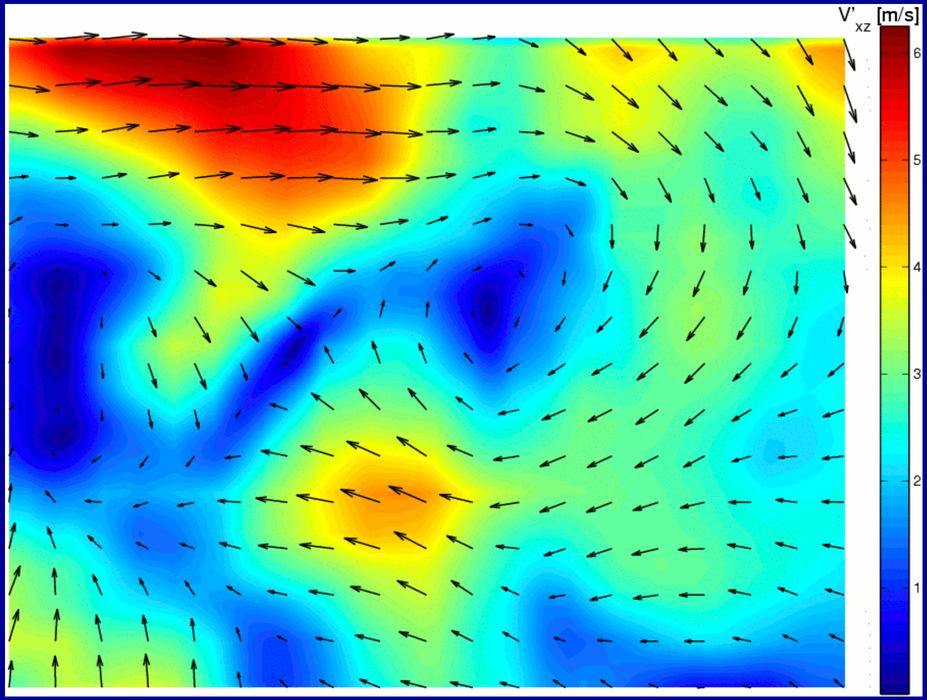
flow rate = 0.204 dm^3/s

Micro-PIV RESULTS

Instantaneous velocity field and fluctuations field

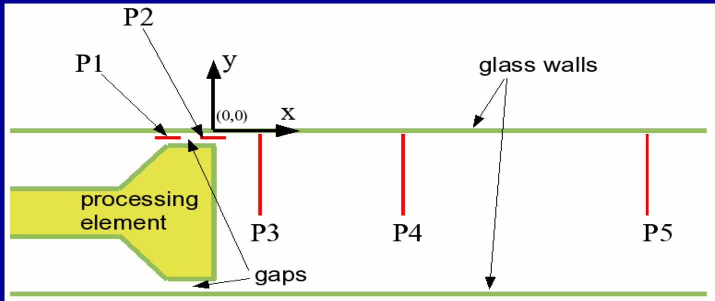


velocity field



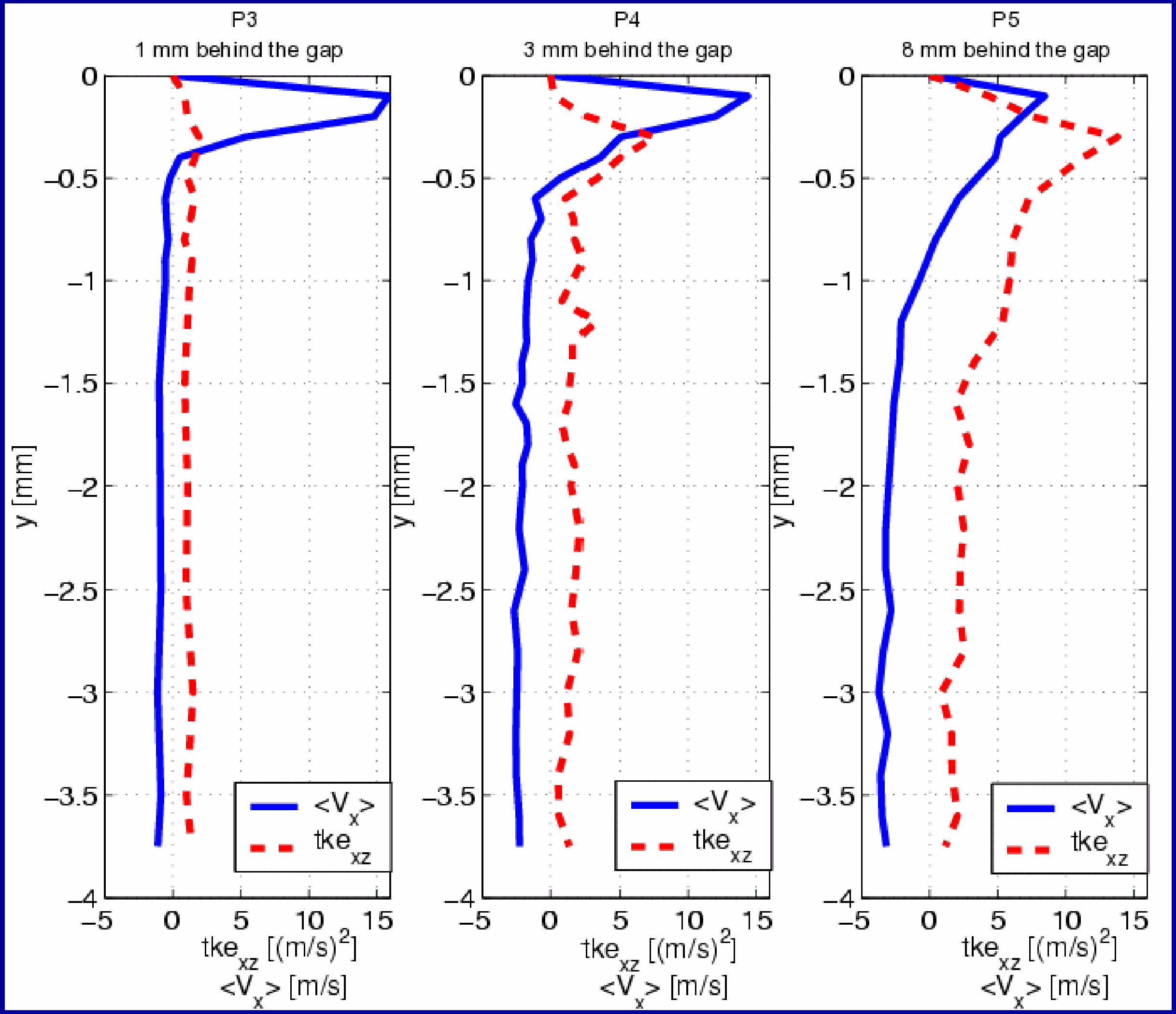
fluctuations field

Position P4: 3mm behind, 0.3mm below glass wall



Micro-PIV RESULTS

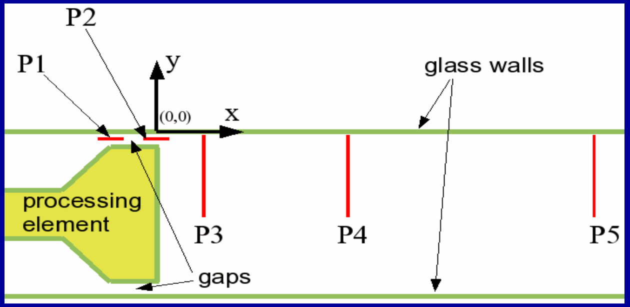
P3, P4 and P5 profiles of the X-Velocity and mean turbulent kinetic energy (xz)



