Smart Systems Integration by using advanced MEMS technologies

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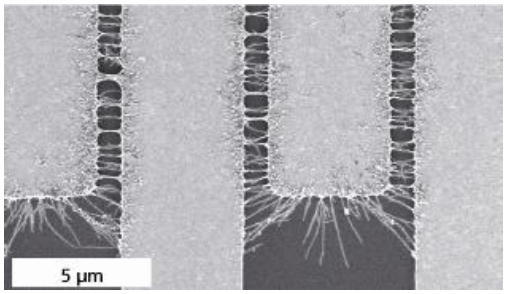
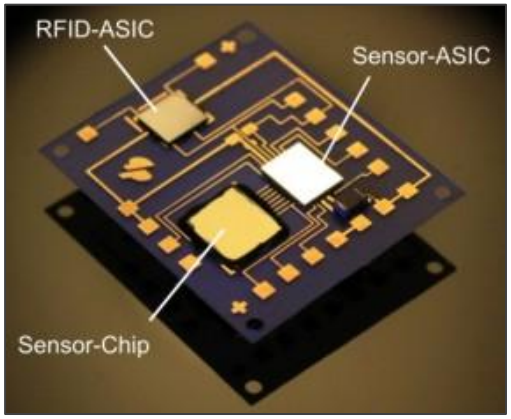
WPI, Tohoku University Sendai





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Outline

1. Introduction Fraunhofer ENAS and ZfM
2. International Trends in Smart Systems Integration
3. Examples
   - AIM technology for high precision MEMS
   - Smart label
   - Fabry Perot interferometer
4. Conclusion

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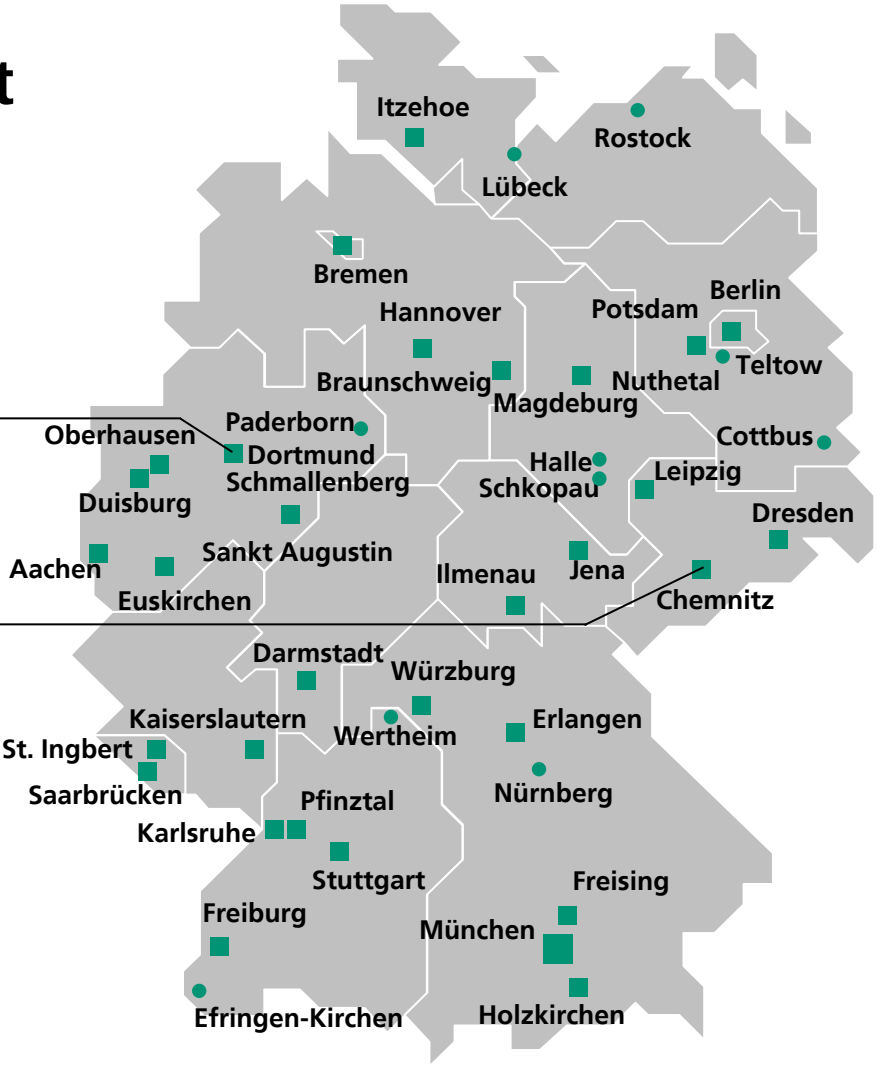
Fraunhofer-Gesellschaft in Germany

60 Institutes at 40 locations

Paderborn

Fraunhofer ENAS

Chemnitz



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Smart Systems Campus Chemnitz

smart systems campus
TechnoPark Chemnitz

CUT, Lightweight Structures Engineering

3D-Micromac AG

Start-up building

Fraunhofer ENAS

CUT, Institute of Physics and ZfM

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Fraunhofer Institute 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

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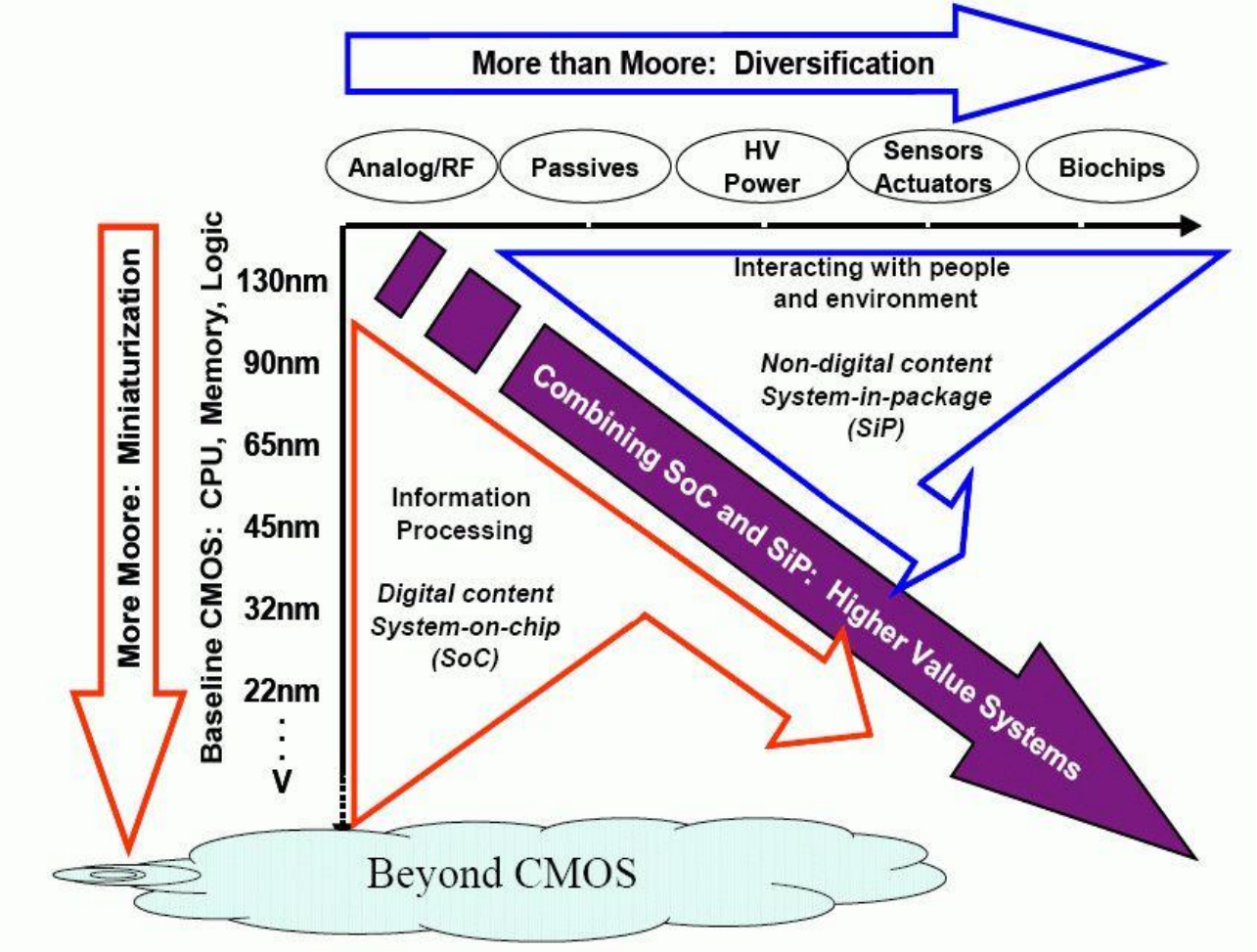
More than Moore / Smart Systems



