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)***

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:***

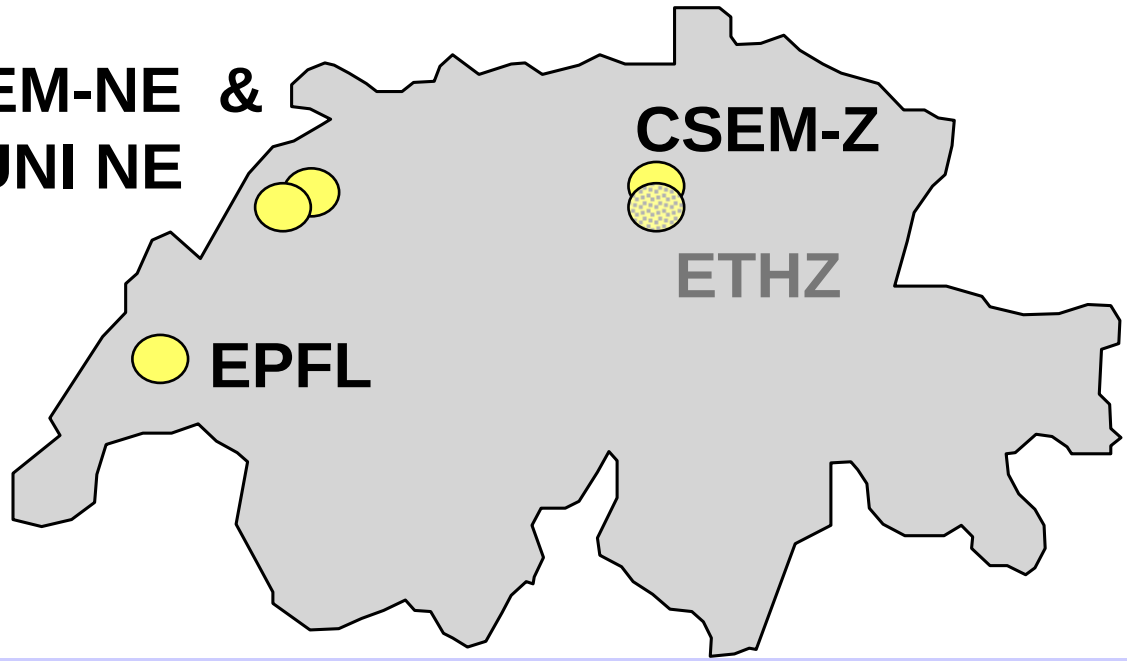
  Education

  Applied Research

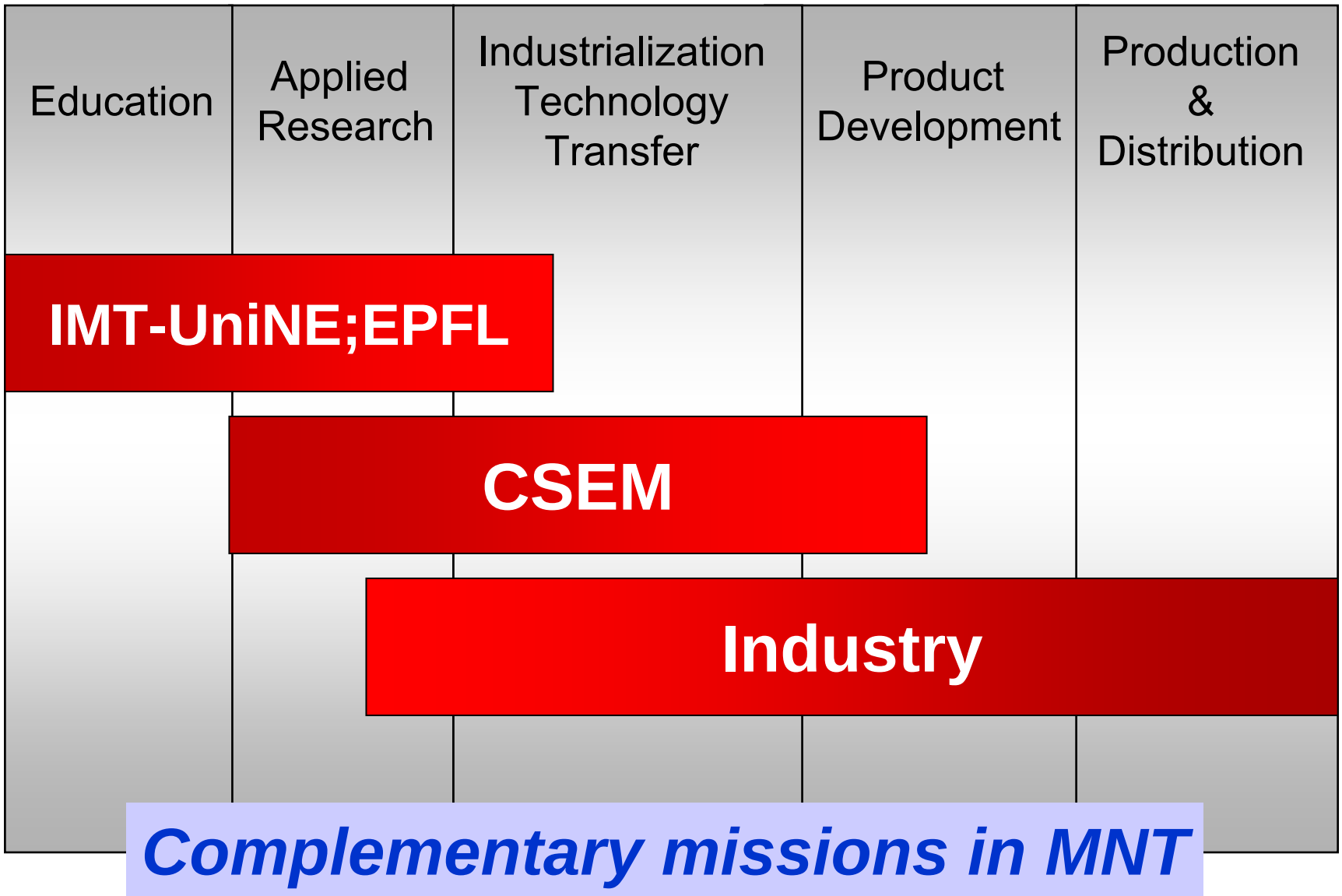
  Support Local Industry

Regional Network in MNT

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

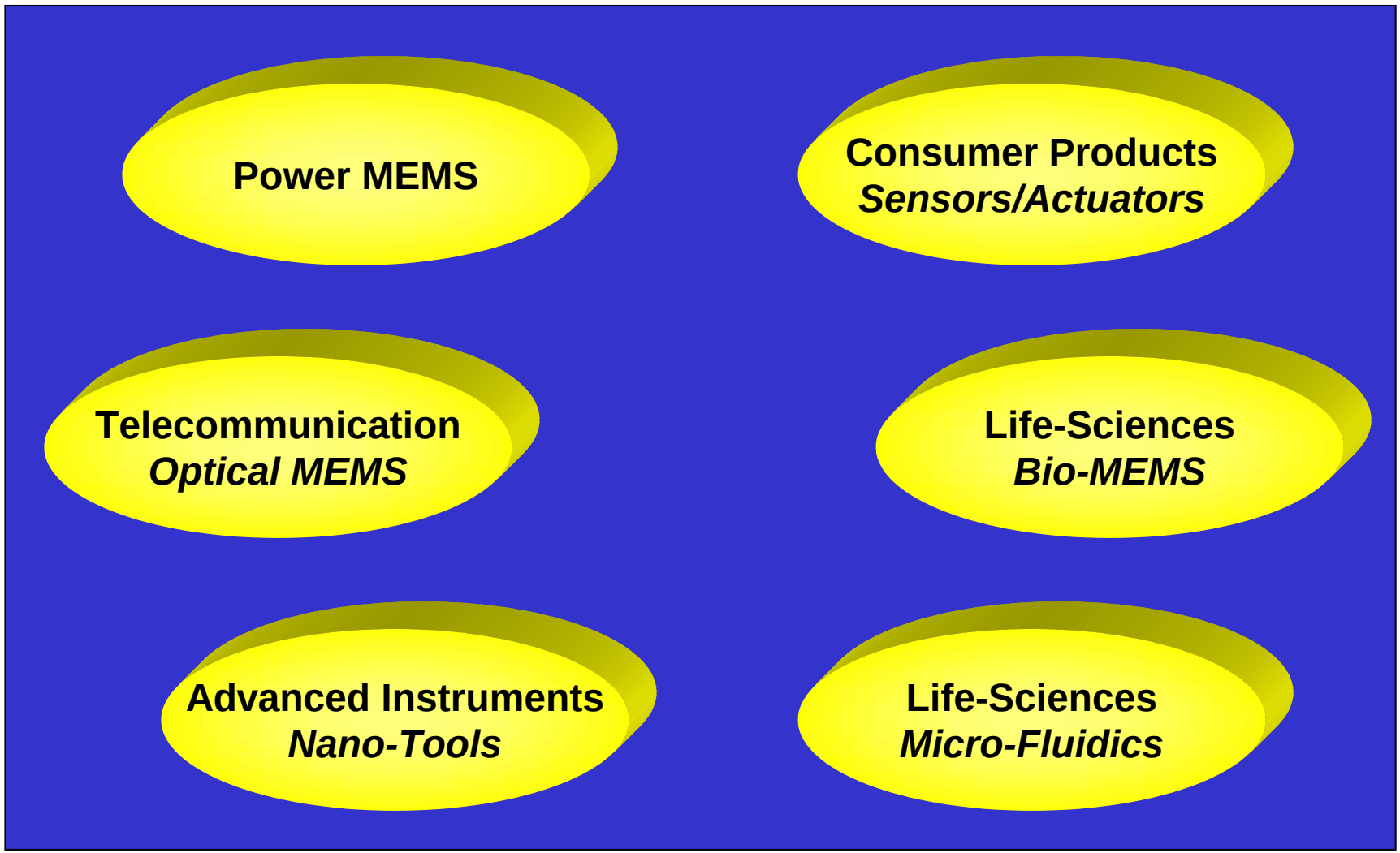


Goal: Benefit from the complementary strengths of the members


Education
Applied Research
Industrialization Technology Transfer
Product Development
Production & Distribution
IMT-UniNE;EPFL
CSEM
Industry
Complementary missions in MNT

Mission of the "Pôle"

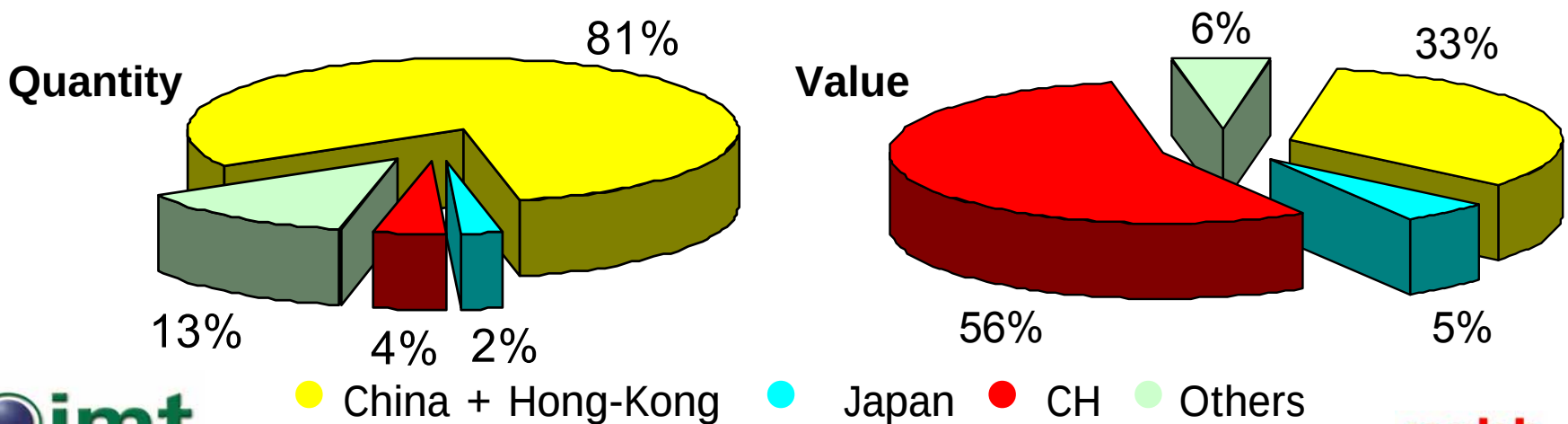
- ***Collaboration in educational programmes***
- ***Dual appointments for selected key people***
- ***Establishment of joint research programs***
- ***Co-ordination of investments in laboratory equipment***
- ***Joint research laboratories: CMI and ComLab***
- ***Joint industry cont(r)acts***


