Challenges of Smart Systems Integration

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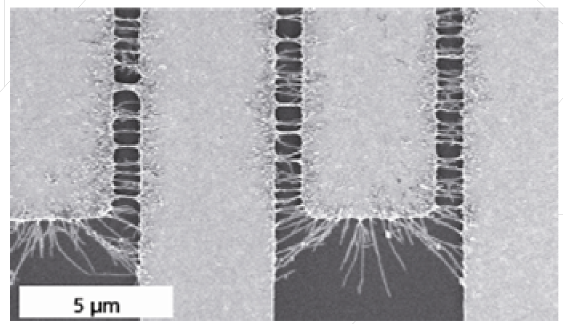

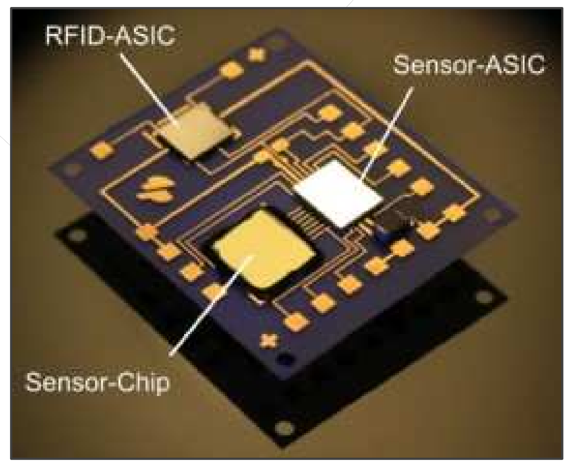

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ZfM Zentrum für Mikrotechnologien

TECHNISCHE UNIVERSITÄT CHEMNITZ

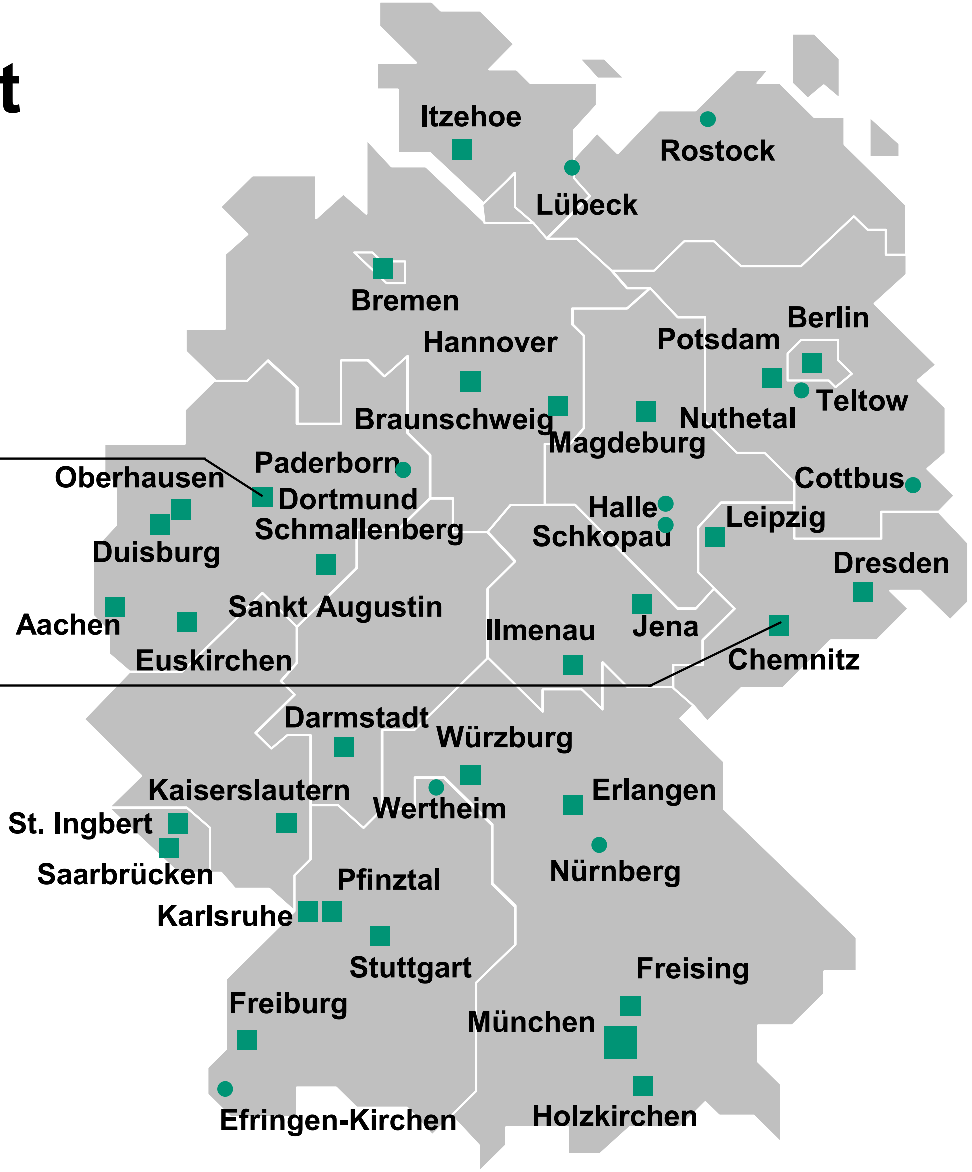
Fraunhofer-Gesellschaft in Germany

57 Institutes at 40 locations

Paderborn

Fraunhofer ENAS

Chemnitz



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Smart Systems Campus Chemnitz

CUT, Lightweight Structures Engineering

3D-Micromac AG

Start-up building

Fraunhofer ENAS

CUT, Institute of Physics and ZfM

Fraunhofer Research Institution for Electronic Nano Systems ENAS

Fraunhofer ENAS in Chemnitz

International Offices:

Since 2001 / 2005 Tokyo/Sendai-Japan

Since 2002 Shanghai-China

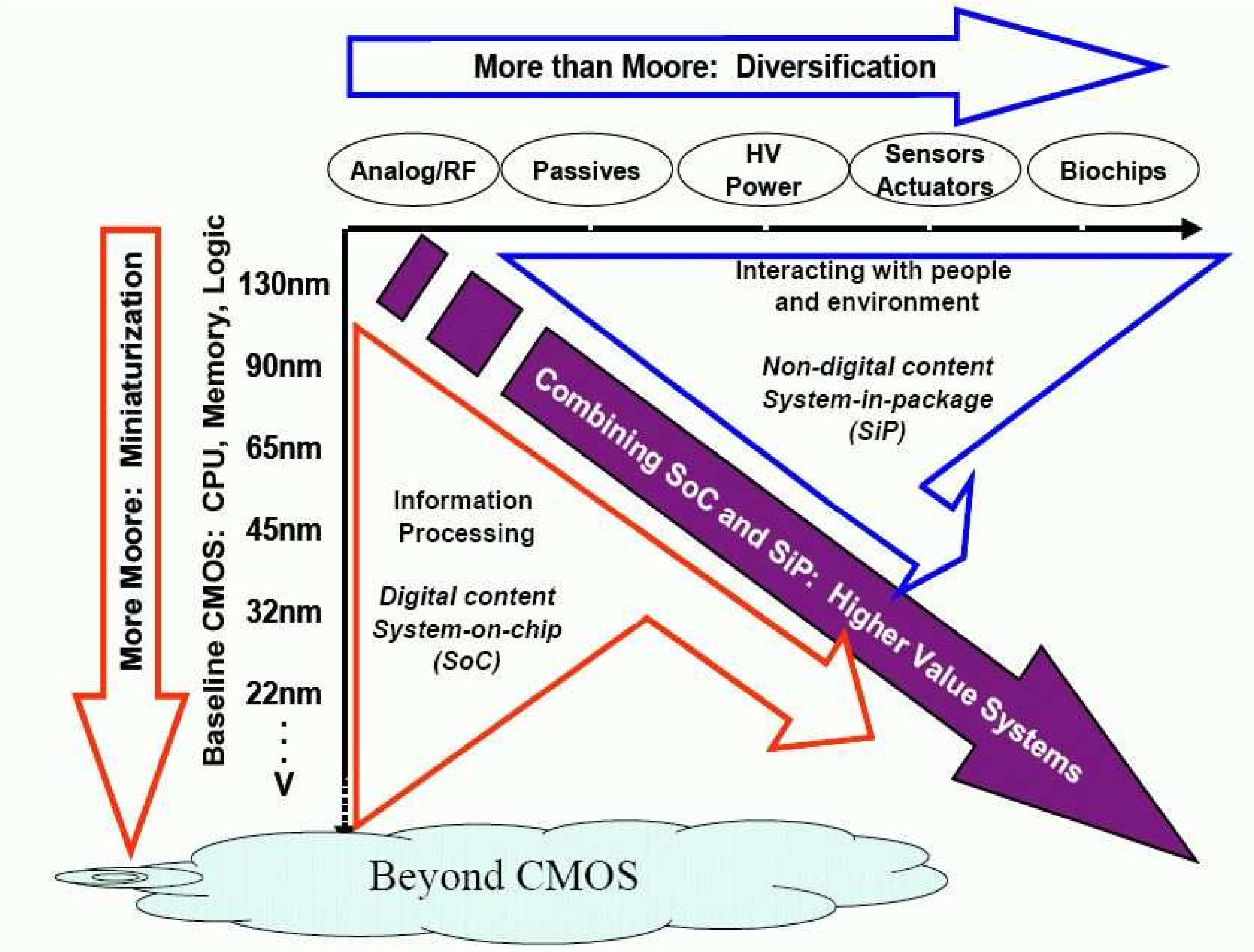
Since 2007 Manaus-Brazil

- MEMS/NEMS Design
- Development of MEMS/NEMS
- MEMS/NEMS Test
- System Packaging / Waferbonding
- Back-End-of-Line Technologies for Micro- and Nanoelectronics
- Process and Equipment Simulation
- Micro and Nano Reliability
- Printed Functionalities
- Advanced System Engineering