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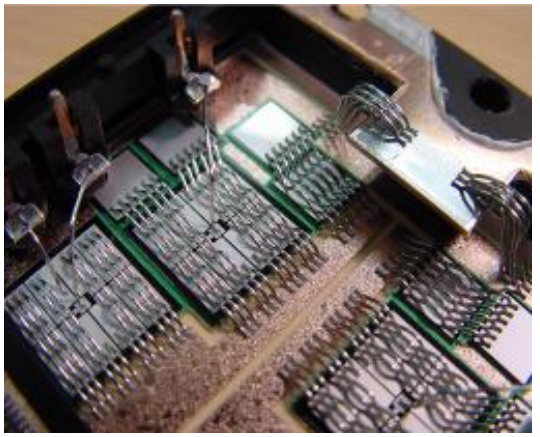
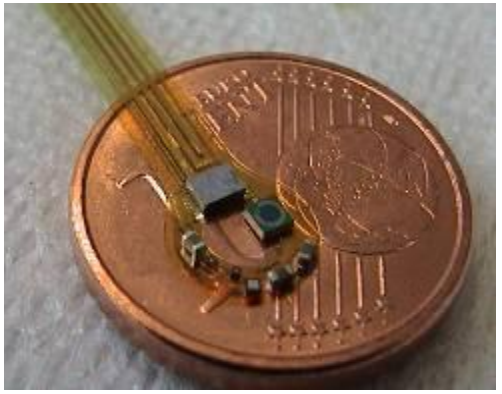
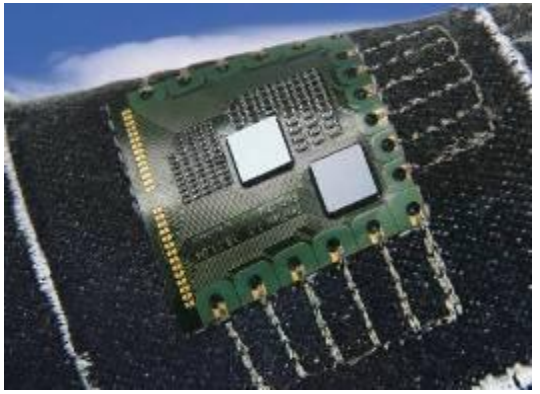
Definition Smart Systems Integration



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

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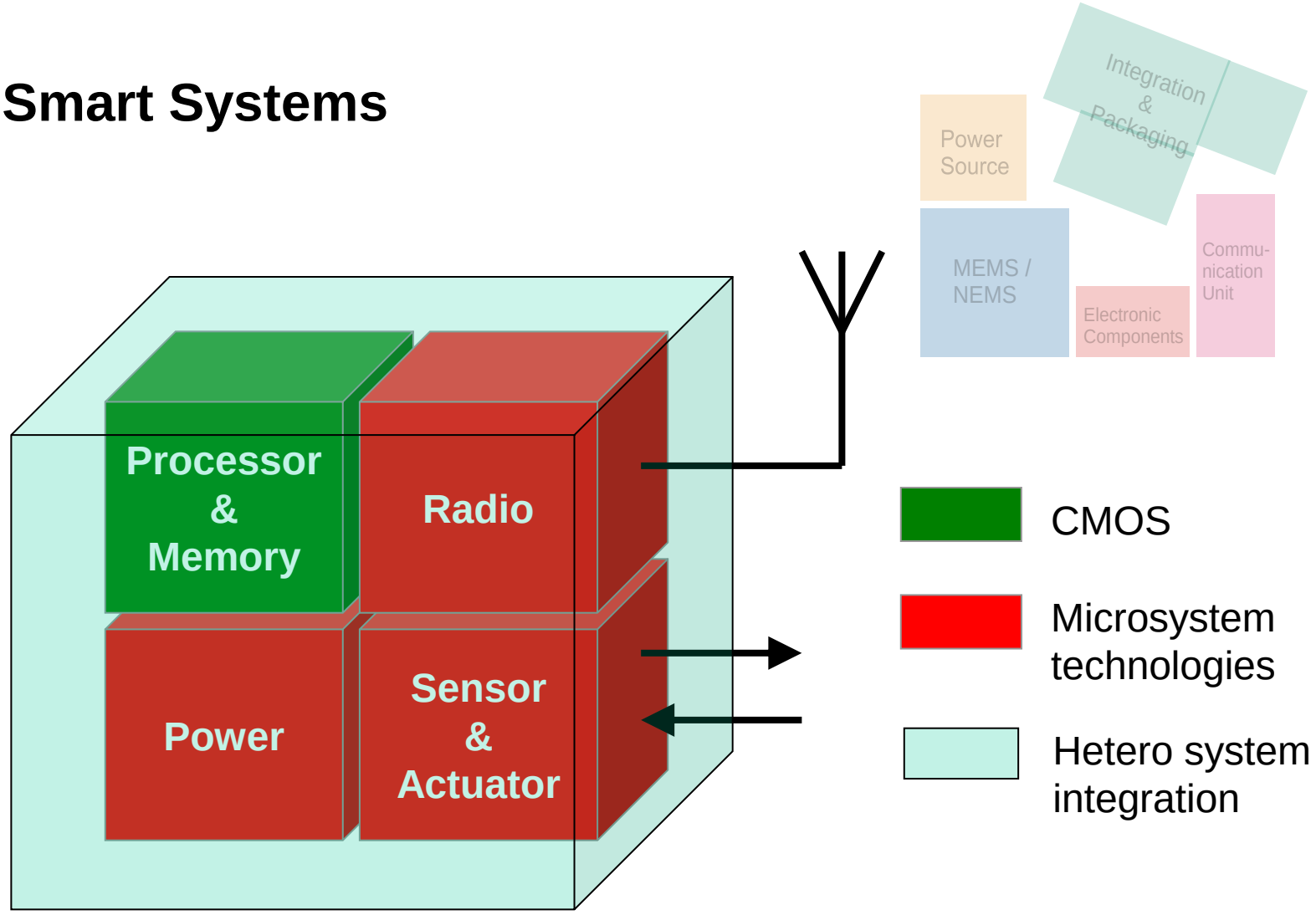
Smart Systems



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Internet of Things - anywhere

Home
Office
Car
Industry
Shops
Street
Hotels
Hospital
Ski Slope
…

Internet of Things (IoT)

- **smart objects**
- **wireless communication**
- **broad band internet**

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Inertial Sensor Systems with High Performance
> focused on low g sensors (0.25 …2 g) <

- material (standard sc Si, no SOI, large signal to area ratio)
- (monolithic) post-CMOS integration compatible
- processes (number of lithographic/critical steps, process yield)
- automation potential of processes
- avoid/reduce time consuming characterization/calibration (T!)
- cost-efficient packaging (zero level, system level)
- IP protection

→ AIM Technology (Airgap Insulation of Microstructures)

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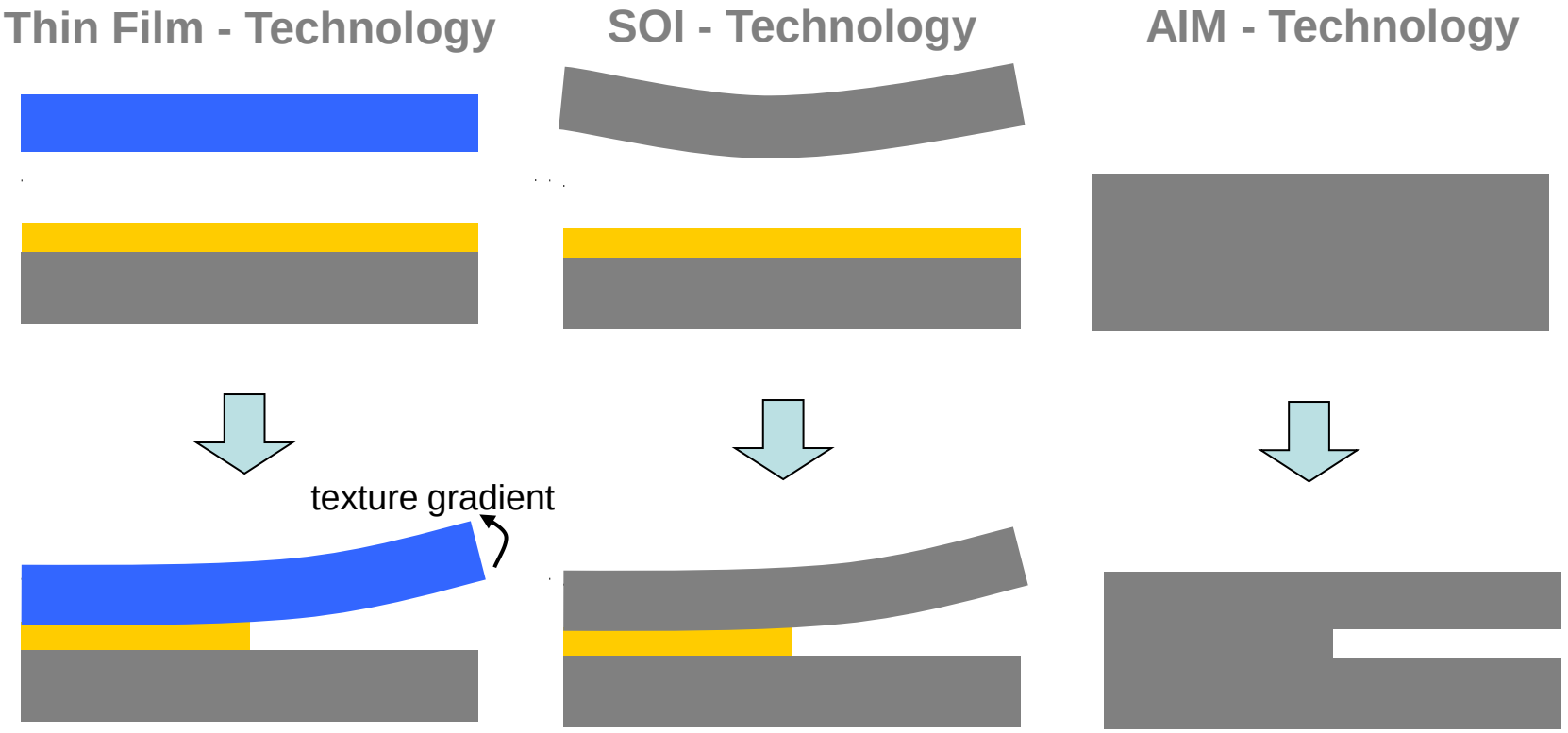
The AIM Benefit



mech. stress = f (depo-sition, temperature, time ...)