Power MEMS
Consumer Products
Sensors/Actuators
Telecommunication
Optical MEMS
Life-Sciences
Bio-MEMS
Advanced Instruments
Nano-Tools
Life-Sciences
Micro-Fluidics

Global Watch Business

For 2002 / Source: www.fhs.ch

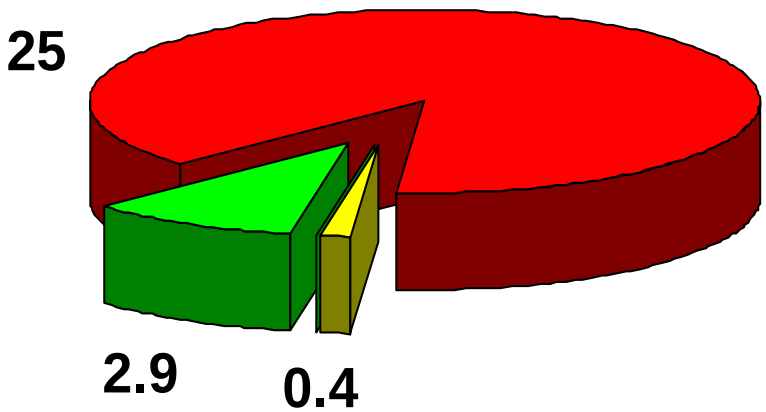
- **Watches, movements and components (globally):**
  - **1.5 Billion pieces / year**
  - **16 to 17 Billion CHF** **1 CHF ≈ € 0.64; 1 CHF ≈ US$ 0.80 ; 1CHF ≈ ¥87**
- **Switzerland:**
  - **120 Mio. watches, movements and components**
  - **28 Mio. finished watches = 10.5 Billion CHF**
  - **Average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



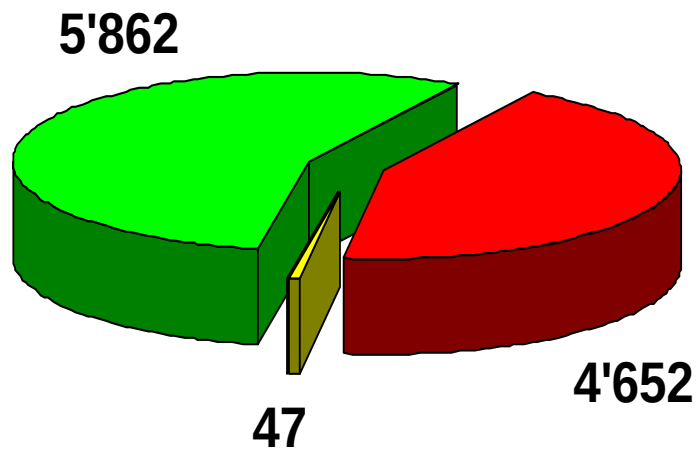
Swiss Export of Finished Watches

For 2002 / Source: www.fhs.ch

Pieces (in Mio.)



Value (in Mio. CHF)



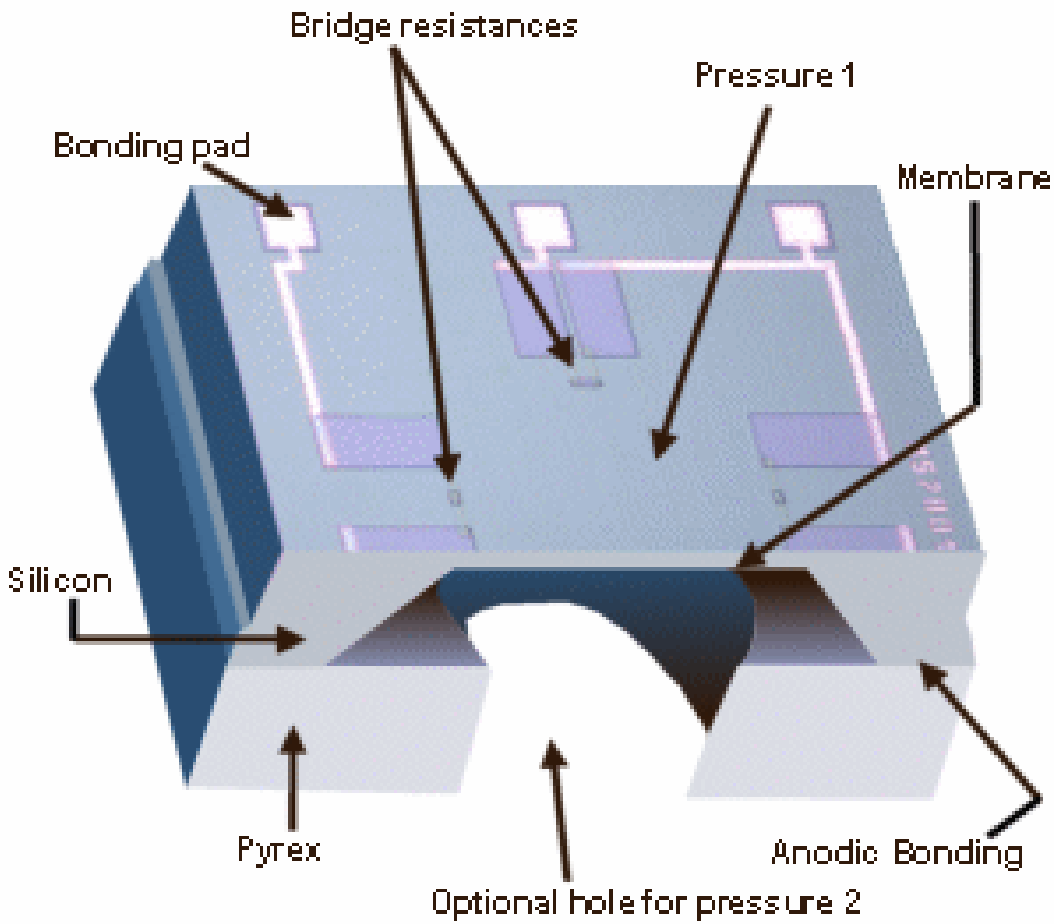
Mechanical Quartz anal. Quartz digit.

Altimeter/Barometer Module

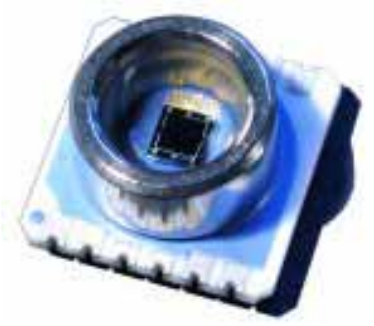
intersema
PRESSURE SENSOR PRODUCTS

Process features:

- Implanted piezoresistors
- Precise electrochemical etch stop
- Anodic Bonding



Altimeter/Barometer Module

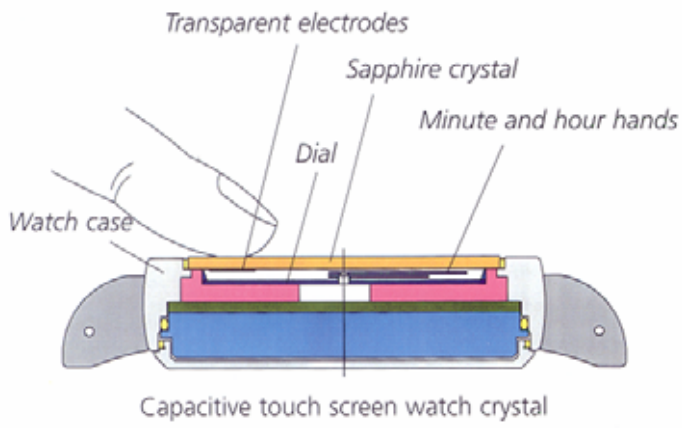


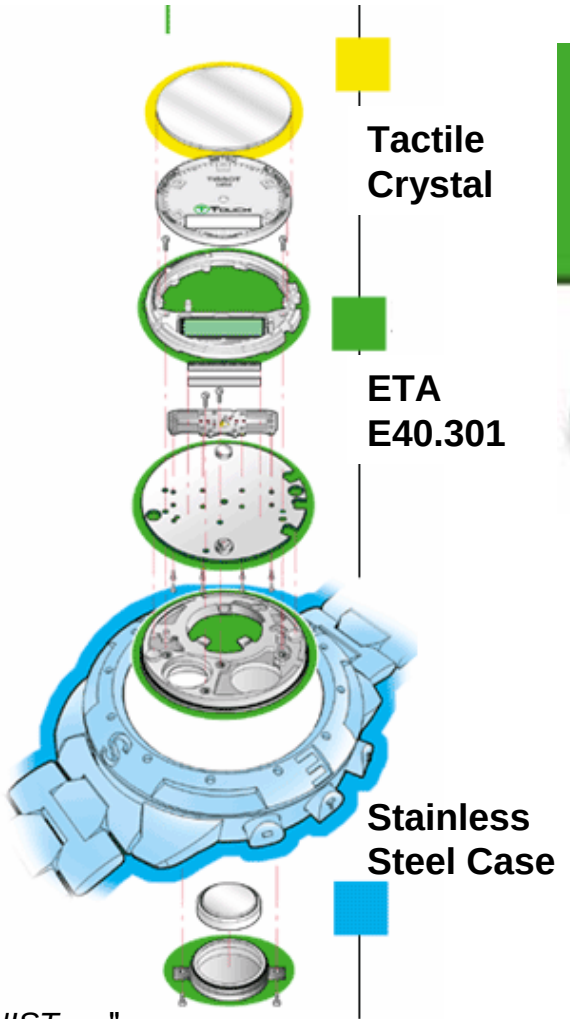
- **Altitude variation of *1 m*:**
  - ~0.1 mbar ≡ ~150 pm
- **Resolution:**
  - ~3µbar ≡ ~3cm altitude variation
- **Sensor power consumption:**
  - ~1.3µW

Tissot T-Touch (Tactile Crystal)