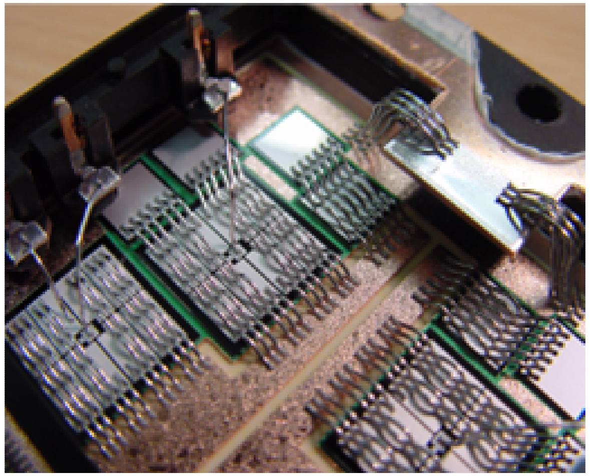
Content

- International Trends
- Smart Systems for different Applications
  - Smart Label
  - Fabry-Perot Interferometer
  - Laser micromachining for different applications
- Summary and Conclusions

More than Moore / Smart Systems



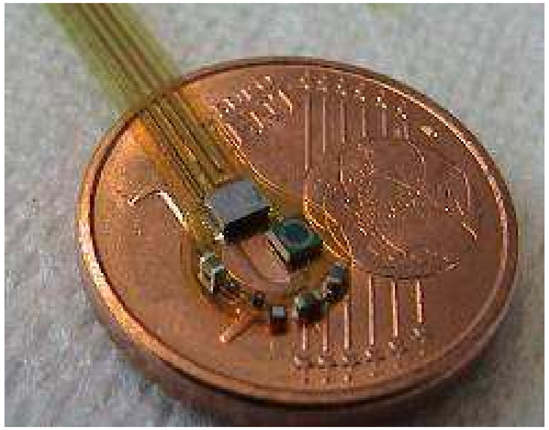
Definition Smart Systems Integration



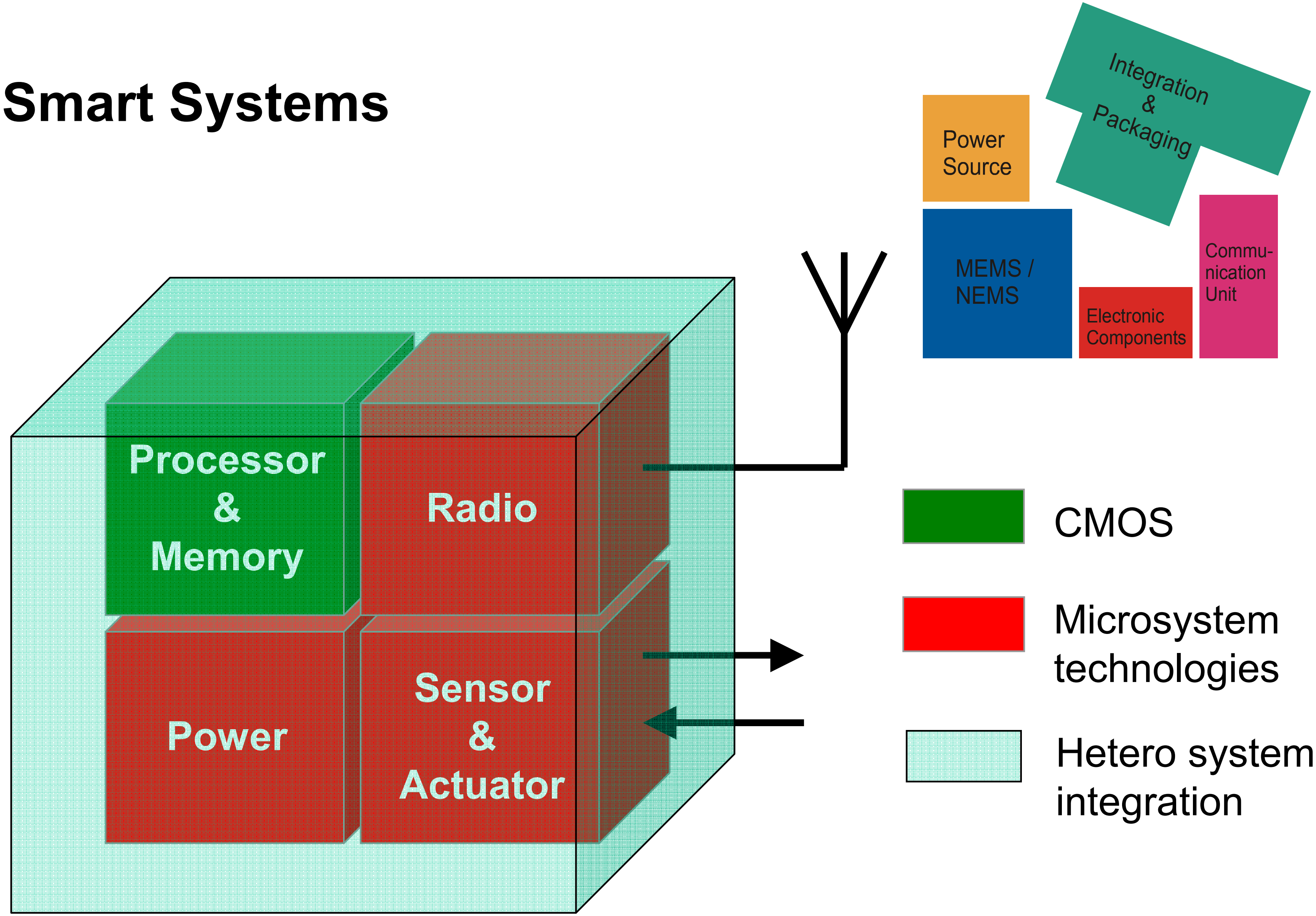
Integration of Different Functionalities

such as Signal Processing, Sensors, Actuators, Photonics, Power, Coolers with a High Degree of Miniaturisation and Flexibility to Reasonable Costs

in one Unit (e.g. Package), that bridges the Gap between Nano-Electronics and Application



Smart Systems



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RFID Applications

Material Tracing

Quelle: ITM/Ruhr-Universität -Bochum

Box Management

Quelle: ITM/Ruhr-Universität -Bochum

Facility Management

Quelle: ITM/Ruhr-Universität -Bochum

RFID Application with Complex Additional Functions

- Detection of temperature – acceleration – pressure - light
- Combination of display and RFID
- Data processing and storage partly on the label

Project ASIL: Active Smart ID Label

BMBF collaborative project: priority topic of the Microsystems framework programme:
Microsystems Technology for Smart Label Applications in Logistics

Objective: development of an active radio frequency identification (RFID) label for the monitoring of shock, inclination and temperature during transportation processes

Partner: KSW Microtec AG
ELMOS Semiconductor
Schenker AG
Memsfab GmbH
TUC-ZfM/ Fraunhofer ENAS

Fraunhofer ENAS

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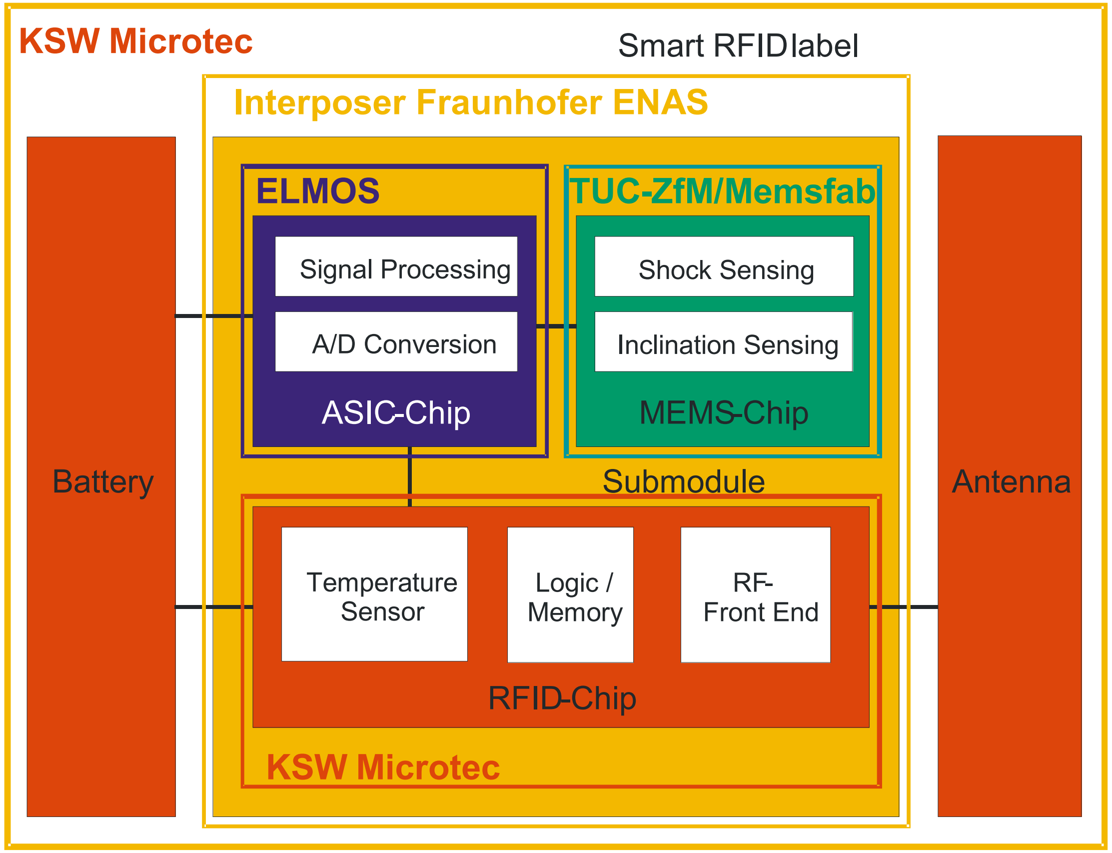
Project ASIL- RFID label concept

<u>The label components:</u>

- RF-chip with antenna
- battery for energy supply
- sensor system consisting of the micromechanical transducer and the signal processing electronic

The system has to detect and record inclination and mechanical shock. In order to reduce the complexity of the system, it is reasonable to measure both with the same microstructure.