mech. stress = f (wafer flatness / warp, temperature)

no thin film mech. stress (scSi = functional material); no wafer bonding stress

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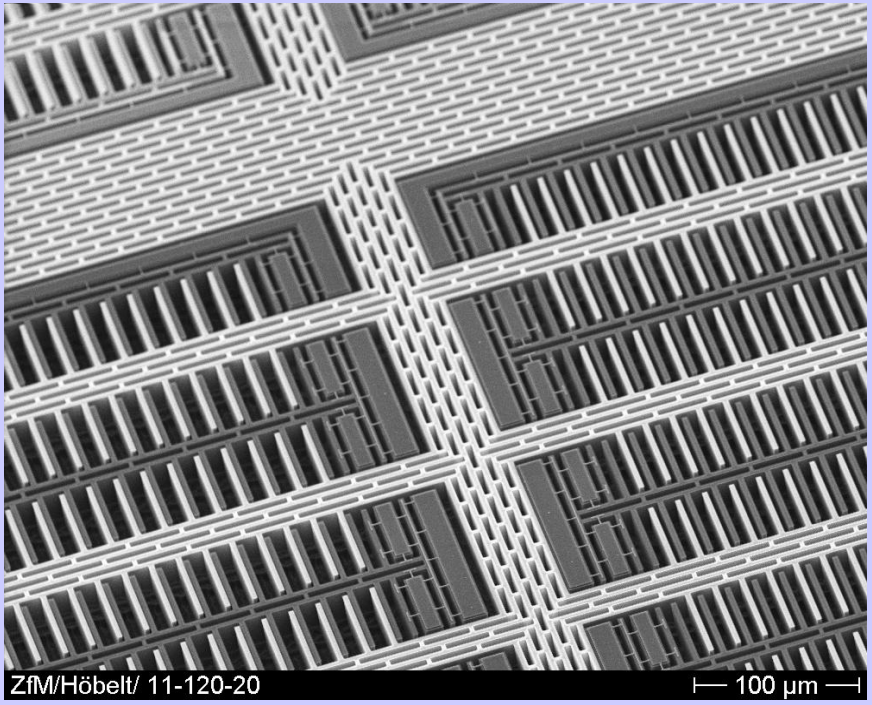
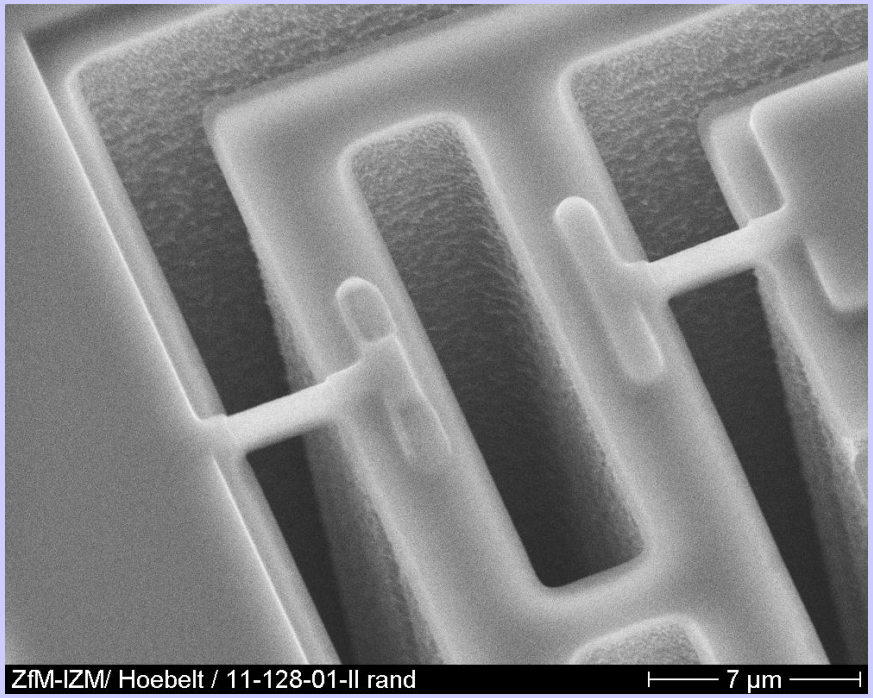
AIM Fabrication: Devices

SEM micrograph of AIM low-g device;
(note: charging of seismic mass by e- beam)



SEM micrograph: detail view



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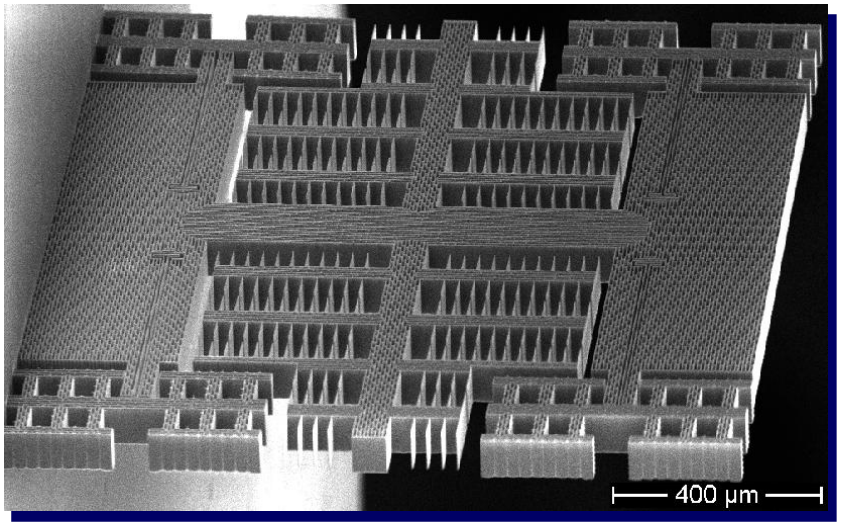
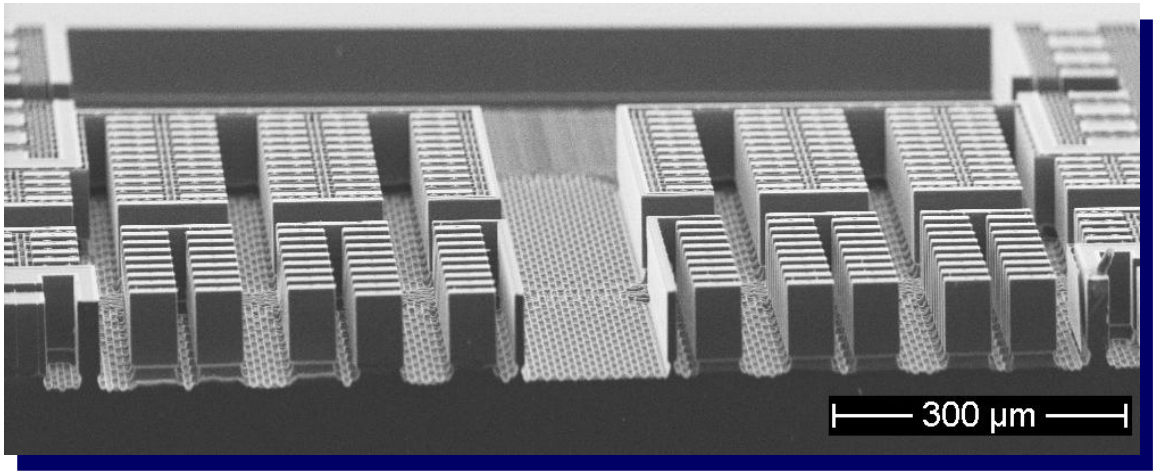
AIM7E– SEM