$V_x = <V_x> + V'_x$

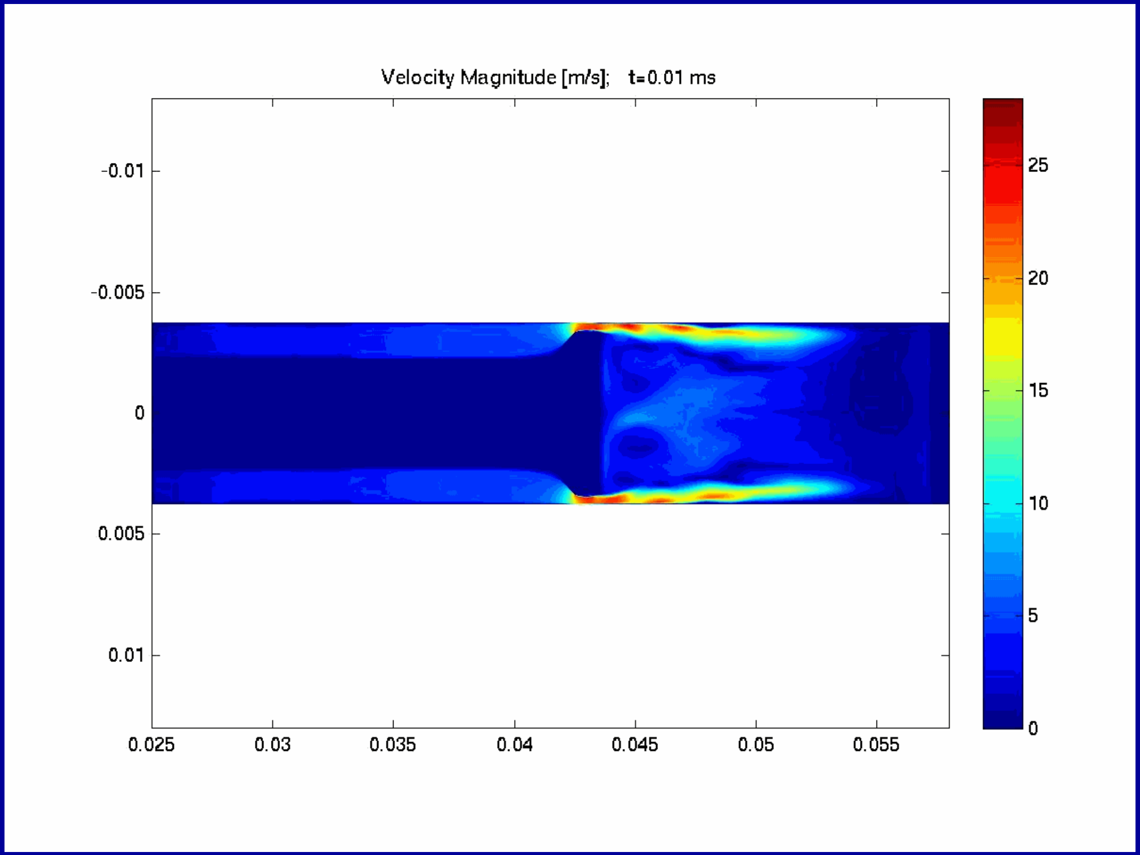
$V_z = <V_z> + V'_z$

$tke_{xz} = <V'^2_x> + <V'^2_z>$



NUMERICAL SIMULATION

Contours of averaged velocity magnitude

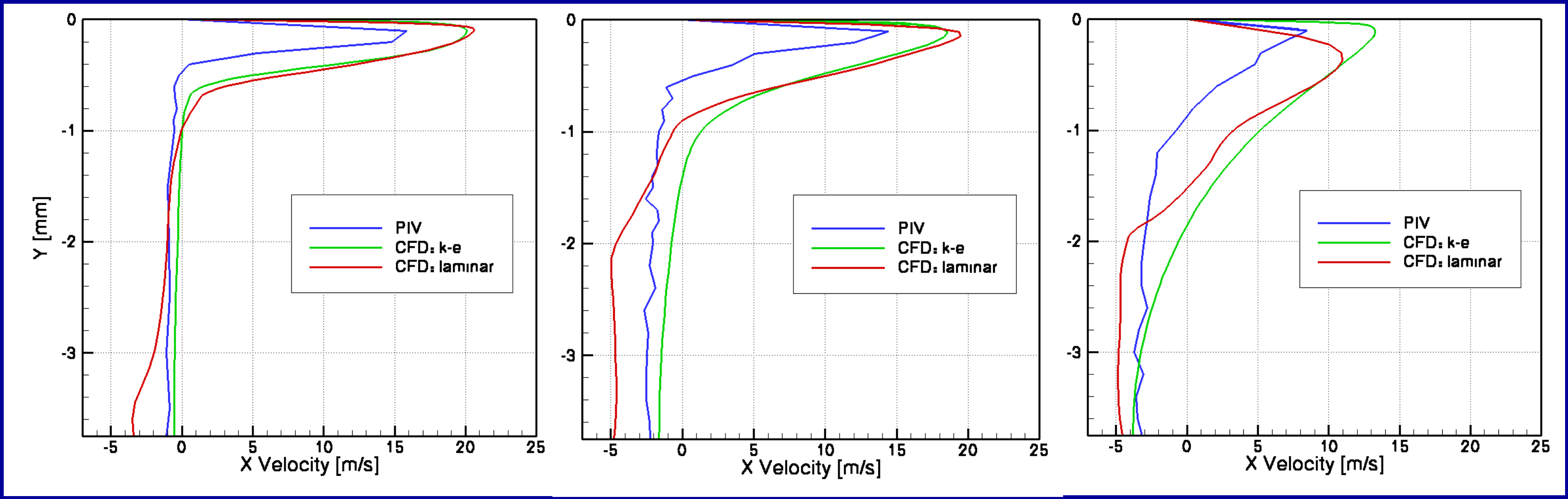


DNS simulation, Q_2 = 0.204 dm^3/s

time step $\Delta t = 1 \cdot 10^{-7}$ s

NUMERICAL vs. EXPERIMENTAL RESULTS

Comparison of the numerical and experimental x-velocity profiles:



