# *Neuchatel Transformation from Watch Industry to MEMS-based Cluster Role of Universities*

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# Outline

- *Introduction*
- *Consumer Products (watches)*
- *Microfluidic Dispensing Systems*
- *Chemical Sensors*
- *Tools for Nanoscience*
- *Optical MEMS*
- *Power MEMS*
- *Concluding remarks*

# *University Role/Mission*

- ***Education***
  - ***Bachelor, Master, PhD Program***

- ***Conduct Fundamental and/or Applied Research***

- ***Applied Research***
  - ***University/Industry Collaboration***
    - ***"Successful" Research : Technology Transfer***
  - ***Independent Research***
    - ***"Successful" Research : Technology Transfer***
      ***Start-up Companies***
  - ***Intellectual Property Right (IPR)***
  - ***Incubators (NEODE)***

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# *Institute of Microtechnology University of Neuchatel (IMT UniNE)*

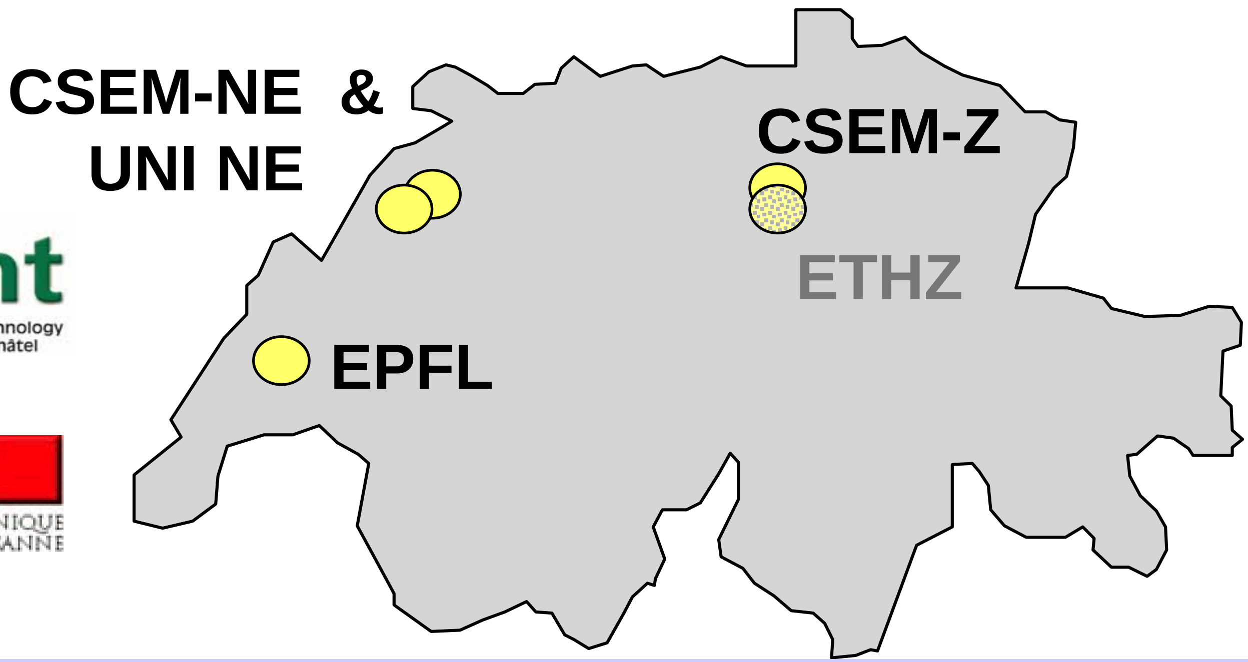
- ***IMT UniNE started its activities in 1975***

- ***The Jurassic Arc was in an economic crisis, due to massive job losses in the mechanical watch industry (arrival of the quartz watch)***

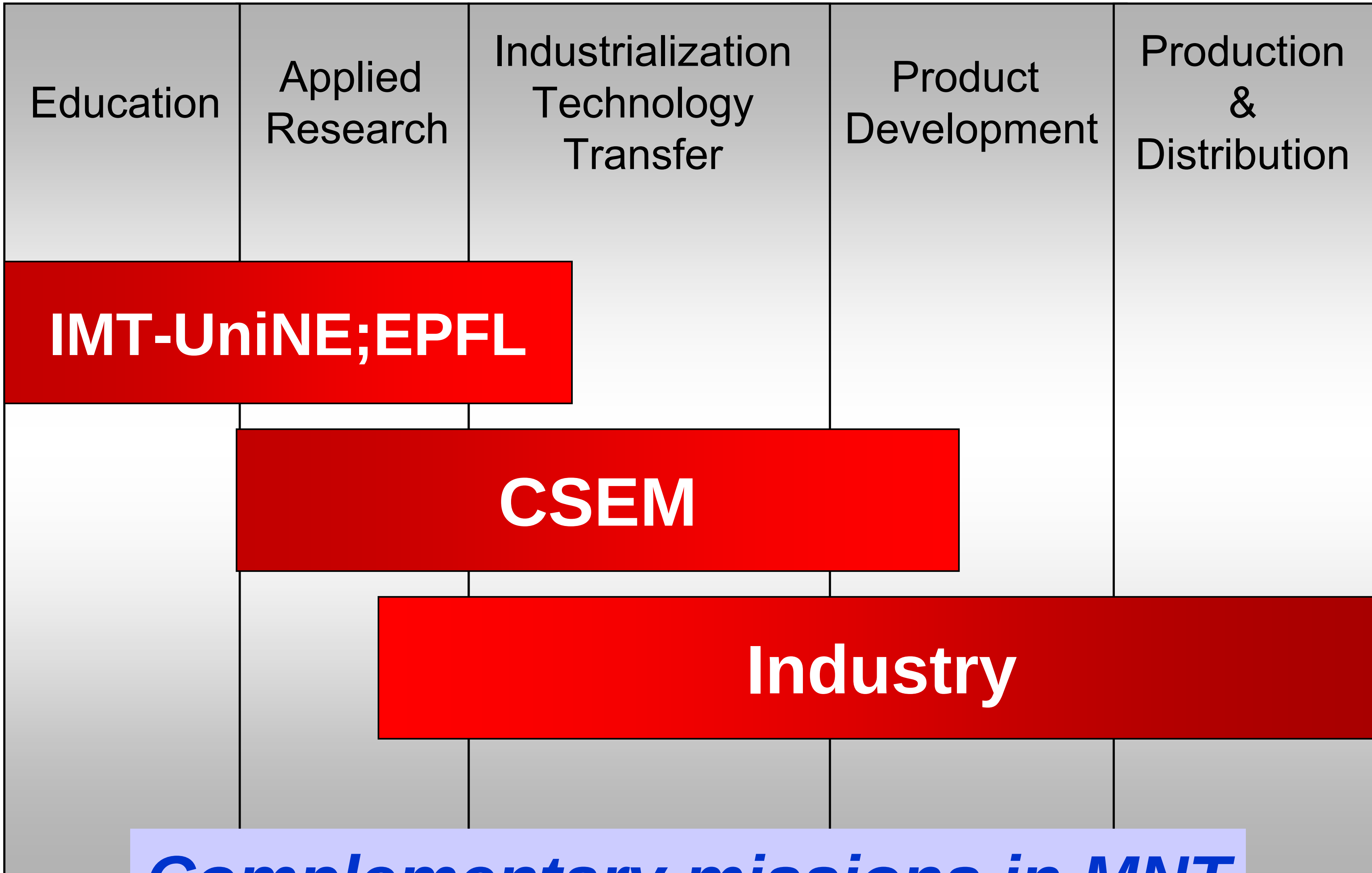
- ***IMT UniNE's original mission:***
  - ***Education***
  - ***Applied Research***
  - ***Support Local Industry***

# Regional Network in MNT

***Joint efforts for education and research in the fields of Micro- and Nanotechnology (MNT)***




***Goal: Benefit from the complementary strengths of the members***




***Complementary missions in MNT***

# *Mission of the “Pôle”*

- ***Collaboration in educational programmes***
- ***Dual appointments for selected key people***
- ***Establishment of joint research programs***
- ***Co-ordination of investments in laboratory equipment***
- ***Joint research laboratories: CMI and ComLab***
- ***Joint industry cont(r)acts***

**Power MEMS**

**Consumer Products**
***Sensors/Actuators***

**Telecommunication**
***Optical MEMS***

**Life-Sciences**
***Bio-MEMS***

**Advanced Instruments**
***Nano-Tools***

**Life-Sciences**
***Micro-Fluidics***

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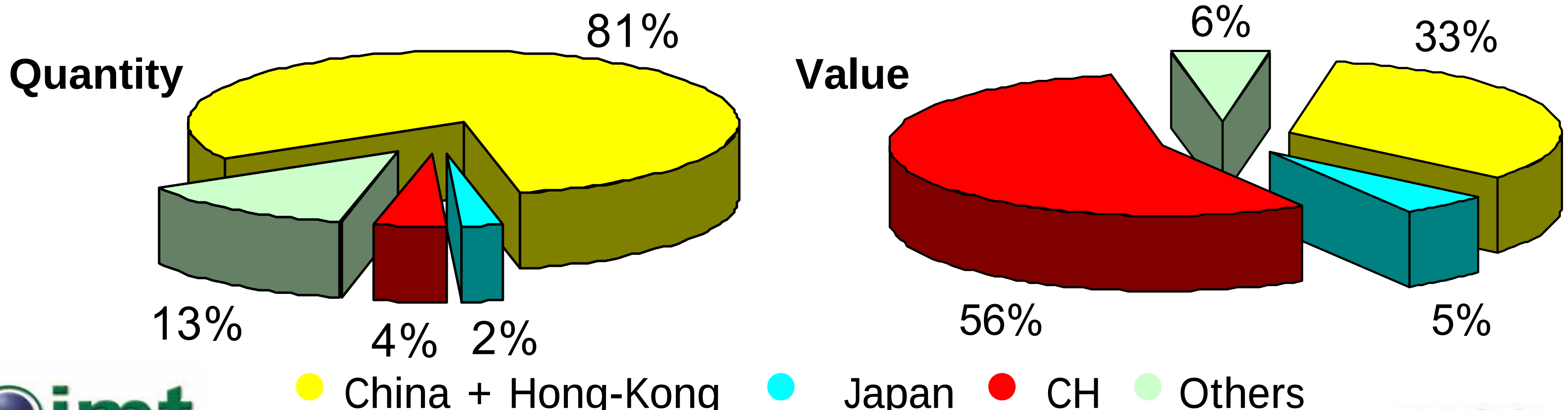
# Global Watch Business

For 2002 / Source: www.fhs.ch

- **Watches, movements and components (globally):**
  - 1.5 Billion pieces / year
  - 16 to 17 Billion CHF — 1 CHF ≈ € 0.64; 1 CHF ≈ US$ 0.80 ; 1CHF ≈ ¥87
- **Switzerland:**
  - 120 Mio. watches, movements and components
  - 28 Mio. finished watches = 10.5 Billion CHF
  - Average export price: 362 CHF (J: 30 CHF / HK: 7CHF)
- **Global Production of finished watches:**