seismic mass





electrodes

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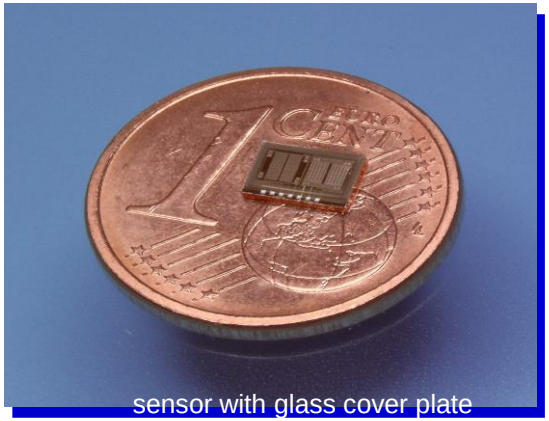
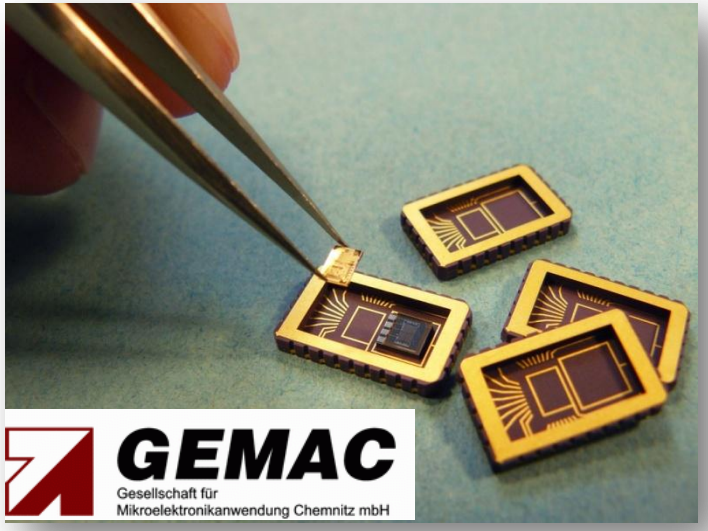
MEMS in AIM technology

- High precision inertial sensors
  - acceleration sensors
  - inclination sensors
  - vibration sensors
  - gyroscopes
- RF-MEMS
  - MEMS varactor for active tuning
  - High Q resonator for IF frequency range
  - RF switch





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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

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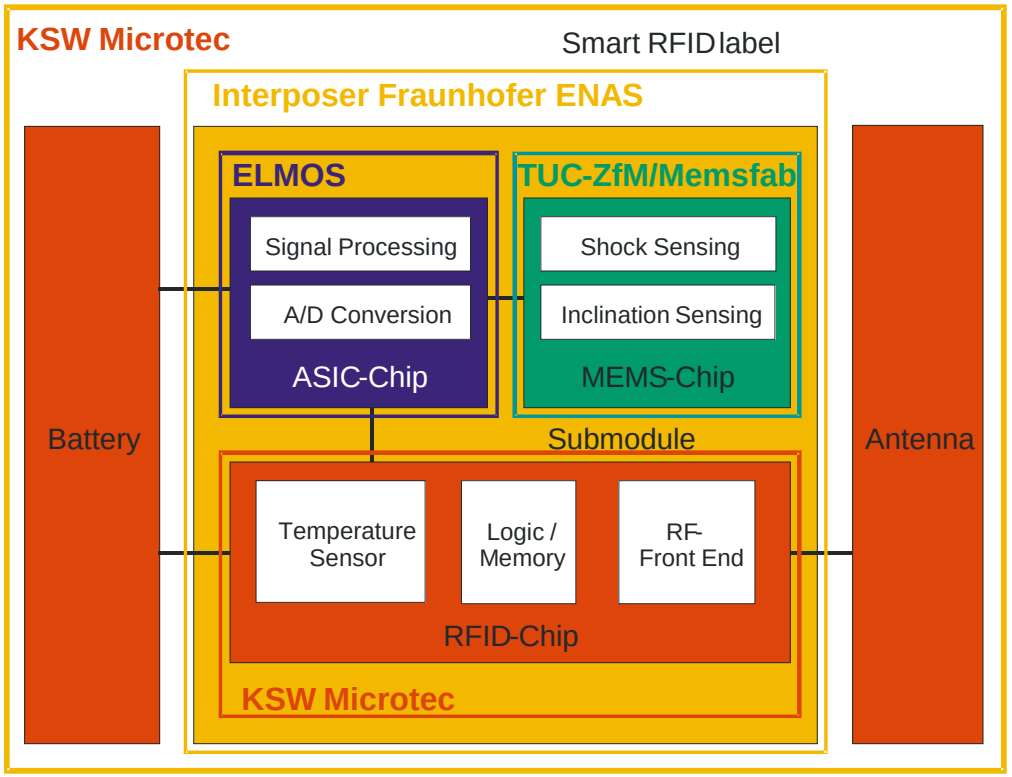
RFID label concept

The label components:

- 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

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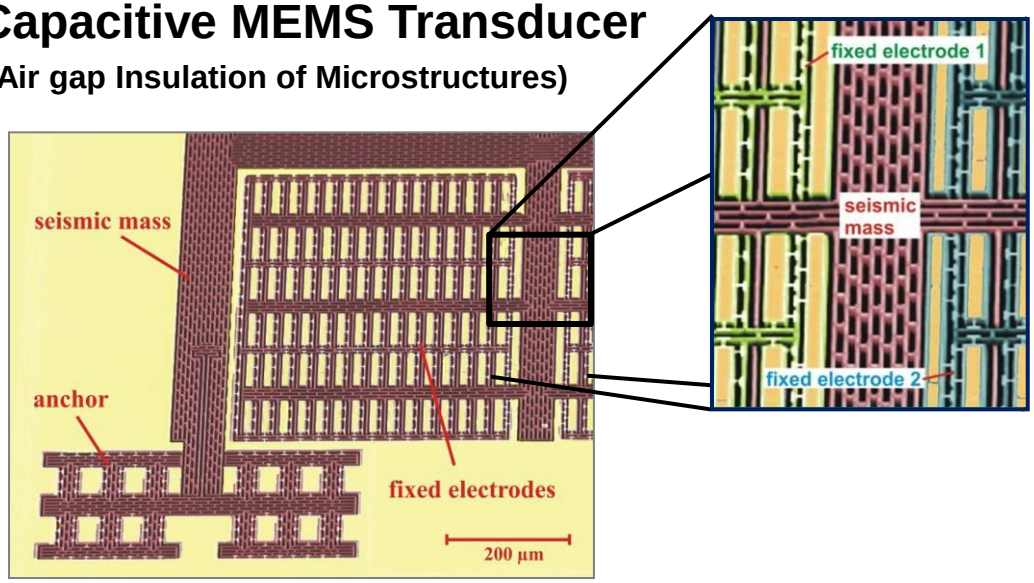
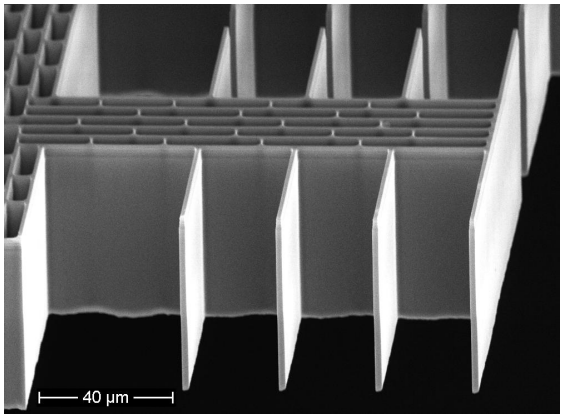
Concept of the sensor system

Capacitive MEMS Transducer

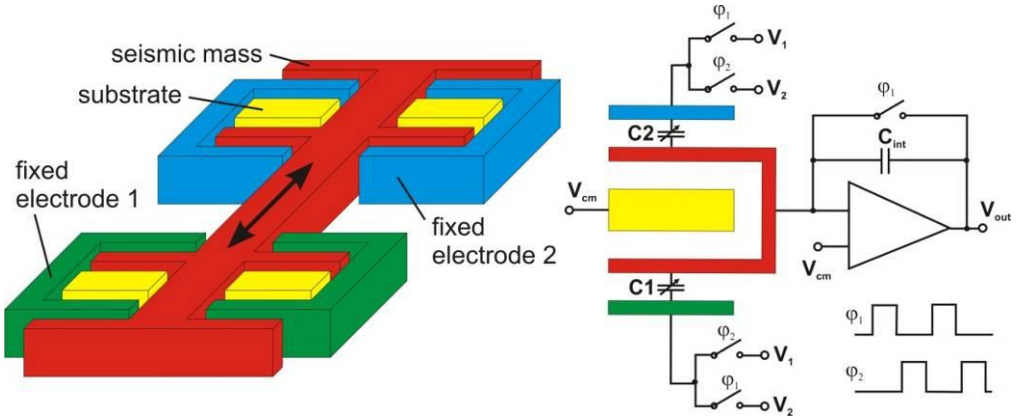
(Air gap Insulation of Microstructures)



