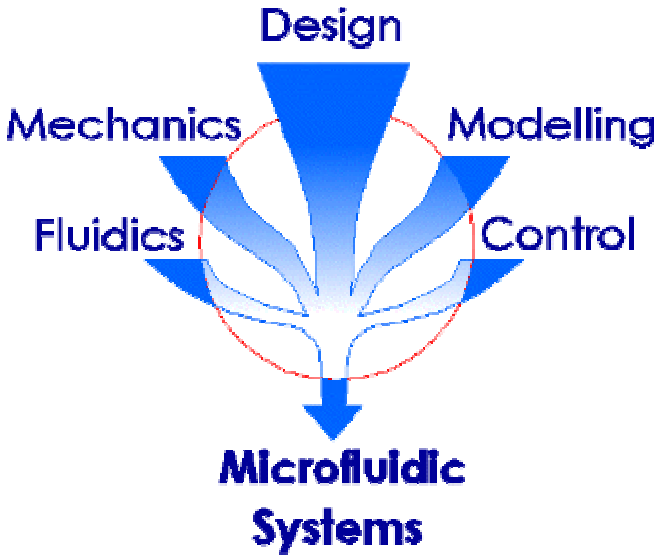
Micro-Fluidics의 이해와 최근 연구동향

Related Sites

- **University & Institute Lab.**
  - Stanford Microfluidics Lab.(http://microfluidics.stanford.edu)
  - MIT's Microsystems Technology Lab.(http://www-mtl.mit.edu/mtlhome)
  - Lawrence Livermore National Lab.(http://www.llnl.gov/IPandC)
  - Sandia National Lab.(http://www.mdl.sandia.gov/micromachine)

- **Organization**
  - Microsystems Technology Office at DARPA (http://www.darpa.mil/MTO/MEMS)
  - Information regarding Lab-on-a-chip (http://www.lab-on-a-chip.com)

- **Company**
  - ACLARA Biosciences, Inc. (http://www.aclara.com)
  - Agilent Technologies, Inc.(http://www.agilent.com)
  - Caliper Technologies, Corp.(http://www.calipertech.com)
  - Microfluidics, Inc.(http://www.microfluidicscorp.com)
  - Mildendo GmbH (http://www.mildendo-fluidics.com)



Micro-Fluidics is one of the major fields of application of Micro Systems Technology. Micro-Fluidics aims at investigating and developing miniature devices which can sense, pump, mix, monitor or control small volumes of fluids or utilize fluids for producing actuating forces. Micro-Fluidics has the potential to revolutionize the processes and products that handle or use fluids by reducing their dimensional scale and by introducing high integration with a process.

Miniaturized channels and reservoirs

- Increase speed of reaction
- Reduce cost of reagents and power consumption
- High surface to volume ratio / low Reynolds number
- Precise mixing / dosage and heating

Integration

- Reduce cost of manufacture
- Minimize dead space, void volume, and sample carryover
- Multiplex capability: increased number of parameters monitored per assay

Micro-Fluidics 연구현황

	USA	EUROPE	JAPAN
Microfluid Connector/valve/ Pump/distributor	- Univ. of Albany - Ohio state Univ.. - UC Berkeley - Univ. of Michigan - Univ. of Utah - UCLA - California Institute of Technology - Defense Medical Research Institute - Lucas Varity Co.	- HSG-IMIT - IMEC - MESA - EPFL - LETI - Fraunhofer - Forschungszentrum Karlsruhe GmbH - Royal Institute of Technology	- Advance Co. - Nagoya Univ.
Micromixer	- Univ. of Hawaii at Manoa - Univ. of Illinois at Urbana Champaign - Stanford Univ.	- Technical Univ. of Denmark	- Mechanical Engineering Lab. - RIKEN
Micro flow controller	- UC Berkeley - UCLA - Intertech Incorporation - Quinn-Curtis Incorporation - Michigan financial Corporation		
Microchip cooler	- UCLA - NASA - JPL - ARC - JSC - MSFC - Univ. of Cincinnati - Case Western Reserve Univ.		
Microcryocooler	- Sienna Tech. Inc. - NASA	- Univ. of Twente	
Microengine	- Dyncorp. - Univ. of Michigan - MIT - UCLA - DARPA - JPL - Caliper technologies corp. - Univ. of Cincinnati - Univ. of California Davis - Case Western Reserve Univ.	- Univ. of Neuchatel	- Instruments Inc. - Univ. of Tokyo
Microgenerator Micromotor	- MIT - UCLA - Maxwell Technologies Inc. - Univ. of Southern California - Georgia Institute of Technology - Case Western Reserve Univ. - Pacific Northwest National Laboratory	- Univ. of South hampton	- Mitsubishi Electric Co. - Seiko Epson Co. - Seiko Instruments inc. - Univ. of Tokyo - Yokohama National Univ.