1mm (P3) **3mm (P4)** **8mm (P5)**

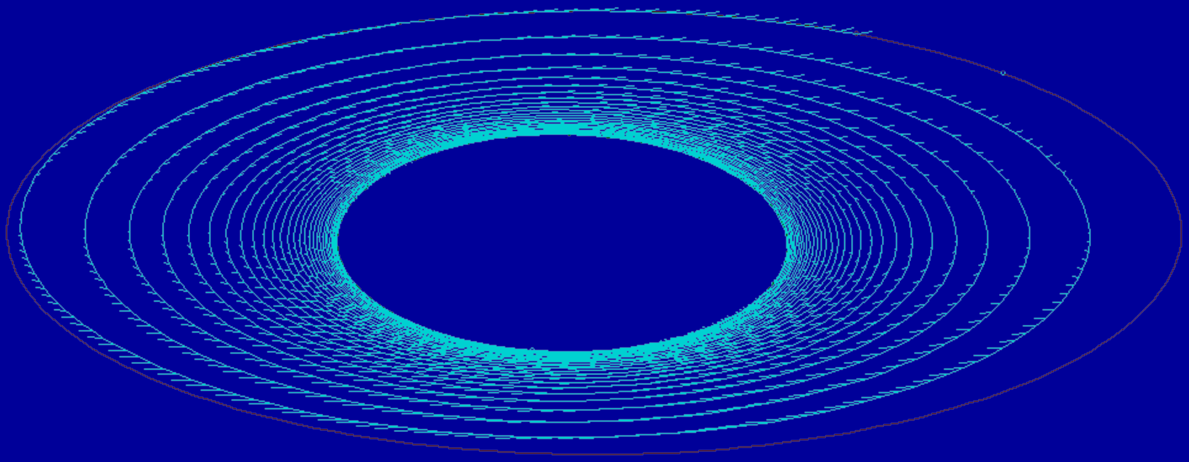
behind processing element

<u>CFD:</u> k-ε turbulence model

DNS

Q = 0.204 dm^3/s

Experiments and Modelling of Electrospinning Process



Spider web

NANOFIBRES

Nanofibres background

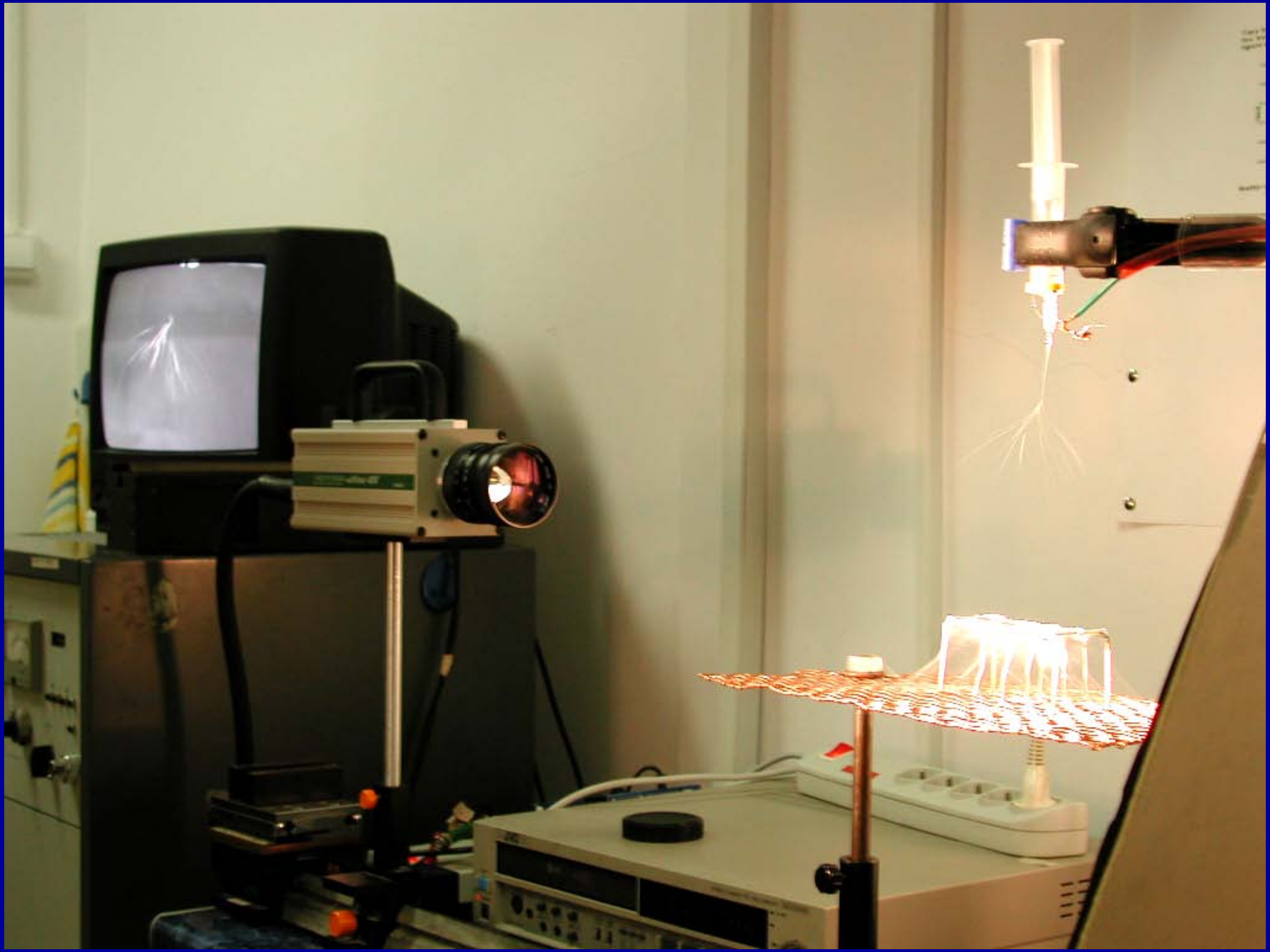
1. Nanofibres properties

   - Increase of the surface to volume ratio -> solar and light sails and mirrors in space
   - Reduction of characteristic dimension -> nano-biotechnology, tissue engineering, chemical catalysts, electronic devices
   - Bio-active fibres: catalysis of tissue cells growth
   - Mechanical properties improvement -> new materials and composite materials by alignment in arrays and ropes

2. Nanofibres production:

   - Air-blast atomisation
   - Pulling from melts
   - Electrospinning of polymer solutions

Nanofibres – basic setup



http://fluid.ippt.gov.pl/nano/

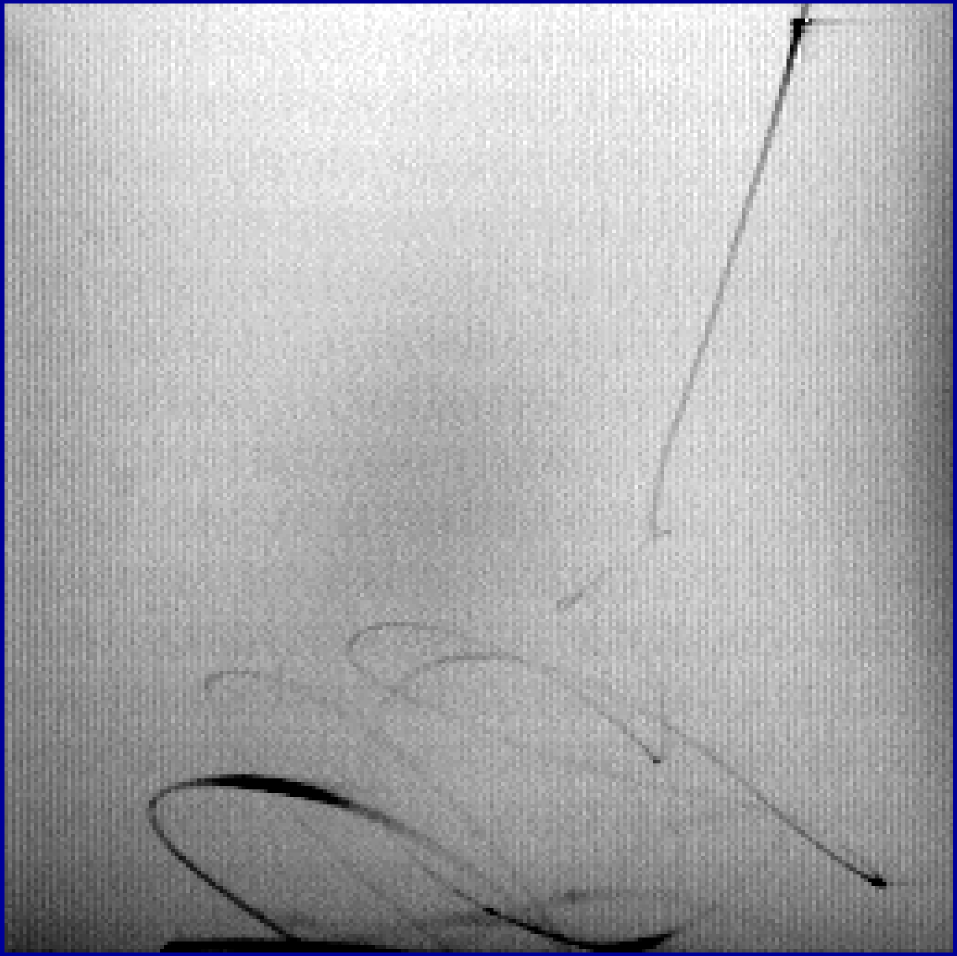
Nanofibres collection

http://fluid.ippt.gov.pl/nano/

Nanofibres collection

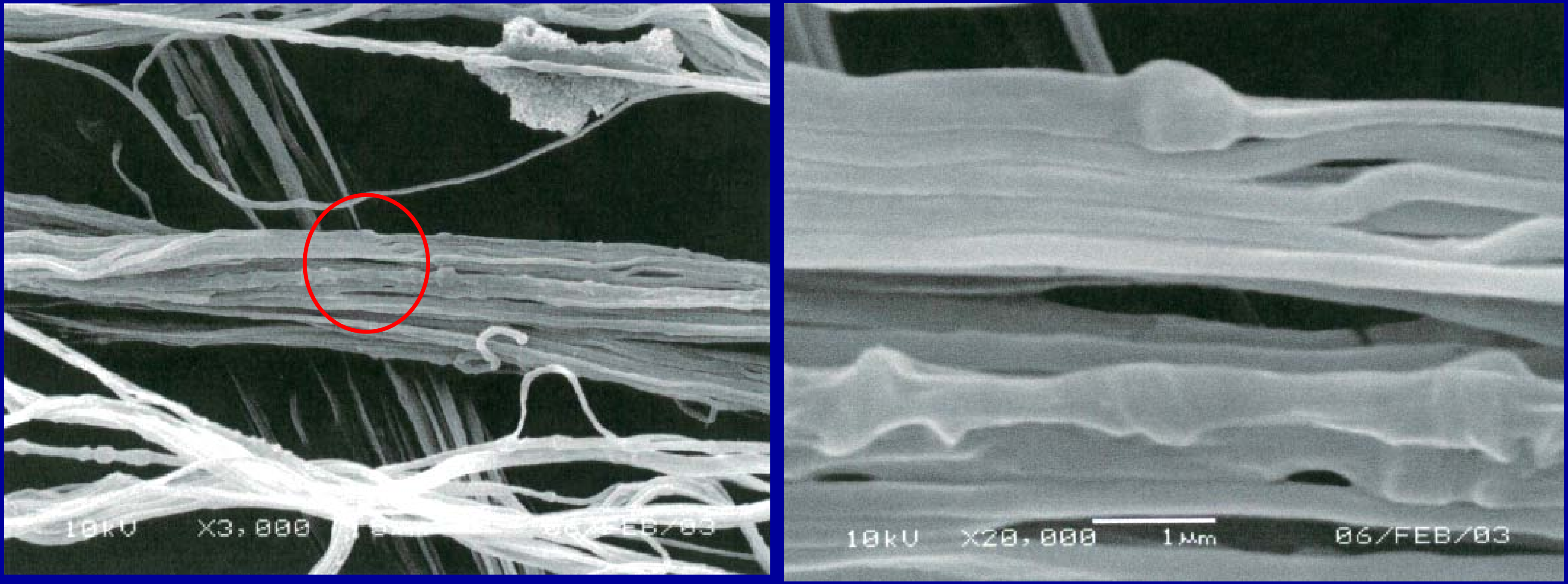
Electrospinning observed at 4500fps

5 cm



Average velocity of the fibre: 2 m/s

Electron microscopy

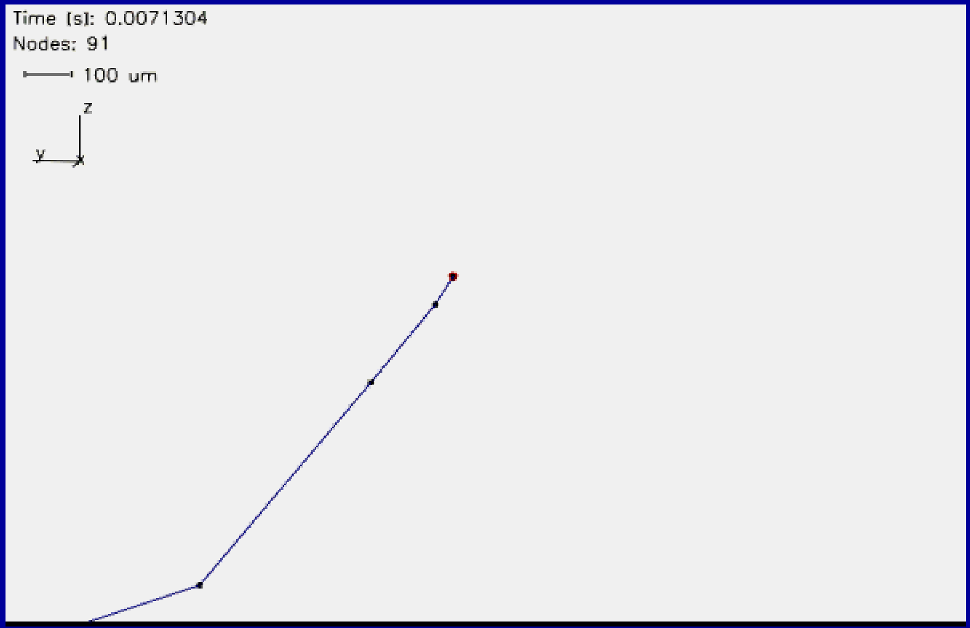


PEO nanofibres

α = 0.07 N/m
Φ = 5000 V
μ = 10 Pa.s
$G = 10^5$ Pa
$\rho = 1000\ kg/m^3$
a_0 = 150 μm
H = 20 cm
l_0 = 1 μm
$q = 200\ C/m^3$
$Q = 3.6\ cm^3/h$