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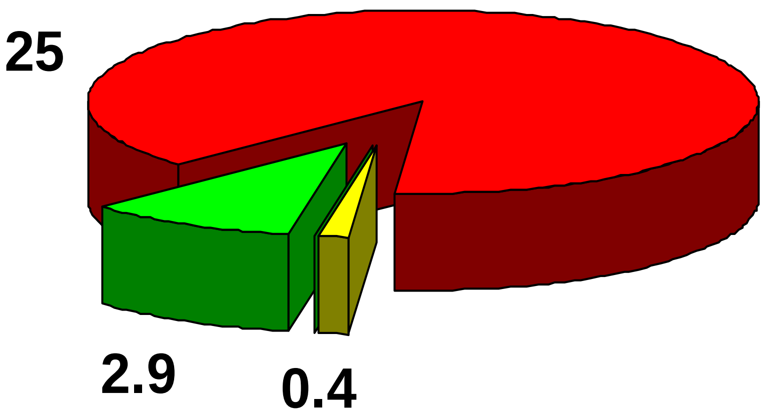
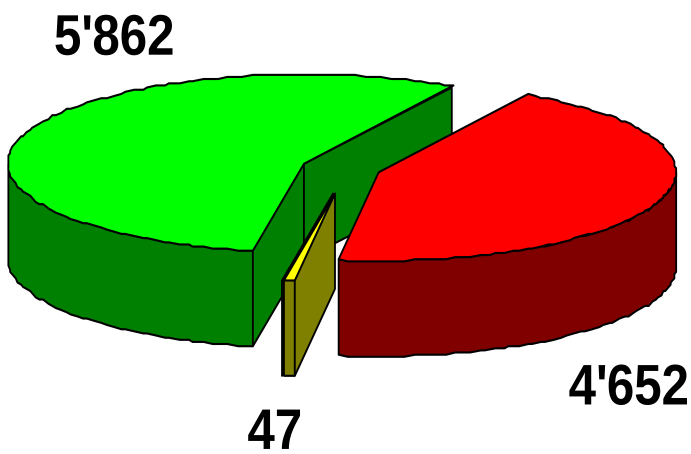
# *Swiss Export of Finished Watches*

**For 2002 / Source: www.fhs.ch**

## Pieces (in Mio.)




## Value (in Mio. CHF)



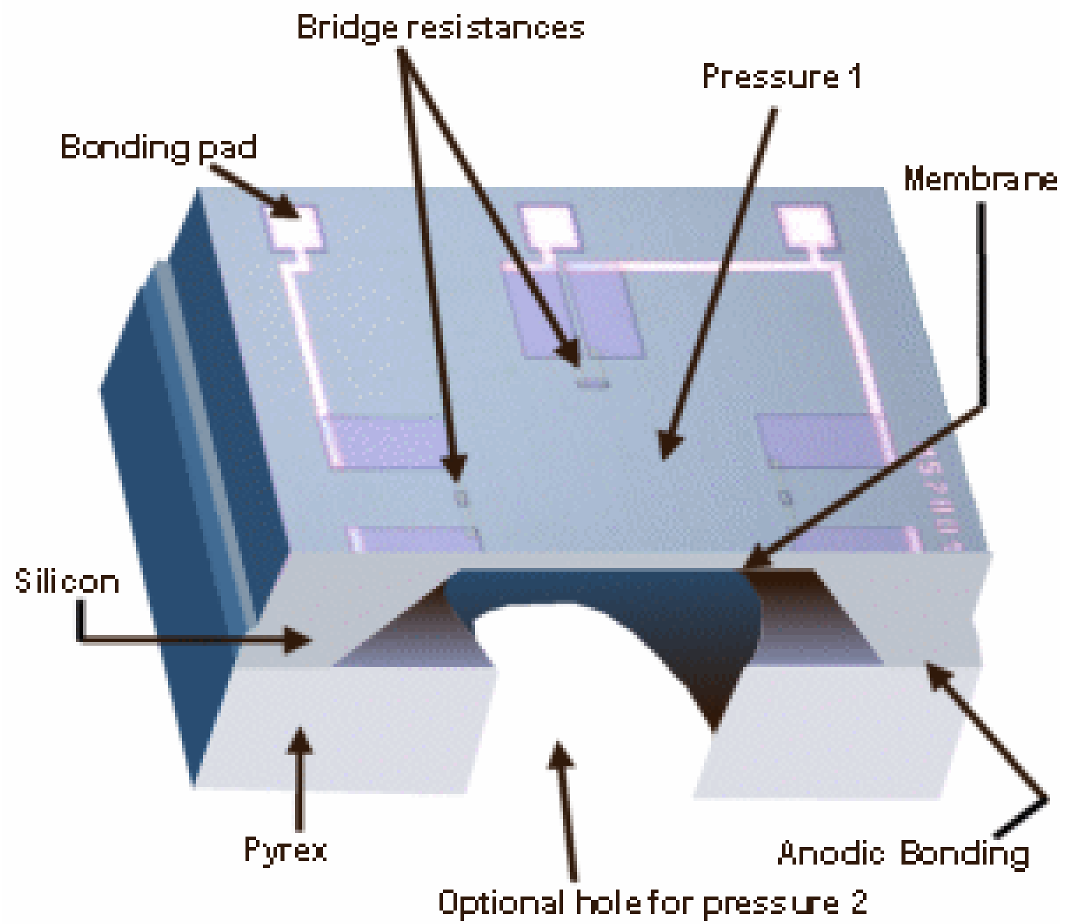

**Mechanical** **Quartz anal.** **Quartz digit.**

# Altimeter/Barometer Module



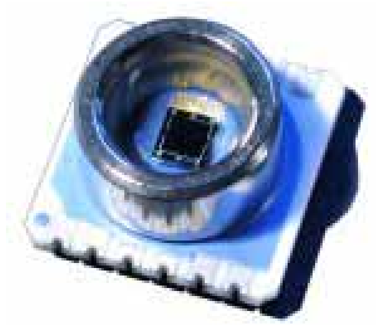
**Process features:**

- Implanted piezoresistors
- Precise electrochemical etch stop
- Anodic Bonding



# *Altimeter/Barometer Module*






- **Altitude variation of *1 m*:**
  - ~0.1 mbar ≡ ~150 pm
- **Resolution:**
  - ~3µbar ≡ ~3cm altitude variation
- **Sensor power consumption:**
  - ~1.3µW

# Tissot T-Touch (Tactile Crystal)

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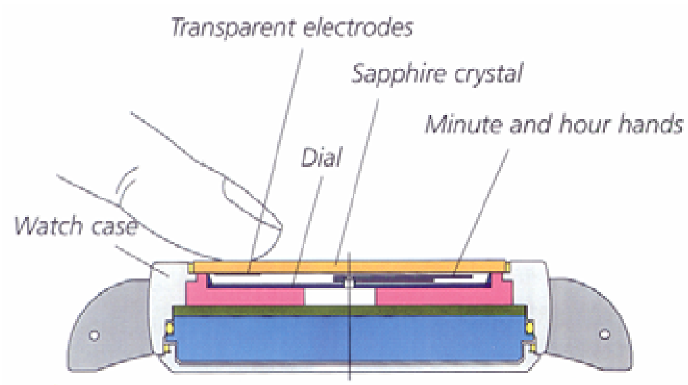
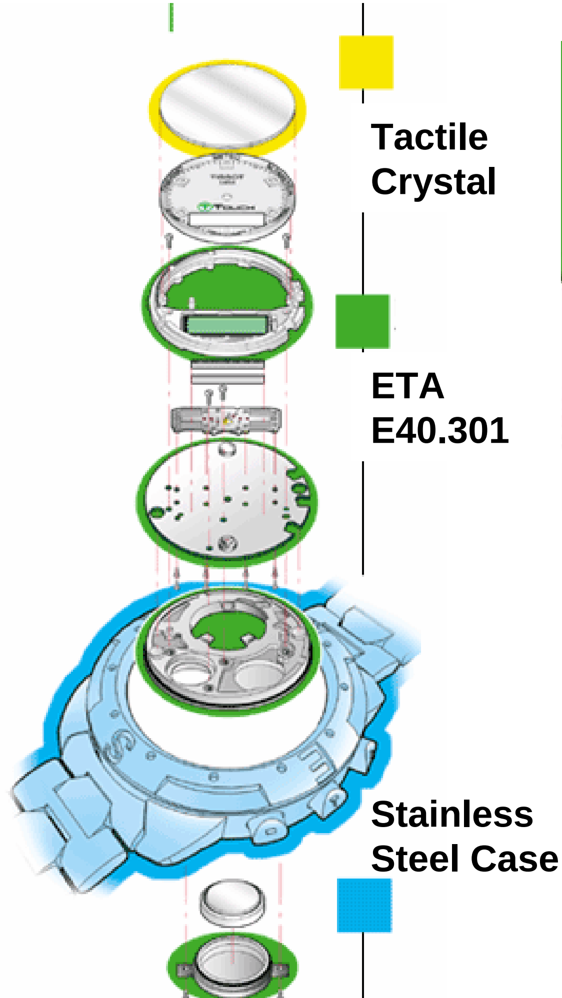
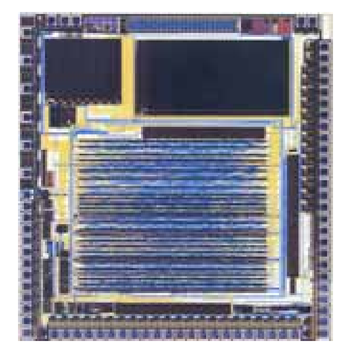
A COMPANY OF THE SWATCH GROUP




Capacitive touch screen watch crystal



- **User interface by tactile capacitive touch screen**
- **Altimeter**
- **Weather forecast**
- **Temperature (with US/EU Units)**
- **Compass, chrono, alarm**

C. Germiquet, R. Dinger et al., "*ALPINIST, …*",
Proc. Société Suisse de Chronométrie, Le Sentier, (Oct. 1999)

*www.asulab.ch*

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# Mechanical Watches


www.tagheuer.com

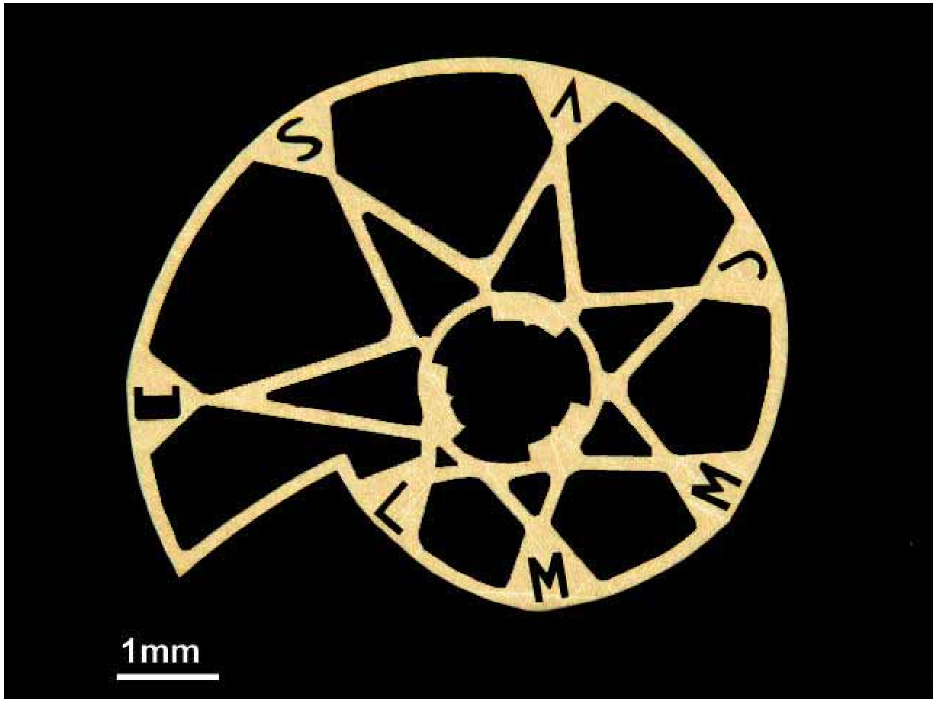
# *UV-LIGA (SU-8)*


- *M.Despont, H. Lorenz, N. Fahrni, J. Brugger, P. Renaud, P. Vettiger, "High aspect ratio ultrathick, negative-tone near-UV photoresist for MEMS applications", Proc. IEEE MEMS, Nagoya 1997, pp. 518-522.*

- *H. Lorenz, M. Despont, P. Vettiger, P. Renaud, "Fabrication of photoplastic high-aspect ratio microparts and micromolds using SU-8 UV resist", Microsystem Technologies,* ***4*** *(1998), pp. 42-47.*