HARMS – High Aspect Ratio Microstructure



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



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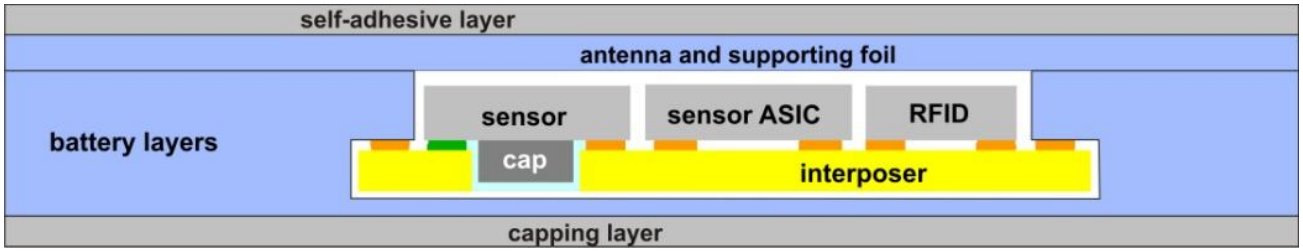
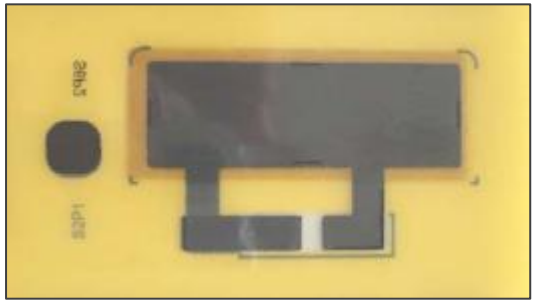
Packaging and Assembly Concept

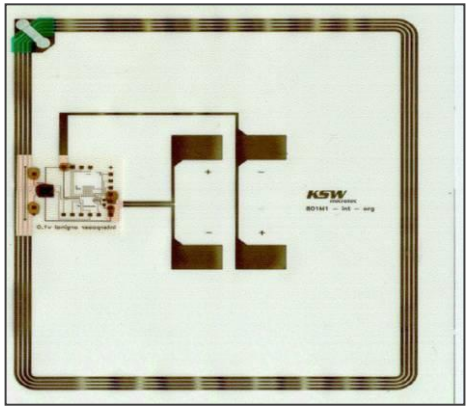
Fabrication technology:

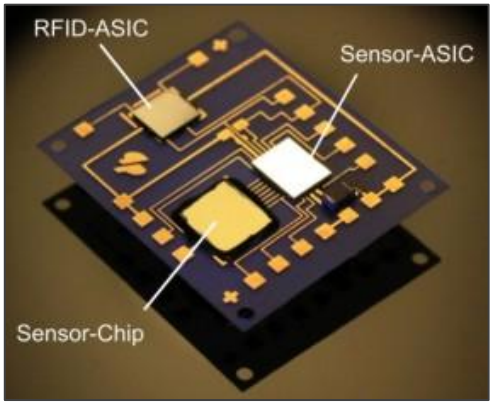
- Roll to roll fabrication demands flexibility of the layers
- Overall thickness of the label is limited

→ **Restricted chip height**









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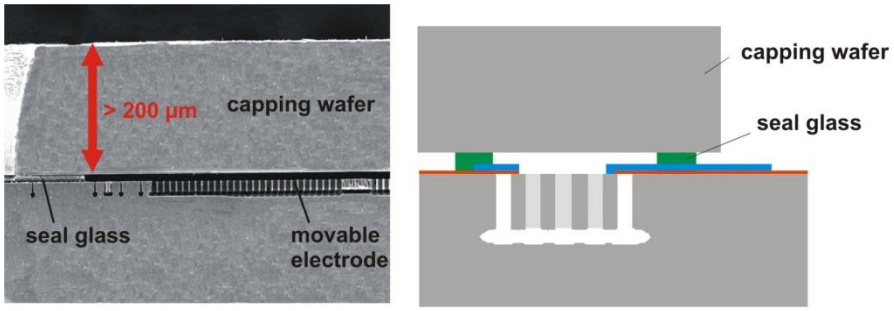
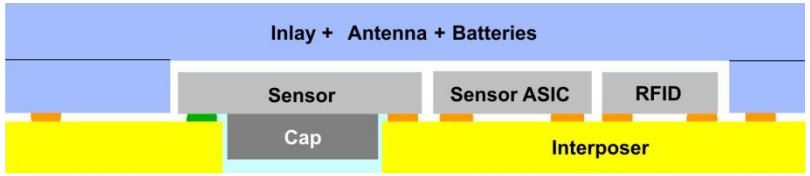
Packaging and Assembly Concept

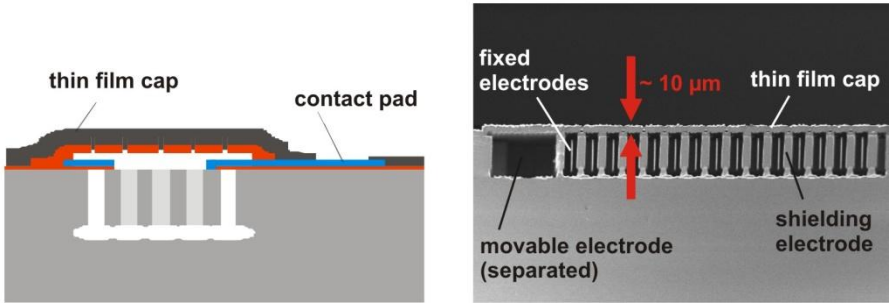
Wafer-Level-Packaging by seal glass wafer bonding

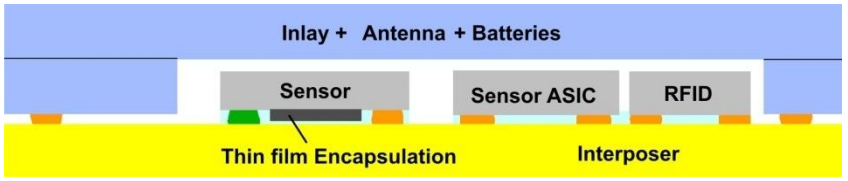




- industrial established process
- high reliability
- proven hermeticity

Wafer-Level-Packaging by thin film encapsulation





- reduction of the chip height
- reduction of the chip area
- reduction of cost

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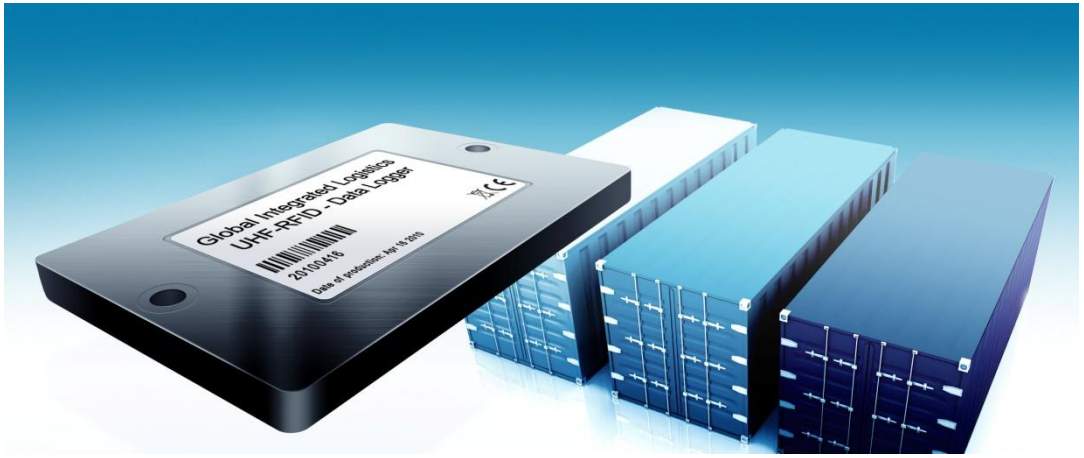
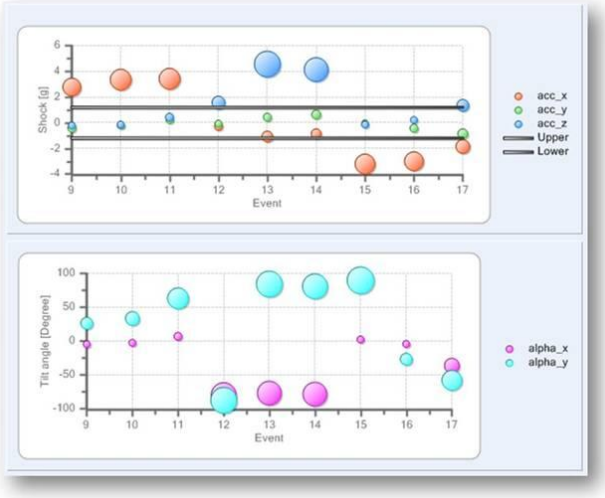
UHF-RFID Data Logger

SensLog

demo kit July 2010



- measure und record on a constant basis or triggered by events
- temperature and acceleration events (shock, inclination)
- events logged with a time stamp
- read out via UHF RFID interface