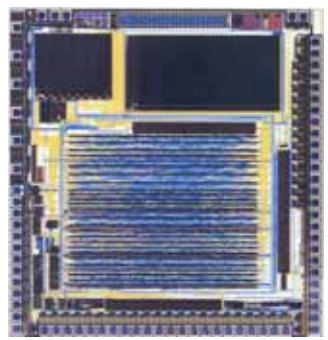
ASULAB

A COMPANY OF THE SWATCH GROUP





- **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

imt institute of microtechnology university of neuchâtel

samlab

Mechanical Watches

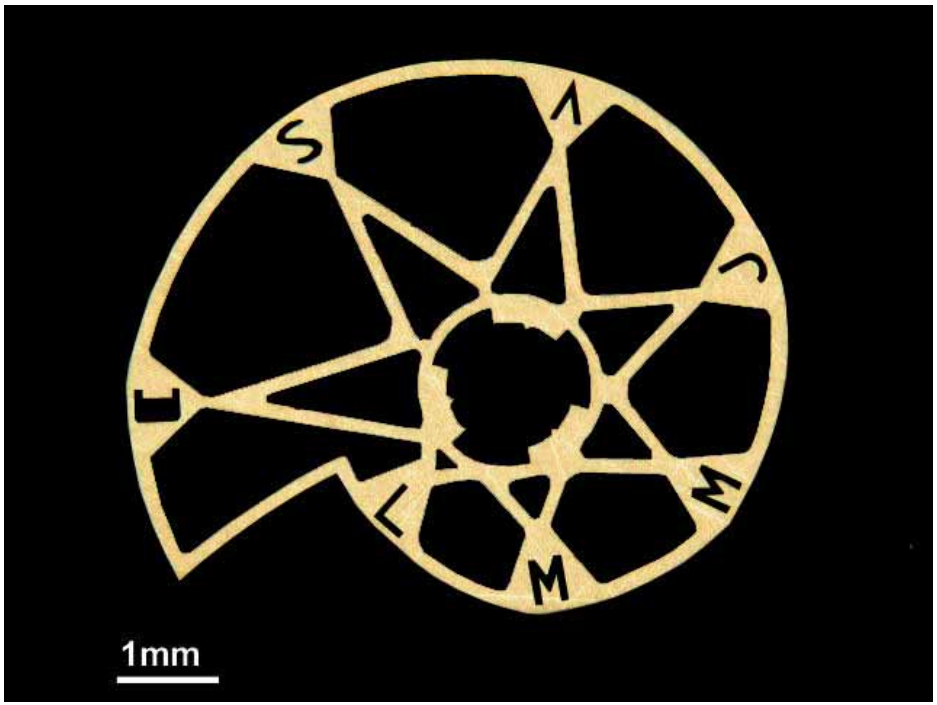
www.tagheuer.com

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.*

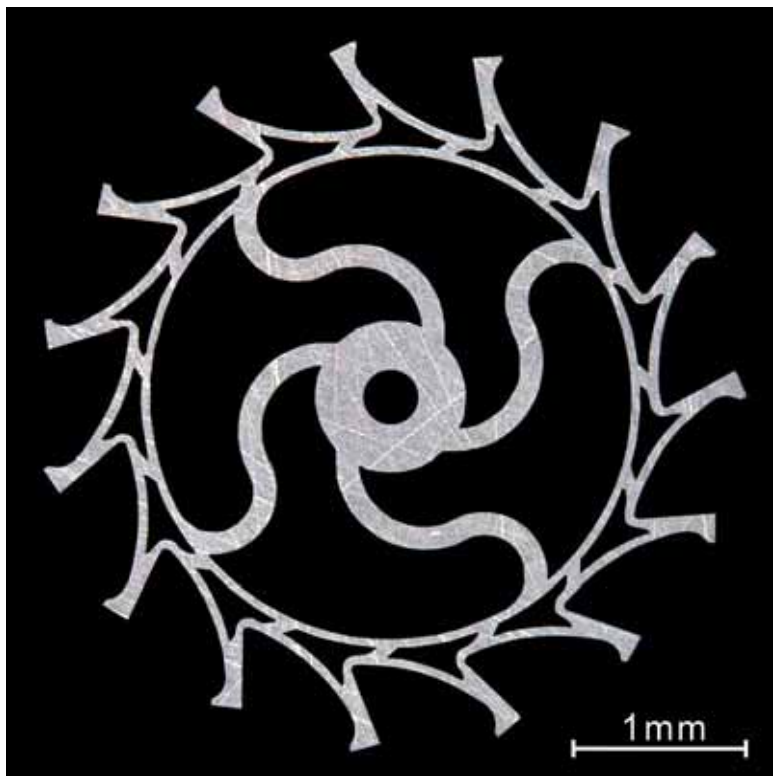
- *H. Lorenz, M. Despont, P. Vettiger, P. Renaud, "Fabrication of photoplastic high-aspect ratio microparts and micromolds using SU-8 UV resist", Microsystem Technologies, **4** (1998), pp. 42-47.*

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**

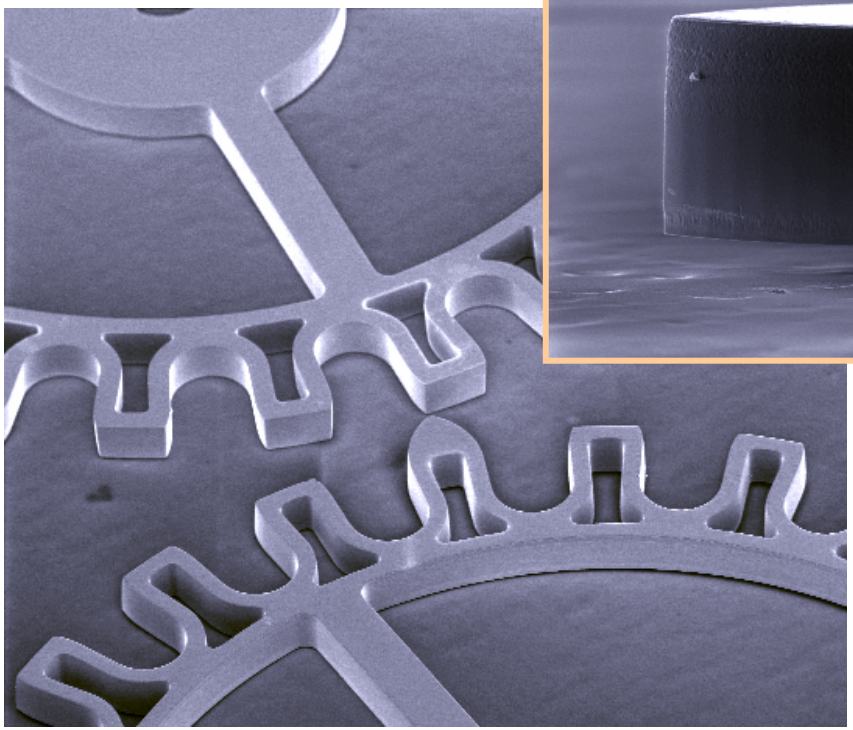
- **Low density (2.33), amagnetic, electrical conductor, easy to overcoat, …**

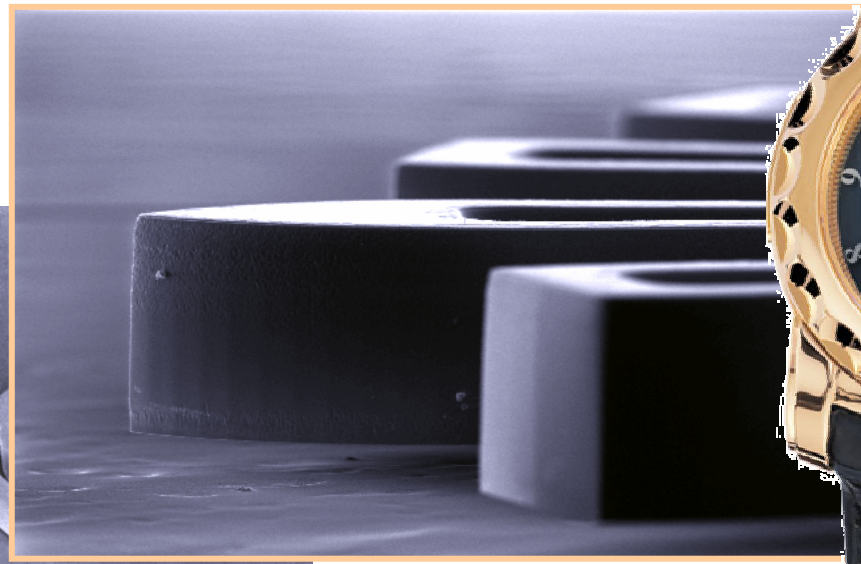
- **Machining by Deep Reactive Ion Etching (DRIE).**

Elastic behavior of Silicon

Silicon Structures of Watch Components

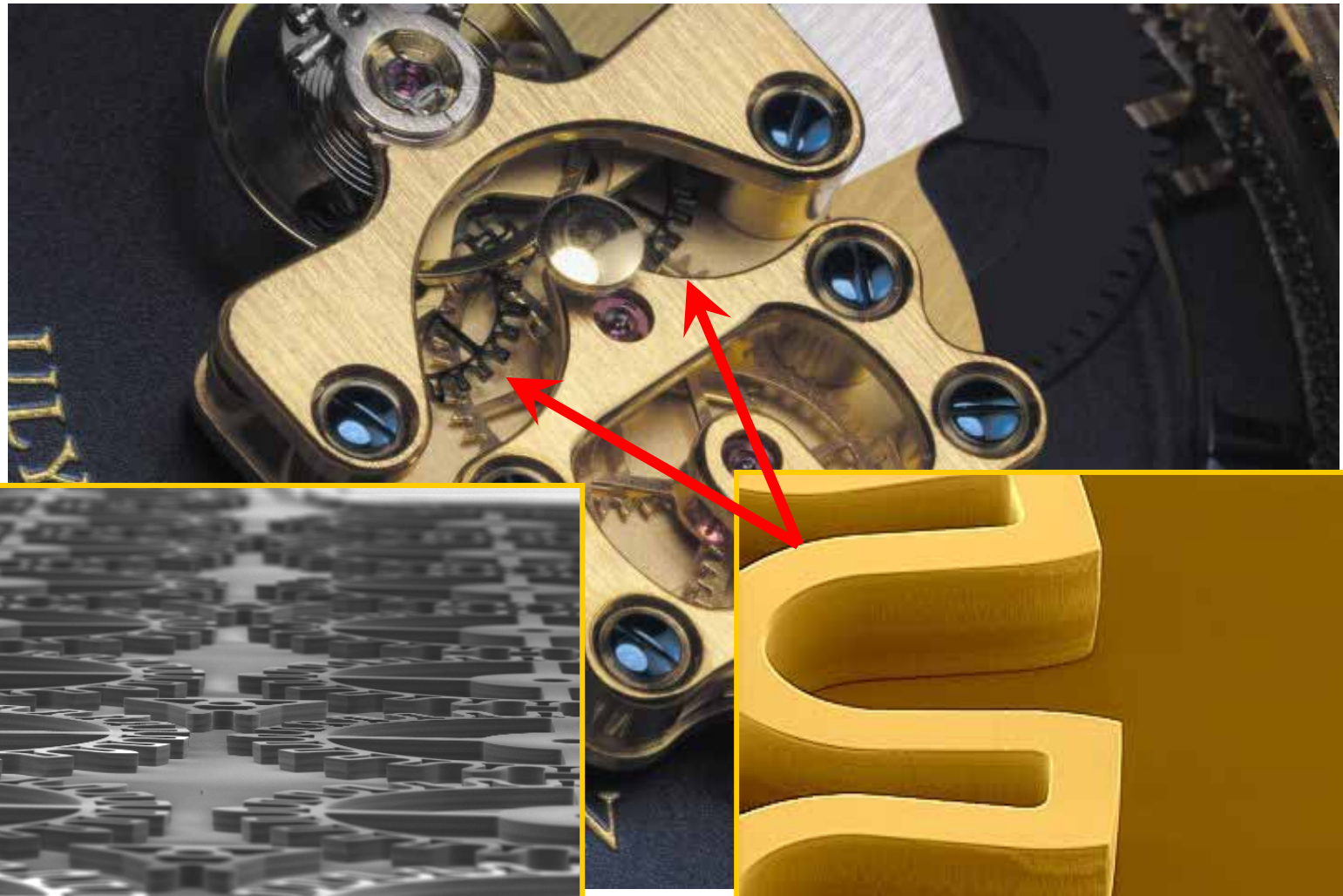
- Machining of complex mechanisms with sharp edges
- Reduced friction
- Higher lifetime