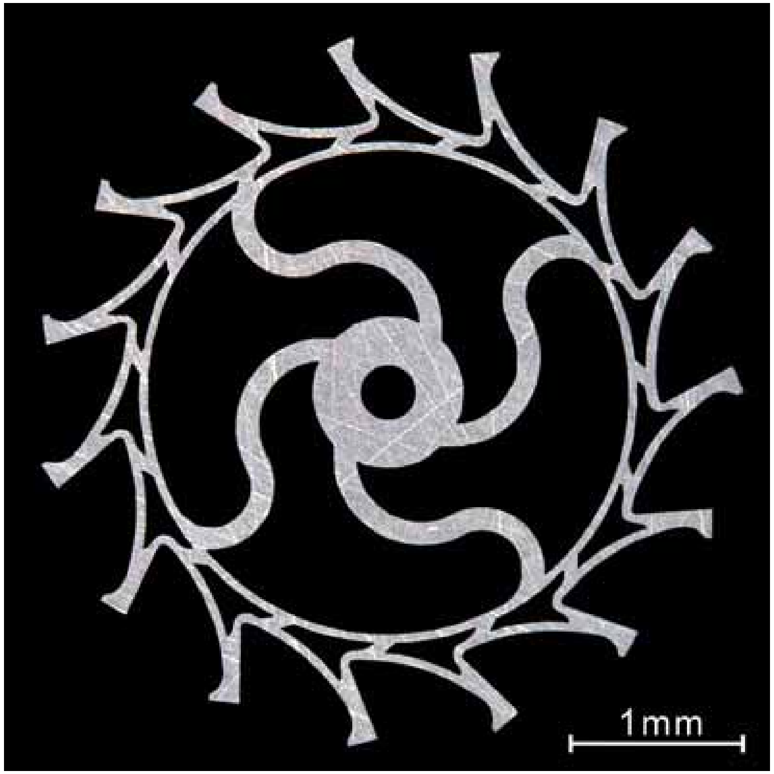
# *Watch microcomponents*






**Cam of the days**

**Escape-wheel**



# *Why Single Crystal Silicon ?*

- **Kurt Petersen, *"Silicon as a Mechanical Material"*, Proceedings of the IEEE, vol.70, no.5, May 1982, pp. 420-57.**

- **Well-known and controlled properties**

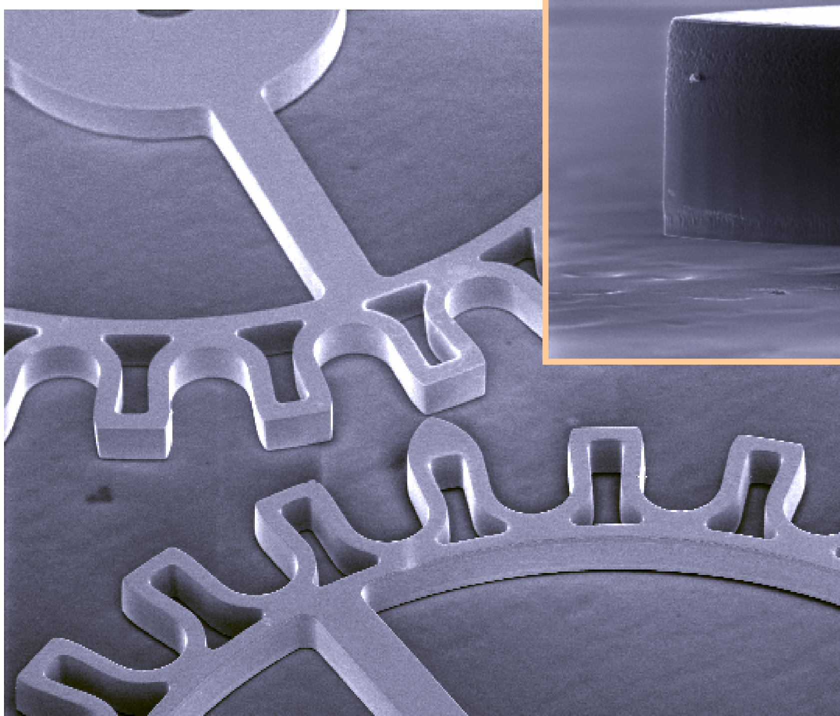
- **Low density (2.33), amagnetic, electrical conductor, easy to overcoat, …**

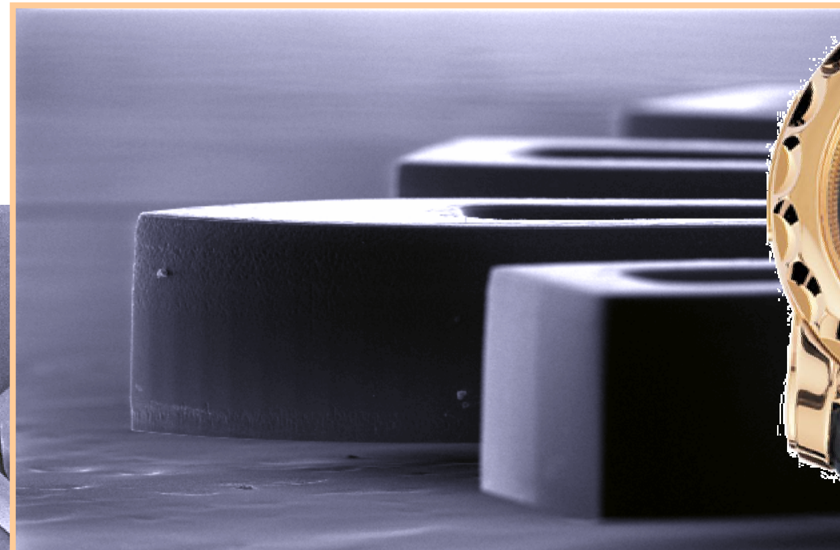
- **Machining by Deep Reactive Ion Etching (DRIE).**

# Elastic behavior of Silicon

# *Silicon Structures of Watch Components*

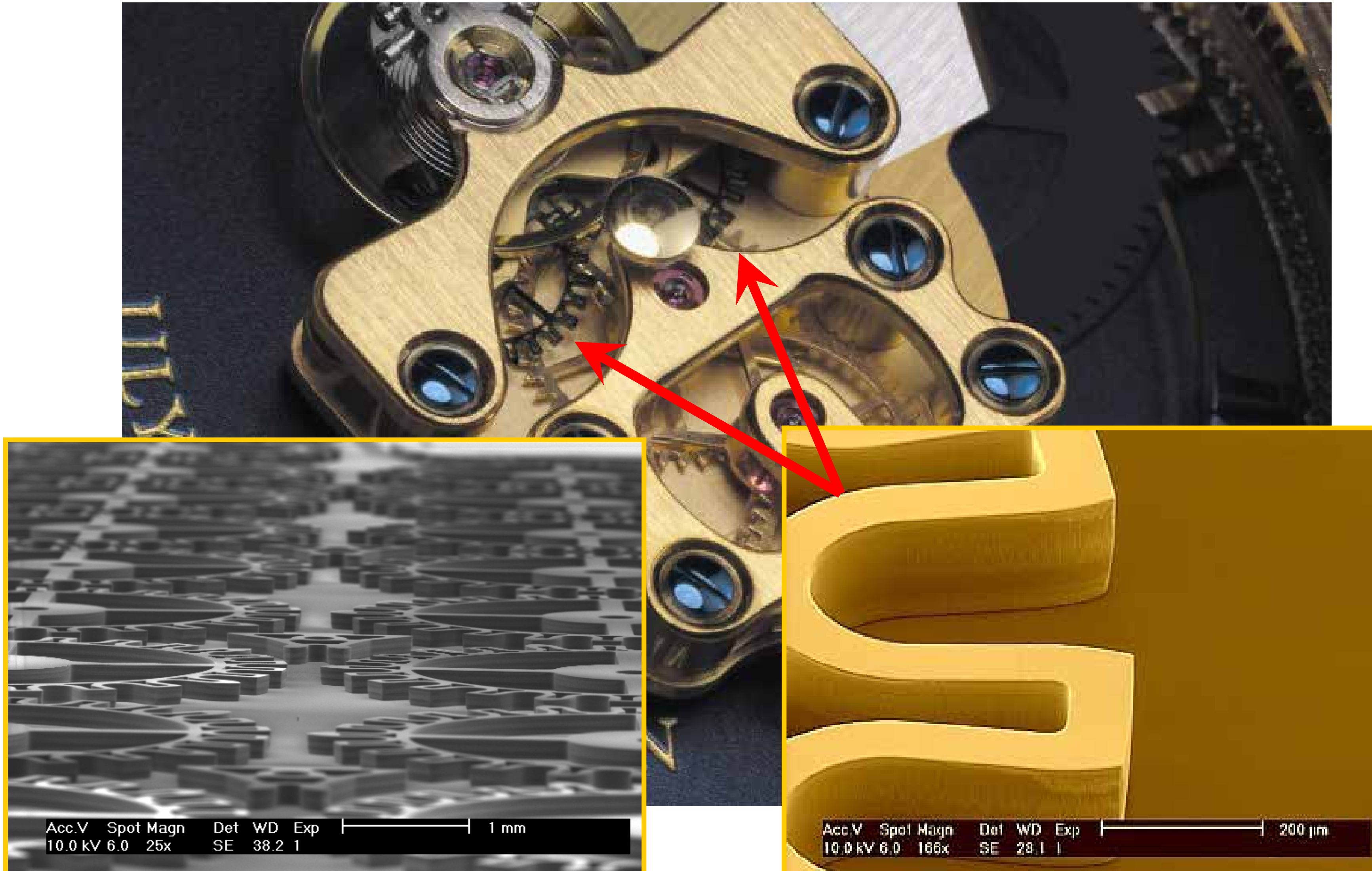
- **Machining of complex mechanisms with sharp edges**
- **Reduced friction**
- **Higher lifetime**






ULYSSE NARDIN
SINCE 1846 LE LOCLE - SUISSE

# Dual Wheel Escapement with Si-Wheels

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# Dual Wheel Escapement with Si-Wheels

- **Complex silicon wheels with stopper teeth**
- **Reduced friction**
- **Reduced moment of inertia**



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# MST based instruments

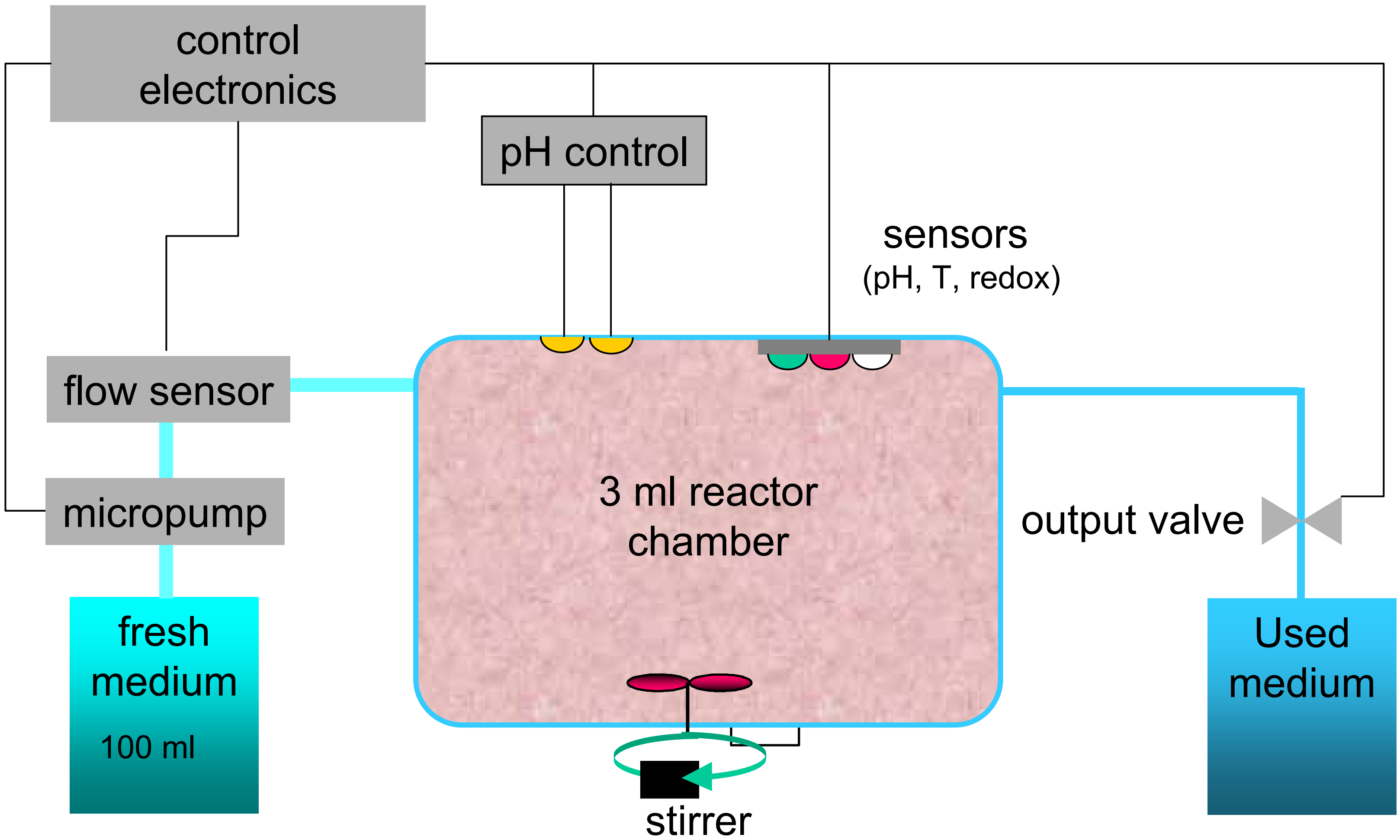
***Spin-off Activities:***
***µfluidics***
***chemical sensors***
***lab-on-chip***