Numerical model

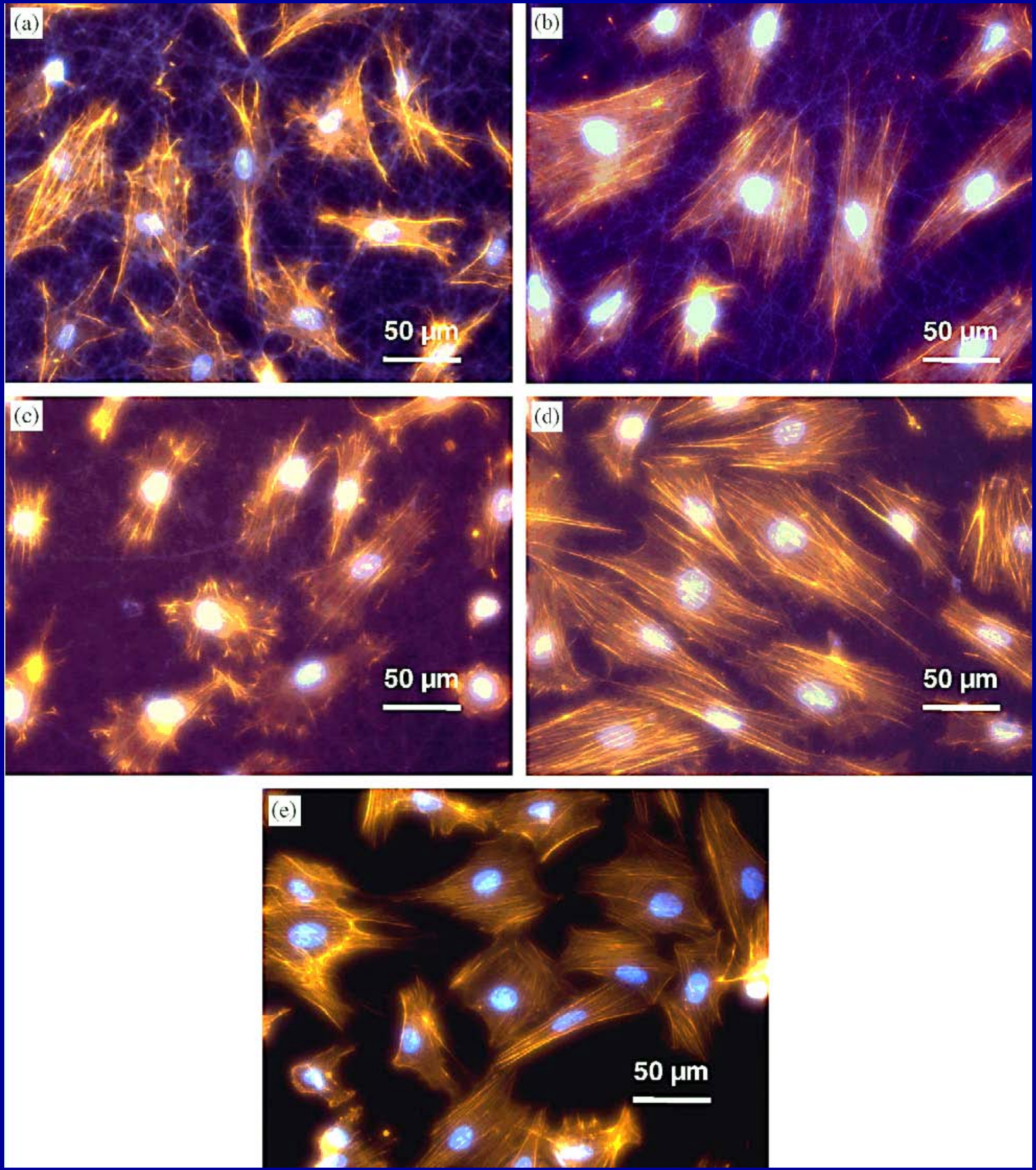
Reference case:



Near future applications => electrospinning of bio-materials.

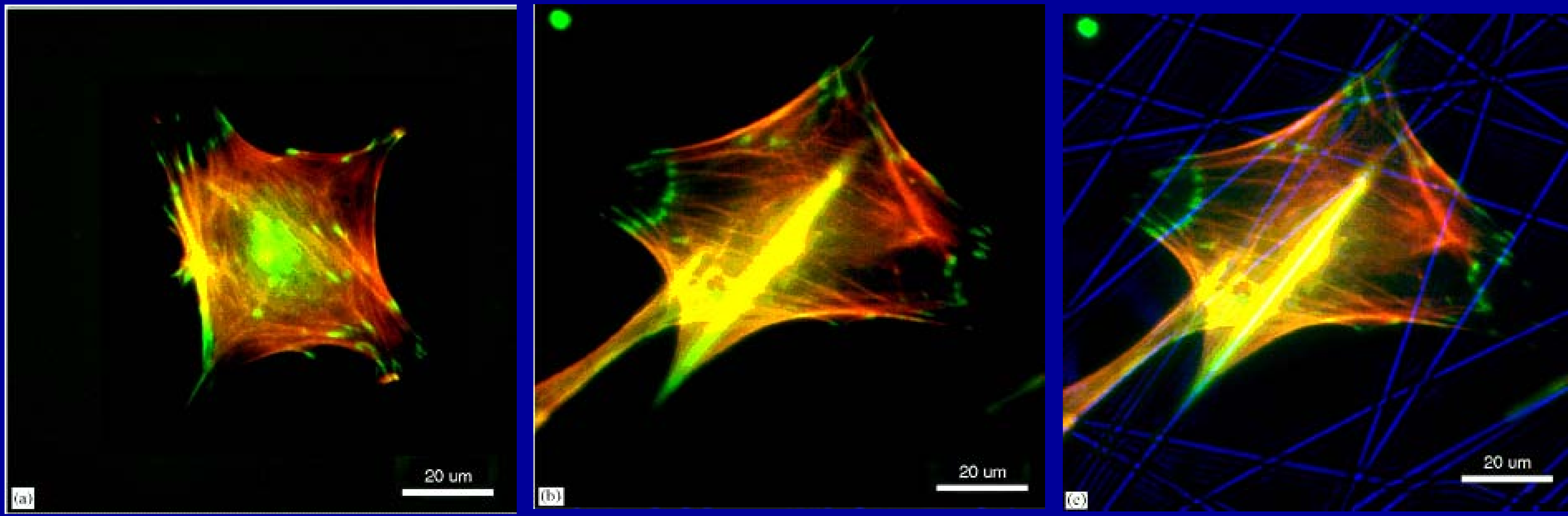
- Bio-absorbable polymer membranes,
  nanofibre membranes containing natural proteins and enzyme
- Biodegradable scaffolds for tissue engineering
- Natural extra cellular collagen matrix built of nano-fibers
- Drugs encapsulated in electrospun polymer matrix
- Nanofibres produced from chitosan
- Electrospinning of poly(ethylene-co-vinyl alcohol) copolymer
  and its use for tissue cell culturing and wound dressing

Electrospinning nanofibers for tissue engineering applications



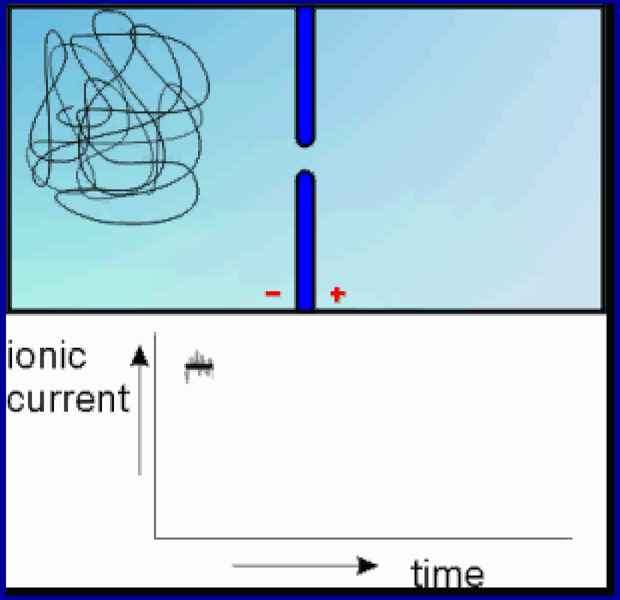
Mangyan et al, Biomaterials 27 (2006) 2705–2715

Osteoblastic cells on electrospun substrates



Immunofluorescent staining of adherent cells on (a) spin-coated PDLLA, and (b) 2.1 um PDLLAfibers. Green corresponds to vinculin; blue corresponds to actin. (c) Immunofluorescent staining image (b) superimposed onto a phase contrast image of PDLLAfibers (Anand et al.., Biomaterials 27, 2006).