Classification of MEMS Devices

(자료 참고: 산학연 연구교류회 268회, “Micro/Nano Fluid-Thermal Engineering”, 2001.6.)

대분류	중분류	소분류				
기반 (공통복합)	공통 도구별	물성 신뢰성 분석/계측		접속, 조립 시스템		모듈구성, 표준화
	유체 부품	- 초미세 소재의 열, 유체, 기계, 화학적 물성 및 신뢰성 - 소재, 부품, 연결/조립의 수명 및 신뢰성		- 초미세 유체 접속 기술 (절단, 연마, 처리 등) - 마이크로 부품 조립 및 취급 기술		- 마이크로 부품 연결 표준화 (광, 유체, 전기) - 모듈화 및 시스템 구성
	광기계 부품	- 초미세 소재의 광, 전기적 물성 및 신뢰성 - 소재, 부품, 연결/조립의 신뢰성		- 초미세 광 접속 기술 - 마이크로부품 조립 및 취급기술		
제품 (핵심부품)	기능별	source/detector, internal path	interconnection	distribution, switching	control, modulation	reaction, conversion synthesis
	유체 부품	- Reservoir - Drain tank - Channel/Pipe - Heater	- 초미세 유체 커넥터 - 초미세 유체입자 필터	- 초미세 밸브 - 초미세 유체 분배기	- 초미세 유체 혼합기 및 유량 제어기	- 초미세 칩 냉각기 - 초미세 극저온 냉각기 - 초미세 엔진 - 초미세 발전기
	광기계 부품	- Laser diode - Photo detector - Optical fiber - Wave guide	- 초미세 광 접속 어레이 및 광 렌즈 어레이	- 초미세 광 단속기	- 초미세 광 감쇄기 및 광 필터	- 초미세 광학 분석기 및 분광기

MEMS Market and Industry(DARPA)

Technology Area	Typical Devices/ Applications	Companies	Market Baseline ($Millions)	Market 2003 (Est.) ($Millions)
Inertial Measurement	**Accelerometers, Rate Sensors, Vibration Sensors**	TI, Sarcos, Boeing, ADI, EG&G IC Sensors, AMMi, Motorola, Delco, Breed, Systron Donner, Honeywell, Allied Signals	$350-$540	$700-$1400
Microfluidics and Chemical Testing/Processing	**Gene Chip, Lab on Chip, Chemical Sensors, FlowControllers, Micronozzles, Microvalves**	Battelle, Sarnoff, Microcosm, ISSYS, Berkeley MicroInstruments, Redwood, TiNi Alloy, Affymetrix, EG&G IC Sensors, Motorola, Hewlett Packard, TI, Xerox, Canon, Epson	$400-$550	$3000-$4450
Optical MEMS (MOEMS)	Displays, Optical Switches, Adaptive Optics	Tanner, SDL, GE, Sarnoff, Northrop-Grumman, Westinghouse, Interscience, SRI, CoreTek, Lucent, Iridigm, Silicon Light Machines, TI, MEMS Optical, Honeywell	$25-$40	$450-$950
Pressure Measurement	**Pressure Sensors for Automotive, Medical, and Industrial Applications**	Goodyear, Delco, Motorola, Ford, EG&G ICSensors, Lucas NovaSensor, Siemens, TI	$390-$760	$1100-$2150
RF Technology	RF switches, Filters, Capacitors, Inductors, Antennas, Phase Shifters, Scanned Apertures	Rockwell, Hughes, ADI, Raytheon, TI, Aether	(Essentially $0as of 1998)	$40-$120
Other	**Actuators, Microrelays, Humidity Sensors,** DataStorage, **Strain Sensors, Microsatellite Components**	Boeing, Exponent, HP, Sarcos, Xerox, Aerospace, SRI, Hughes, AMMI, Lucas Novasensor, Sarnoff, ADI, EG&G IC Sensors, CP Clare, Siemens, ISSYS, Honeywell, Northrop Grumman, IBM, Kionix, TRW	$510-$1050	$1230-$2470

Companies currently under contract. Companies with past contracts.