# *Life Sciences : Space Bioreactor*

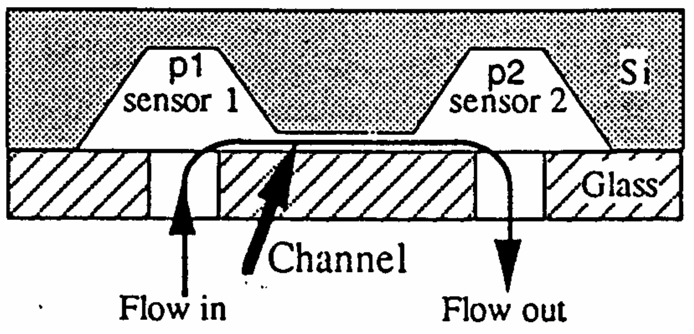
**Built to evaluate the growth characteristics of yeast cells in microgravity**
**Flown by ESA onboard IML Spacelab July 1994, March 1996 and January 2003**

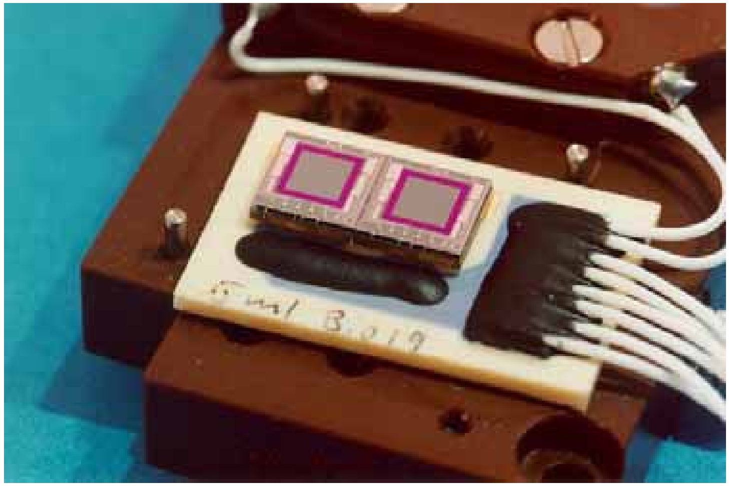


# Working principle

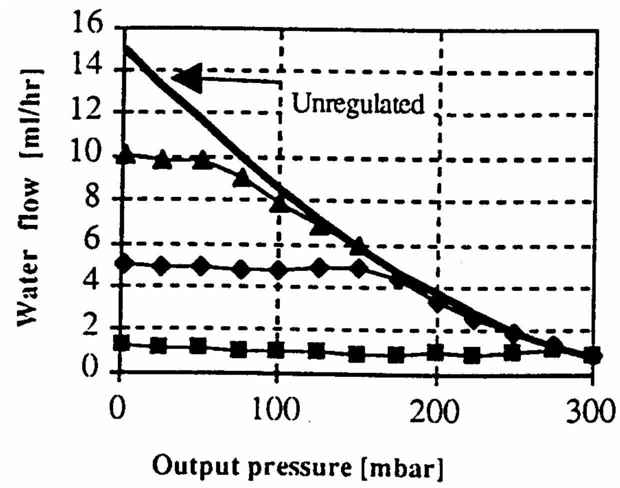


# Flow Sensor

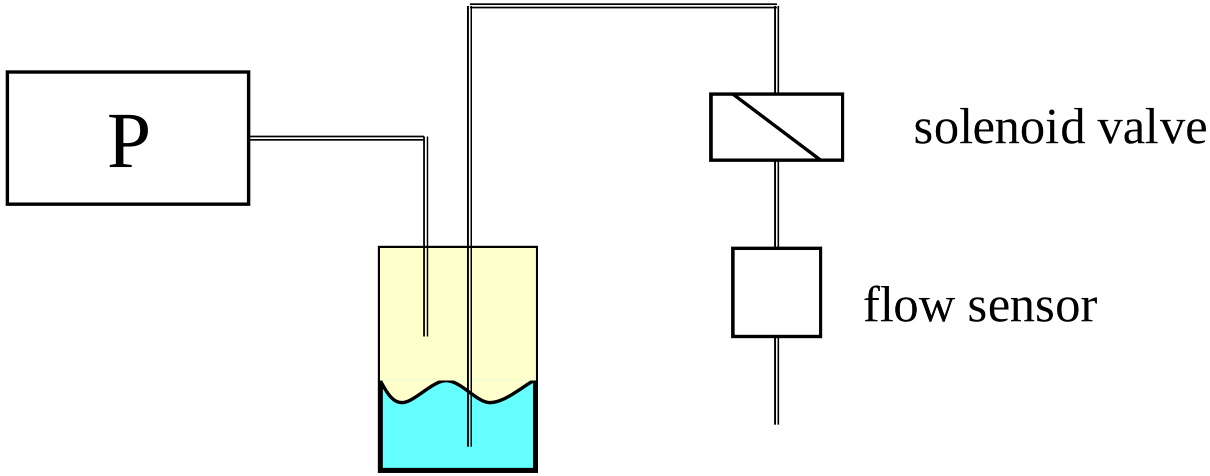


- dual piezo-resistive low pressure sensor
- 4.75 x 9.5 x 1 $mm^3$
- 5 mL/h full scale
- accuracy ~ 2%



# Dispensing Systems

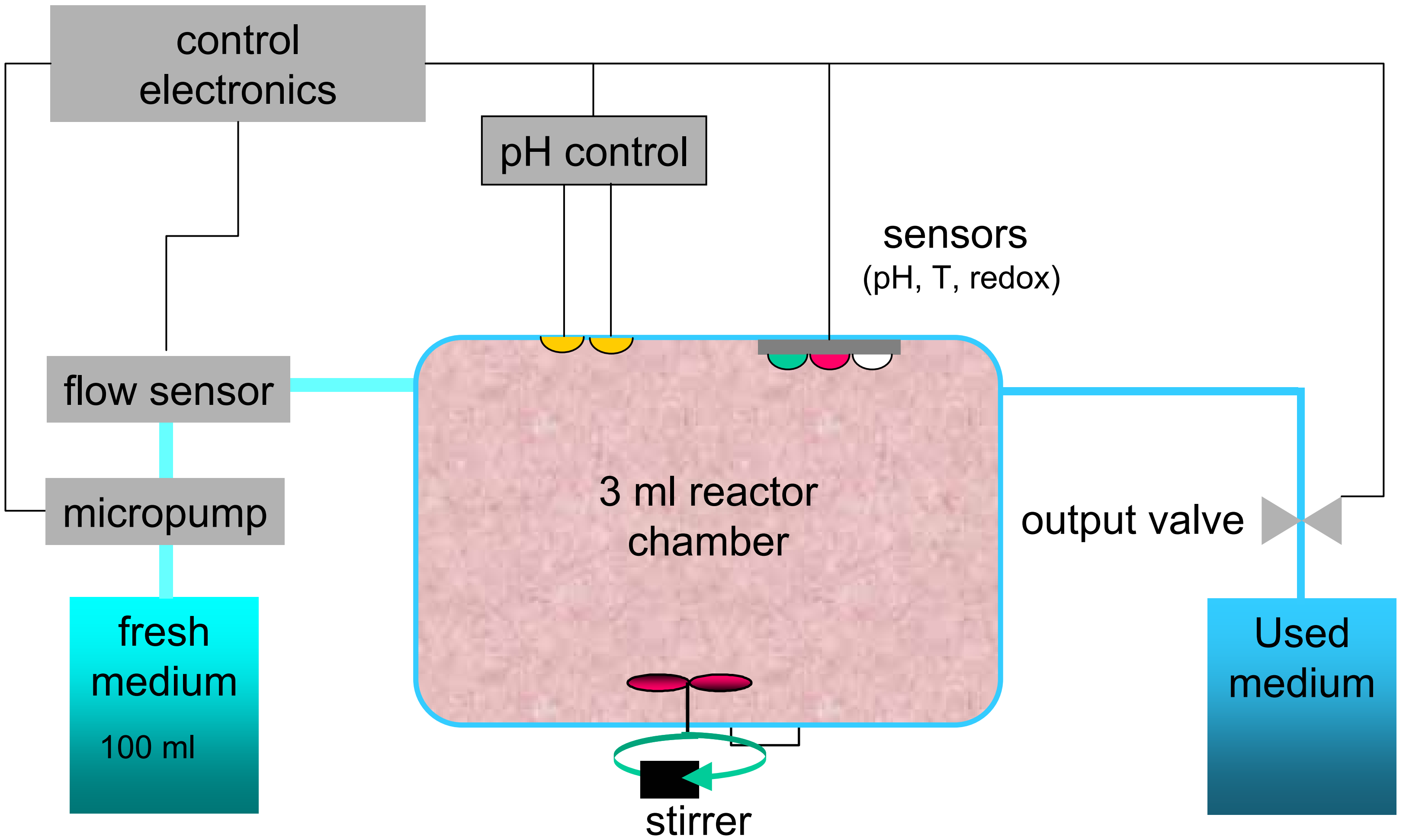



*Advantages:*

- *Control of the liquid quantity at the dispensing site.*
- *Direct, real time measurement of the aspirated or dispensed volume.*
- *Status/diagnostic of the system functionality (clogging, etc.).*