Micro-Flow and Nano-fibers



Translocation of polymers blocks ionic current

Detecting DNA structure in 10nm nano-pores
A.J. Storm, TU Delft, 2004

Micro-
&
Nano-fluidics

What can be done ?

ZMiFP 2007 -2017

Part 2

Micro- and Nano-Fluidics Laboratory. We have lift up!

Micro- and Nano-Flows: Challenges in Fluid Mechanics

part 2

dr inż. Justyna Czerwinska
Micro- and Nano- Fluidics Laboratory
Department of Mechanics and Physics of Fluids
Institute of Fundamental Technological Research
http://fluid.ippt.gov.pl/nano

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List of Proposals

Ideas

- Thermal And Viscous Transport Effects in Nanofluids(TAVTEN)
- Non-equilibrium Effects Micro- And Nanofluidics (NEMAN)
- Electrospinning of nanofibers optimization (ELSPINOPT)

Cooperation

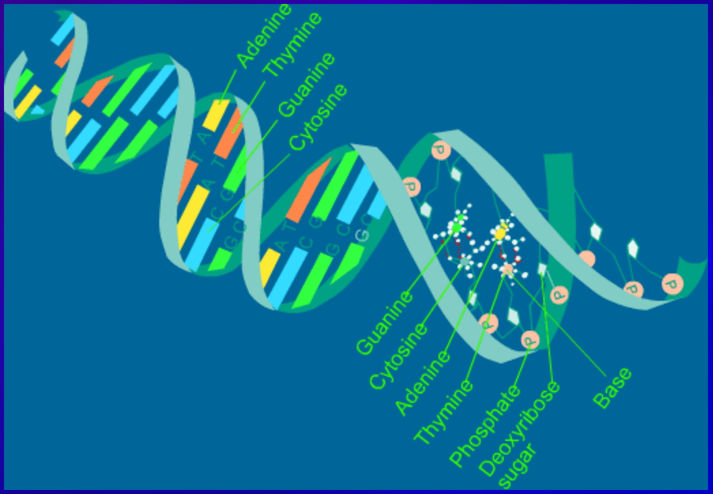
- Flow Efficient DNA Amplifier (FEDA)
- Mesoscopic modeling Applied to Cell manipulation; Lab-On-Chip design (MACLOC)
- Drug delivery system based on nanofibers and polymers membranes: production modelling and application (DDSNANOFIB)

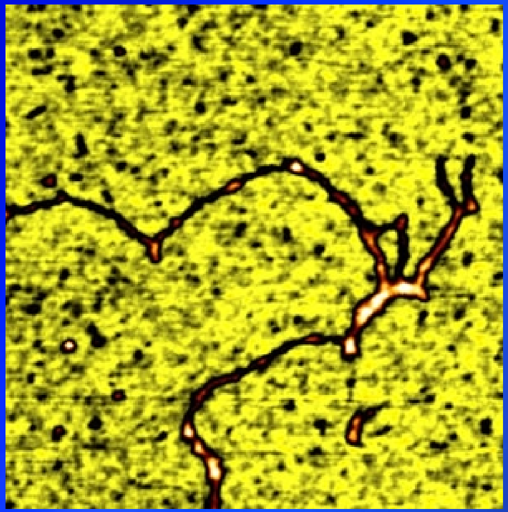
Center of Excellence

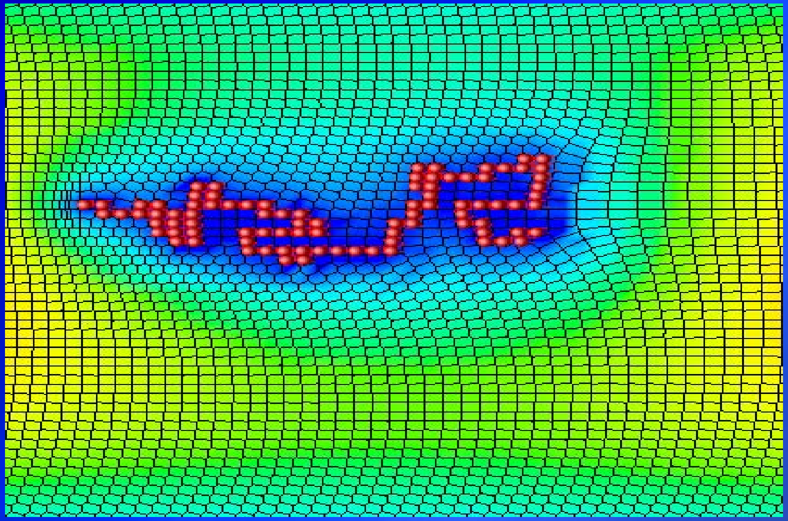
- NANOfluids: Simulations, Experiment and Theory (NANOSET)

FEDA - *Flow Efficient DNA Amplifier* (COOPERATION)

Motivation Cheap (currently about 2500USD) and more efficient (currently ~ 11h) DNA multiplication tool







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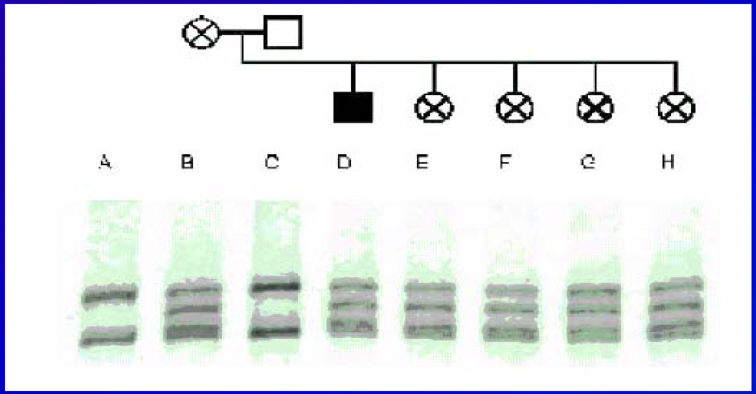
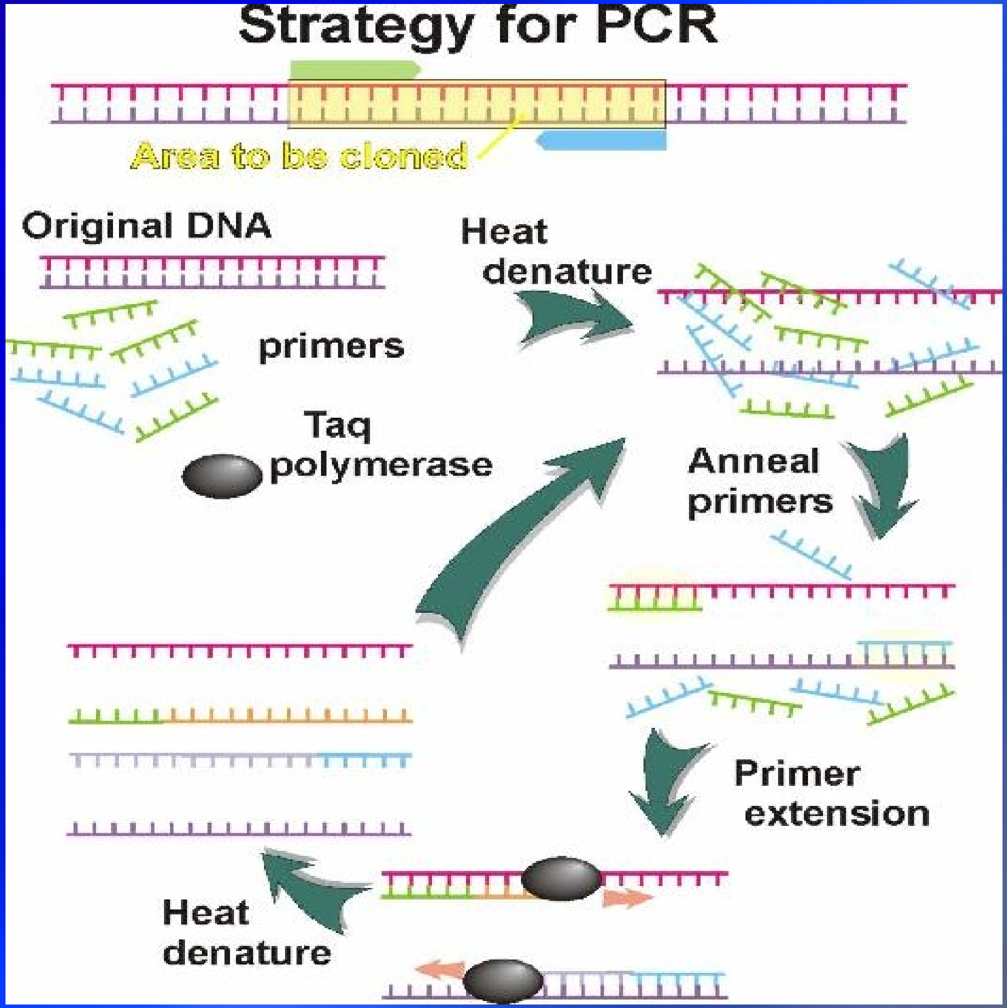
FEDA - *Flow Efficient DNA Amplifier* (COOPERATION)

Polymerase chain reaction enzymatically replifying DNA





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techniki elektroforetyczne

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FEDA - *Flow Efficient DNA Amplifier* (COOPERATION)

AIM

- Models and experimental investigation of the flow structures to increase every step of PCR process
- Obtain efficient (time and cost) DNA amplifier.