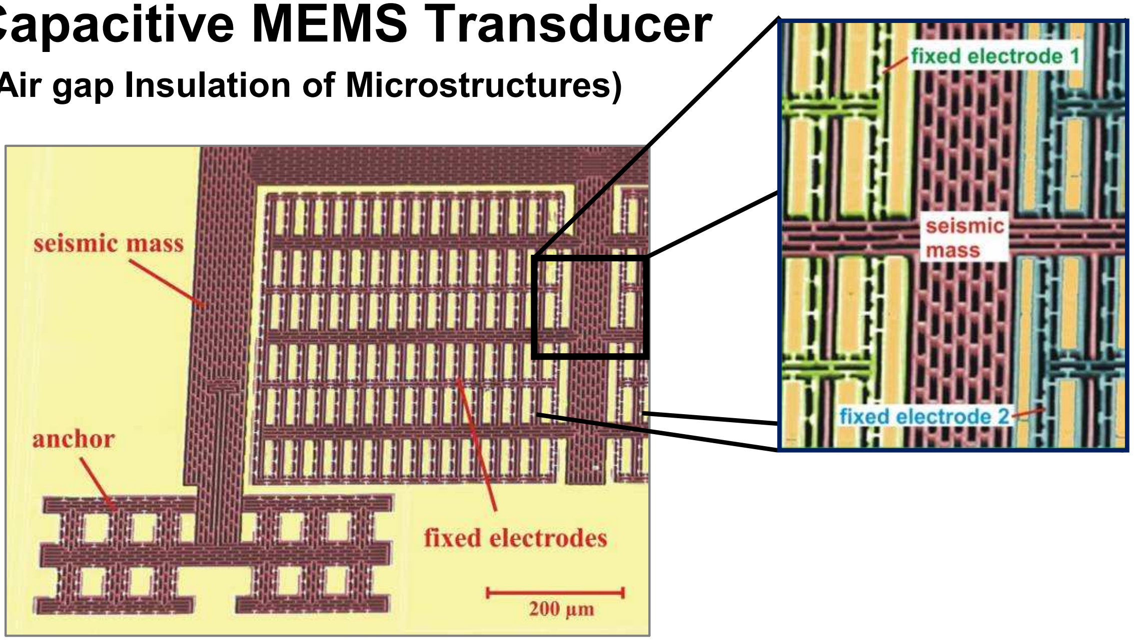
Specific requirements for the sensor system:

- low energy consumption
- high temperature stability
- high signal to noise ratio
- low device / sensor thickness

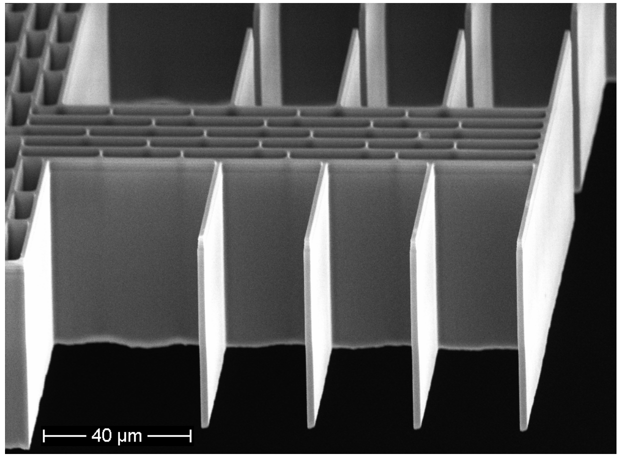
Concept of the sensor system

Capacitive MEMS Transducer

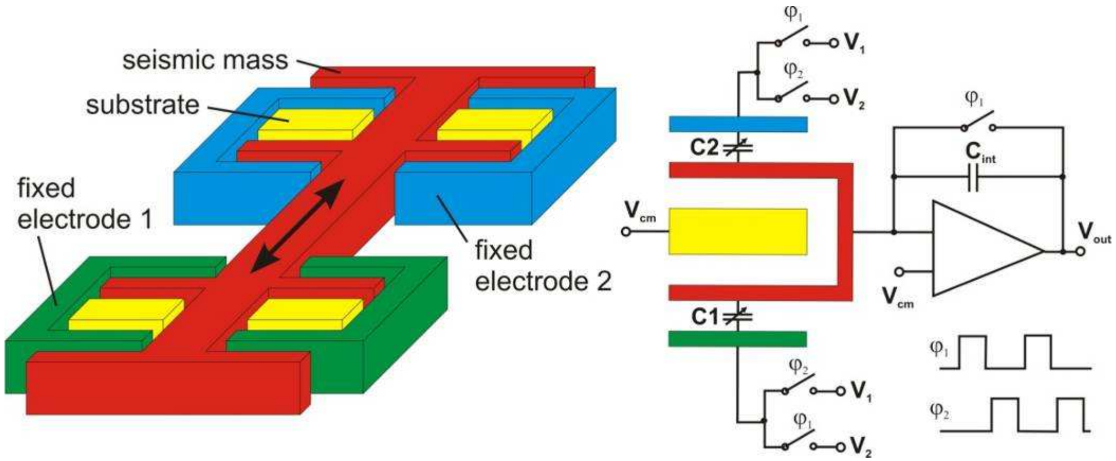
(Air gap Insulation of Microstructures)



HARMS – High Aspect Ratio Microstructure



- four mask level technology
- high capacitive sensitivity
- low parasitic capacitance
- small thermal sensitivity
- low manufacturing costs

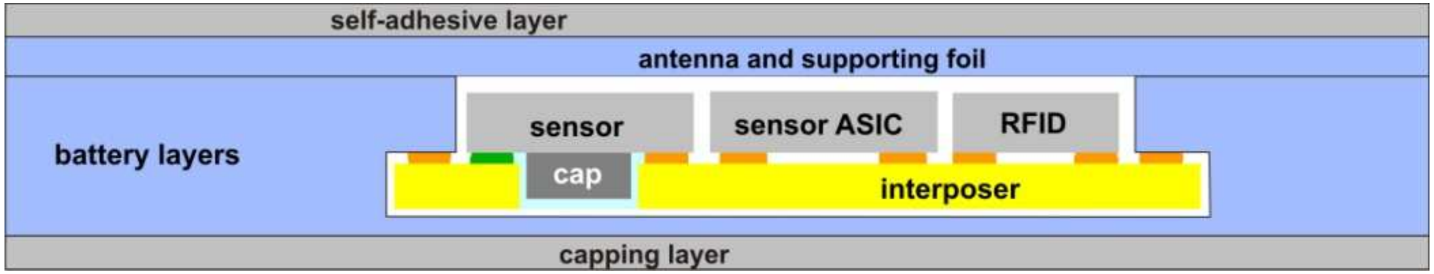


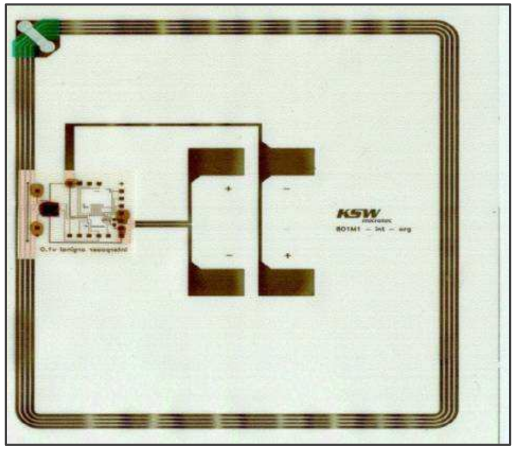
Packaging and Assembly Concept

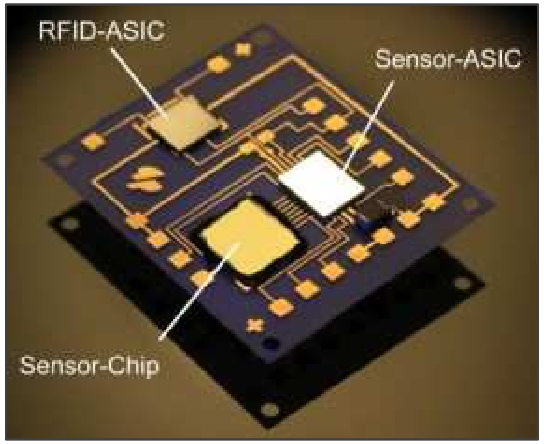
Fabrication technology:

- Roll to roll fabrication demands flexibility of the layers
- Overall thickness of the label is limited