# Sensor Controlled Liquid Handling

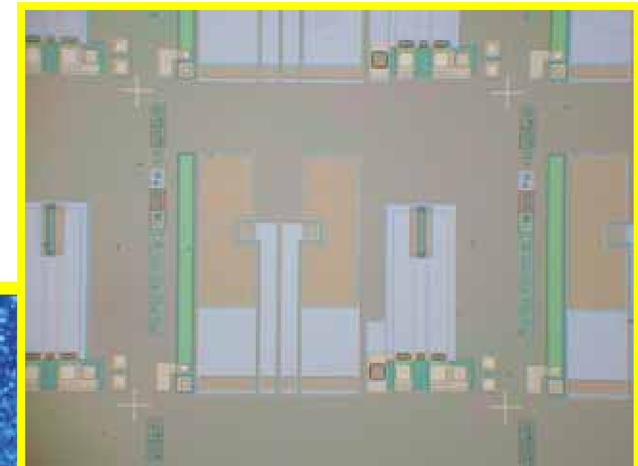

# Working principle



**single sensors**
**pH-ISFET**

**multiple sensors**
**(pH, ORP, Conductivity, T)**


**ThermoOrion**

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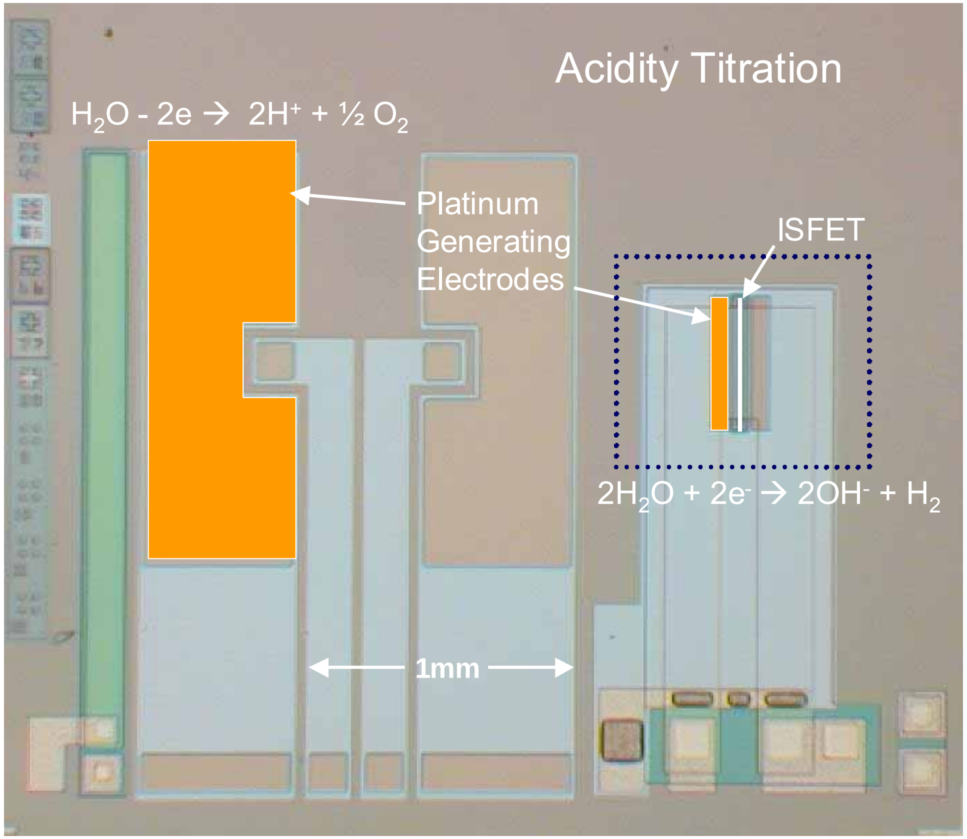
# *Dynamic FLASH Titration Process (1)*