ULYSSE NARDIN
SINCE 1846 LE LOCLE - SUISSE

Dual Wheel Escapement with Si-Wheels



Dual Wheel Escapement with Si-Wheels

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

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imt
institute of microtechnology
university of neuchâtel

samlab

csem

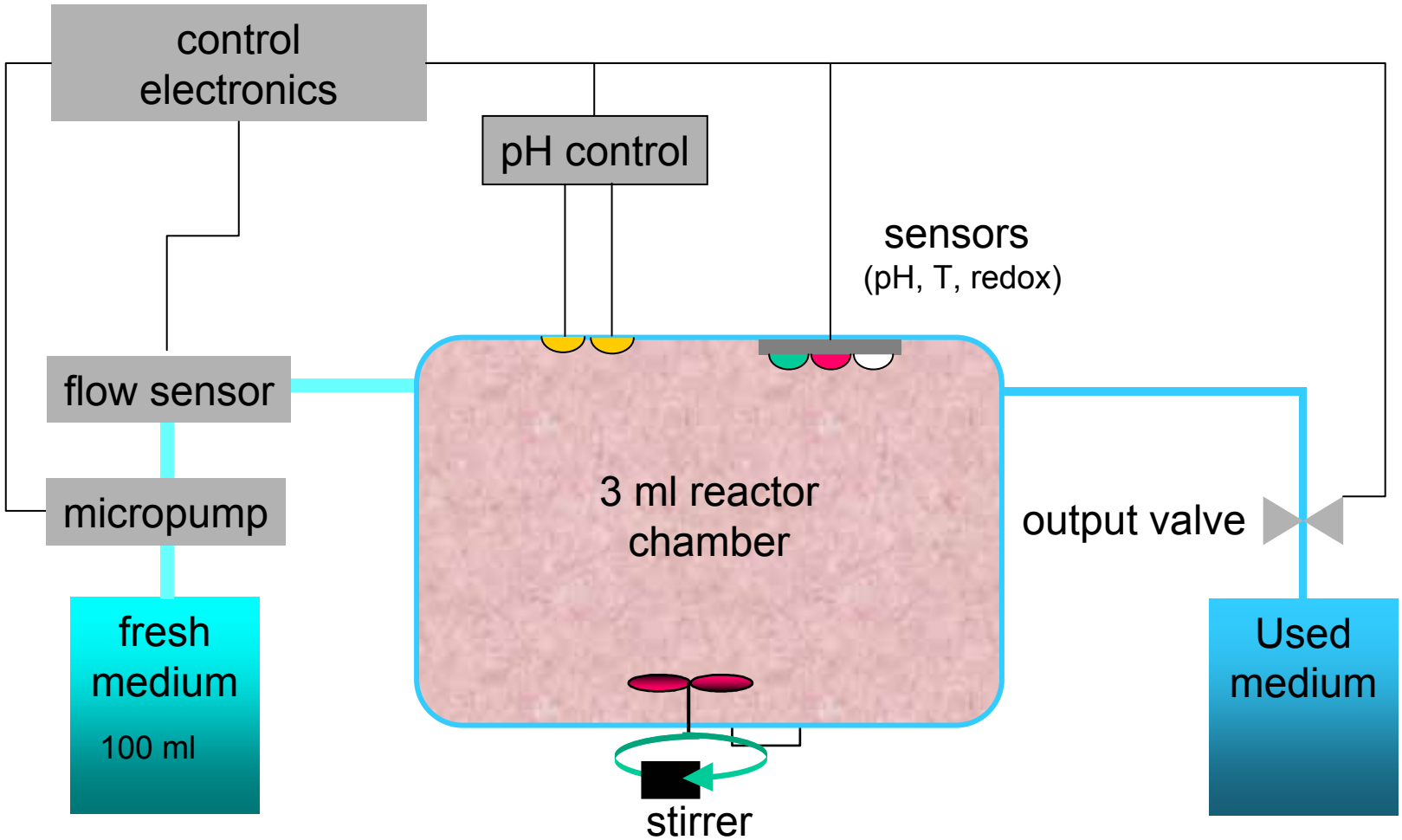
MST based instruments

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

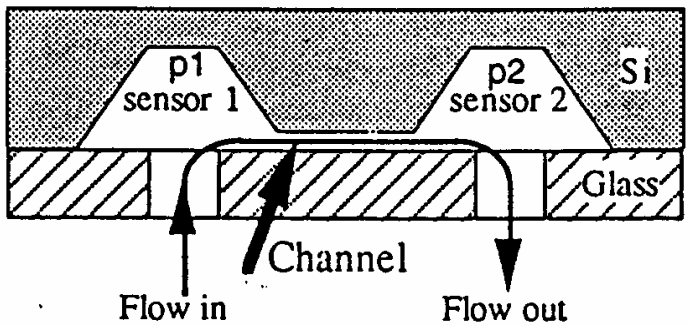
Life Sciences : Space Bioreactor

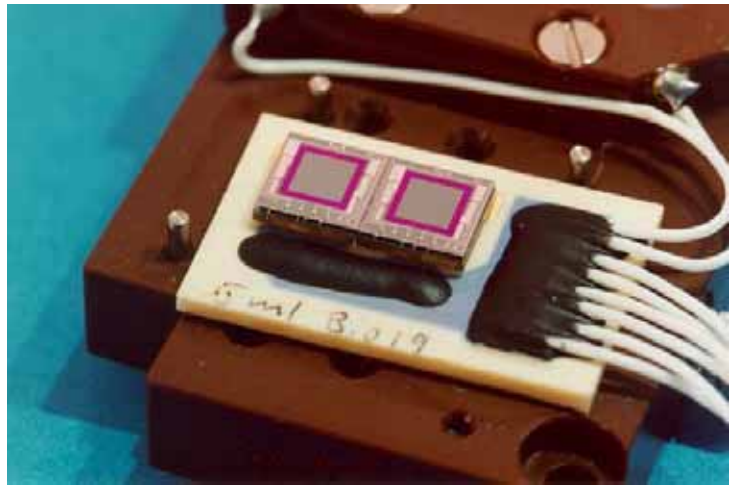
Built to evaluate the growth characteristics of yeast cells in microgravity
Flown by ESA onboard IML Spacelab July 1994, March 1996 and January 2003

Working principle

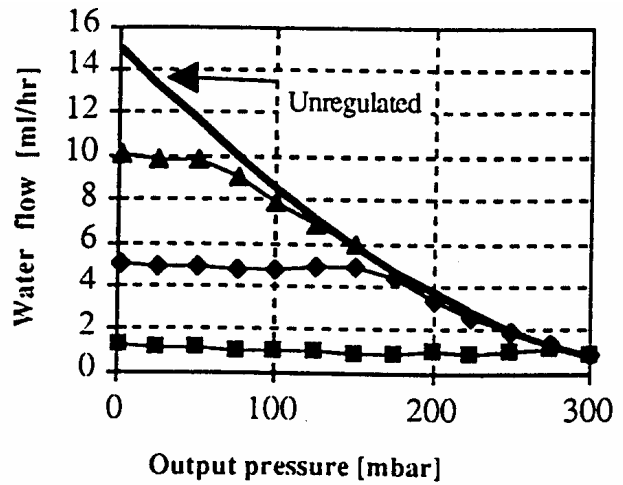


Flow Sensor

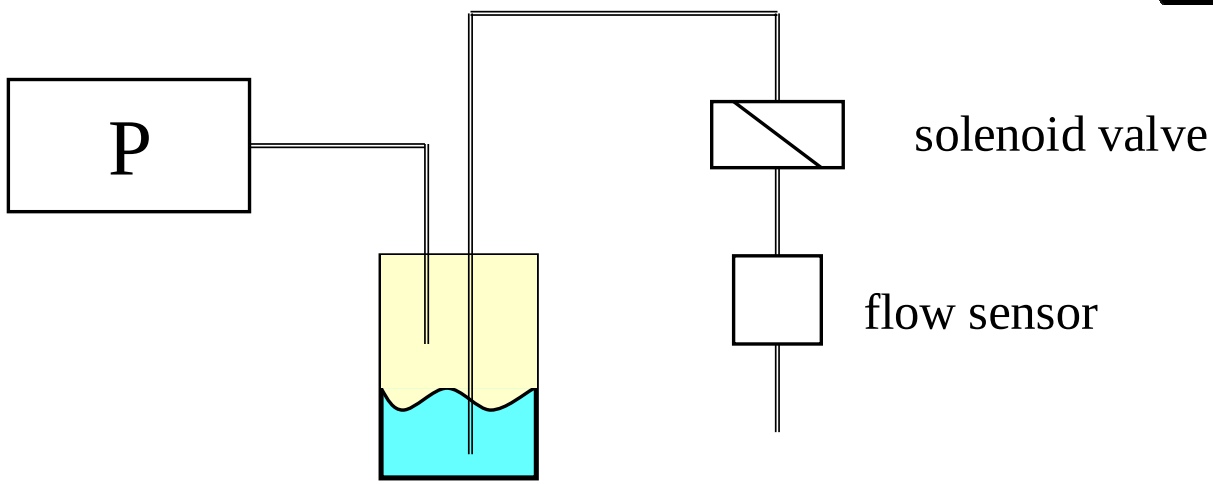




- dual piezo-resistive low pressure sensor
- 4.75 x 9.5 x 1 mm^3
- 5 mL/h full scale
- accuracy ~ 2%



Dispensing Systems

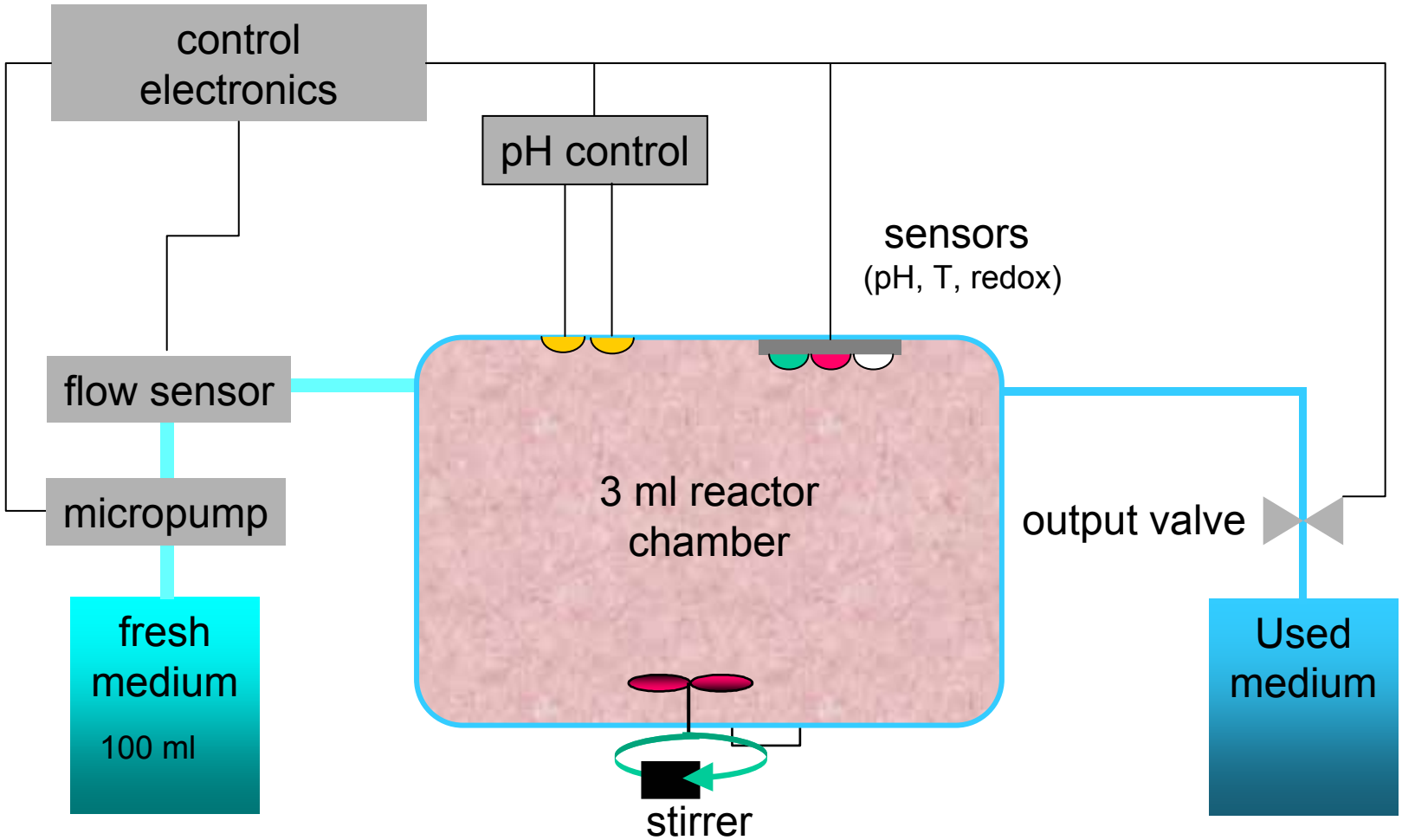


Advantages:

- *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

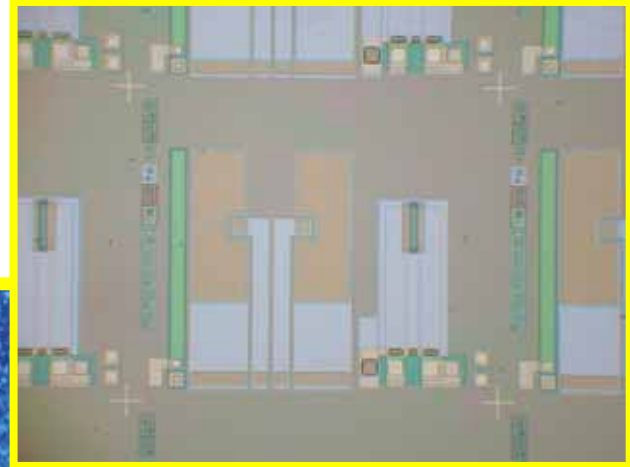
Working principle



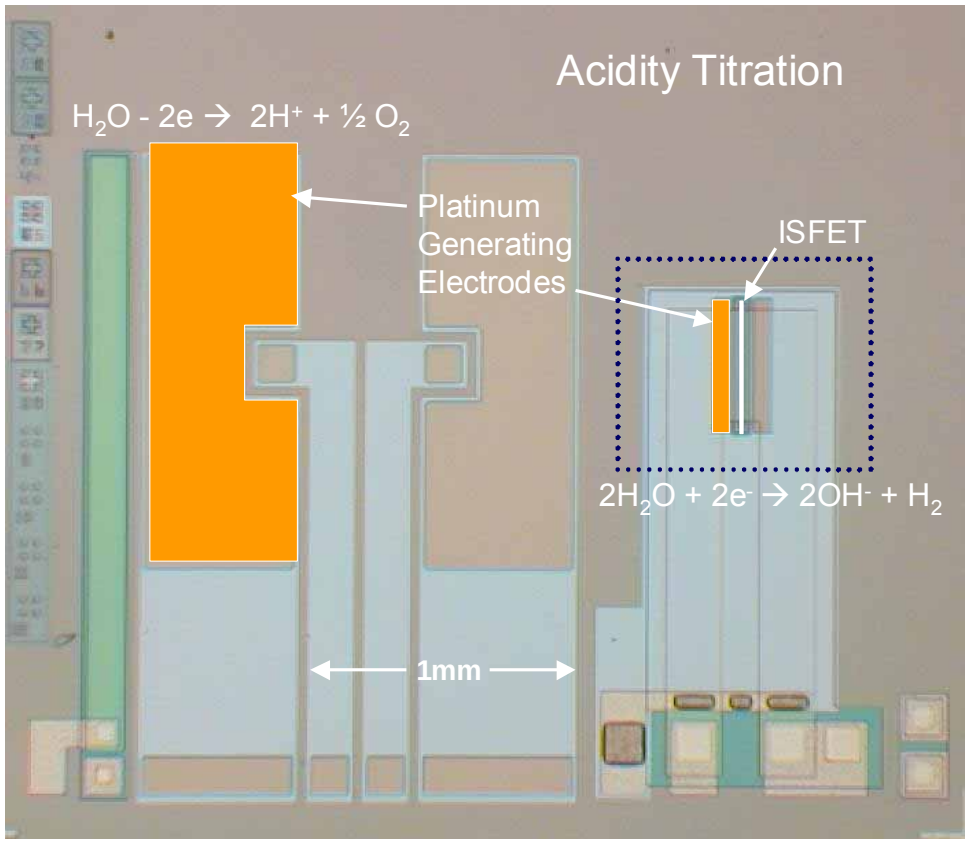
single sensors pH-ISFET

multiple sensors (pH, ORP, Conductivity, T)

ThermoOrion



Dynamic FLASH Titration Process (1)

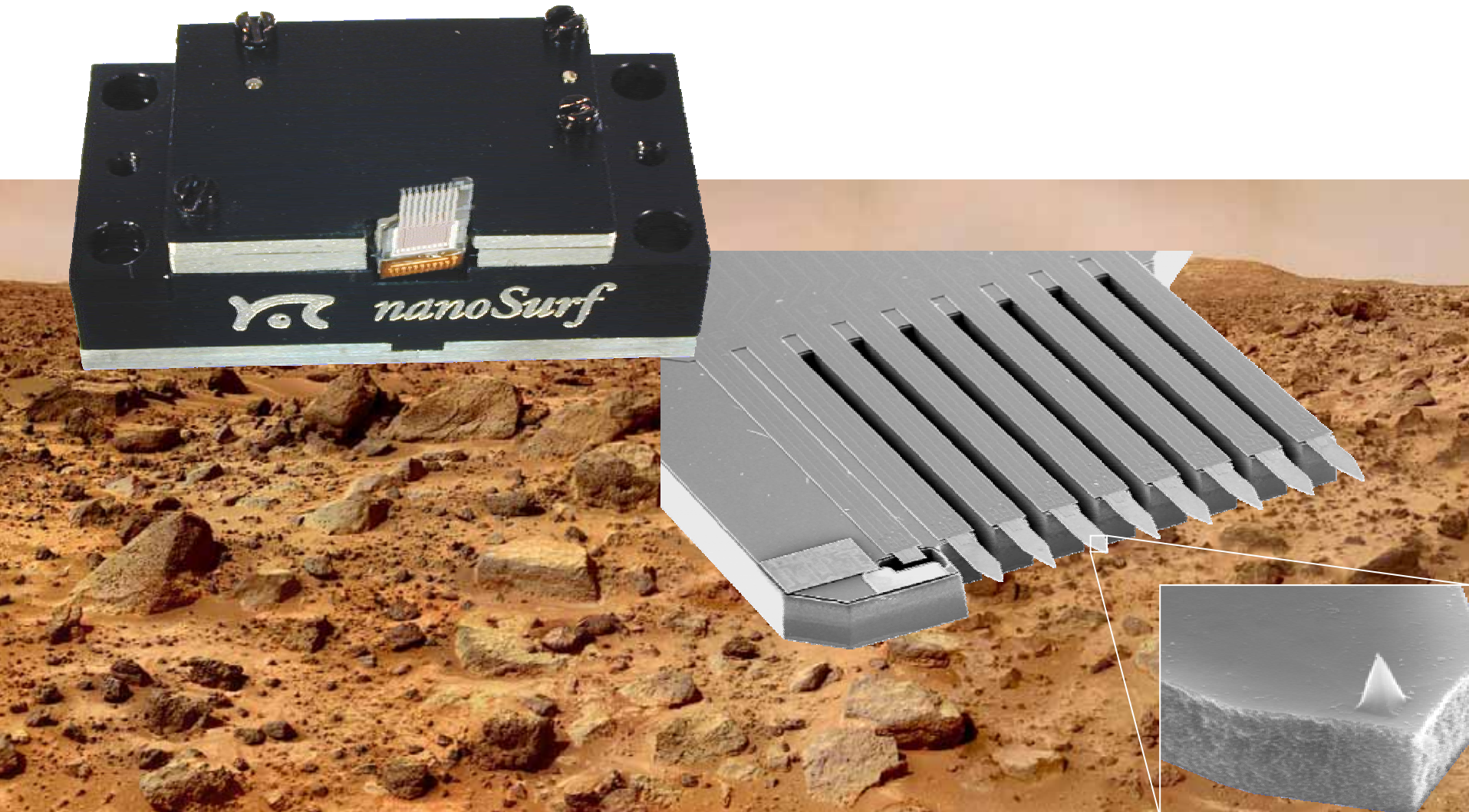


ThermoOrion *Flash Titrator*

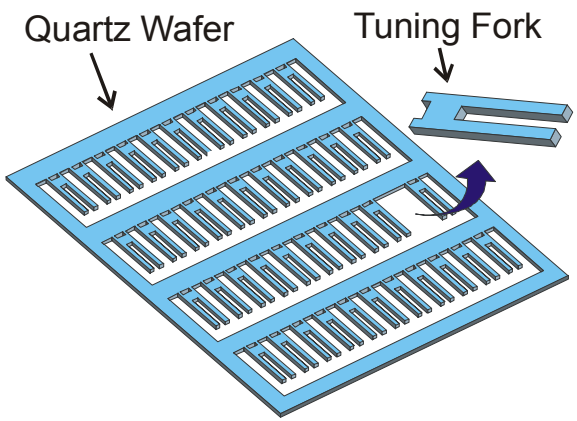
Nanotools

Phoenix mission to Mars: 2007

AFM on MARS

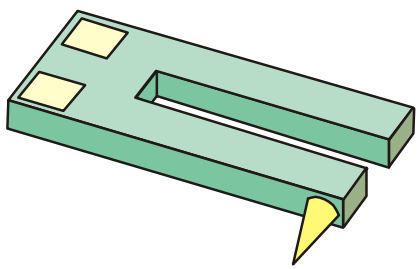


Tuning Fork based AFM Probes



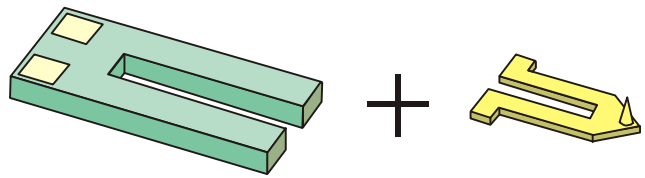
1.5 inch square wafer
about 350 tuning forks