→ **Restricted chip height**







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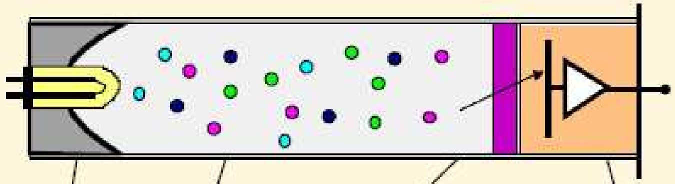
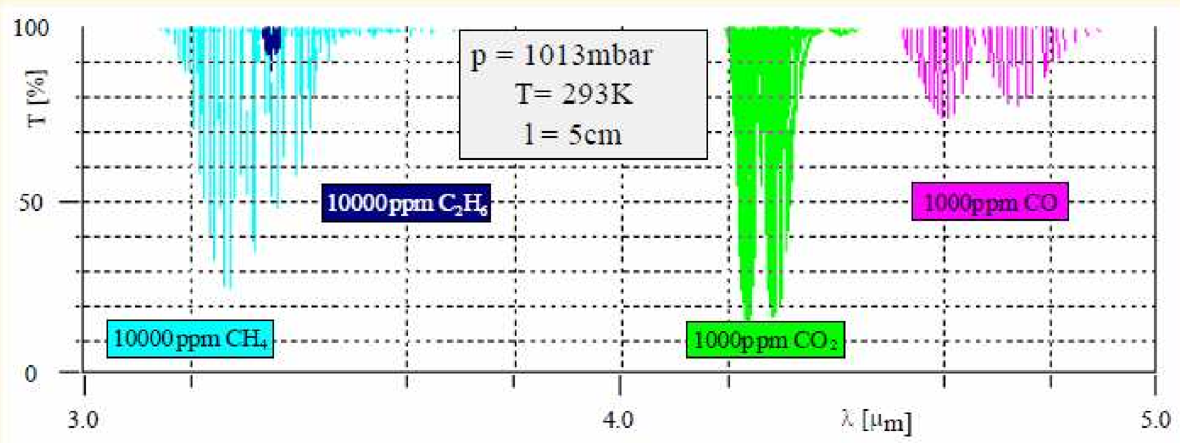
Fabry-Perot-Interferometer (FPI)

Application:

Tunable Filter for Infrared Gas Analyzer

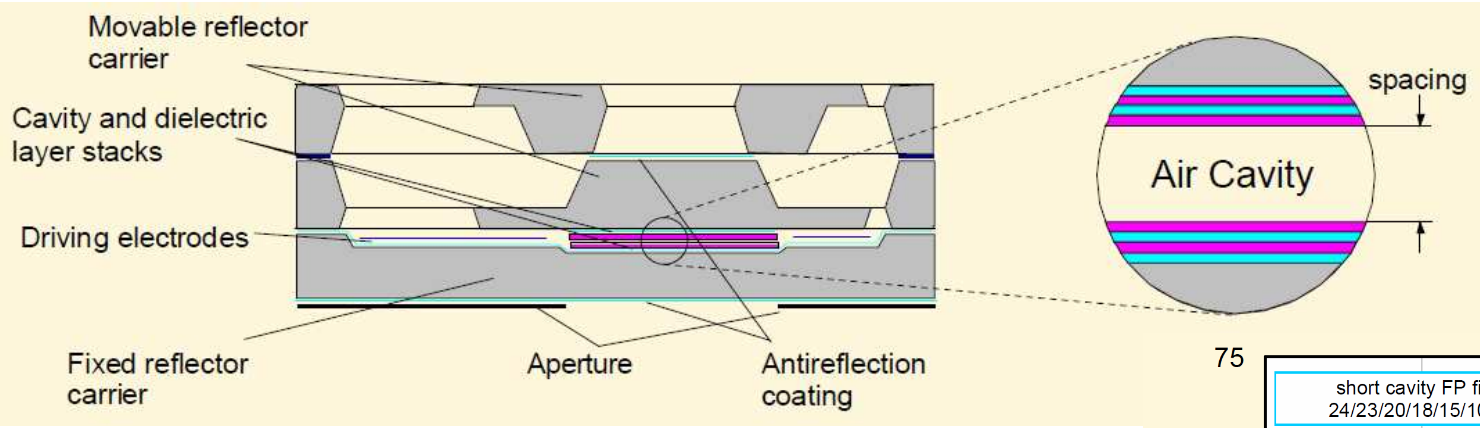
- Spectral Bandwidth: 50nm
- Tuning Range: 1000nm
- Peak transmission: 70%
- Aperture: 4mm²

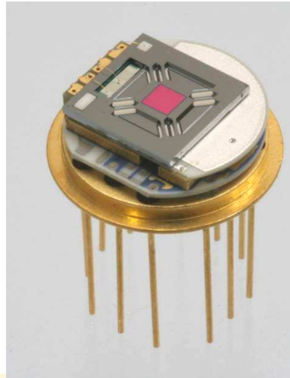




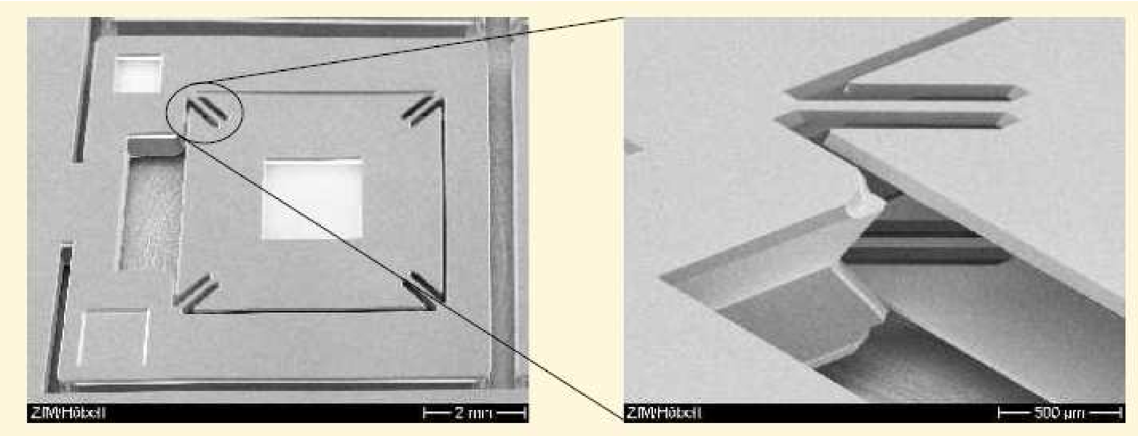
Fabry-Perot-Interferometer (FPI)

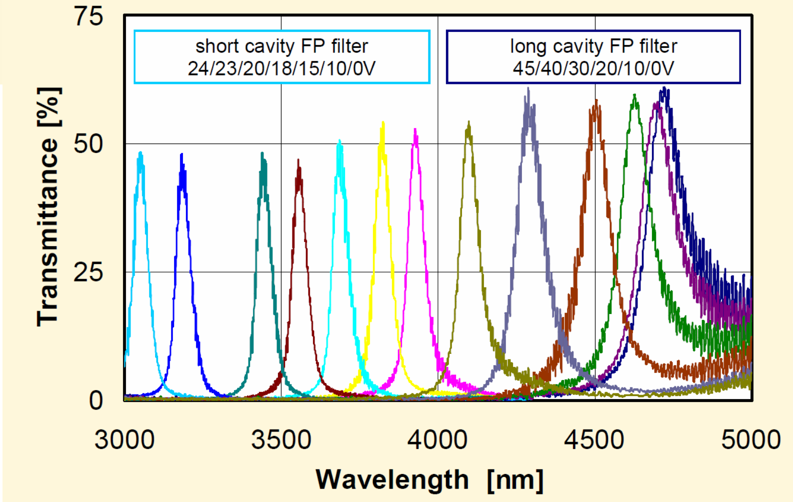
InfraTec





Cross section of FPI filter chip





Transmission curves

SEM images showing the movable reflector and elastic suspension

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        - Micro mirrors for spectrometer
        - Microfluidic cartridges
- Summary and Conclusions

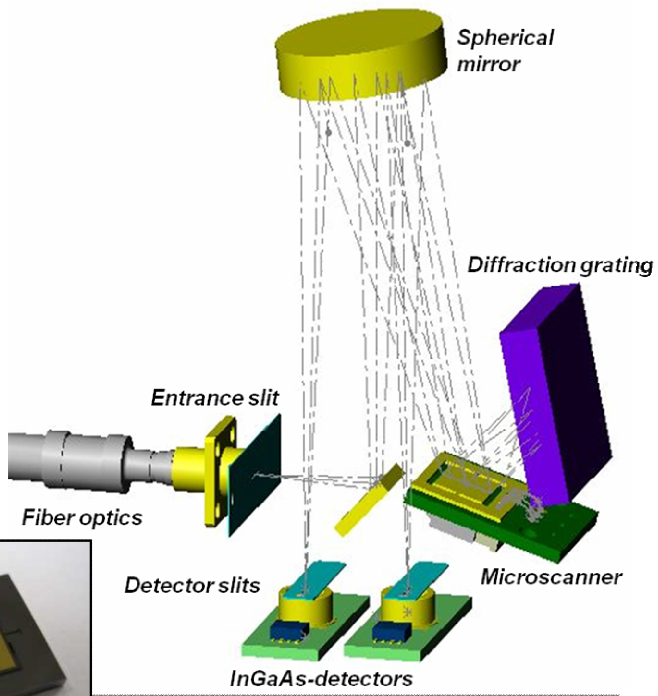
MEMS-spectrometer

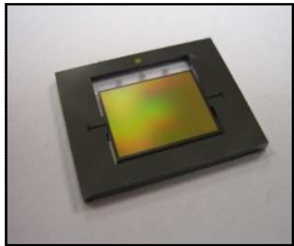
MEMS spectrometers enable realizing smart systems to supplement or replace traditional technology for particular demands

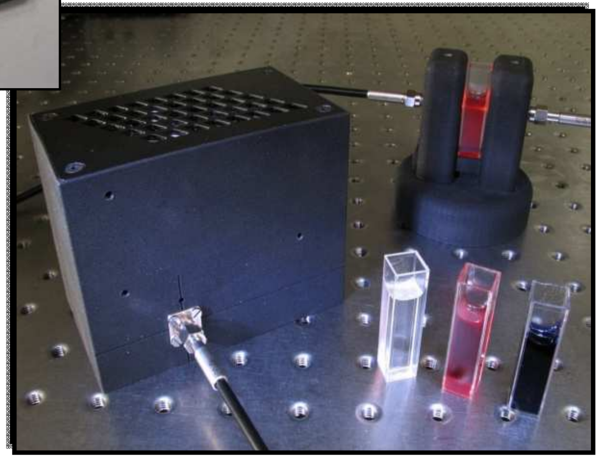
- ✓ Miniaturization and Portability
- ✓ Flexibility
- ✓ Cost efficiency