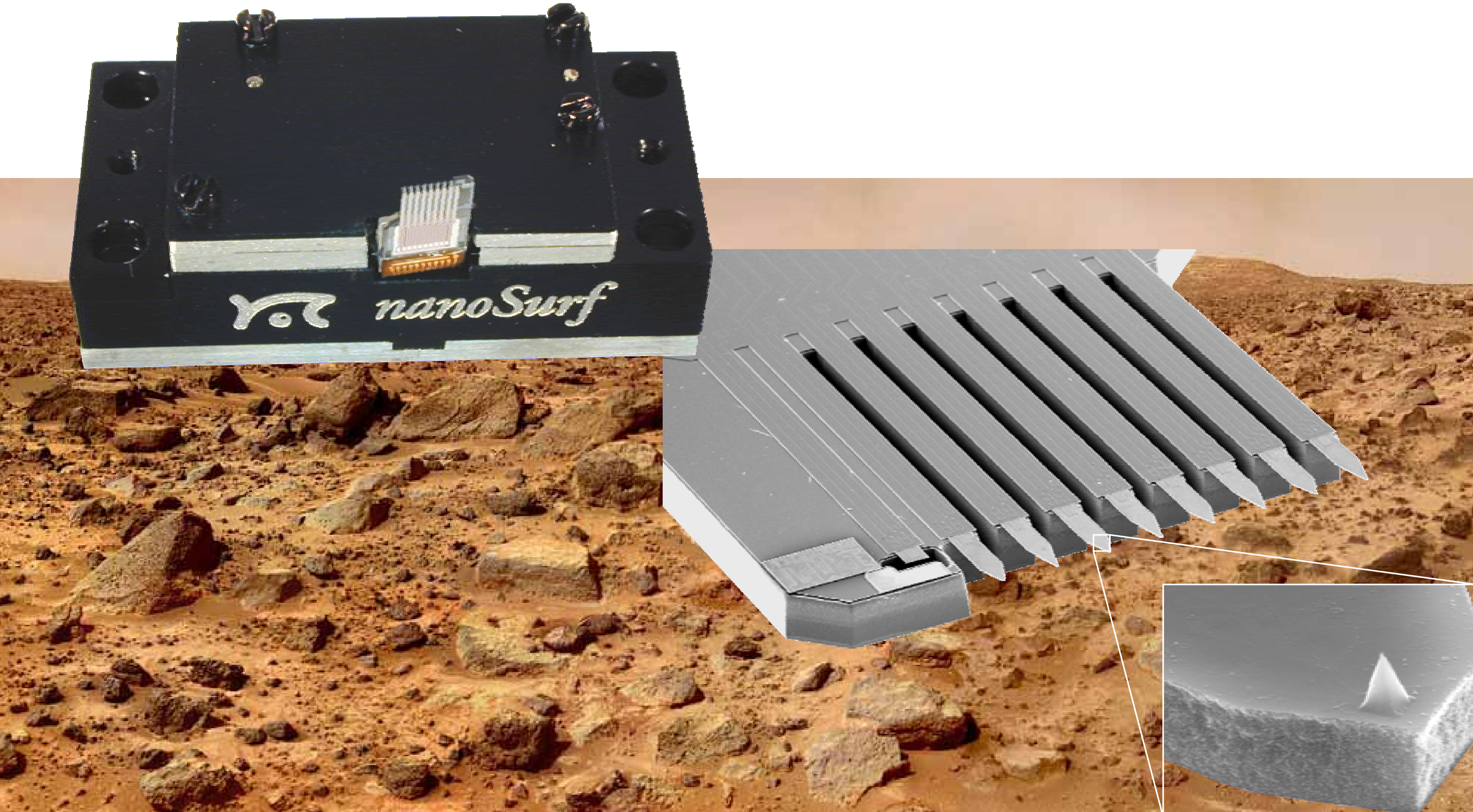



**ThermoOrion *Flash Titrator***

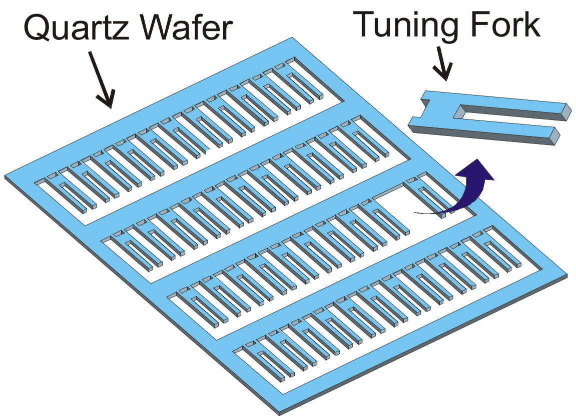
# Nanotools

# Phoenix mission to Mars: 2007

# AFM on MARS

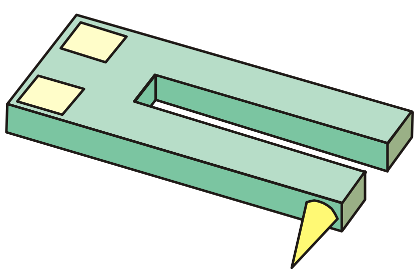


# Tuning Fork based AFM Probes



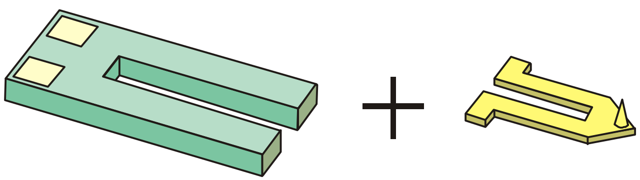

1.5 inch square wafer
about 350 tuning forks

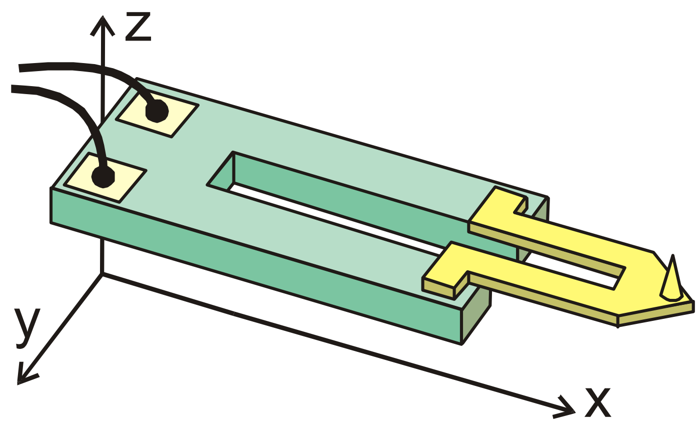
## Conventional setup



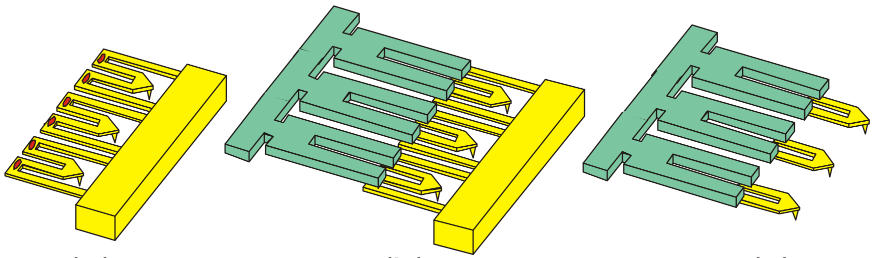
## New probe concept

**Tuning fork + Cantilever**



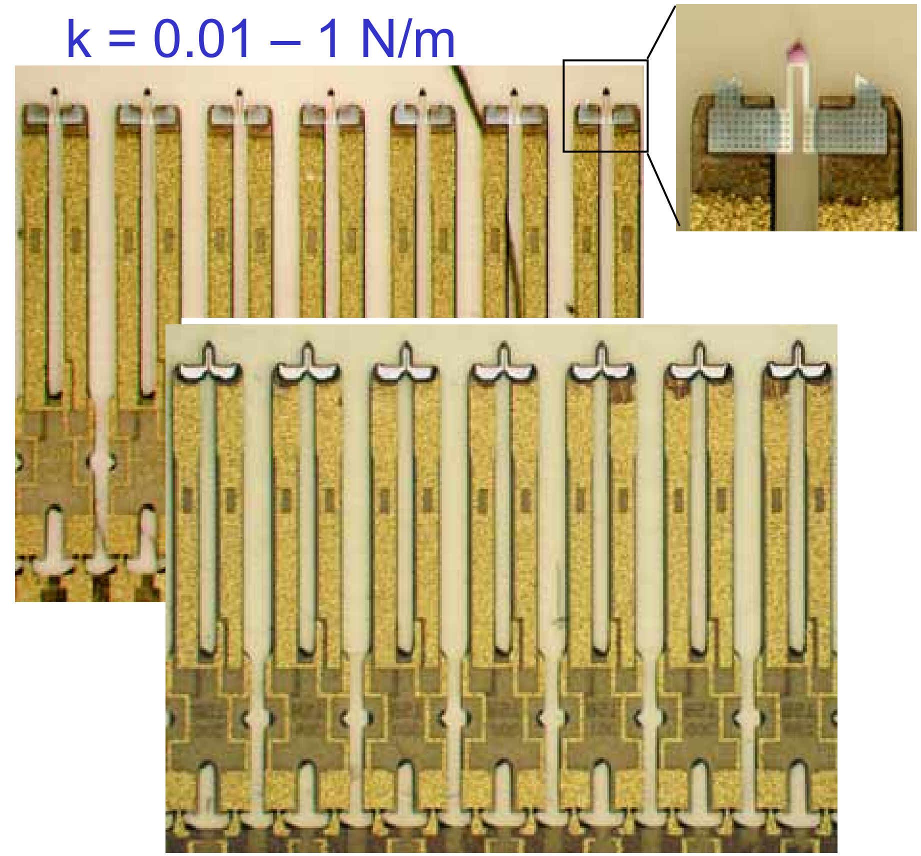


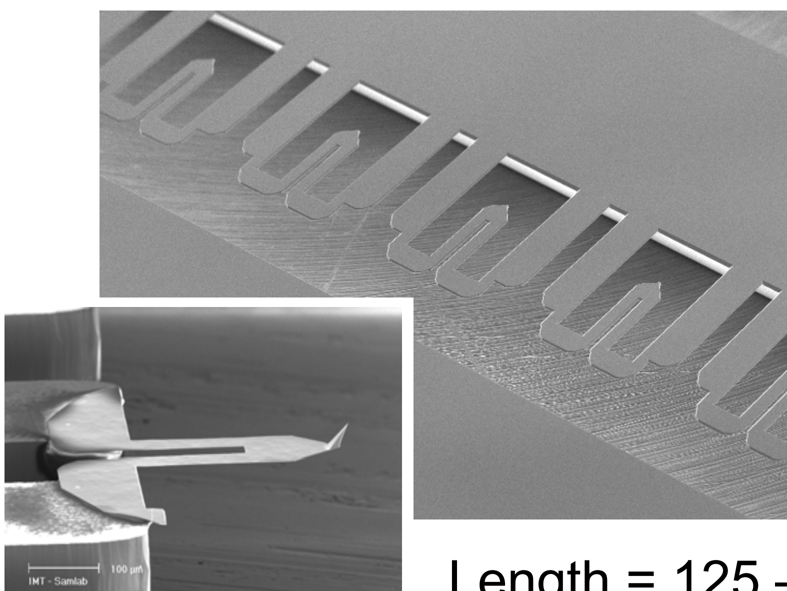
# Batch fabrication of the probe



(a) (b) (c)

SiN cantilever
k = 0.01 – 1 N/m

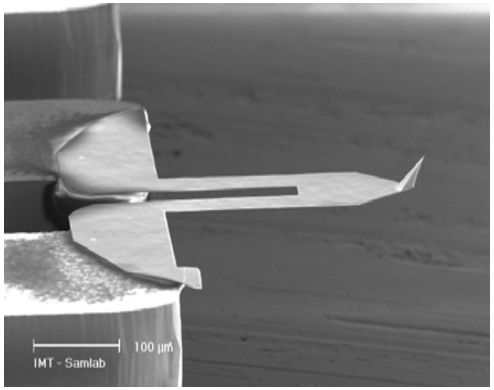





Length = 125 – 700 µm

Si cantilever
k = 1 – 550 N/m

# The A-Probe (The Akiyama Probe)




1. ***Technology Transfer initiated***
2. ***Commercialization of A-probe AFM by NanoWorld Inc.***
3. ***Development of a dedicated A-probe AFM Instument by NanoSurf Inc.***

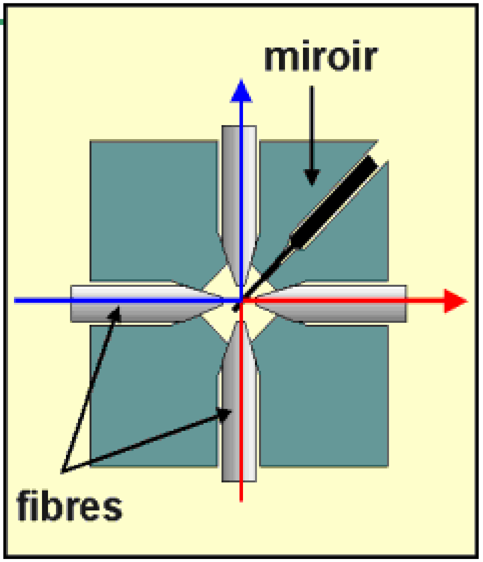
# Optical MEMS

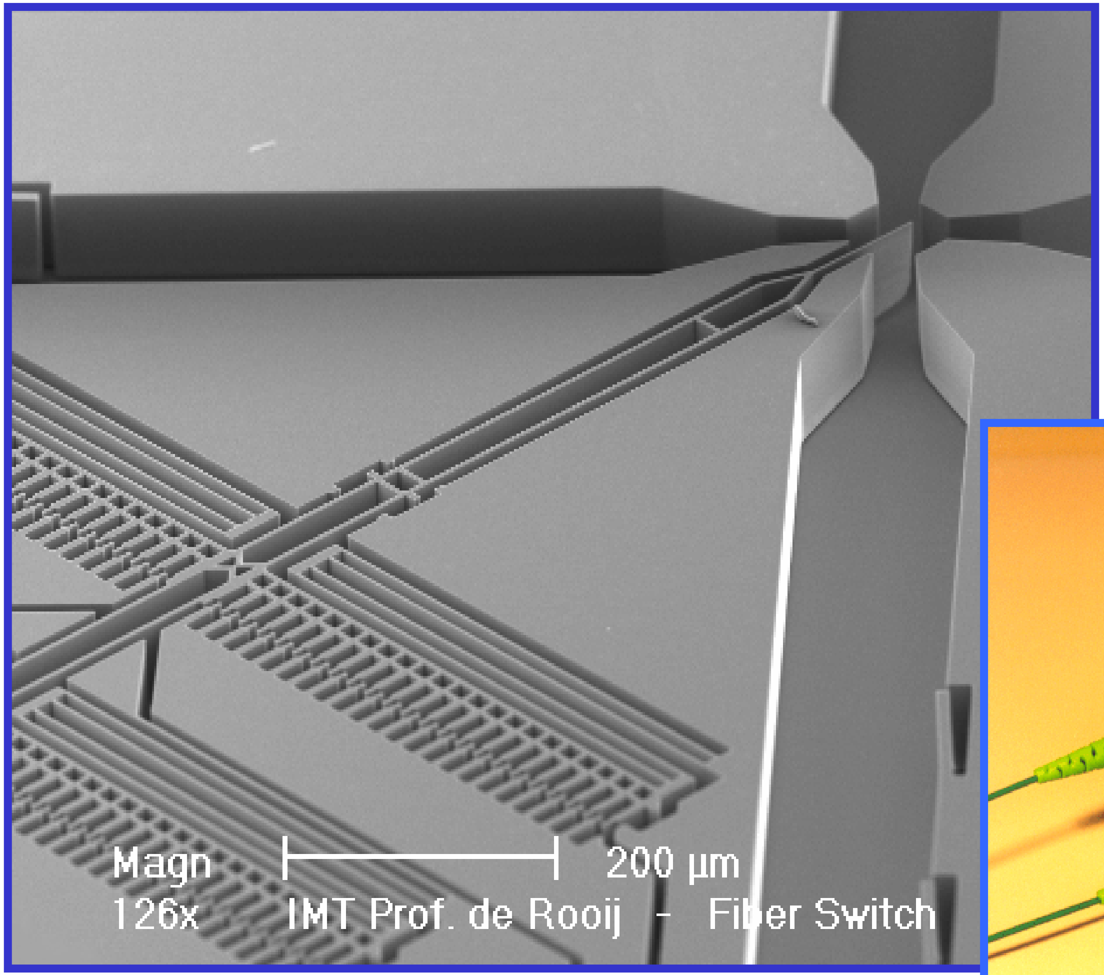
# *MEMS for Fiber Communication*

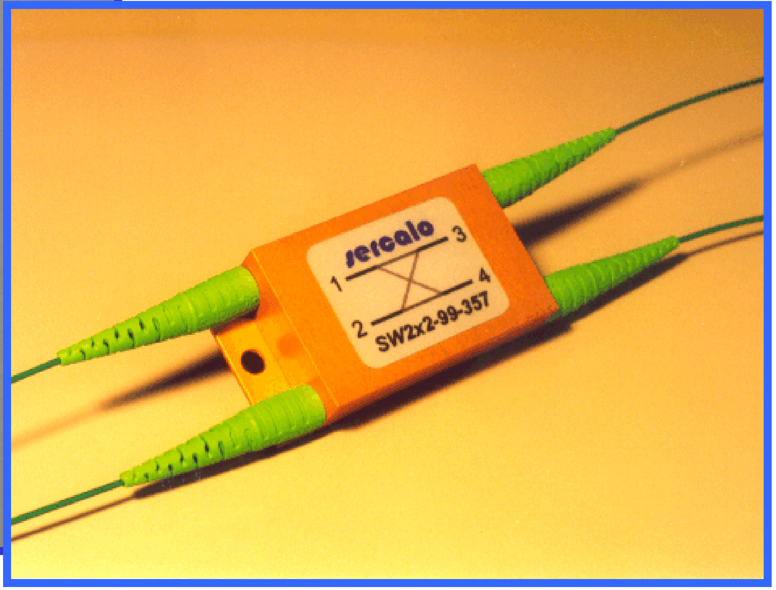
Optical MEMS

- Size of Single Mode Fibers
- Integrated Passive Alignment
- Low Polarization Sensitivity
- Low Cross-talk
- Reliable