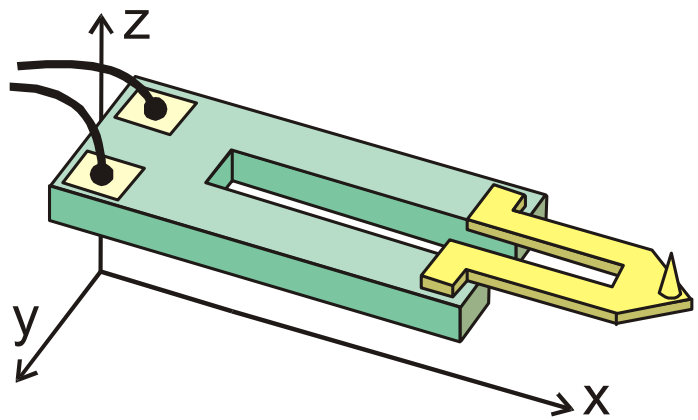
Conventional setup



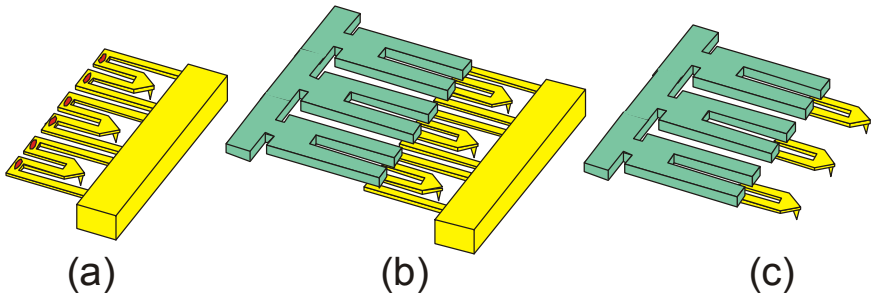
New probe concept

Tuning fork + Cantilever

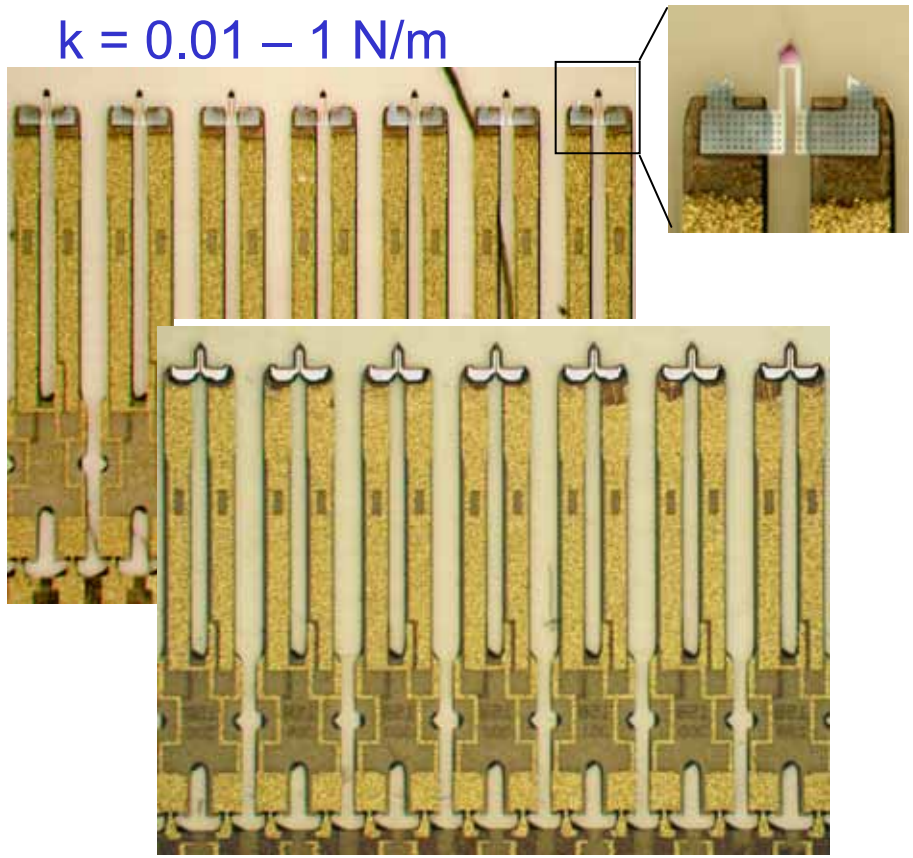


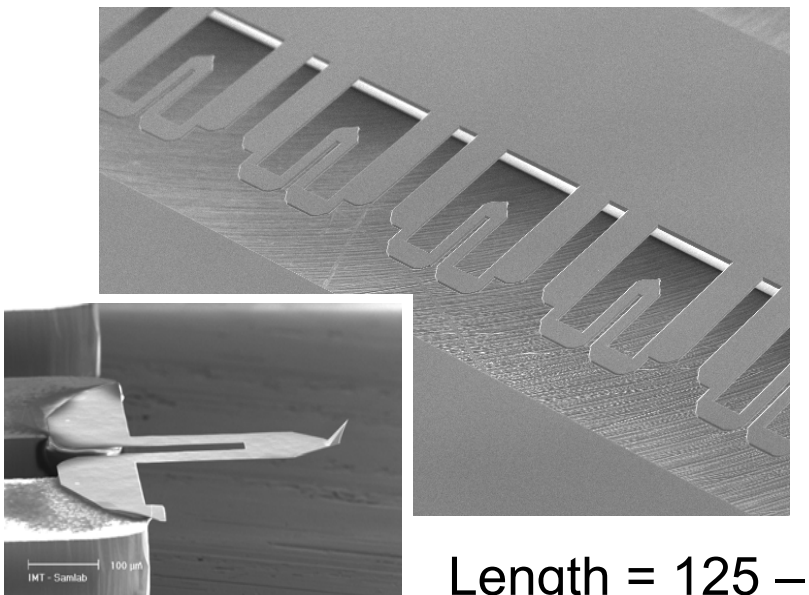


Batch fabrication of the probe



SiN cantilever
k = 0.01 – 1 N/m

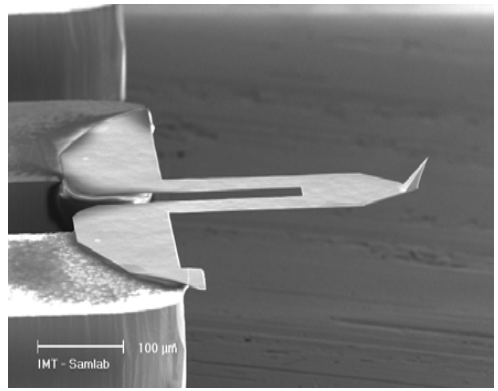




Length = 125 – 700 µm

Si cantilever
k = 1 – 550 N/m

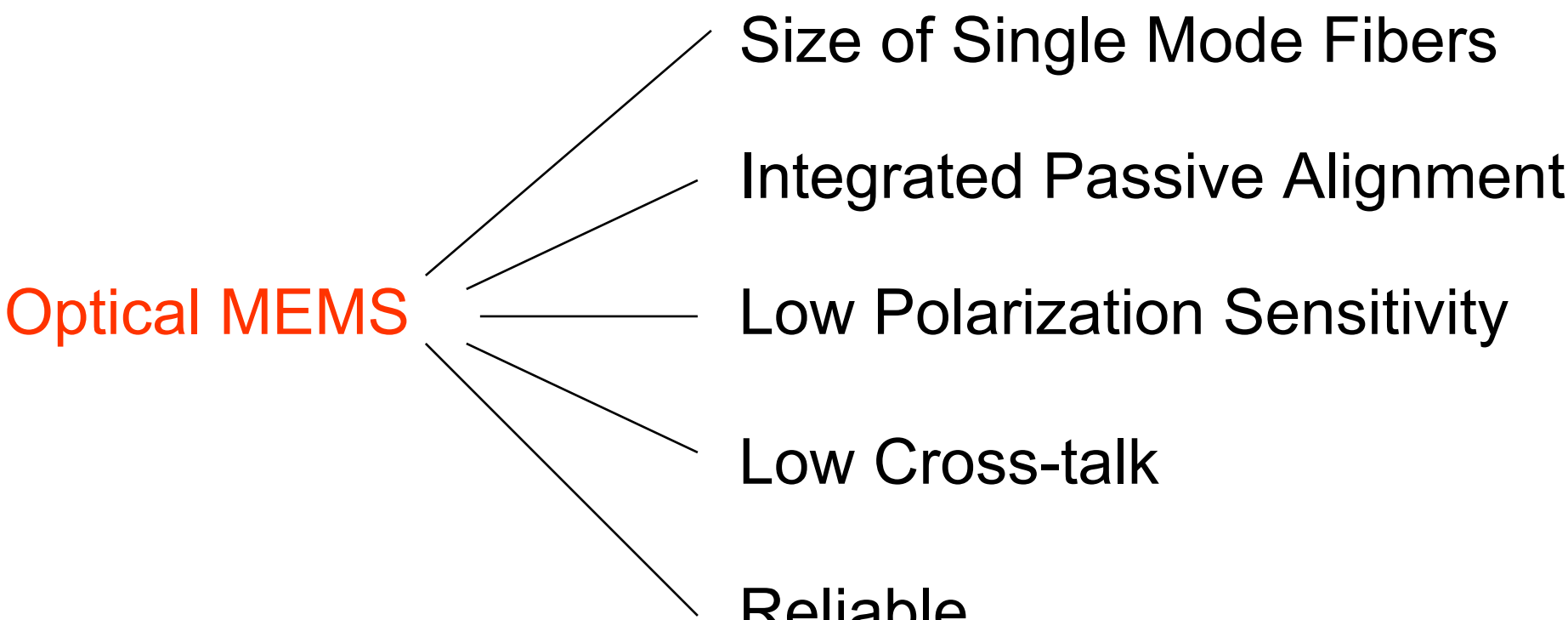
The A-Probe (The Akiyama Probe)



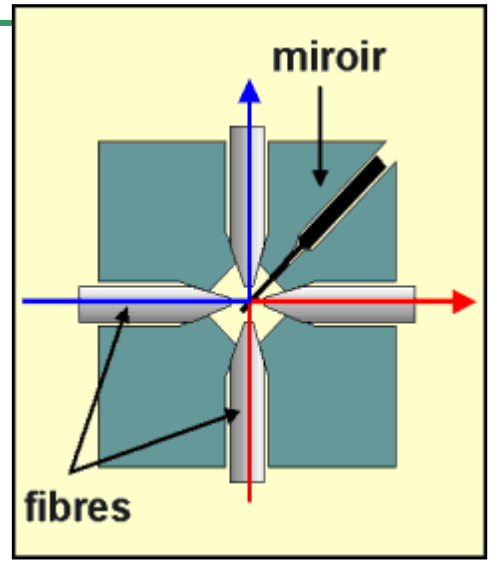
1. *Technology Transfer initiated*
2. *Commercialization of A-probe AFM by NanoWorld Inc.*
3. *Development of a dedicated A-probe AFM Instument by NanoSurf Inc.*