Properties

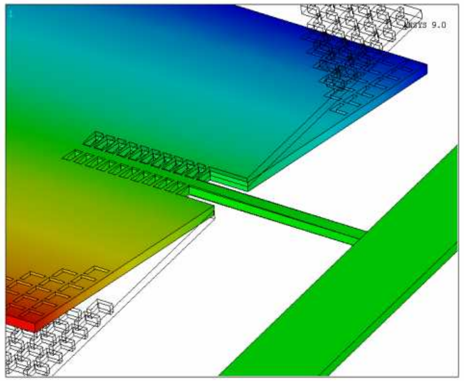
- Configurable in wavelength range 0.8 - 10µm
- High wavelength repeatability (< 0.1nm)
- High sensitivity (SNR > 7.000:1)
- Fast measuring time (2ms) > enables real time measurements
- Flexible measurement setups (ATR, diffuse reflection, transmission)

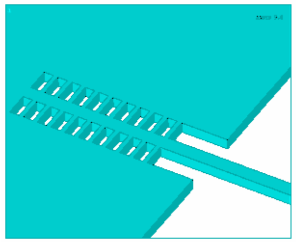




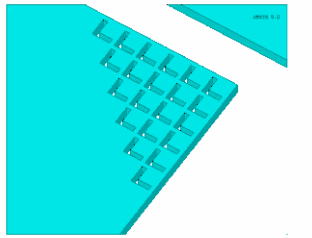


Laser trimming of silicon micro mirror devices

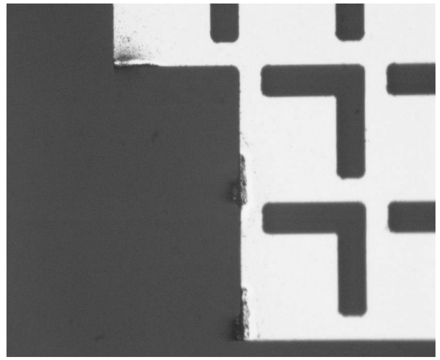




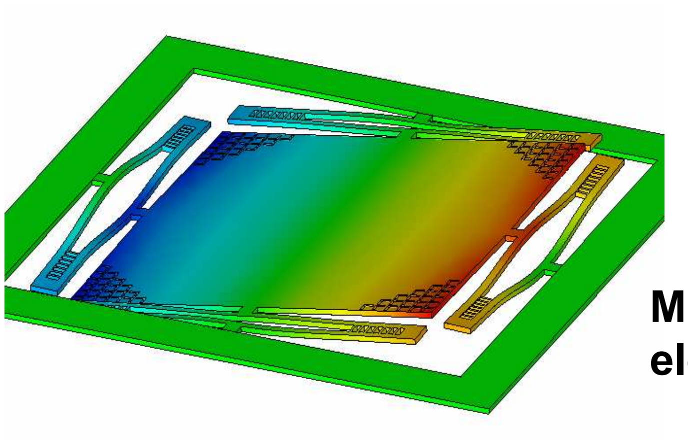
Spring stiffness trimming elements

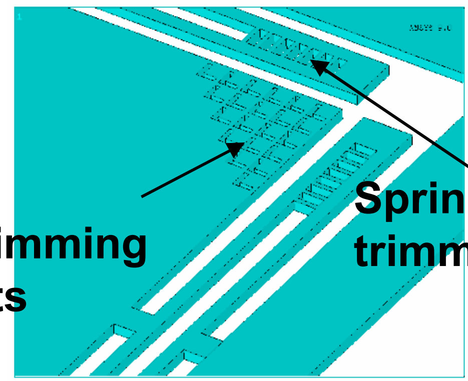


Mass trimming elements



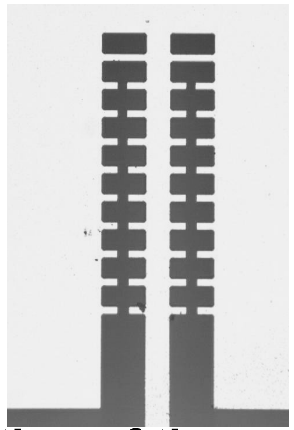
Cutting of mass trimming elements





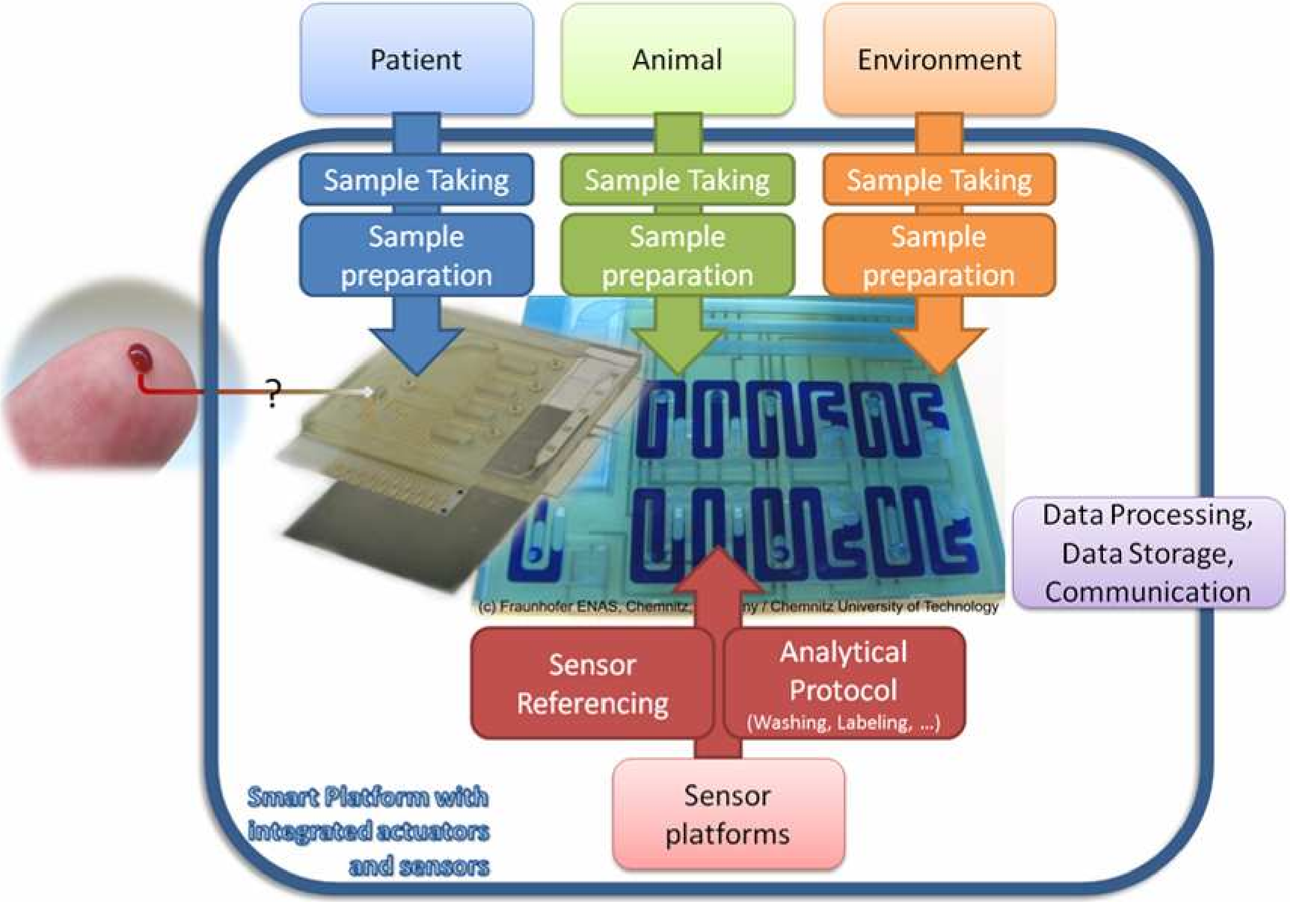
Mass trimming elements

Spring stiffness trimming elements



cutting of the spring bar stiffeners

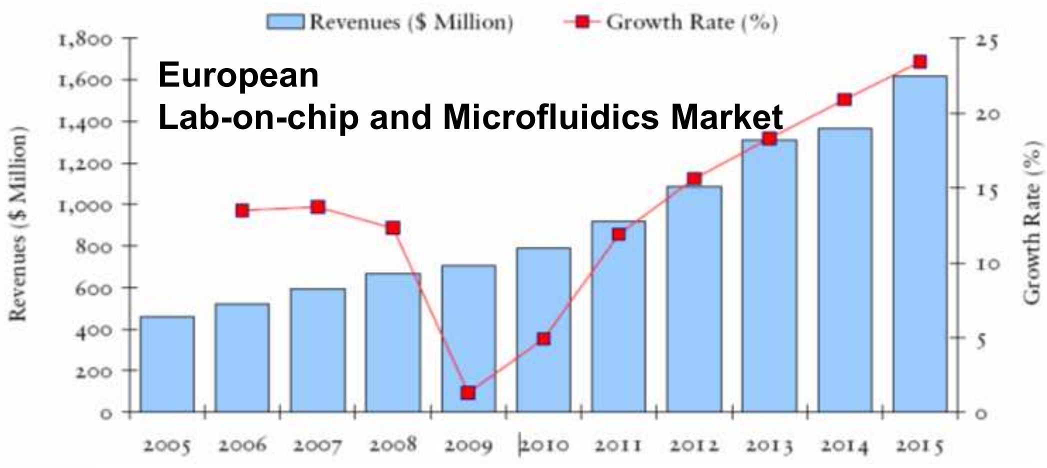
Smart Systems for Molecular Diagnostics: Future needs and perspectives