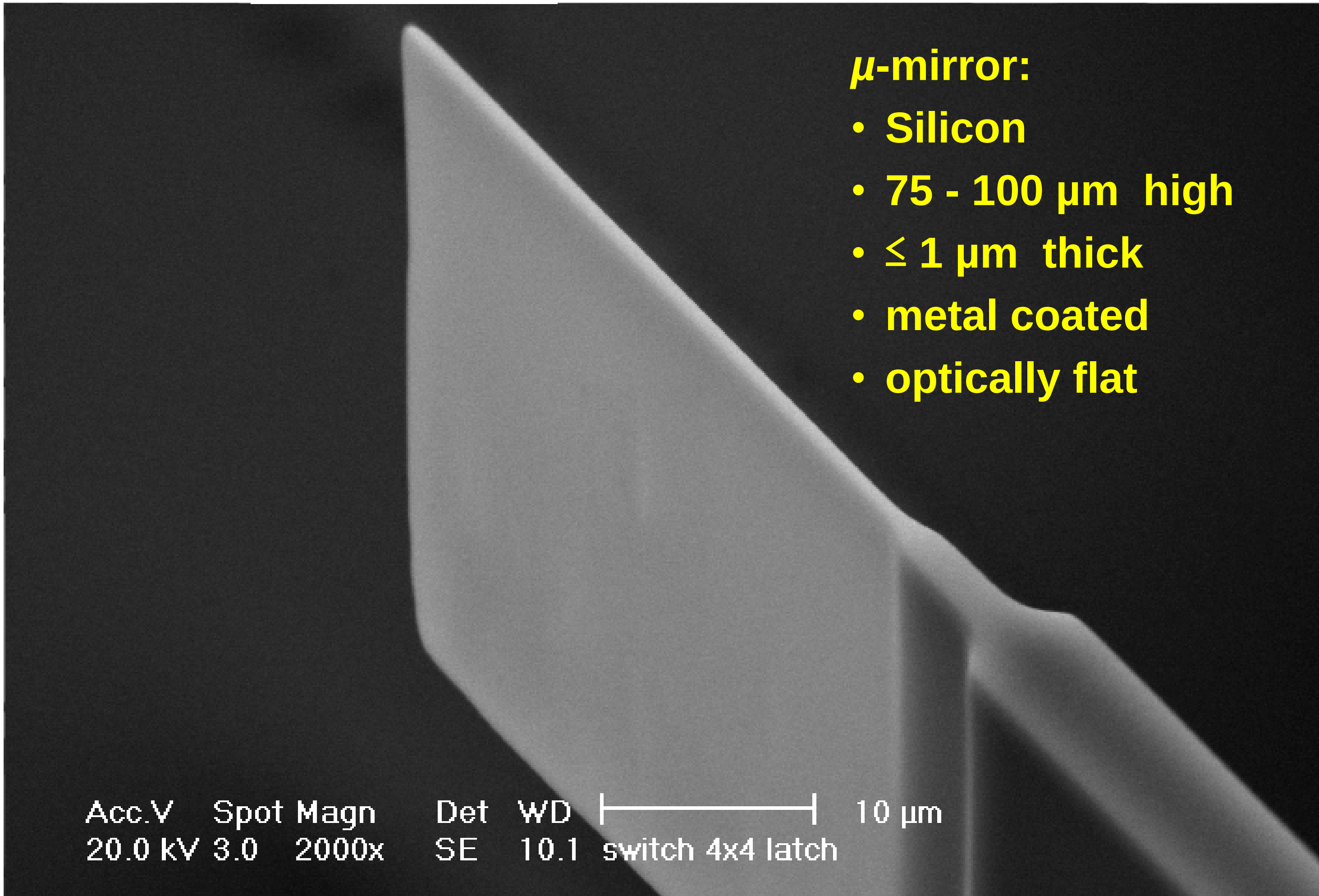
# Actuator, Grooves, Mirror



# *Switch Details*



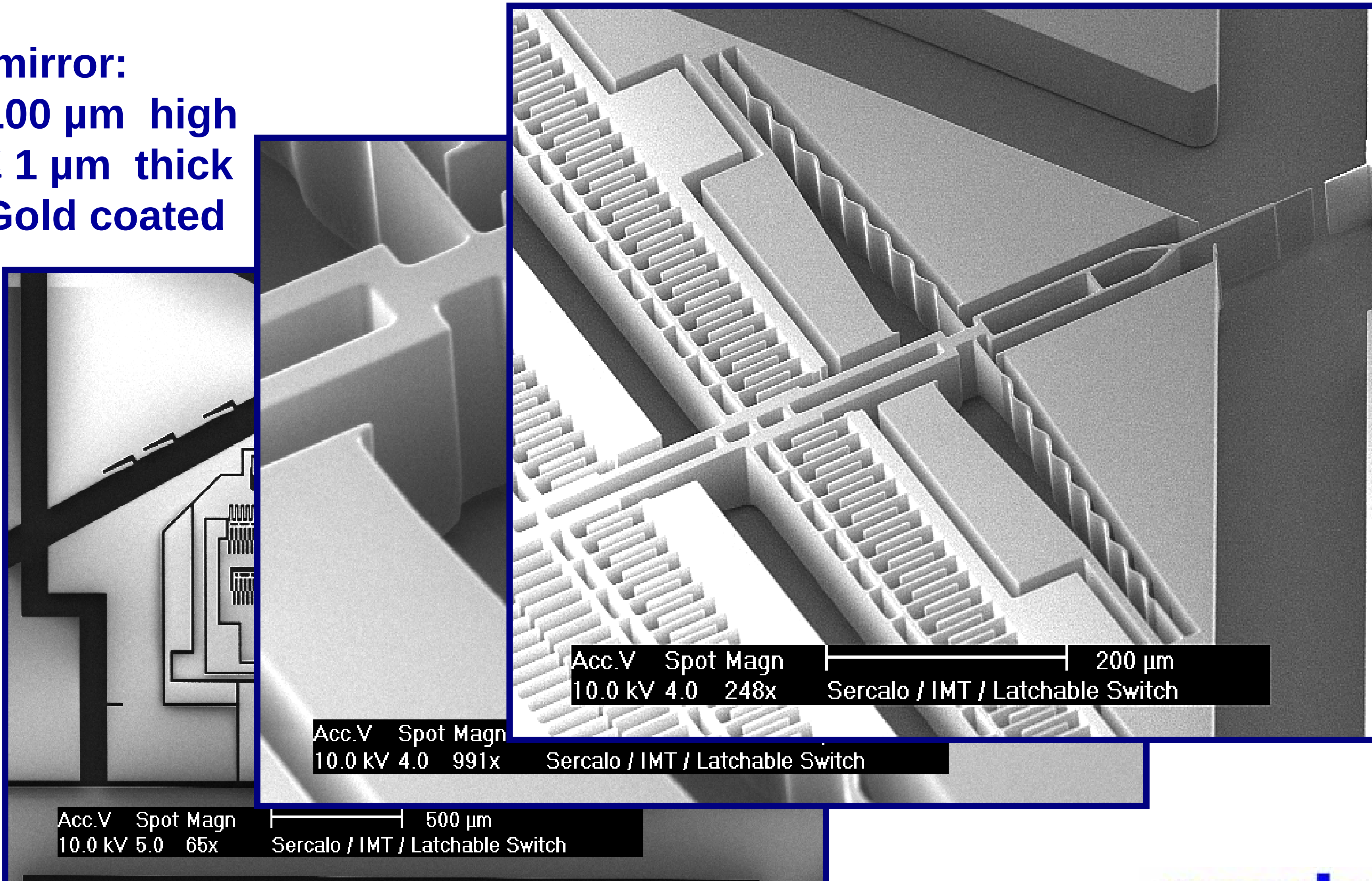

***µ*-mirror:**

- **Silicon**
- **75 - 100 µm high**
- **≤ 1 µm thick**
- **metal coated**
- **optically flat**

# Latching Multimode Fiber 2x2 Switch

**$\mu$-mirror:**

- **100 µm high**
- **≤ 1 µm thick**
- **Gold coated**

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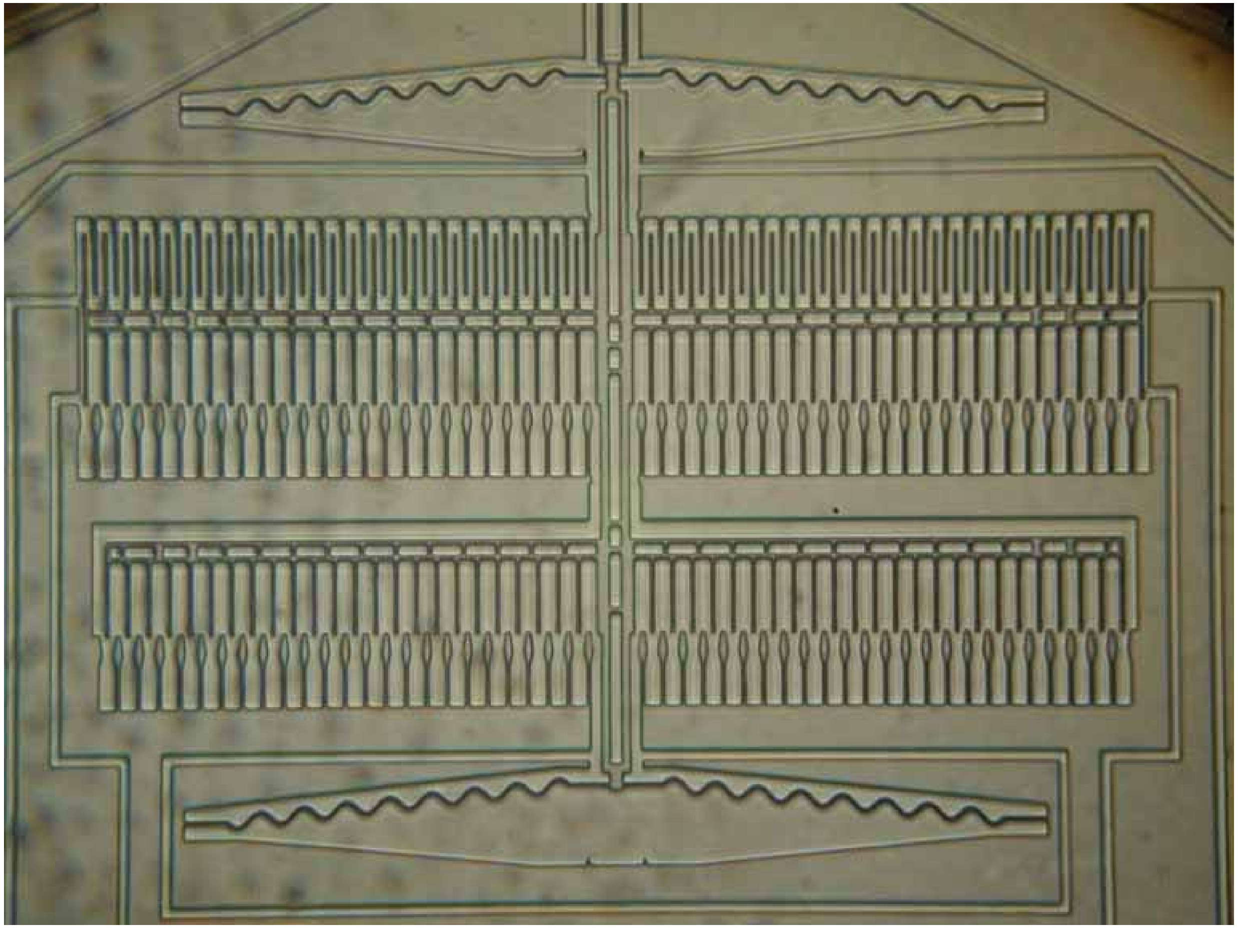
# *Latching on Multimode Switch*



92 V

52 V

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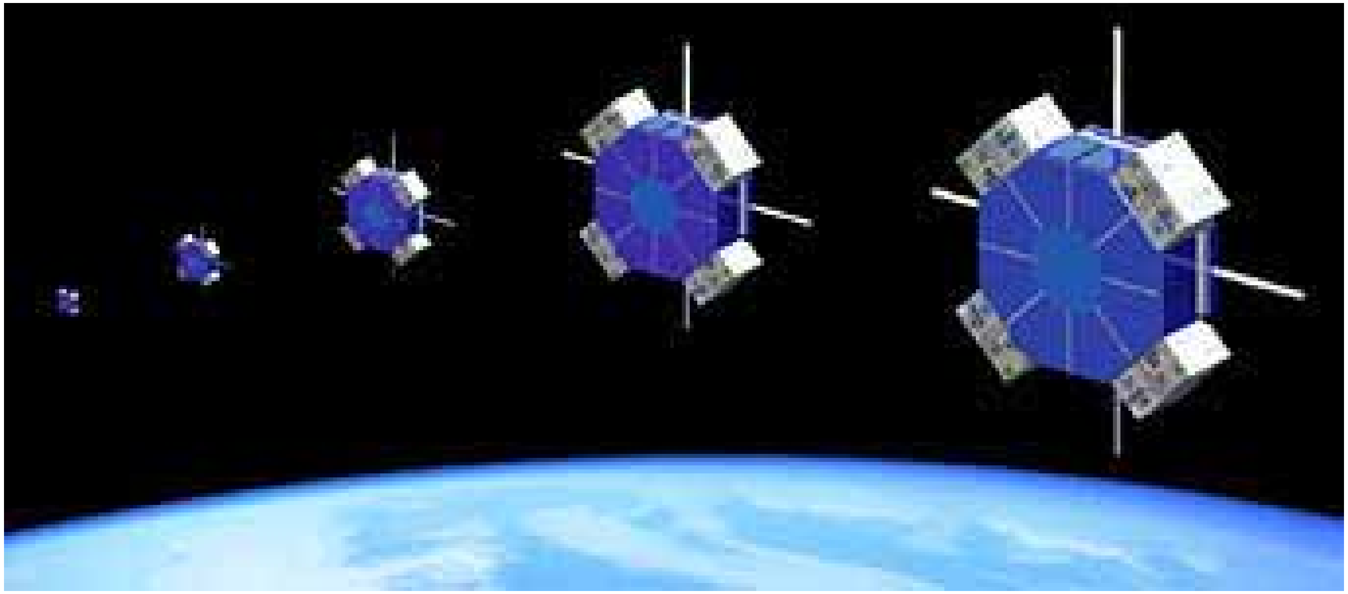
# *Power MEMS using*
# *Solid Propellant Based Actuators*