COOPERATION PARTNERS

- KTH Stockholm, Sweden
- U. Strathclyde, UK
- U. Limerick, Ireland
- LIMSI Paris, France
- ESPCI Paris, France
- Erlangen University, Germany
- Dortmund University, Germany
- Institute of Physical Chemistry PAN, Warsaw, Poland

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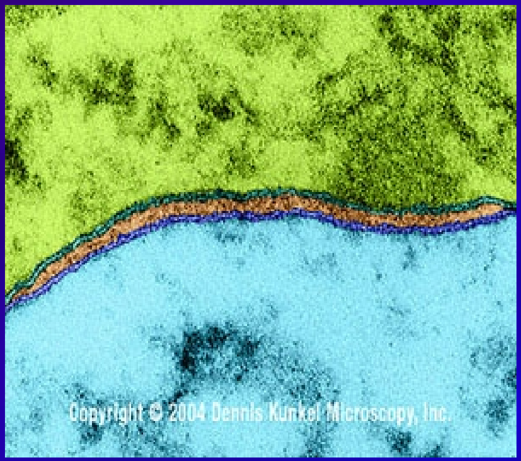
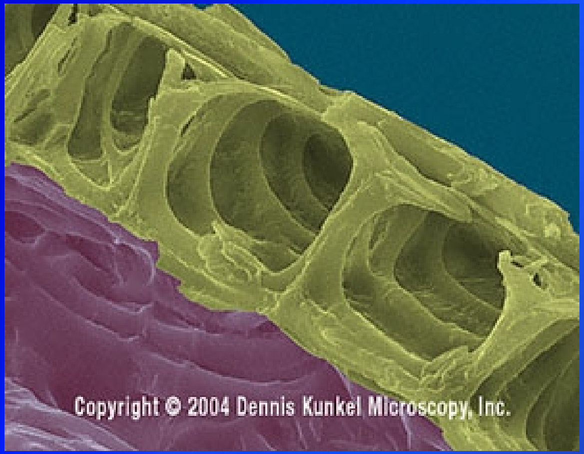
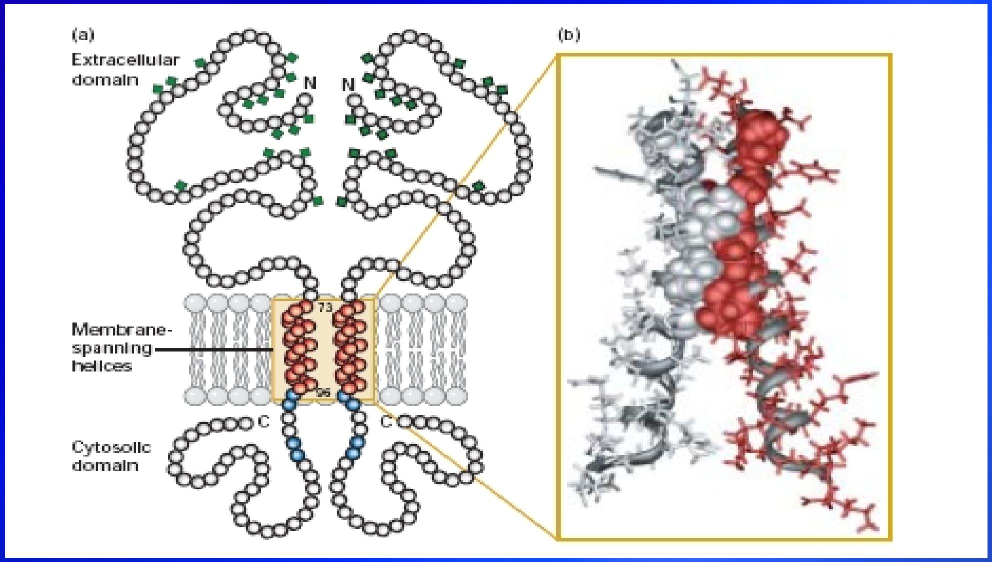
DDSNANOFIB - *Drug delivery systems based on nanofibers and polymer membranes: production, modeling and application* (COOPERATION)

Motivation New type of Drug Delivery Directly to the Cell







Mesoscale Description
Molecular Description

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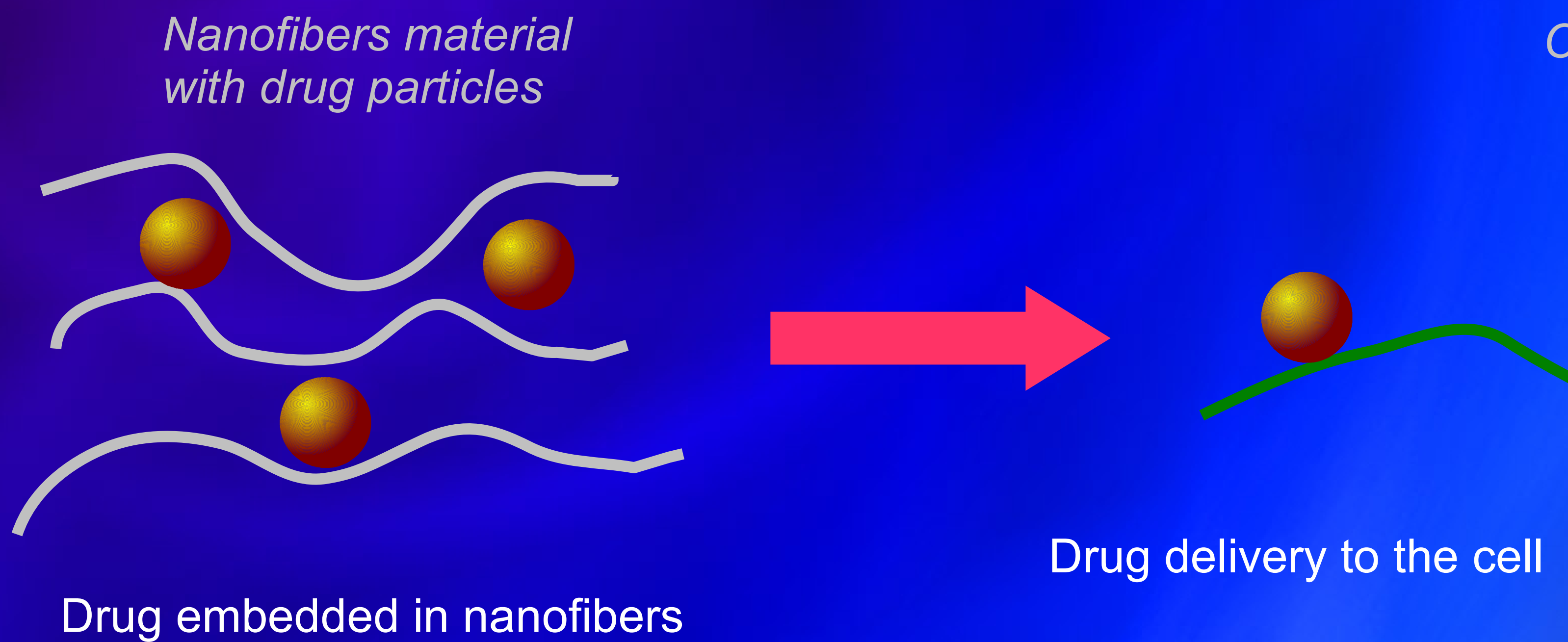
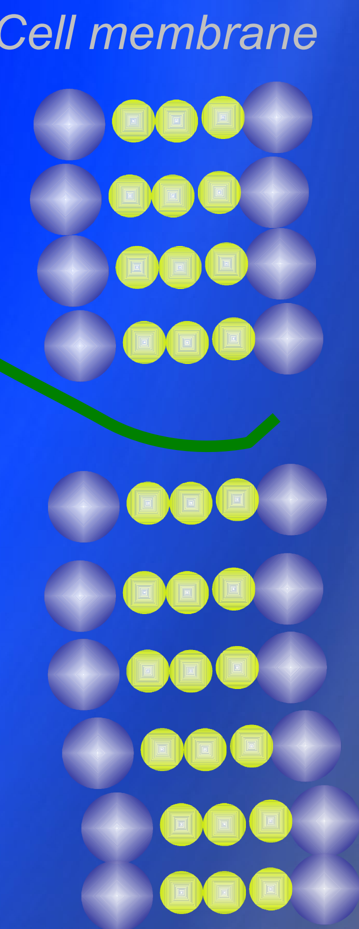
DDSNANOFIB - *Drug delivery systems based on nanofibers and polymer membranes: production, modeling and application* (COOPERATION)