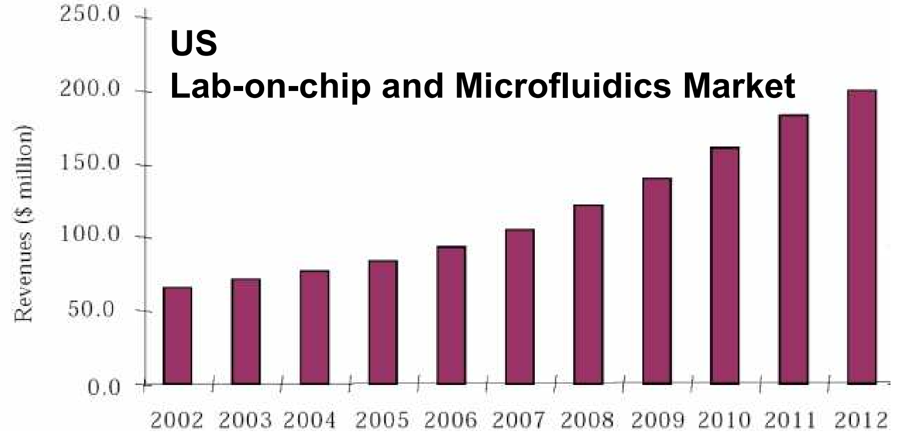
Smart Systems for Molecular Diagnostics in Point-of-Need Applications: *Integrated platforms that provide the entire sample processing chain from Sample Taking and Preparation to Data Processing, Storage and Communication. (Source: Fraunhofer ENAS / EPoSS SRA)*

Microfluidics for Diagnostics - Markets

Increasing market for microfluidics in diagnostics / Lab-on-a-Chip :



(Frost & Sullivan: European Lab-on-a-Chip markets, 2009)



(based on Frost & Sullivan: US Microfluidics/ Lab-on-a-Chip markets, 2008)

„It is well-established […] that ***analysis*** can be miniaturised onto a chip.
However, the real challenge is to miniaturise […] important features such as ***fluid handling*** […]"
(Frost & Sullivan: „European Lab-on-a-Chip markets", 2009)

→ If biosensors were cars, microfluidics would be the roads

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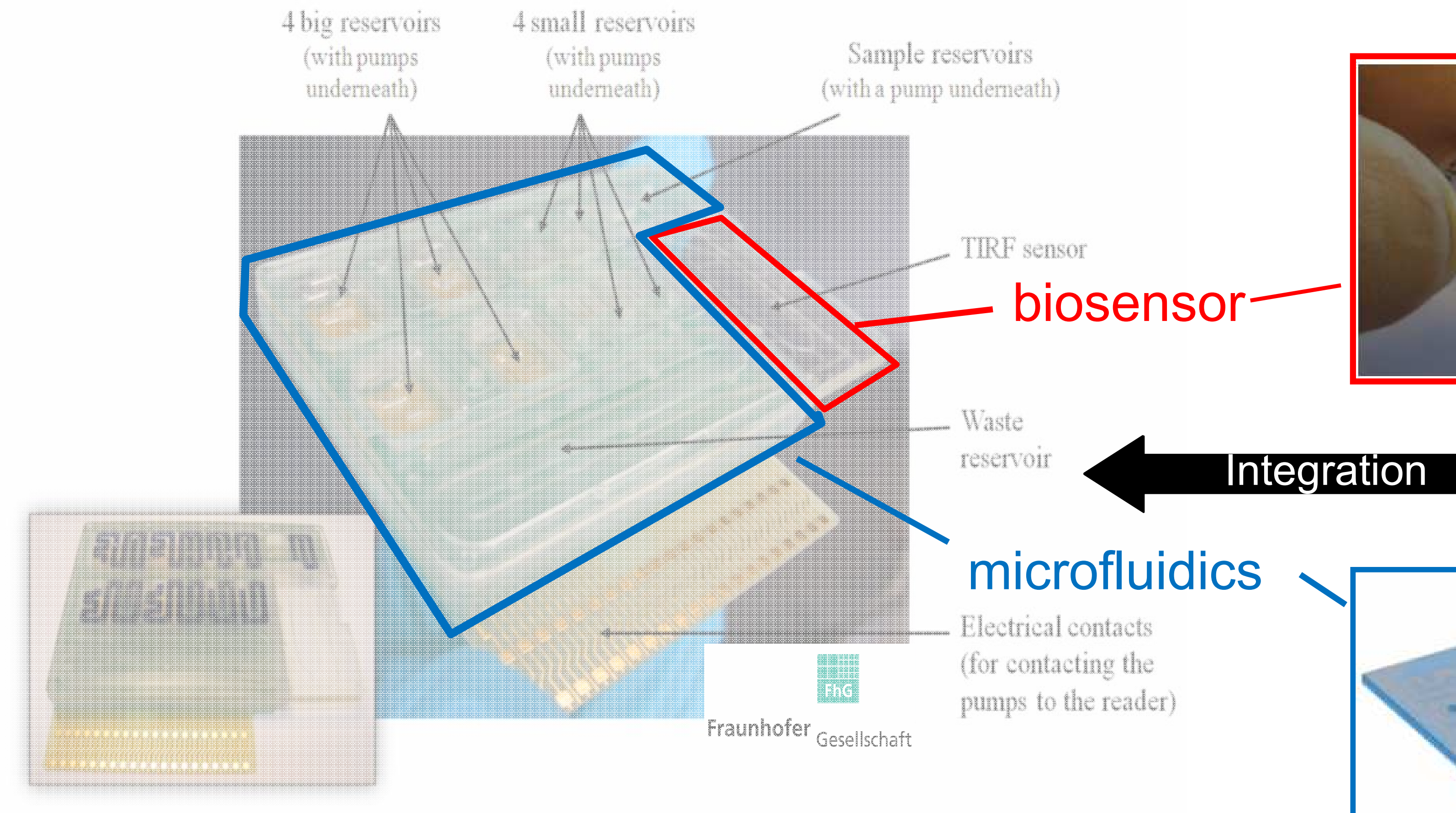
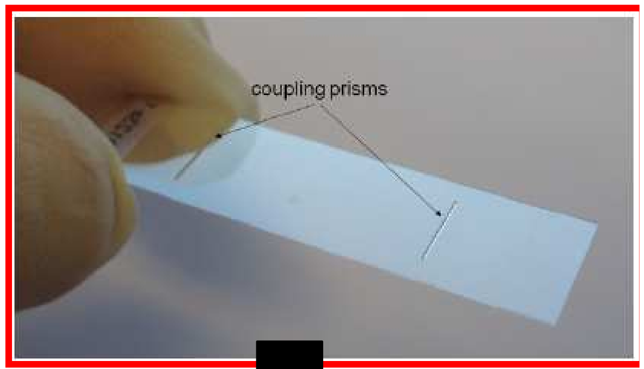
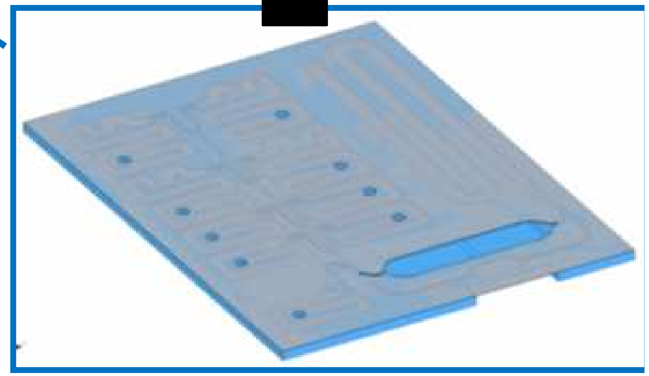
Microfluidic lab-on-a-chip platform @ Fraunhofer





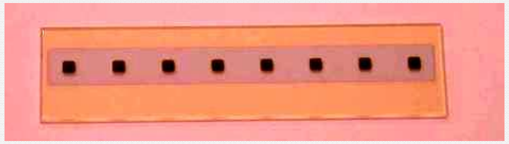


Complete microfluidic cartridge with sensor for fluorescence detection

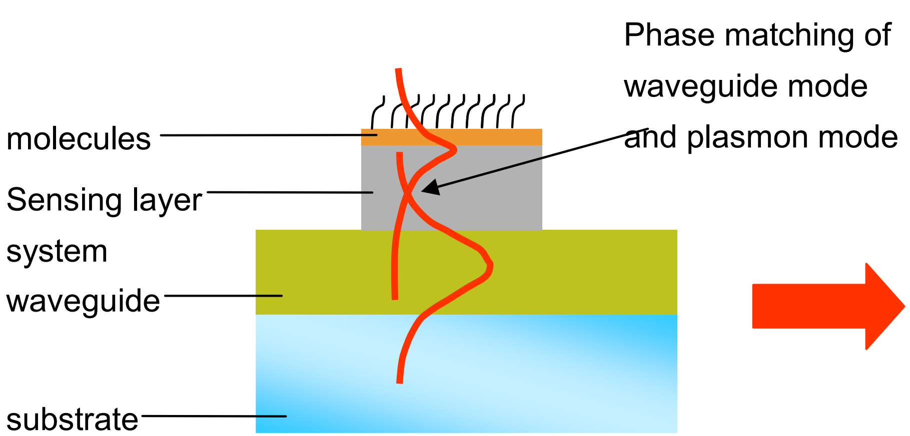
Bio sensing based on NEMS optical sensors 1