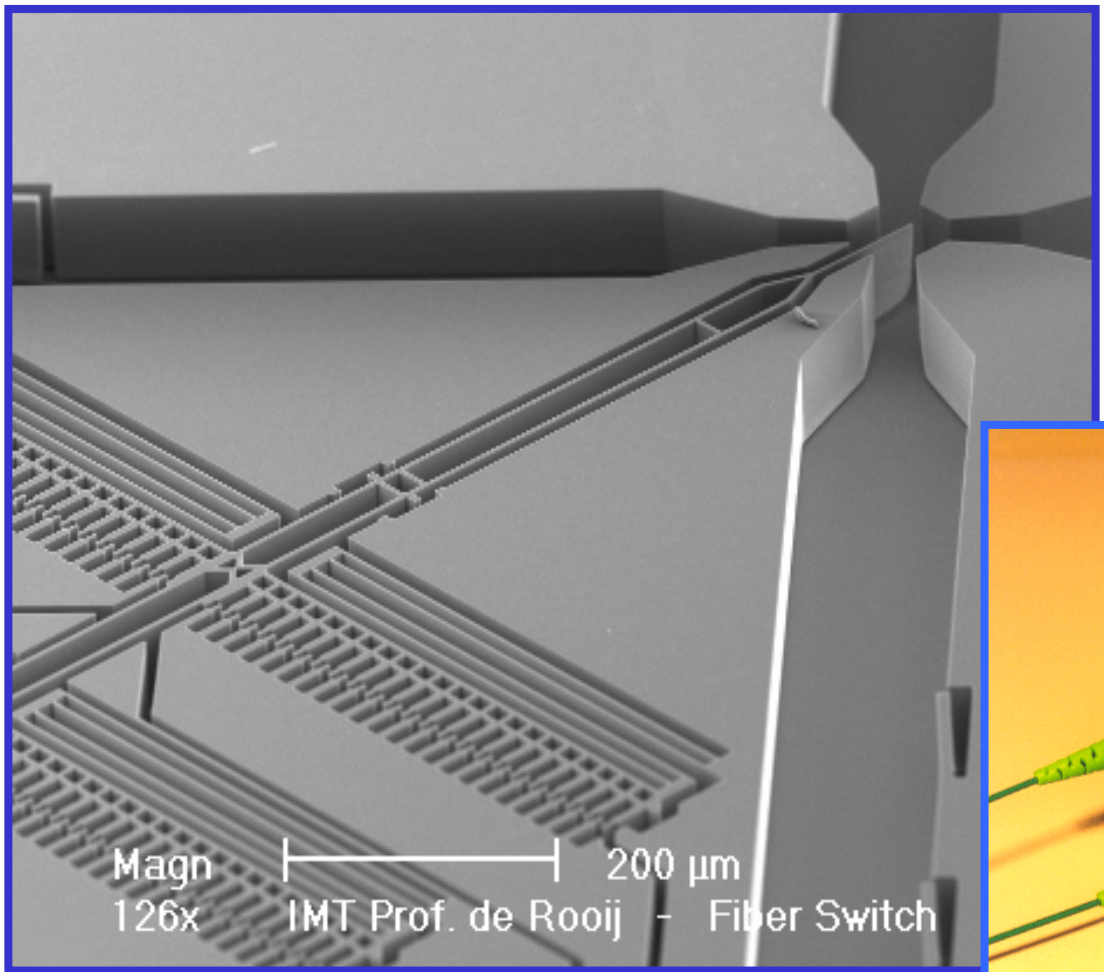
Optical MEMS

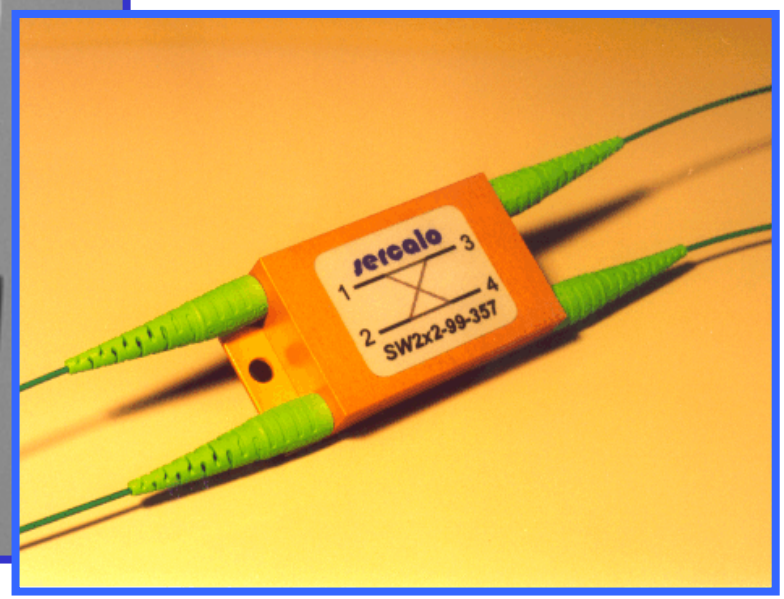
MEMS for Fiber Communication



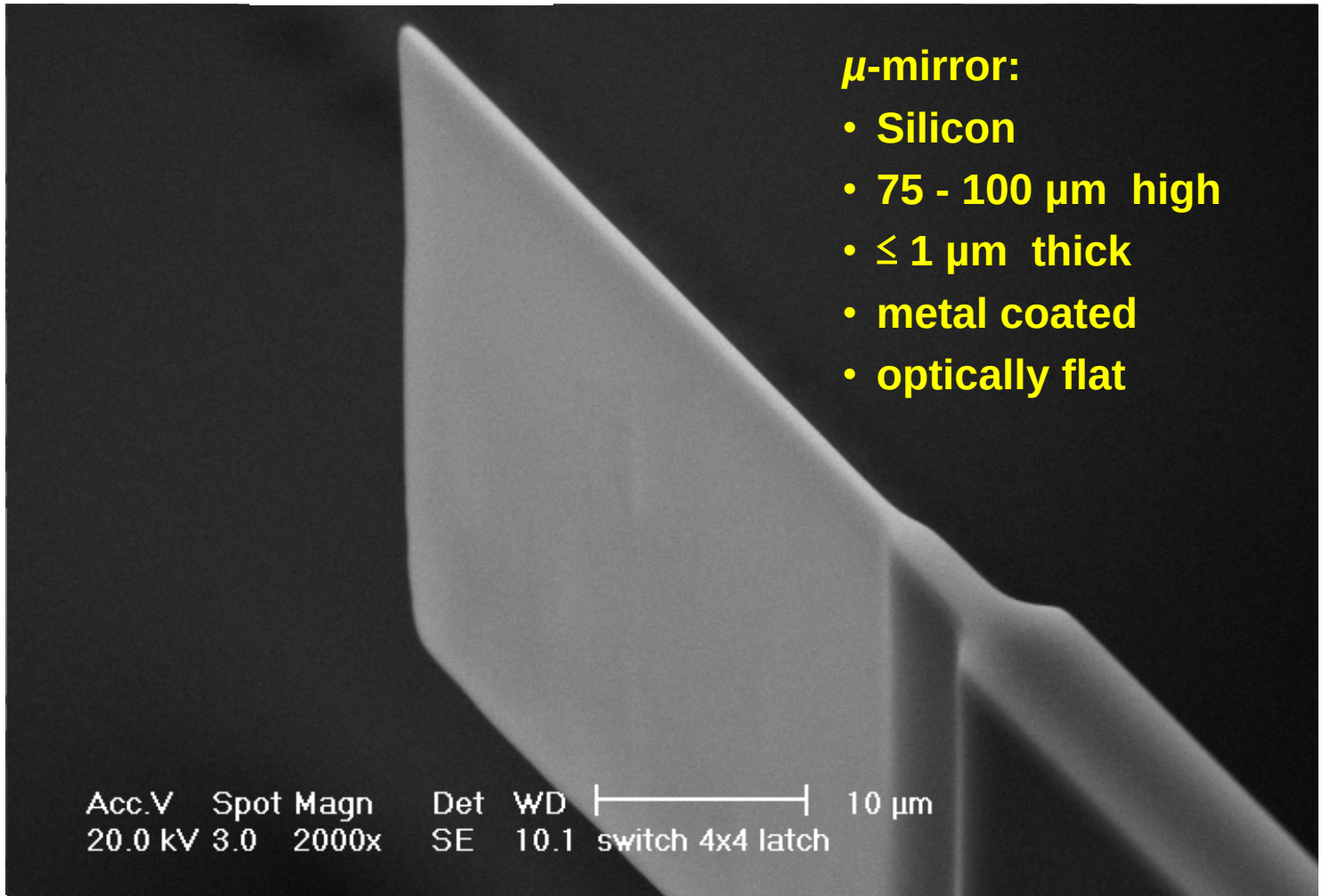
Actuator, Grooves, Mirror







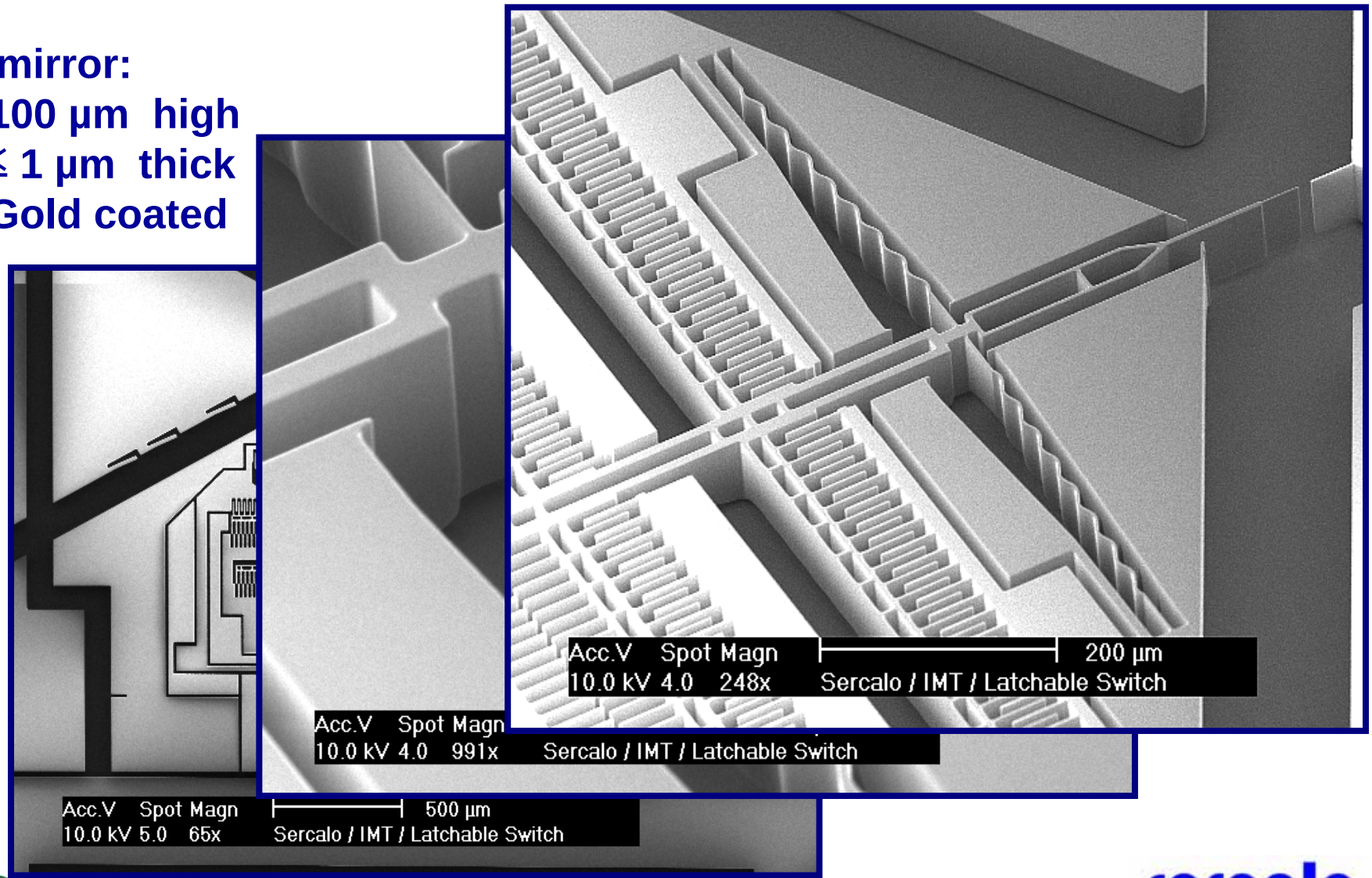
Switch Details



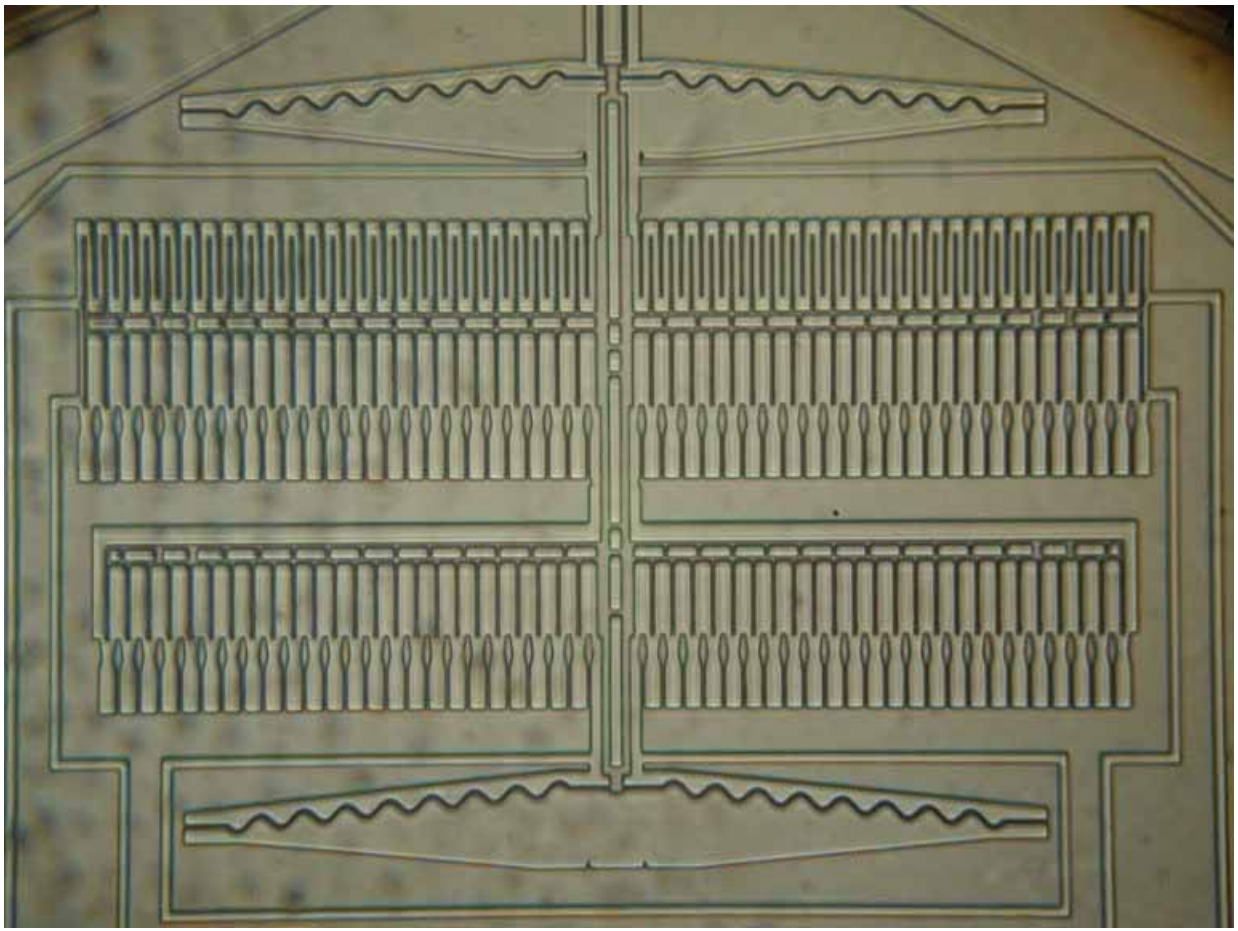
Latching Multimode Fiber 2x2 Switch

μ-mirror:

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

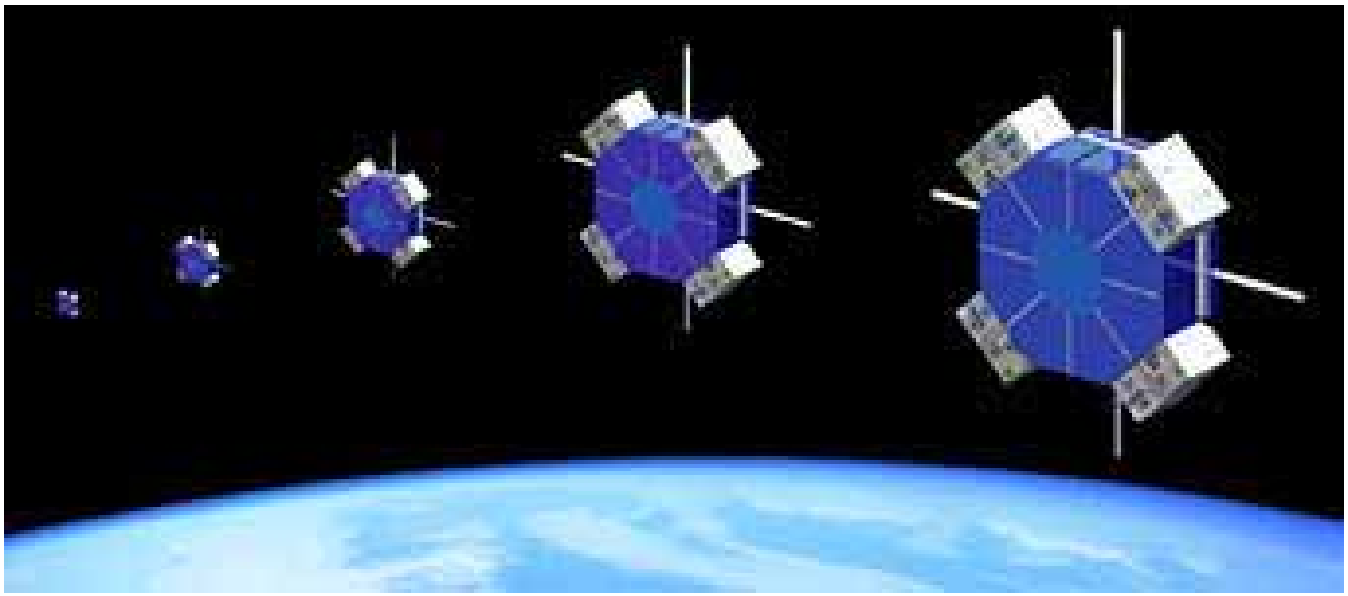


Latching on Multimode Switch



Power MEMS using Solid Propellant Based Actuators

Microthrusters for Nanosatellites/Picosatellites



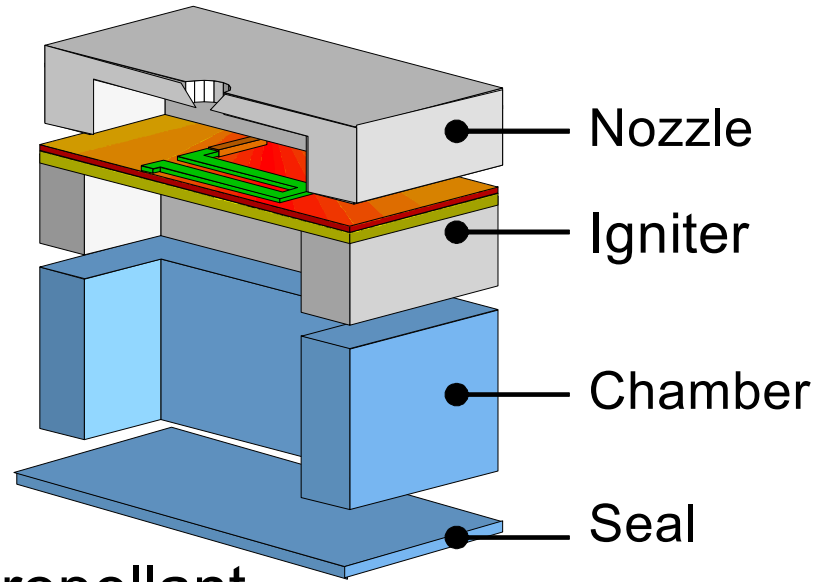
http://www.aero.org/technology/etd.html

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

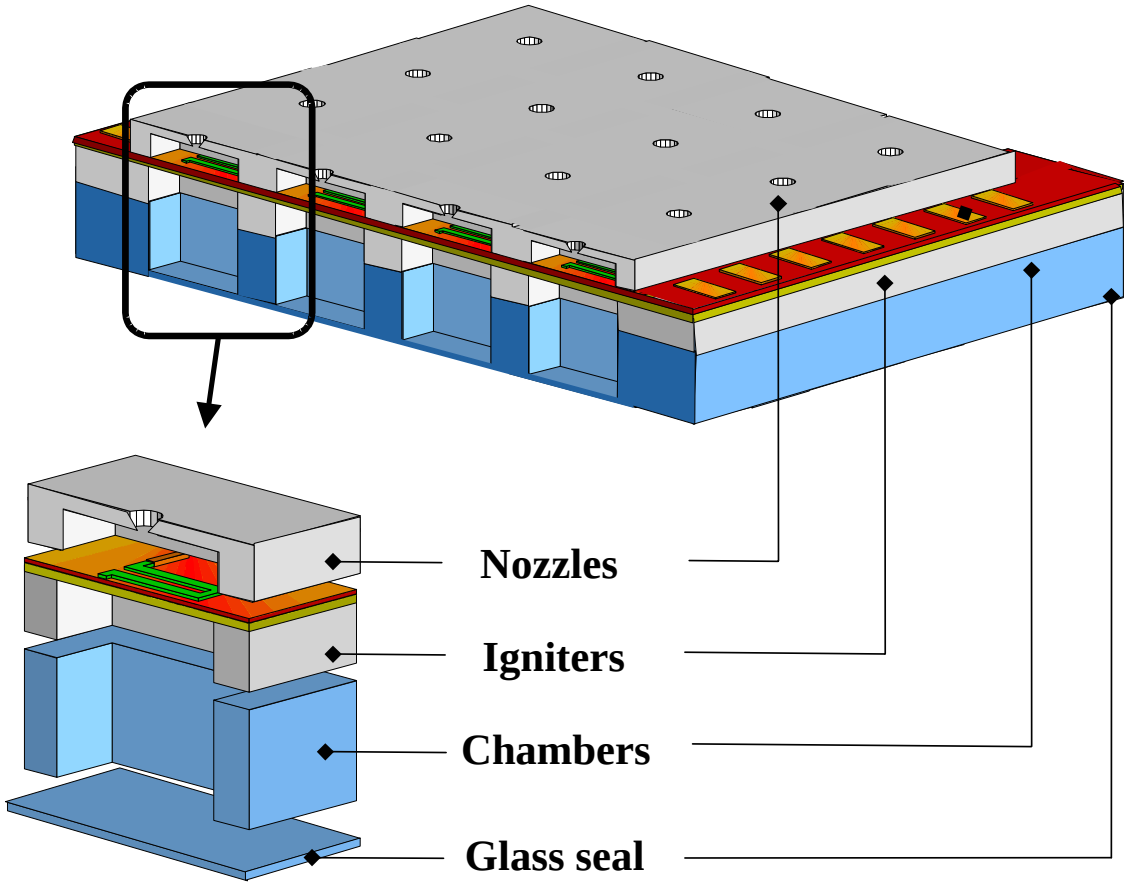


- Operation
  - Chamber filling with solid propellant
  - Propellant heating by Joule effect and ignition
  - Combustion, gas production and thrust force

- Requirements
  - ignition temperature : ~ 200°C

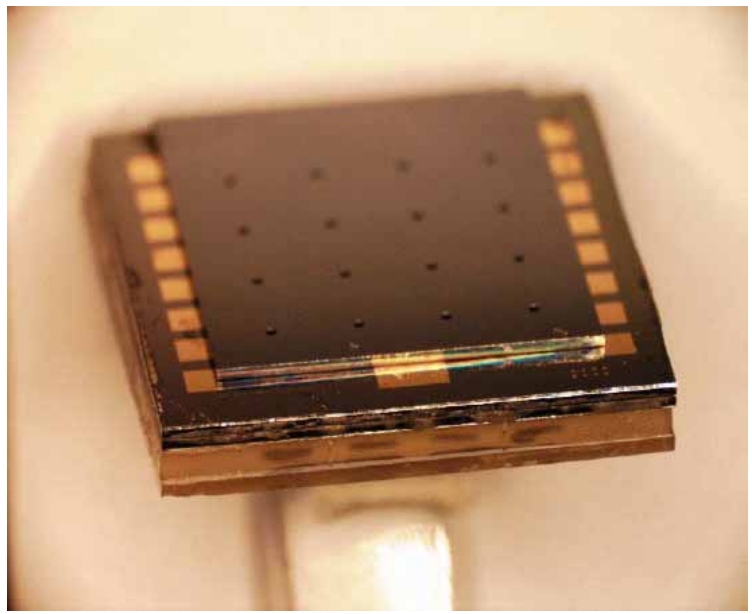
Microthruster : Principle of Operation

- Array of 4x4 microthrusters (16 thrusters)



DEMO Assembling

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

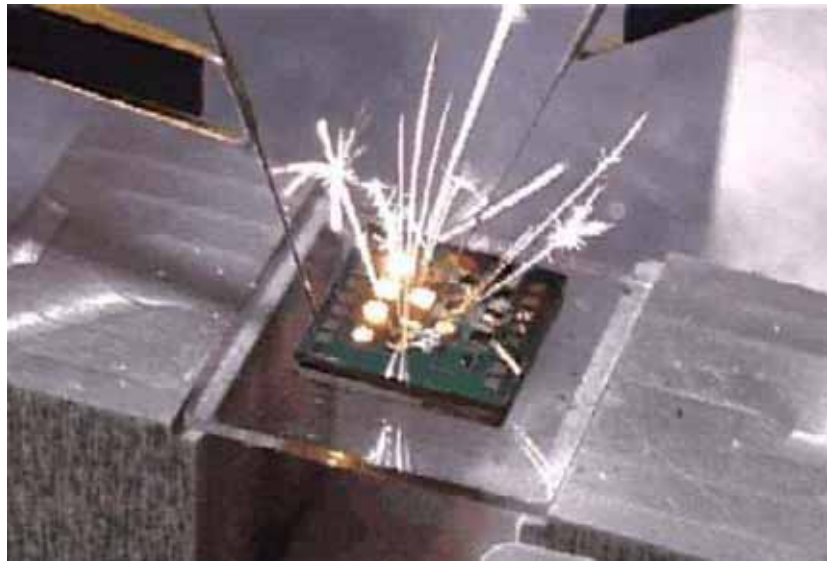


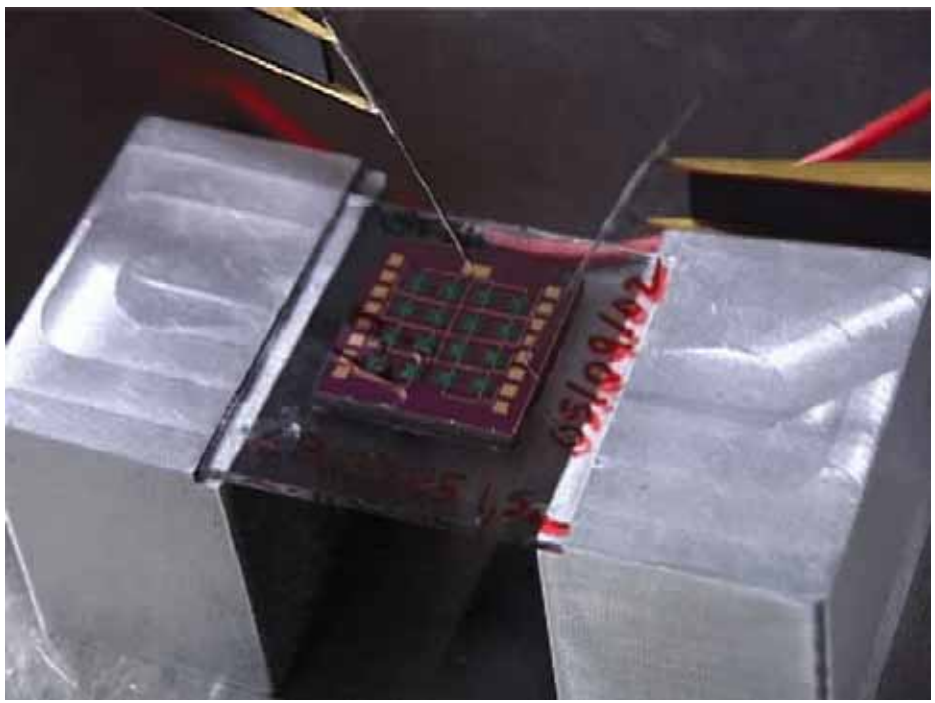
- Bonding
  - Thermal gluing (epoxy glue)

    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

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