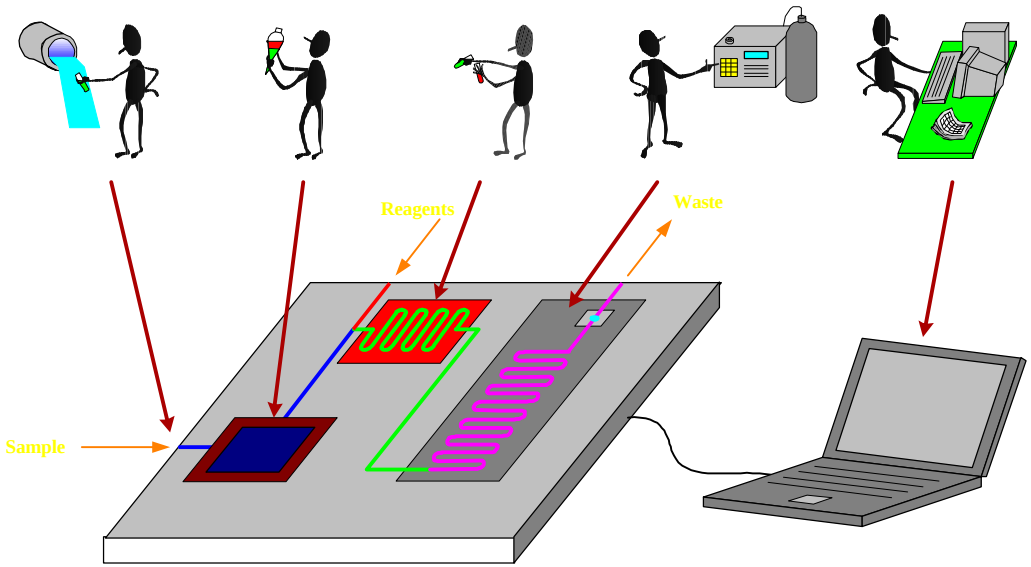
Challenges for Total Integration of Micro-Fluidic Chips

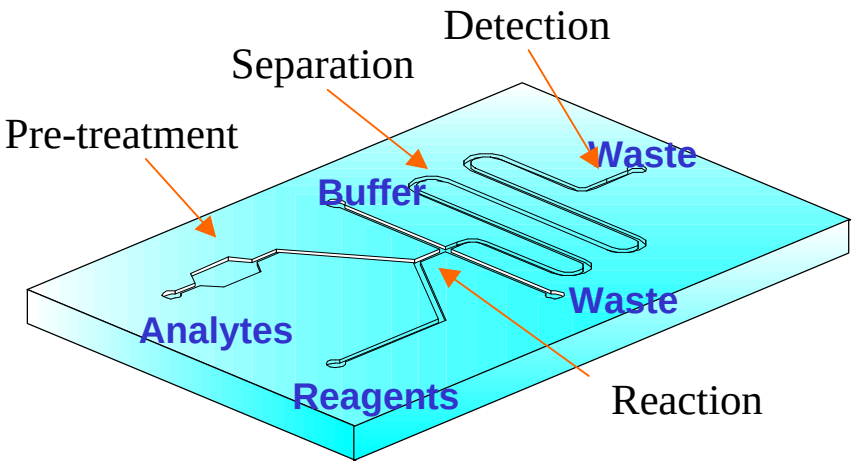
- Reagent storage and reconstitution
- Integrated microvalves and micropumps
- Packaging
  - Interconnects (Optimize, reduce, eliminate)
  - Filling / bubbles / dead volume
  - Leakage
- Surface functionalization
- Microflow measurement and characterization
- Control algorithms, data processing, and communication
- Integrated, ultrasensitive detection
- Heterogeneous material integration
- Sensitivity limited by sample volume
- Low power
  - Harness energy from a host or the ambient?
  - Low power pressure sources?

