First Sensor

“Ein MEMS basiertes Low-g-Sensorsystem für Präzisionsanwendungen”

14th LEIBNIZ CONFERENCE OF ADVANCED SCIENCE
SENSORSYSTEME 2012

Markus Nowack
Schloss Lichtenwalde , 18. - 19. Oktober 2012

Outline

- Introduction
- AIM-Technology and Applications
- Example: Monitoring of power lines
- Performance overview SensIncline
- Outlook
- Summary

Introduction

- AD 132 the first seismoscope was invented by Zhang Heng (AD 78-139)
- Chinese inventor, geographer, mathematician, astronomer… during Eastern Han Dynasty
- The real inside of the "instrument for measuring the seasonal winds and the movements of the Earth“ is unknown

→ pendulum inside the vessel
→ earthquake occurs
→ mechanism opens the mouth of only one dragon
→ A ball is released and falls into a open mouth of the toad below

Figures: *Replica and picture of Zhang Heng’s seismoscope*

Introduction

Industrial application

Inertial motion trackers

Geoengineering & Condition monitoring

Entertainment

Introduction

- Industrial Applications: 5.0-10”
- Geodesy: 0.5-1.0”

$$TNEA = \sqrt{BNEA^2 + CNEA^2}$$

→ Decreasing of total noise

→ Large capacitive change per mass displacement

→ Low Brownian noise

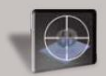
$$BNEA = \sqrt{\frac{4k_B T \omega_0}{mQ}}$$

Technical specifications Leica TM6100A

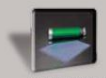
Accuracy	
Std. Dev. Hz, V, ISO 17123-3	0.15 mgon (0.5")
Display least count	0.01 mgon (0.01")
Focussing distance	
(Shortest focussing distance)	
from telescope front lens	0.51 m
from telescope tilting axis	0.60 m
Telescope	
Type	Panfocal alignment telescope
Image	Erect
Objective aperture	52 mm
Clear objective diameter	40 mm
Focusing	Coarse and fine
Telescope tilt	
pointing direction down	–55° (–60 gon)
pointing direction up	+47° (+52 gon)
Compensator	
Setting Accuracy	0.15 mgon (0.5")
Setting range	0.07 gon (4")
Special features	
Built-in autocollimation device (green negative crosshair)	
Illumination	AL51 plug-in lamp keyboard switch

Field of view and magnification

Focussing distance	0.6 m	3 m	10 m	100 m	∞
Field of view	0.04 m	0.11 m	0.26 m	2.08 m	1°08'
Magnification					
Standard Eyepiece	13x	24x	32x	41x	43x
Eyepiece FOK53	18x	33x	44x	56x	59x



Autocollimation



Extended battery life

Piezo technology

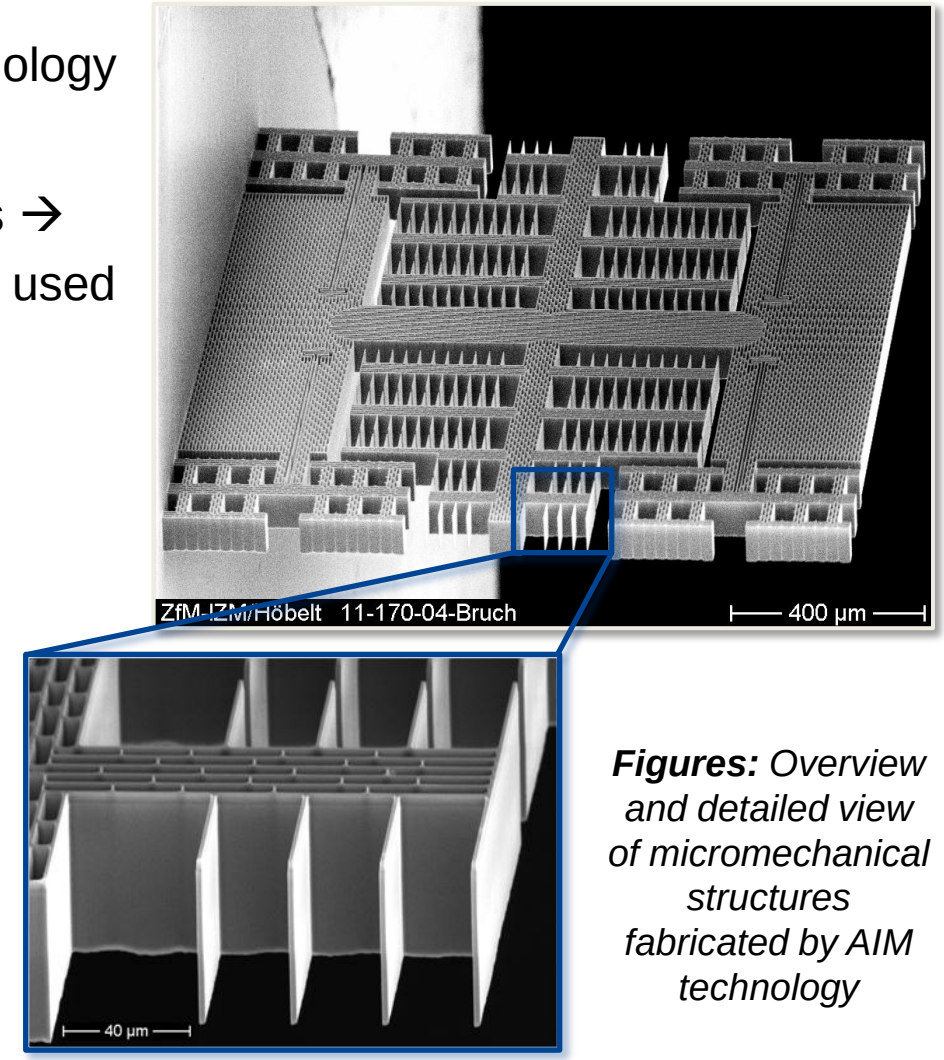
Theodolite TM6100A
Accuracy: 0.5” ≈ 0.00014°