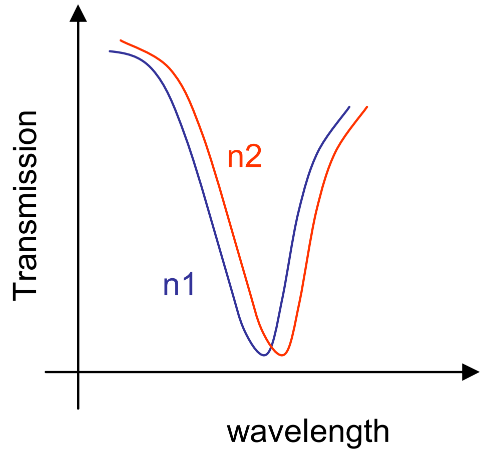
Sensing layer:

Multi layer stack based on Au or Ag, thickness < 150 nm



SPR sensor with waveguides:





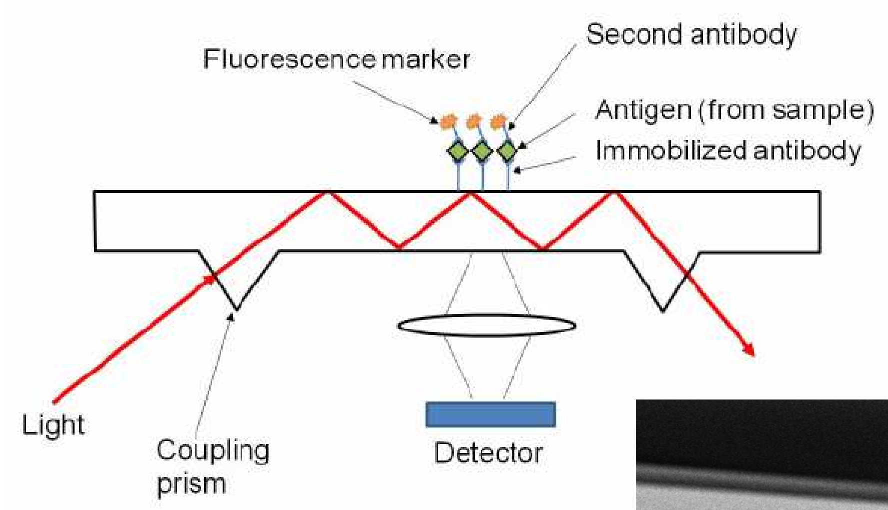
Sensing principle:

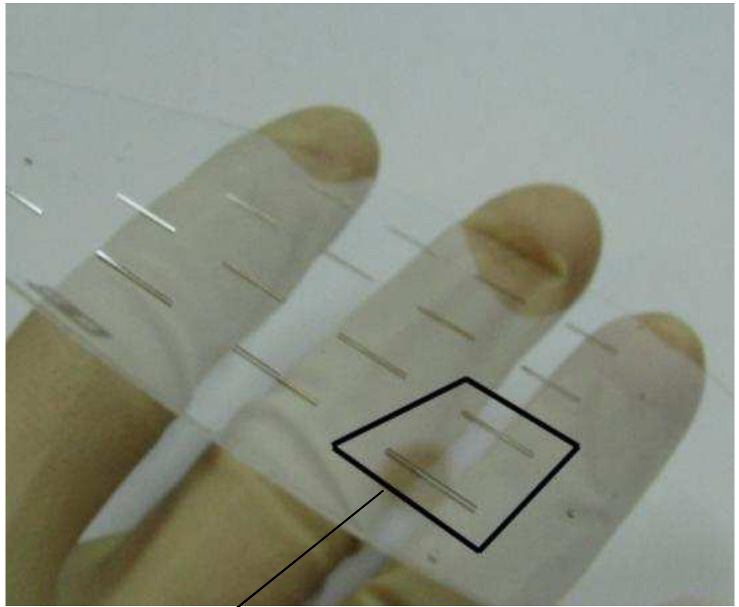
- Surface plasmon resonance at a metal-dielectric interface
- Light projected to the surface interacts with the plasma waves
- Absorption peak depending on the refractive index
- Refractive index changes due to bio molecules attached to the surface

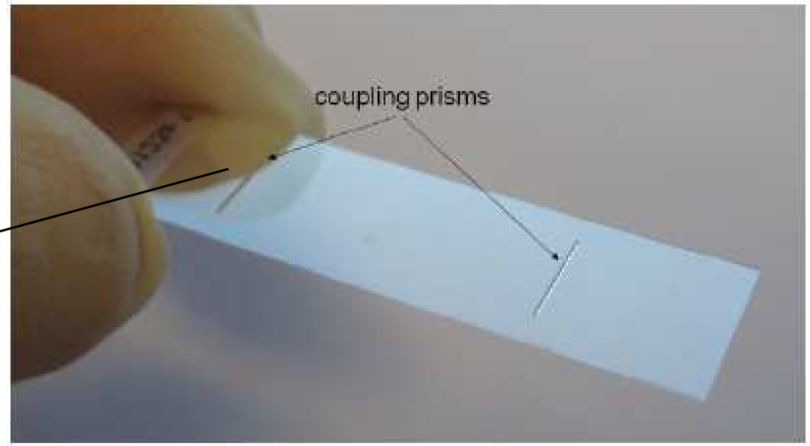
Bio sensing based on NEMS optical sensors 2

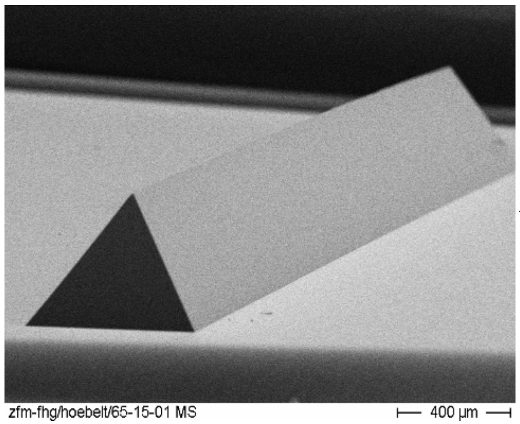
TIRF sensor with coupling prisms:

→ TIRF=total internal reflection fluorescence
→ Sensor slide fabrication by polymer hot embossing