Micro-Fluidic based Bio-Chips

Lab-on-a-chip : capillary electrophoresis separation, DNA fragments separation

- micro-fluidics: sample handling, pumps/valves, micro-reactors
- microseparations: capillary electrophoresis
- biocompatibility: patterned biochemical arrays
- packaging and integration: μ-total analysis systems





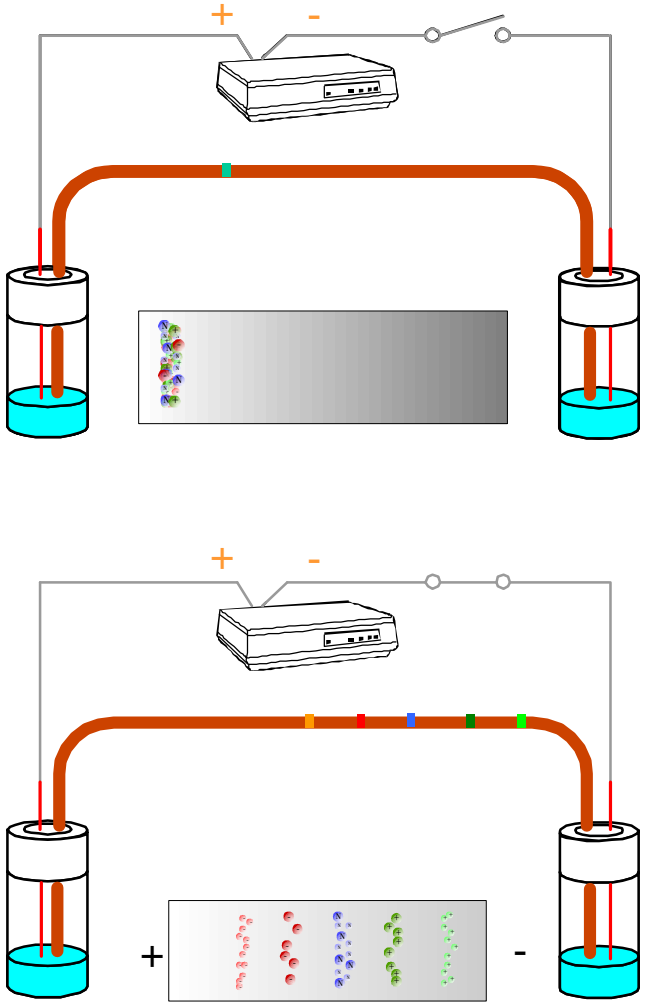
DNA chip, Protein chip

- genetic research
- clinical diagnostics
- drug screening
- biological detection

Neuron chip

- cell-based sensor
- electrophysiological tools
- neuroelectric devices

Micro-biosensors



capillary electrophoresis (CE)

Full-field Experimental Micro-Fluidic Velocimetry

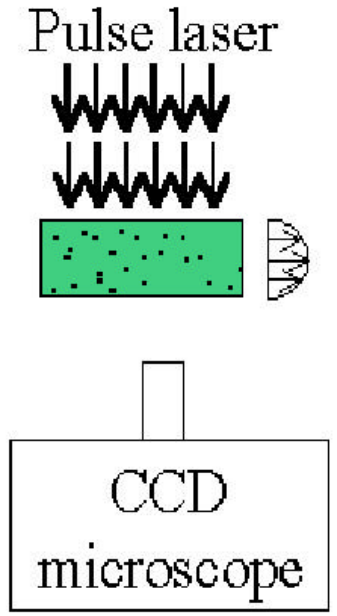
- **X-ray micro-imaging :** Lanzillotto et al.(1996), *Proceedings from Solid-state sensors and actuators workshop*
- **Caged-dye technique :** Paul et al.(1998), *Analytical Chemistry*
- **Micro-PIV :** Santiago et al.(1998), *Experiments in Fluids*

Particle Image Velocimetry (PIV)

- **Seed flow with small particles**
  - don't affect fluid characteristics
- **Illuminate flow at two time instances (Δt)**
  - record images of particle positions
- **Determine particle displacements between two images (ΔX)**
- **Calculate velocity as $V \approx \Delta X / \Delta t$**