Cooperation:
ZfM
Fraunhofer ENAS
memsfab
MPD GmbH
Talk-ID
Fraunhofer IPMS

Fraunhofer ENAS

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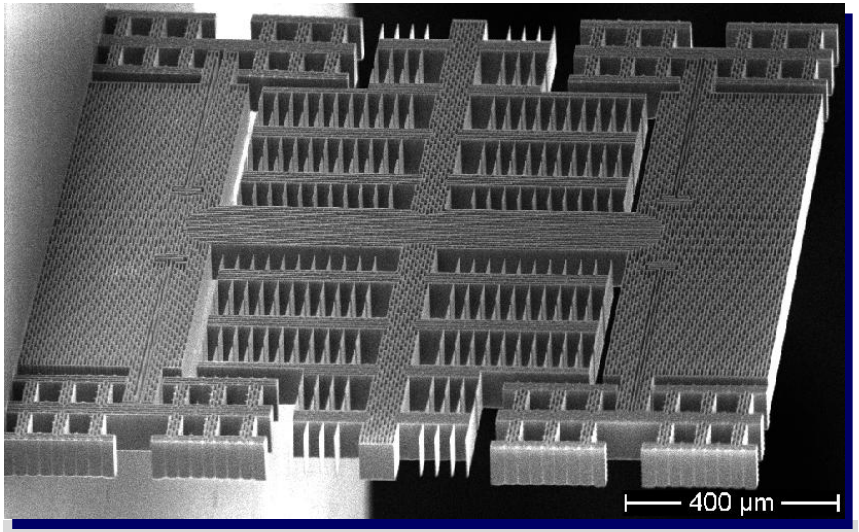
UHF-RFID Data Logger



Technical data:

- plastic housing
- primary battery included
- EEPROM, non-volatile for data storage
- operating temperature: -30°C … 70°C
- storage temperature: -55°C … 70°C
- temperature accuracy: 1K
- Frequency range: 860 -960 MHz

acceleration sensor:

- 3 axes of measurement
- shock measurement range: ±2g; ±8g
- shock trigger value: 17mg (±2g)
  67mg (±8g)
- inclination measurement: round angle
- inclination trigger value: 1° (±2g)
  4° (±8g)

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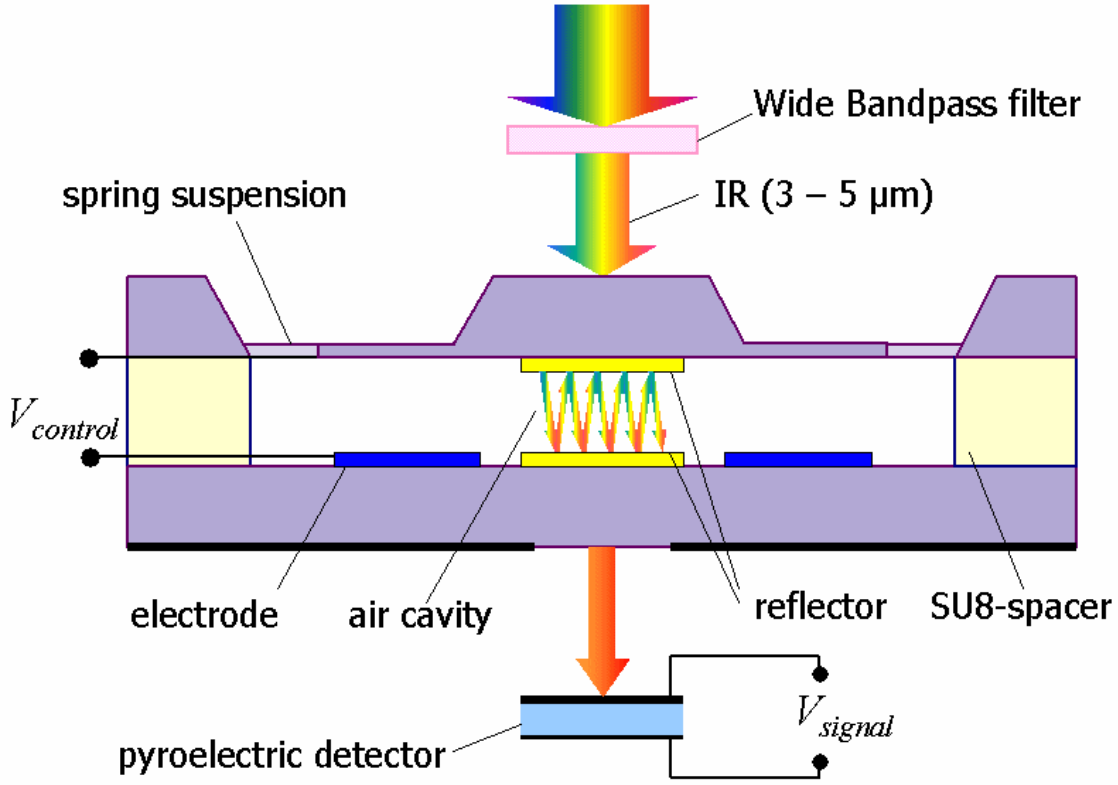
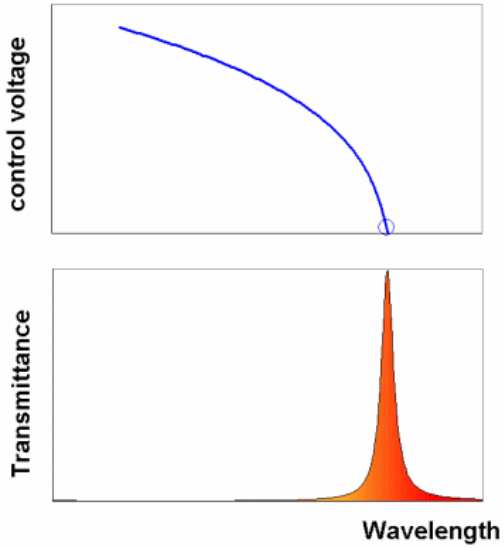
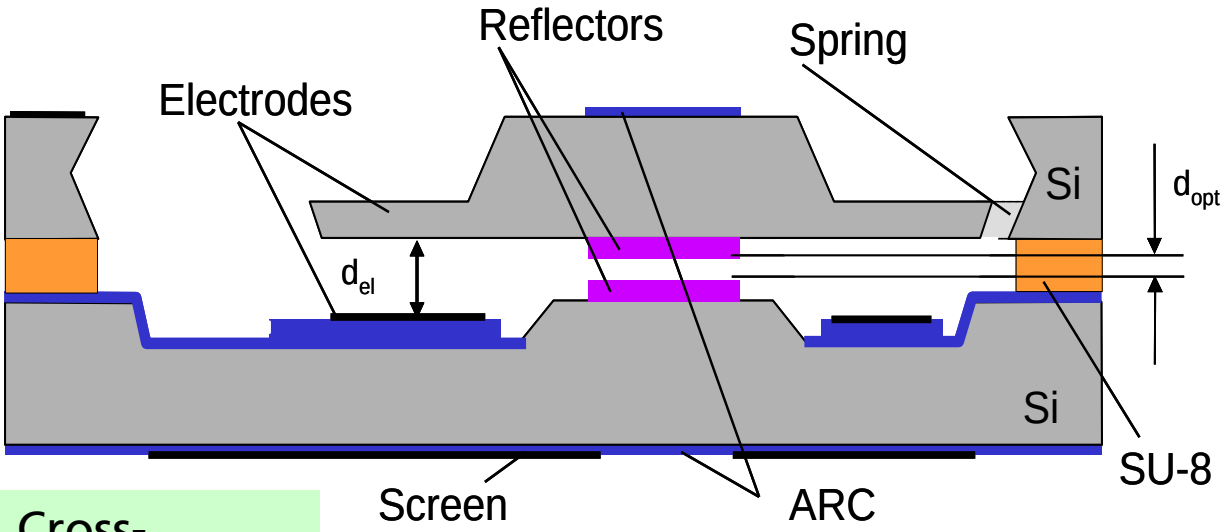
Fabry-Perot filter + IR detector - principle