<u>Steps to investigate</u>

- Production of biodegradable nanofibers materials
- Drug diffusion processes (material - cell)

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DDSNANOFIB - Drug delivery systems based on nanofibers and polymer membranes: production, modeling and application (COOPERATION)

AIM

- Controlled and efficient drug delivery system
- Production of biodegradable materials for internal and external wound dressing
- Study of efficiency of drug diffusion processes

COOPERATION PARTNERS

- Warsaw Institute of Technology, Poland
- Warsaw Medical University, Poland
- Textile Institute Łódź, Poland
- Technion, Haifa, Israel
- U. Illinois, Chicago, USA
- Technical University Łódź, Poland

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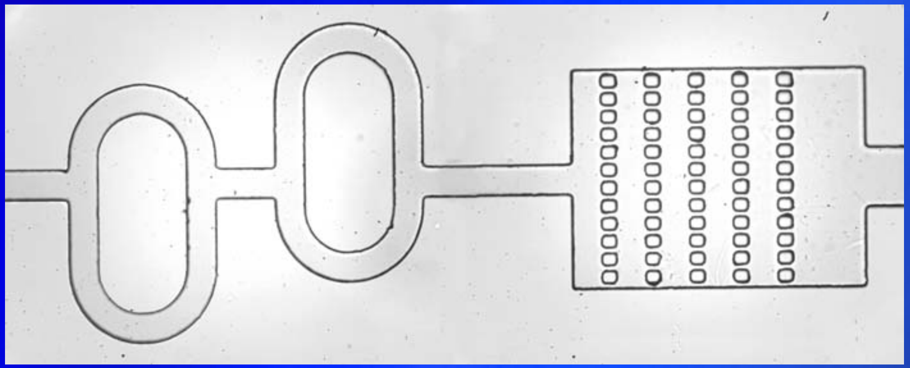
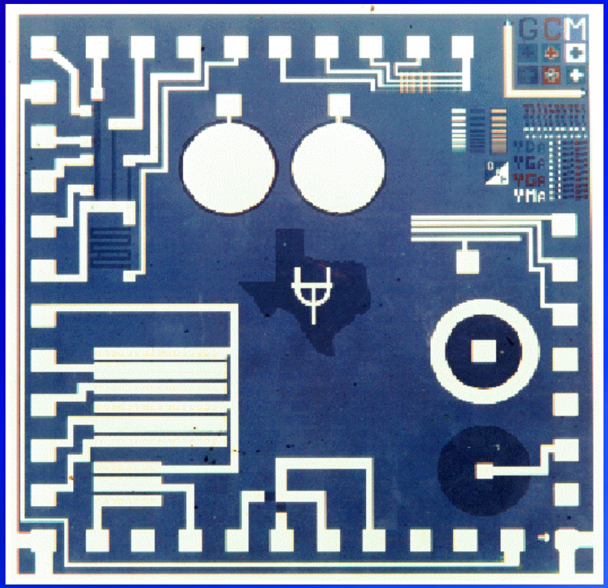
MACLOC - Mesoscopic modelling Applied to Cell manipulation; Lab-On-Chip design (IDEA)

Motivation Efficient and Integrated tool to bio-medical analysis





MACLOC - *Mesoscopic modelling Applied to Cell manipulation; Lab-On-Chip design* (IDEA)

AIM

- Improve efficiency of the design of lab-on-chip by enhancement of numerical models
- Mesoscale simulations and experiments building models and designing lab-on-chip for various applications
- Artificial cell : fluid- electrical control interaction

COOPERATION PARTNERS

- Oxford University, UK
- IAC, Rome, Italy
- TU Dortmund, Germany
- LIMSI, Paris, France
- KTH, Stockholm, Sweden
- Erlangen University, Germany
- Harvard University, USA
- Stanford University, USA
- VCU, Richmond, USA

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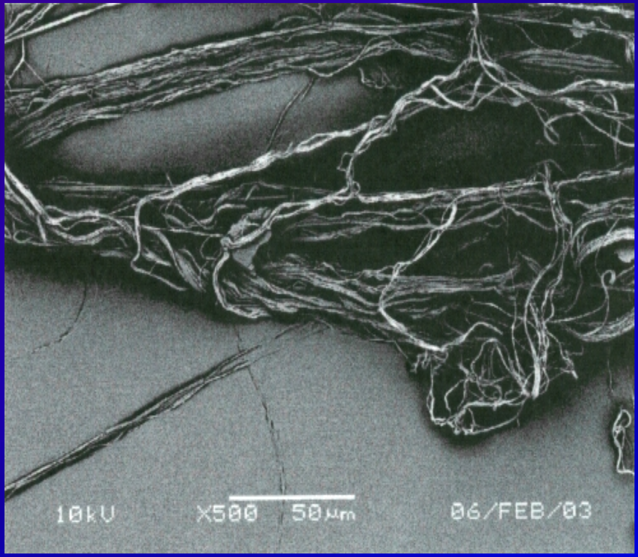
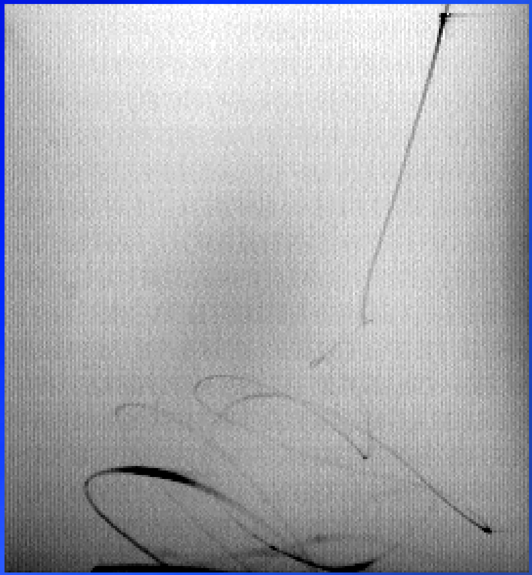
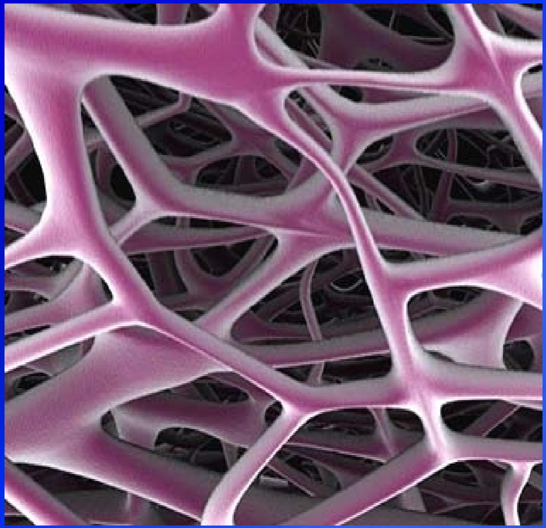
ELSPINOPT - *Electrospinning of nanofibers* (IDEAS)

Motivation Optimization of electrospinning process to obtain desired nanofibers







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ELSPINOPT - *Electrospinning of nanofibers* (IDEAS)

AIM

- Optimization of electrospinning process (voltage, polymer concentration)
- Production of 'smart materials', biodegradable materials, tissue engineering

COOPERATION PARTNERS

- Textile Institute Łódź, Poland
- Imperial College London, UK
- Technion, Haifa, Israel
- U. Illinois, Chicago, USA
- Technical University Warsaw, Poland
- Technical University Łódź, Poland
- Donaldson Inc., USA