Micro-PIV

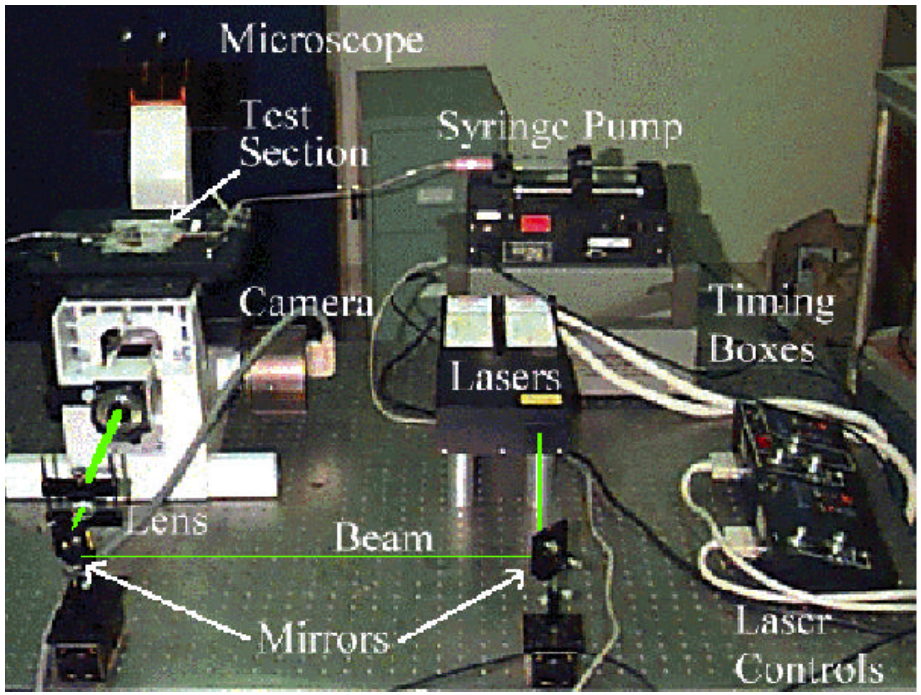
- **Positives**
  - high resolution ~ 1 μm, small depth average ~ 2-10 μm
  - minimally intrusive
- **Negatives**
  - requires seeding flow
  - particles can become charged