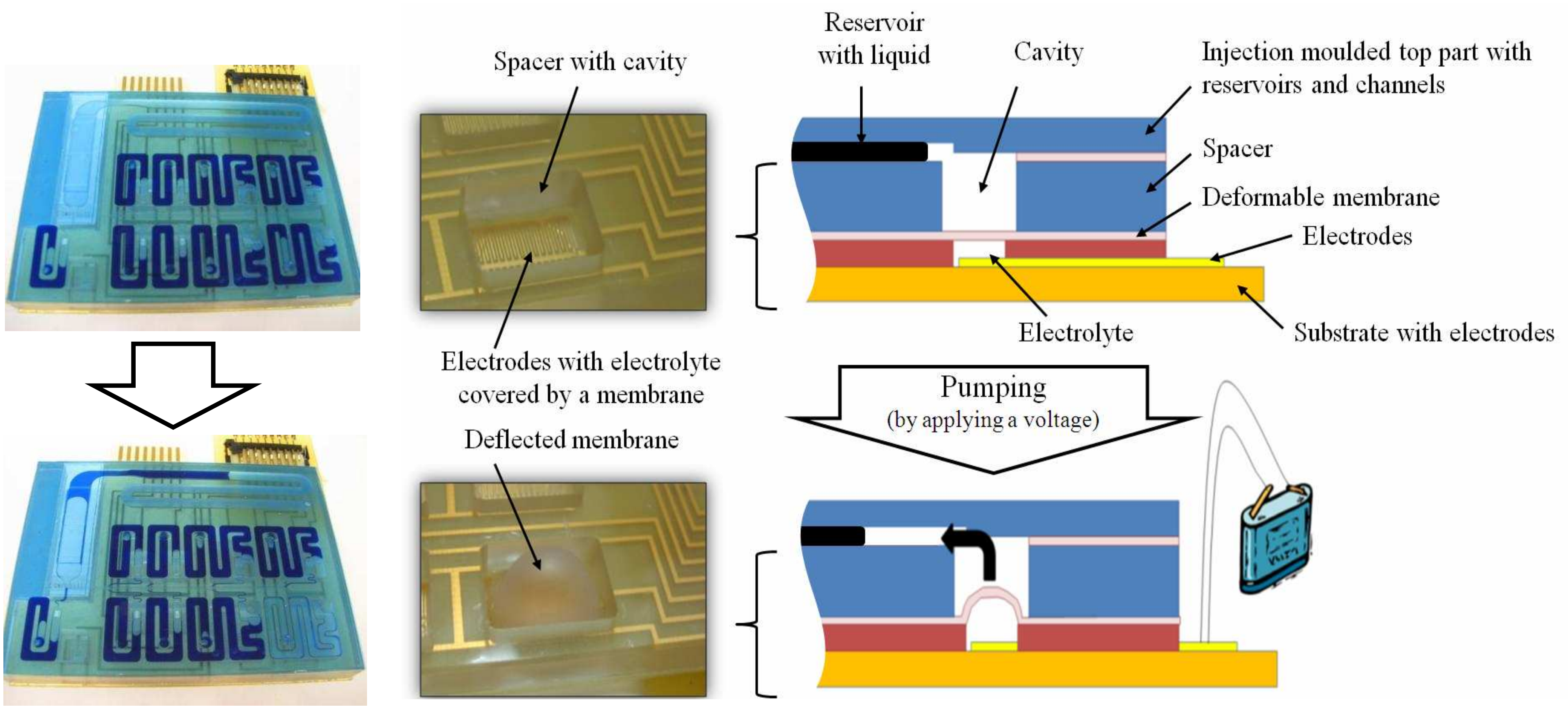




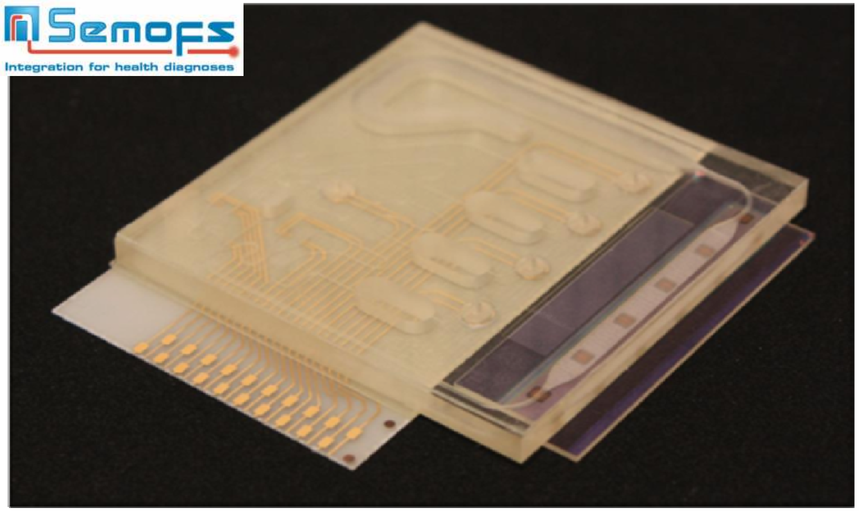


Low-cost integrated micropumps

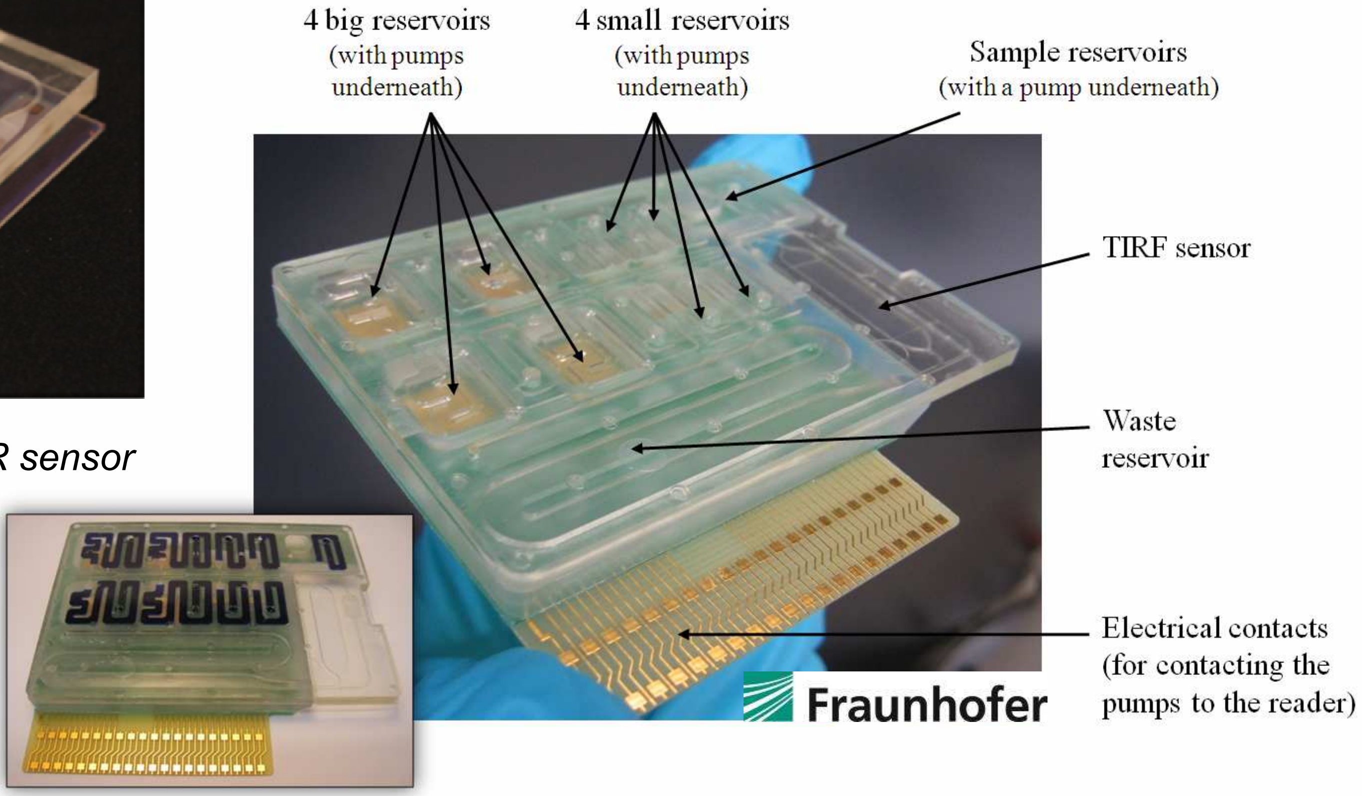
… working principle



Integration (Microfluidics + SPR/Fluorescence + bio)



Complete microfluidic cartridge with SPR sensor



Complete microfluidic cartridge with TIRF sensor for fluorescence detection

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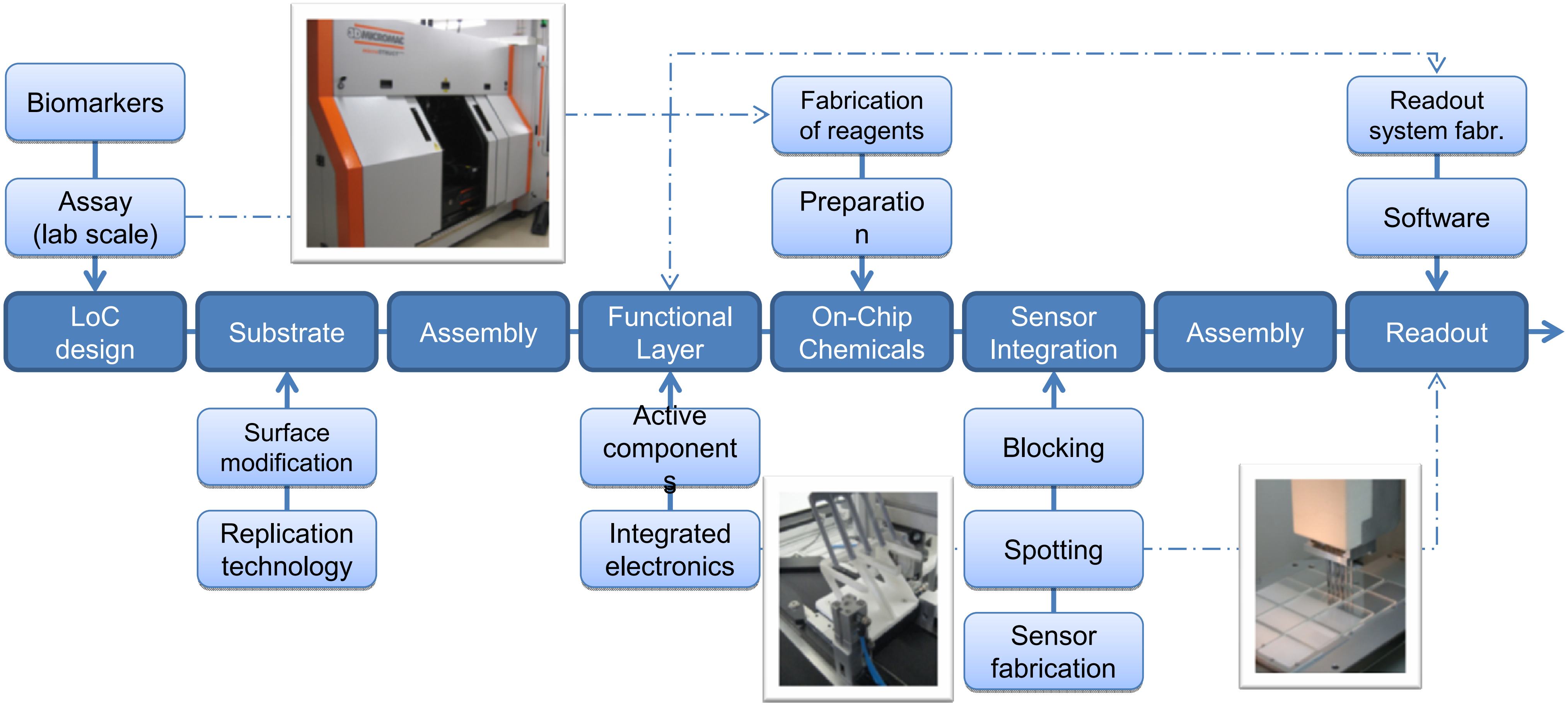
Complexity of design and fabrication – process chain



Example from the Fraunhofer ivD-Platform (www.ivd.fraunhofer.de)

Content

- Research Activities of Fraunhofer ENAS
- International Trends
- Examples of MEMS Devices for RF and Optical Applications
  - Smart Label
  - Wideband Vibration Sensors for Condition Monitoring
  - Fabry-Perot Interferometer
  - RF Microcoils for Nuclear Magnetic Resonance Spectroscopy, RF-MEMS Varactors for Adaptive Impedance Matching
- Summary and Conclusions

Conclusions

- Many products (prototypes) and technologies were developed and transferred in the field of Microelectronics and MEMS

- Future trends are increasing functionality in one system at the same time with degreasing size

- Complex system integration needs advanced packaging methods

European Conference & Exhibition on integration issues of miniaturized systems – MEMS MOEMS, ICs and electronic components

1. Conference : March 2007, Paris
2. Conference: April 2008, Barcelona
3. Conference: March 2009, Brussels
4. Conference: March 2010, Milano/Como
5. Conference: April 2011, Dresden

Organizer: Mesago Messe Frankfurt, Fraunhofer ENAS, Fraunhofer IZM

Part of the activities of: EPoSS European Technology Platform on Smart Systems Integration