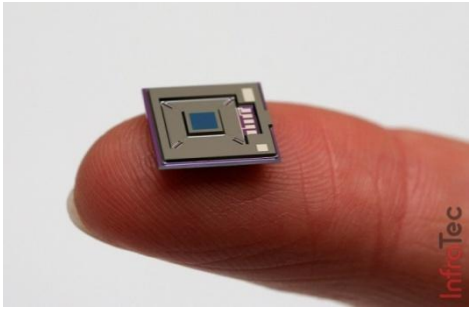


InfraTec



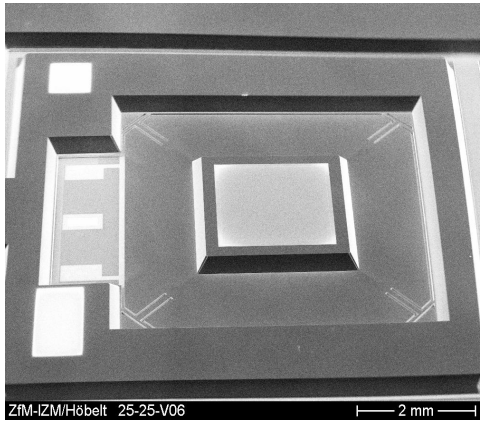
Fabry-Perot filter - design

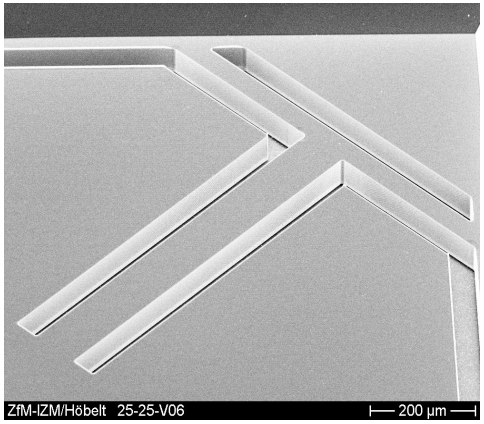




Cross-section

SEM of filter and detail of spring





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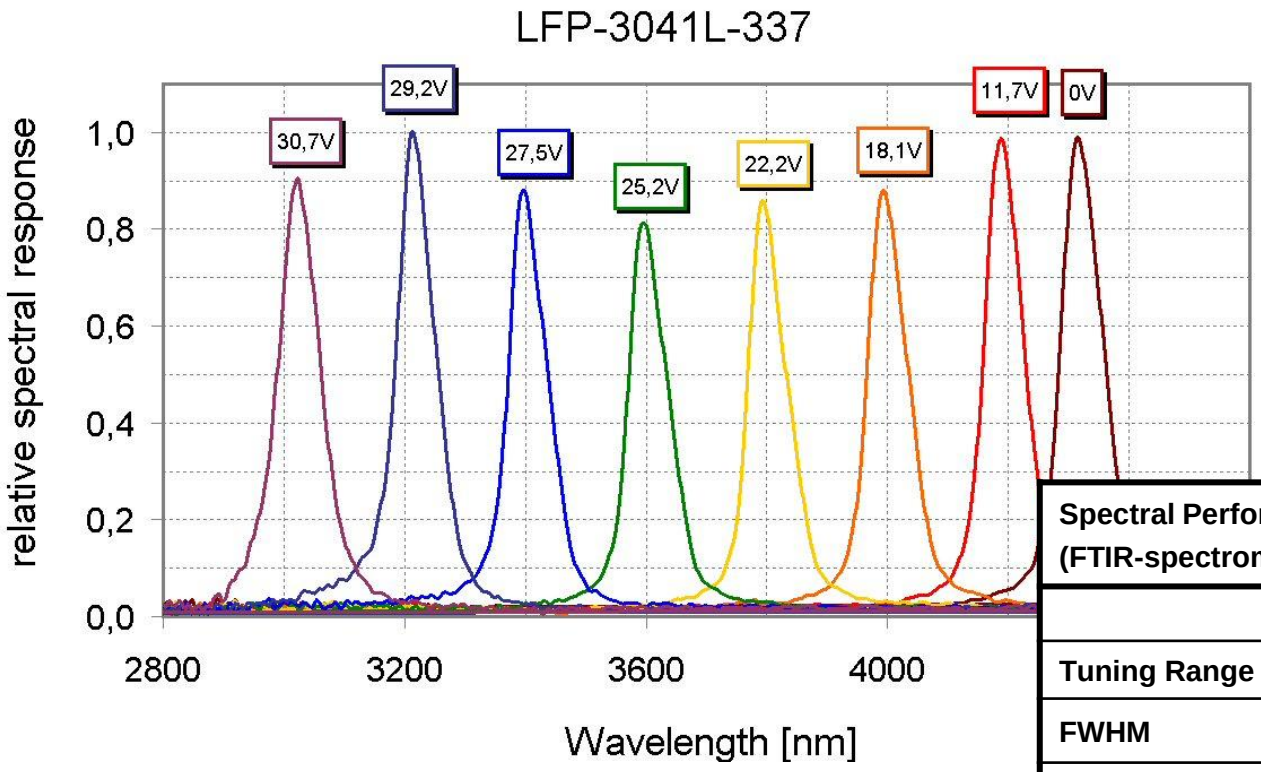
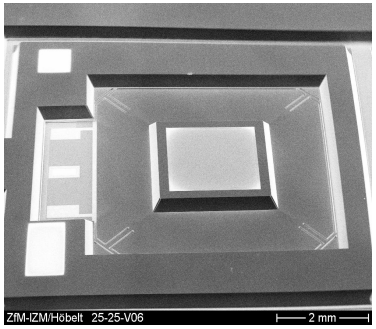
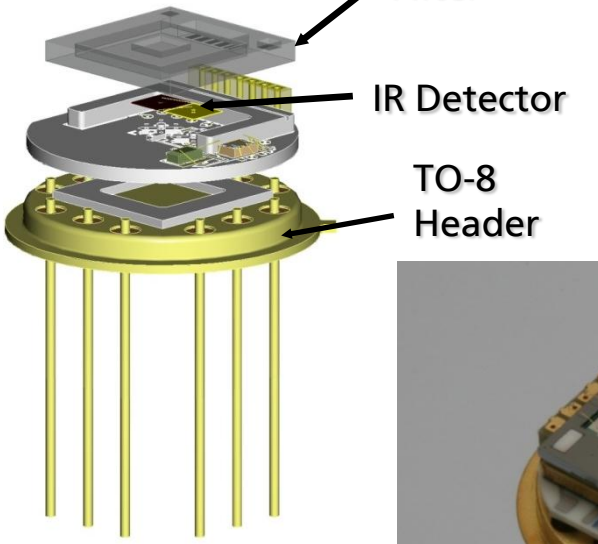
FPF Performance



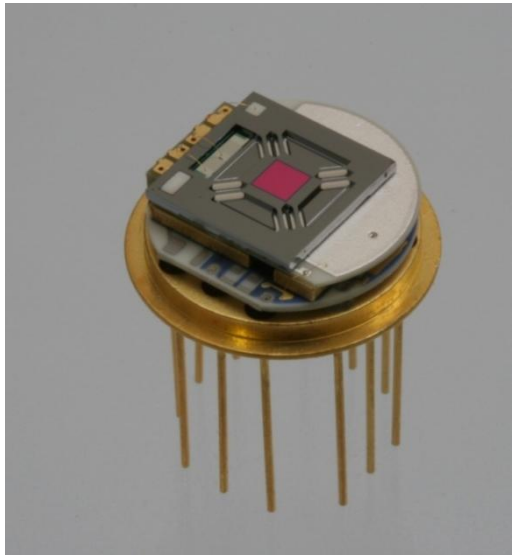


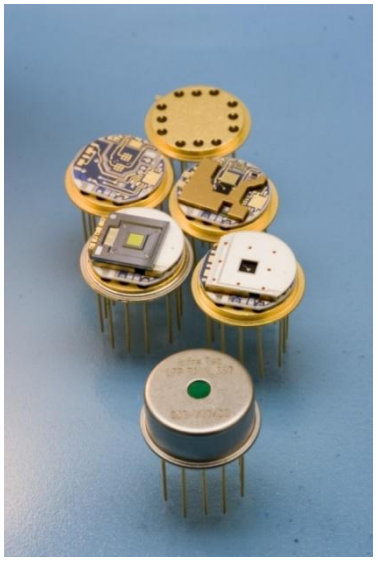
Spectral Performance (FTIR-spectrometer, 8cm^{-1}, ±4°cone)		
	short type	**long type**
Tuning Range	3...4.1µm	3.9...5µm
FWHM	80±20nm	100±20nm
Peak-Transmittance	>50%	
Out-of-band blocking	<0.5%	
Finesse	40...60	

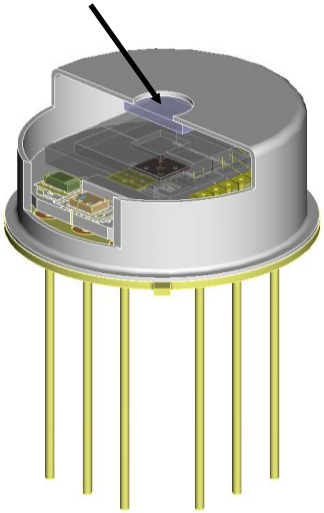
Integration of filter and detector (InfraTec Dresden)



Fotos: FP filter on detector, mounted in a TO-8 housing (by courthesy of InfraTec GmbH, Dresden)







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Further development of FPI

- IR spectroscopy is used to determine unknown gas or liquid mixtures

  → two spectral ranges needed:

  - 3 … 5 µm
  - 8 … 12 µm (absorption characteristic of different gases ist much more specific in this range)

- two different approaches for the range 8 … 12µm

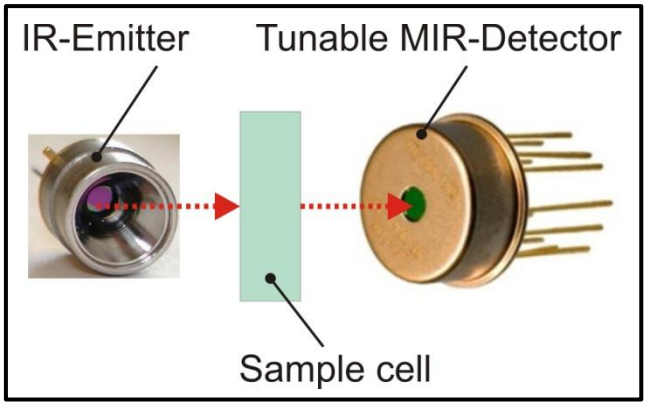
  →Sub-wavelengthstructures for infrared filter

  →New reflectors

Project overview

Build **extremely small**, **tunable** and **robust** detectors based on MEMS Fabry-Pérot filters and their application in MIR-Spectroscopy