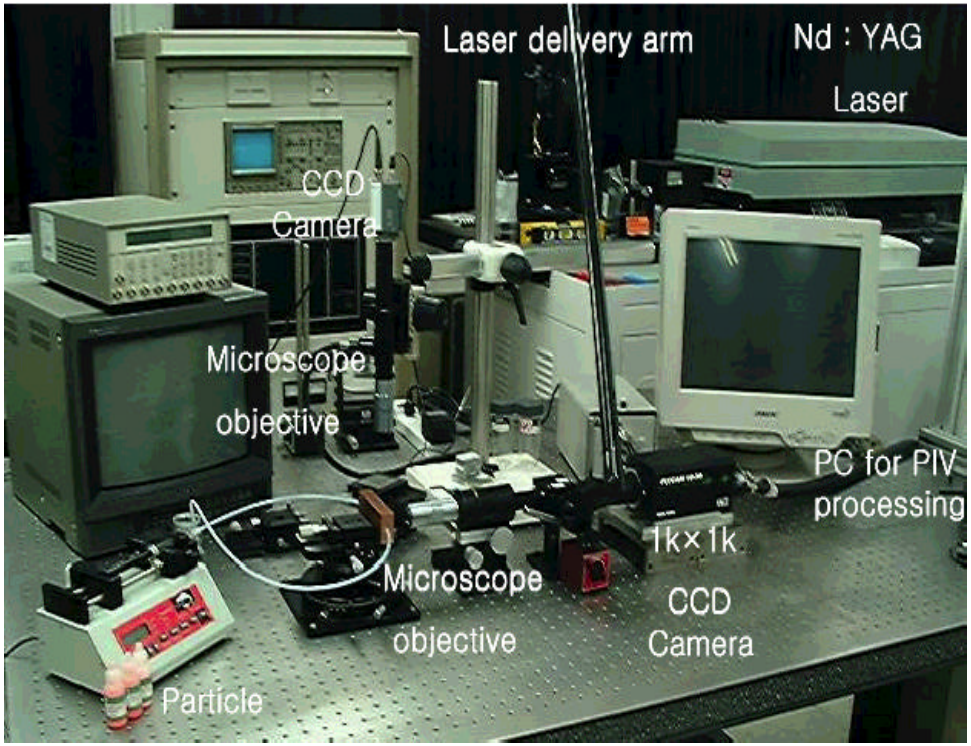


- Purdue U. (Steve Wereley)
- UC Santa Barbara (Carl Meinhart, Rich Chiu, Mike Gray)
- Stanford U. (Juan Santiago)
- MIT (Kenny Breuer, Rob Bayt)

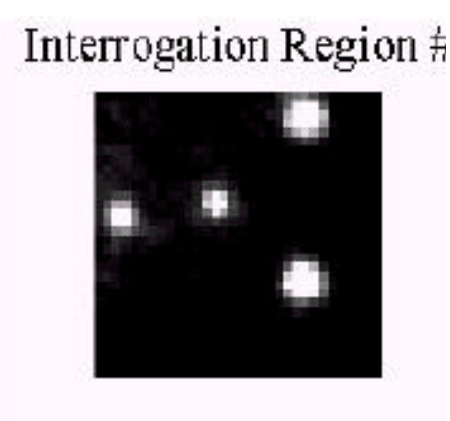
- **Goal: develop an optical diagnostic technique for micro-fluidics**
  - Measure instantaneously 10^3 - 10^4 vectors
  - Spatial resolution of 3 -10 μm
  - Wide velocity range: 50 μm/s ~ 400 m/s
  - Accurate to within 3% full scale