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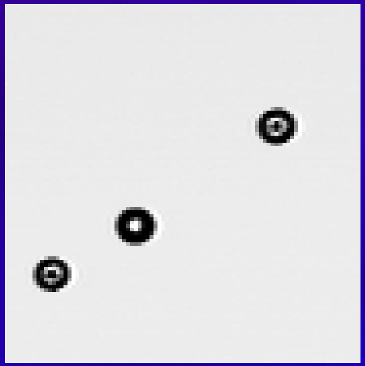
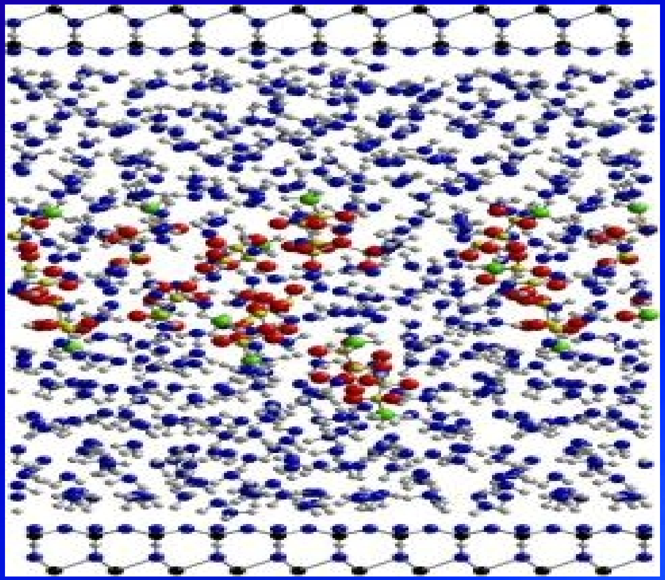
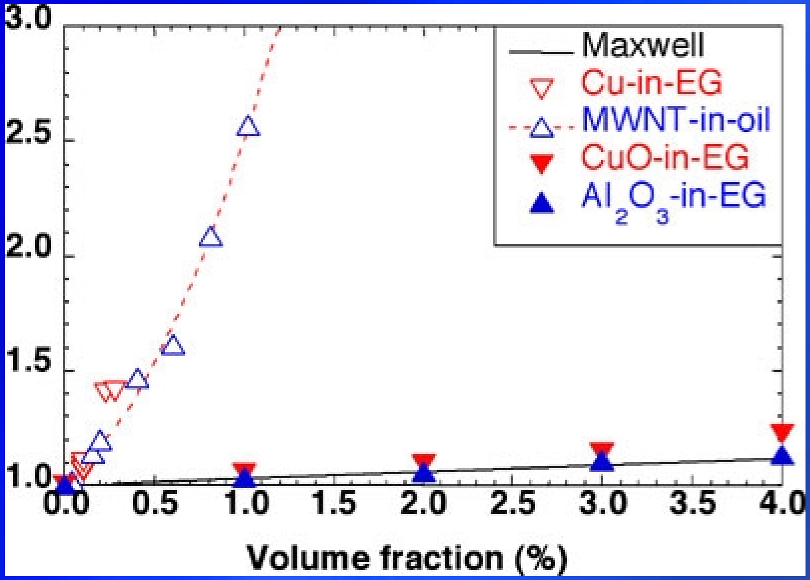
TAVTEN - *Thermal And Viscous Transport Effects in Nanofluids* (COOPERATION)

Motivation dilute suspension of nanoparticles drastically changes global behavior of fluid







Thermal conductivity enhancement of copper, copper oxide, and alumina particles in ethylene glycol (EG); multiwalled nanotubes (MWNT) in oil and predicted by Maxwell's theory

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TAVTEN - Thermal And Viscous Transport Effects in Nanofluids (COOPERATION)

AIM

- Simulation: mesoscopic particle simulation of nanofluids transport coefficients;
- Molecular study of the fluid-solid (nanoparticle -fluid) interaction to control clustering of nanoparticle and sedimentation processes.
- Molecular study of wall-particle interaction to prevent clustering of particles near walls
- Experimental: study of the influence of the nanoparticle concentration on the nanofluid properties;

COOPERATION PARTNERS

- Harvard University, USA
- MIT, USA
- Los Alamos NL, USA
- Yale University, USA
- Institute of Fluid Flow Machinery PAN, Gdansk, Poland

NEMAN - Non-equilibrium Effects Micro- And Nanofluidics (IDEAS)

Motivation surface to volume effects dominance; need for accurate and efficient prediction of solid-fluid interaction

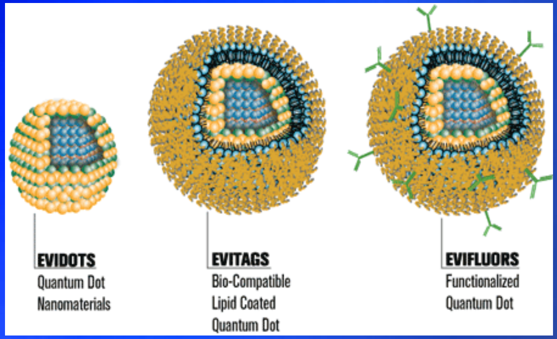
gravity

Macro-scale

surface tension

Micro-scale

quantum dot



Nano-scale

length	surface	volume
1m	$1m^2$	$1m^3$
1μm 10^{-6} m	$1\mu m^2$ 10^{-12} m	$1\mu m^3$ 10^{-18} m
S^1	S^2	S^3

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NEMAN - Non-equilibrium Effects Micro- And Nanofluidics (IDEAS)

AIM

- Mesoscopic models of Fluid-Solid Interaction, theoretical, numerical and experimental validation
- Fast numerical mesoscale algorithms for computation of complex engineering micro- and nano- scale flows

COOPERATION PARTNERS

- Oxford University, UK
- IAC in Rome, Italy
- Harvard University, USA
- VCU, Richmond, USA
- Technical University, Gdansk, Poland
- MIT, USA

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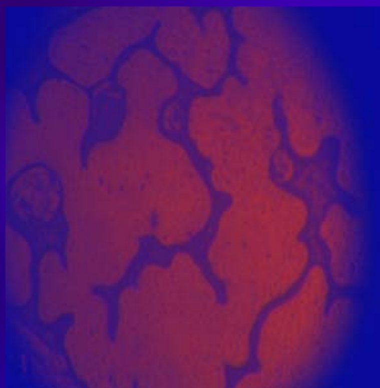
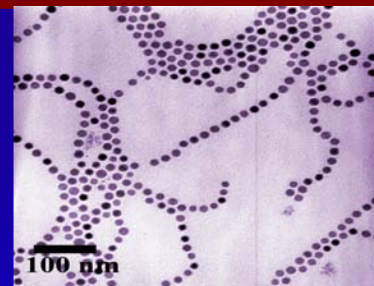
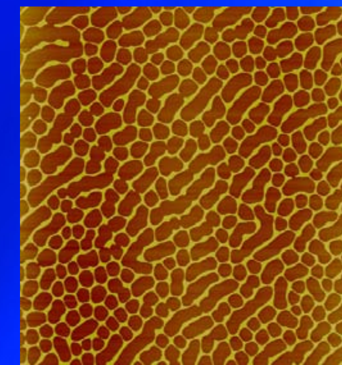
NANOSET - *NANOfluids: Simulations, Experiment and Theory* (CENTER OF EXELENCE)



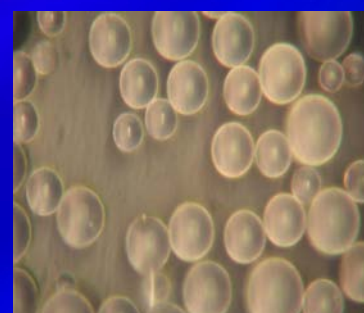
van der Waals self-organization

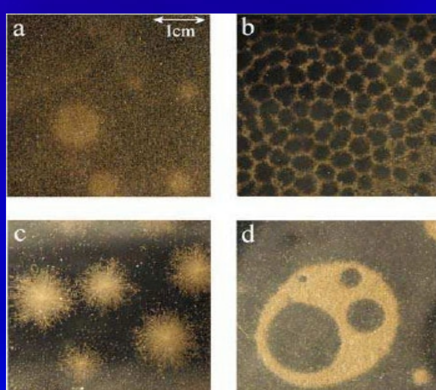




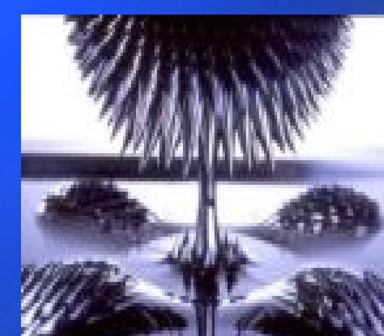
sedimentation pattern

surface tension self-organization





electrofluids



ferrofluids

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NANOSET - *NANOfluids: Simulations, Experiment and Theory* (CENTER OF EXCELLENCE)

AIM

- Collaboration, workshops, experience exchange and conferences in topics of nanofluids

COOPERATION PARTNERS

- LIMSI, Paris, France
- Oxford University, UK
- IAC, Rome, Italy
- Tel-Aviv University, Israel
- KTH, Stockholm, Sweden
- Erlangen University, Germany
- Harvard University, USA
- MIT, USA
- National Nanotechnology Infrastructure Network, USA
- Stanford University, USA
- Los Alamos NL, USA
- Yale University, USA
- VCU, Richmond, USA
- Institute of Physical Chemistry PAN, Warsaw, Poland
- Institute of Fluid Flow Machinery PAN, Gdansk, Poland

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Current funding possibilities

- ERA-NET: small (up to 5) collaboration partners 28.9M€ deadline 31.7.2007
- COOPERATION: NMP 105.723 M€ deadline 4.05.2007
  (possibilities Nano-scale mechanismof bio/non-bio interaction; self-assembling and self-organization; nanostructure coating and thin films)
- COOPERATION with SME 44M€ deadline 4.05.2007
  (Application of new materials including bio-based fibres in high-added value textile products)
- COOPERATION HEALTH 28.9M€ deadline 31.7.2007
  (Nanosicence and converging science 0M€- 2007)
- COOPERATION NMP Large 15M€ Deadline 5.07.2007
  (Examining capacity building in nanobiotechnology)
- COOPERATION ICT 1019M€ Deadline 8.05.2007
  (Personal health systems for monitoring and point of care diagnostics)
- PEOPLE 9.5M€ deadline 26.04.2007 (Marie Curie Awards)

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THANK YOU FOR ATTENTION

AND

WELCOME TO DISSCUSSION