# Microthrusters for Nanosatellites/Picosatellites



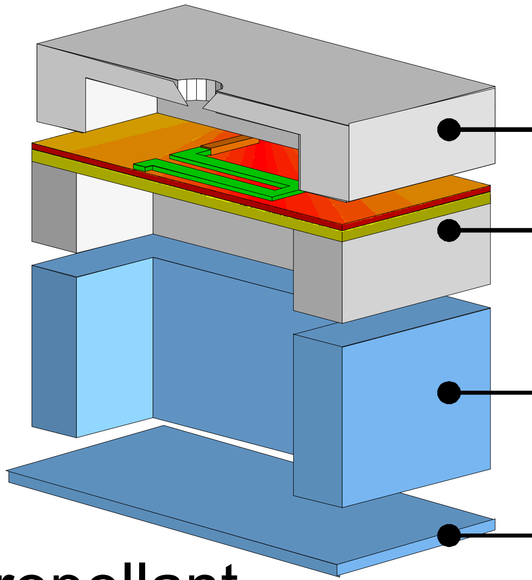
http://www.aero.org/technology/etd.html

# *Solid Propellant Technology*

- ***Combustion : large quantity of energy from small volume***
- ***Solid fuel : no leakage, stability in time***
- ***No moving parts, eliminating frictional force and making technological fabrication easier***
- ***The chamber is not pressurised, the reservoir does not need to be massive***

# Microthruster : Principle of Operation

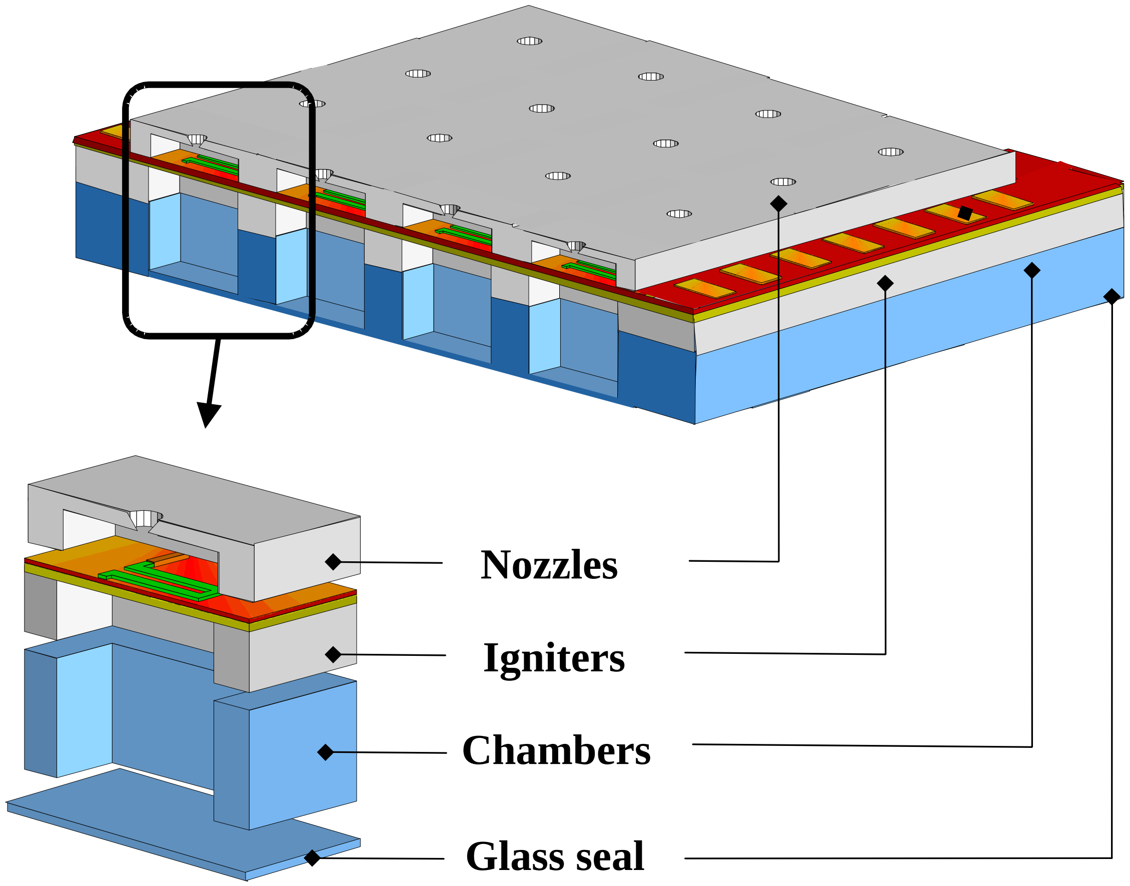
- Microthruster parts
  - Nozzle
  - Igniter
  - Chamber
  - Seal




- Operation
  - Chamber filling with solid propellant
  - Propellant heating by Joule effect and ignition
  - Combustion, gas production and thrust force
- Requirements
  - ignition temperature : ~ 200°C

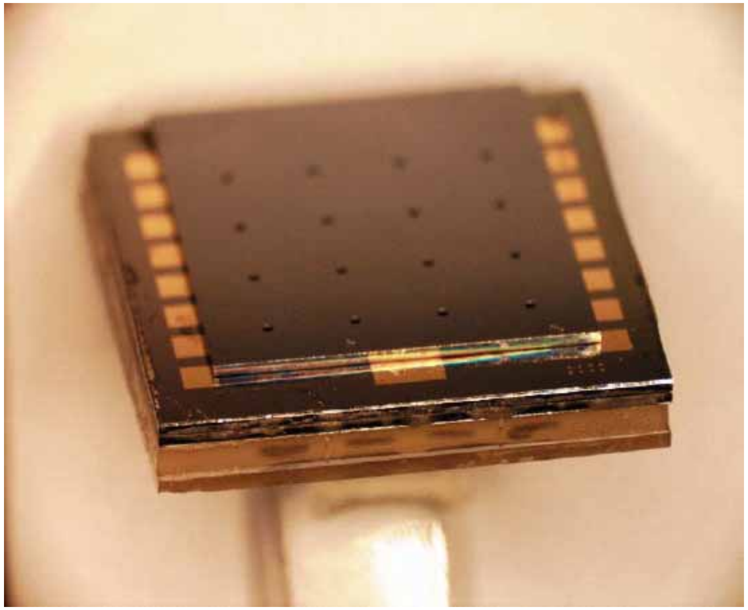
# Microthruster : Principle of Operation

- ► Array of 4x4 microthrusters (16 thrusters)



# DEMO Assembling

- Filling of the parts with propellant
  - Igniter with ZPP
  - Sealed chamber with GAP

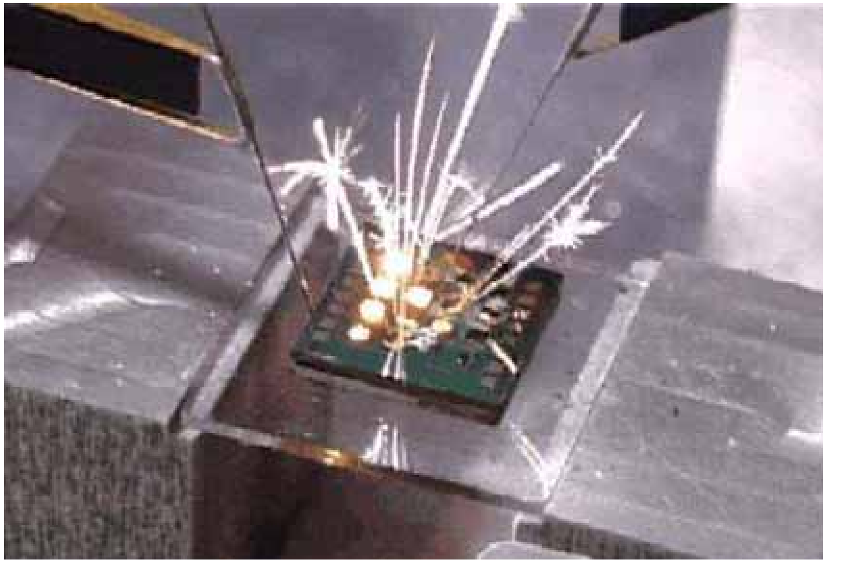


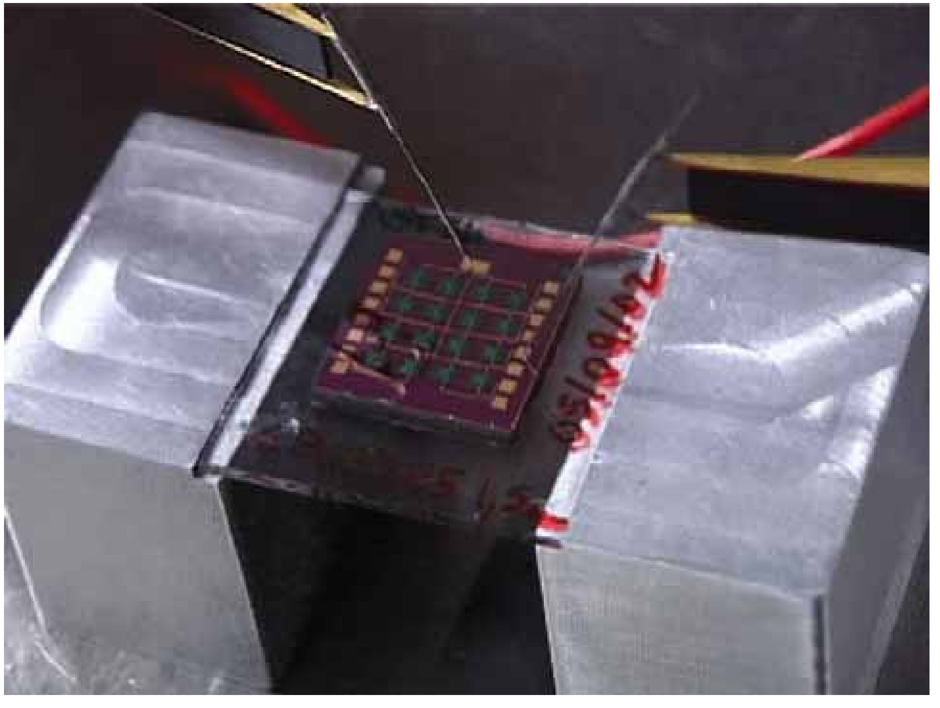
- Bonding
  - Thermal gluing (epoxy glue)

    at low temperature (60-80°C)

# DEMO: Ignition Tests

- Ignition tests
  - Ignition power : 100 – 150 mW
  - Ignition time : 20 – 130 ms
  - Combustion time : ~ 320 ms





**Videos made at LAAS, Toulouse, France**

# Conclusions

- Turn ideas into demonstrators
- Advance the technology base
- Encourage start-up initiatives
  – Seyonic (1998), Sercalo Microtechnology (1999), NanoWorld (2000),...
- Encourage technology transfer
  – Intersema (pressure sensors), MicroFlow Engineering (Inhalers), CSEM, Colibrys, ...

# *Recent Start-up Companies*

## Sercalo Microtechnology SA
Production of Optical MEMS Switches and Attenuators

## Seyonic SA
Engineering and manufacturing of microfluidic devices and systems for life sciences and space research

## NanoWorld SA
Nanotools for Scanning Probe Microscopy

# Remerciements


- Les Autorités de la République et du Canton de Neuchâtel et l'Université de Neuchâtel
- Les membres de SAMLAB
- Le CSEM S.A.
- L'ESA GSTP/AST et l'ESA PRODEX
- Le comité pour la technologie et l'innovation (CTI)
  - $M^2S^2$, MedTech.
- Le Conseil des Ecoles polytechniques fédérales
  - MINAST, Optics, TOP NANO 21.
- Fond national suisse de la recherche scientifique
- Office fédéral de l'éducation et de la science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