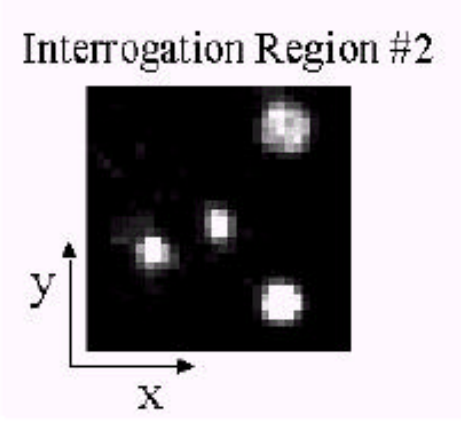
Micro-PIV System

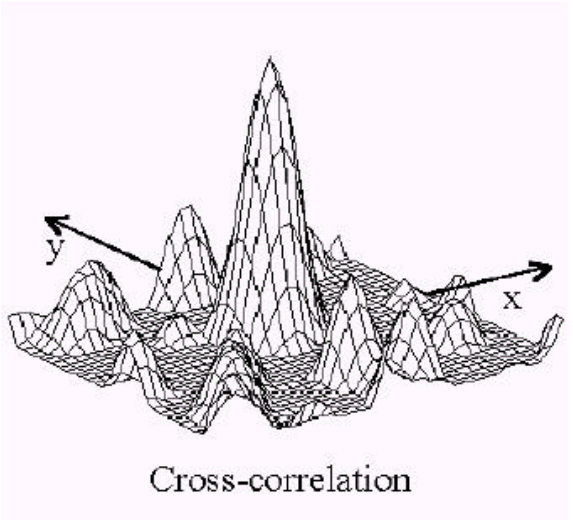




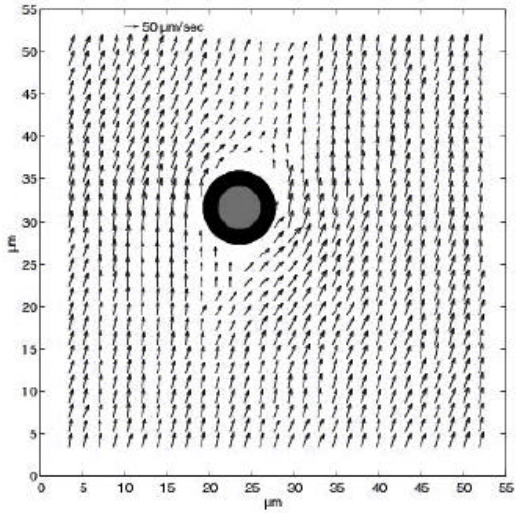
Cross-correlation PIV

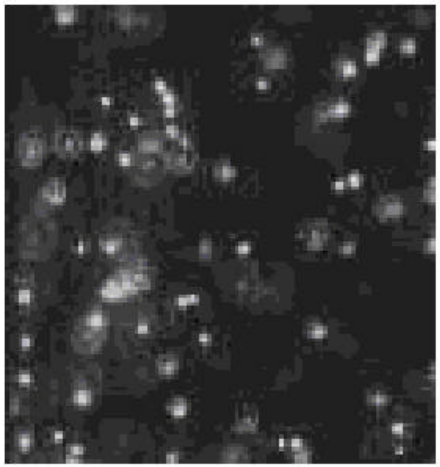






Micro-Particle Image Velocimetry for Micro-Fluidics

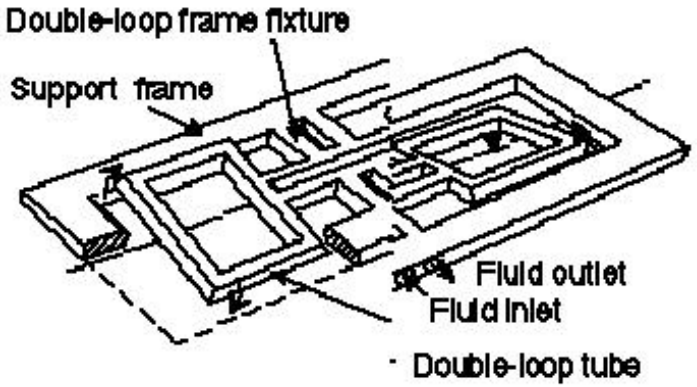




μPIV measurements of the flow around a single (8 micron) red blood cell

Devices for Micro-Fluidics

Resonant Fluid Density and Coriolis mass flow sensor



The fluid density and mass flow sensor design and torsional vibration mode. Thicknesses of the walls are 100 µm.

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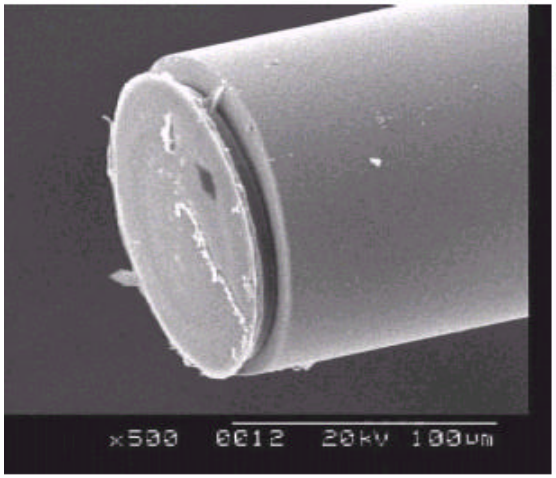
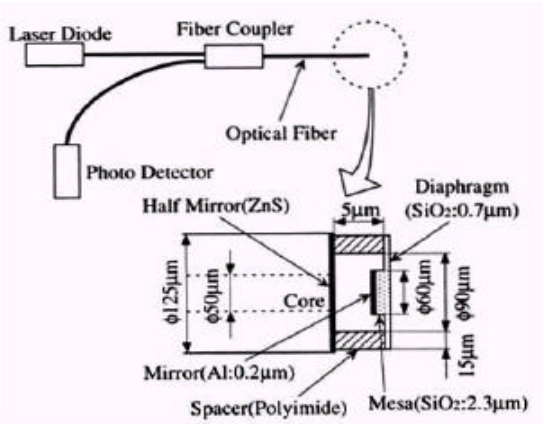
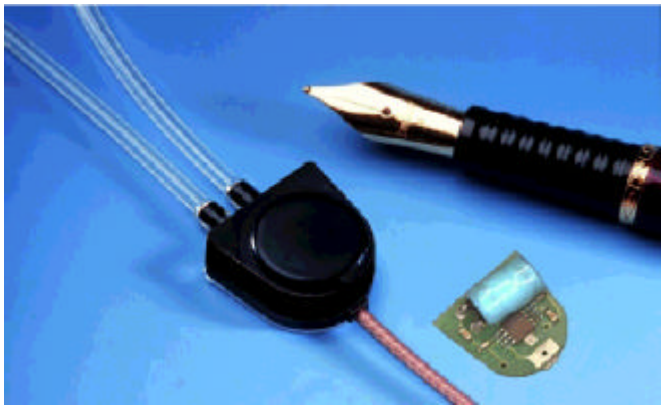
Fiber optic pressure sensors