Courtesy of InfraTec GmbH



Courtesy of InfraTec GmbH

Key features:

- Two spectral ranges from 4 to 5 µm and 8 to 11 µm
- Fits in a TO-8 housing
- Control voltage < 50 V
- Scanning both spectral ranges in < 80 ms
- Shock resistant according to MIL-STD 833, Method 2002, Test condition B (FP filter only)
- Aperture of 2 mm

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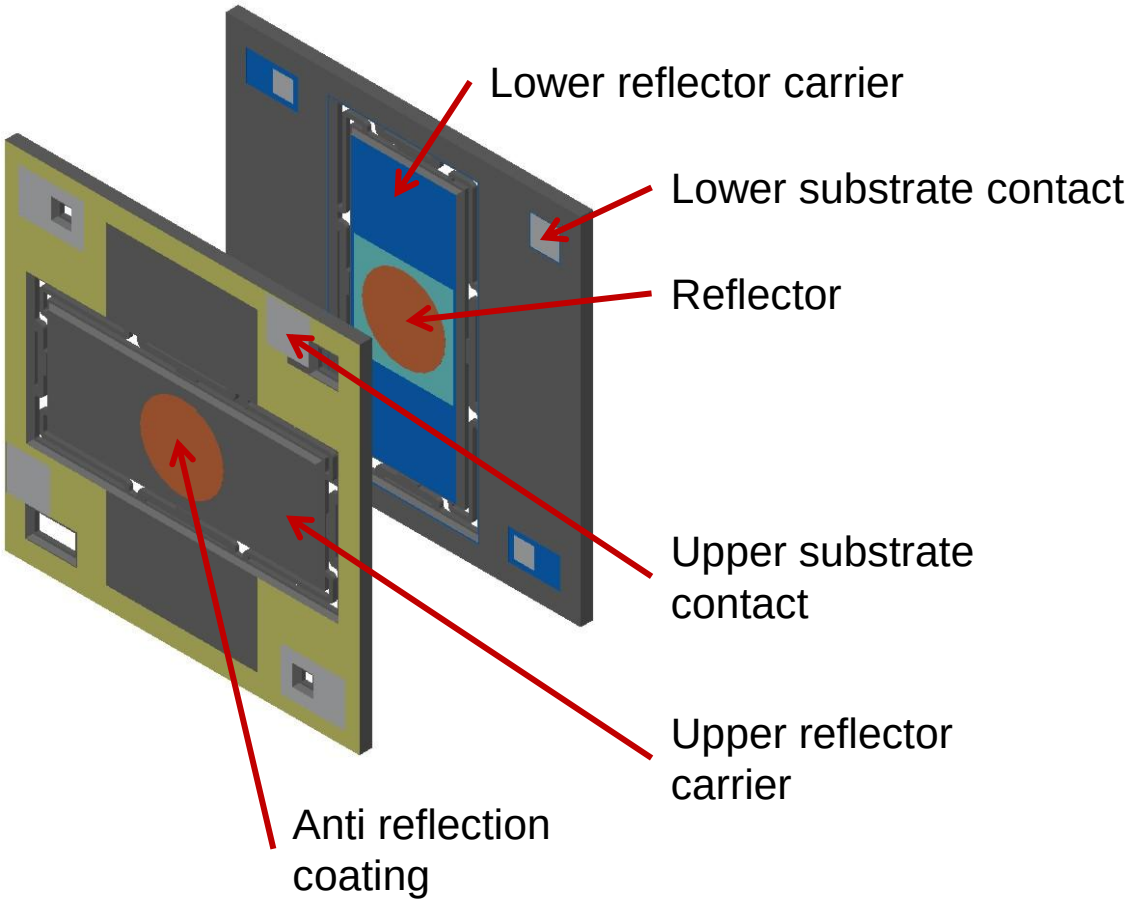
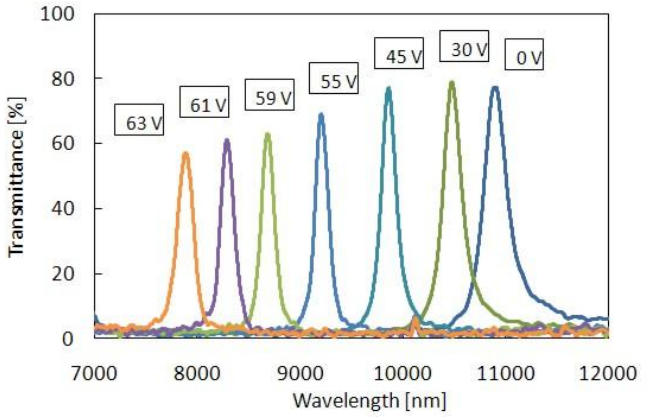
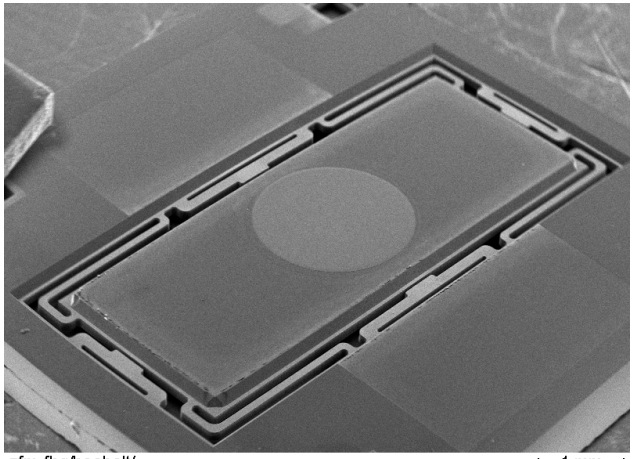
Design of the Fabry-Pérot filter







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Applications for small-sized MIR-Spectrometers

Medical

www.draeger.com

- Analysis of breathing gas (CO_2)
- Detection of general anesthetics (N_2O, halogenated ethers)

Chemical industry

www.endress.com

- ATR probe head
- Process monitoring

Safety and security

- Analysis of breathing gas (alcohol)
- Fire and flame detection

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Outline

1. Introduction Fraunhofer ENAS
2. International Trends in Smart Systems Integration
3. Examples
   - AIM technology for high precision MEMS
   - Inclination and vibration sensors
   - Smart label
   - Fabry Perot interferometer
4. Conclusion

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Conclusions

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

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

- Complex system integration needs advanced packaging methods

→ **Nanotechnologies and Devices**

→ **Smart Systems Integration**

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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: March 2011, Dresden

SMART SYSTEMS INTEGRATION

Organizer: Mesago Messe Frankfurt, Fraunhofer ENAS, Fraunhofer IZM

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

Fraunhofer ENAS, ZfM Zentrum für Mikrotechnologien, Technische Universität Chemnitz

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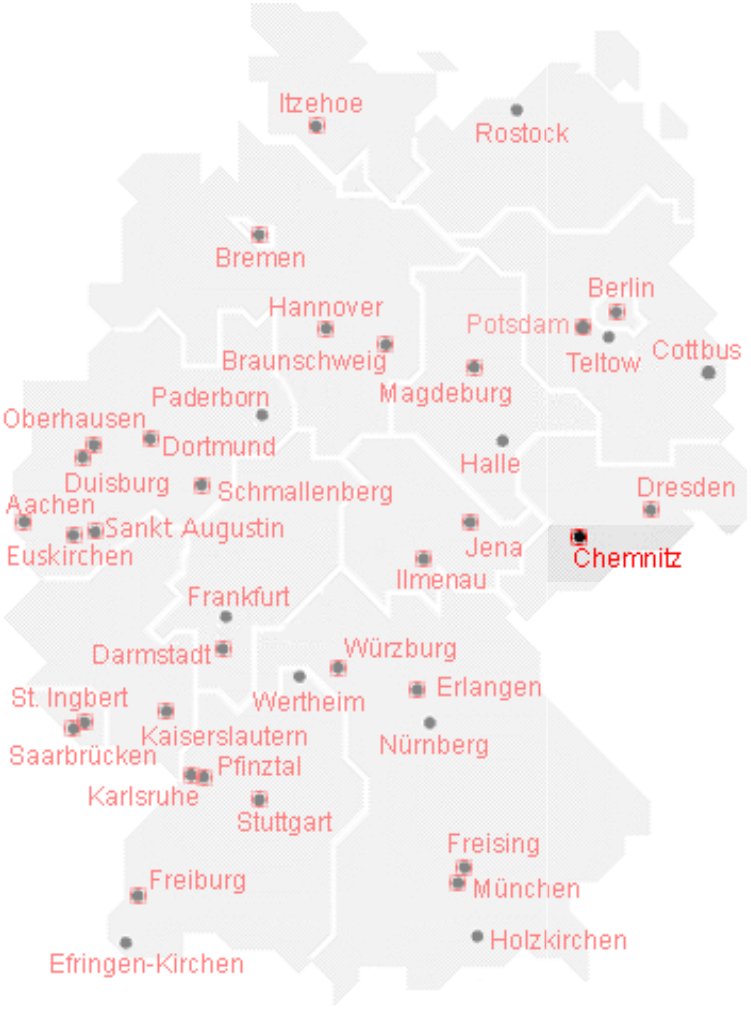

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