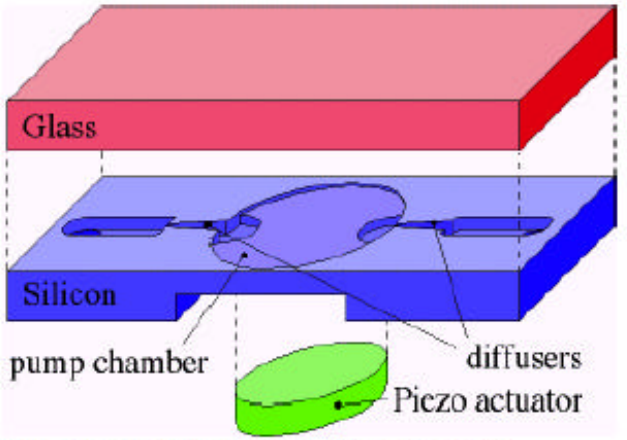
Tohuku U.

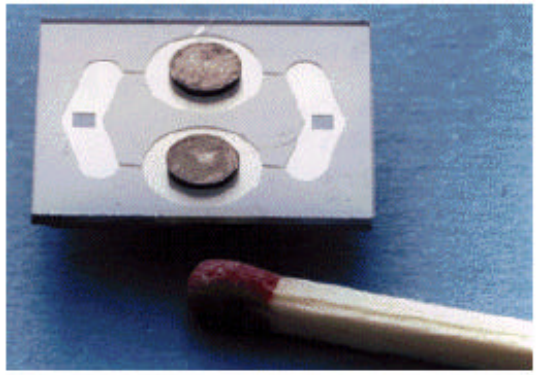
Micropumps



E U R O P R A C T I C E

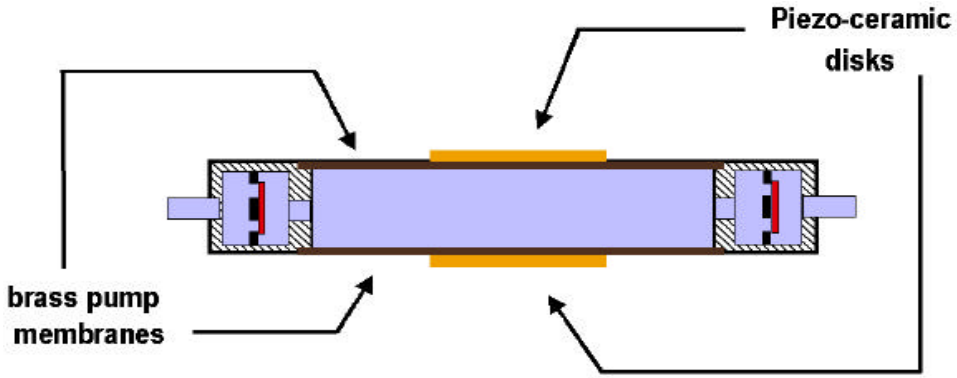
Valve-less Diffuser Micropump





Royal Institute of Technology(KTH/SWEDEN)

Piezoelectric Micropump



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Max Flowrate: 90 micro l/s, Max Delivery Head: 350 mmH_2O, Weight: 2.65 g, Volume: 133 mm^3

Future Directions

- **Continue micro-fluidic diagnostic techniques development**
  - Increase spatial and temporal resolution
  - Bio-chips research
- **Study intrinsically micro-fluidic phenomena**
  - Biological/biomedical flows
  - Non-continuum effects/slip flow
  - Surface tension/electrically driven flows
- **Use micro-fluidic diagnostic techniques to design and evaluate micro-fluidic devices**