Source: *www.leica-geosystems.com*

AIM technology

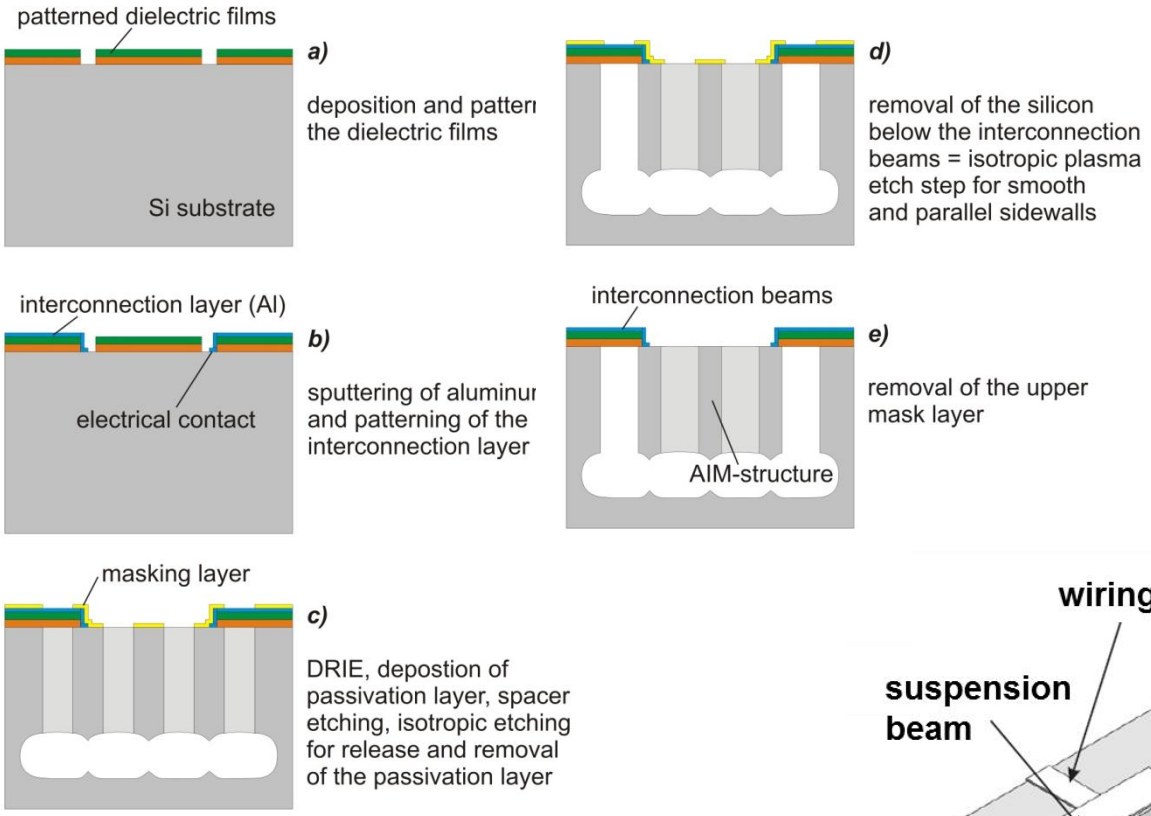
- Surface micromachining by AIM technology (**A**ir gap **I**nsulated **M**icrostructures)
- Thin film free mechanical components → crystalline silicon only, standard wafer used → no mechanical stress
- Minimizing parasitic capacitances
- Complete dry processing
- Excellent thermal performance
- Large signal to noise ratio
- Mechanical over damped
- In situ defect removal

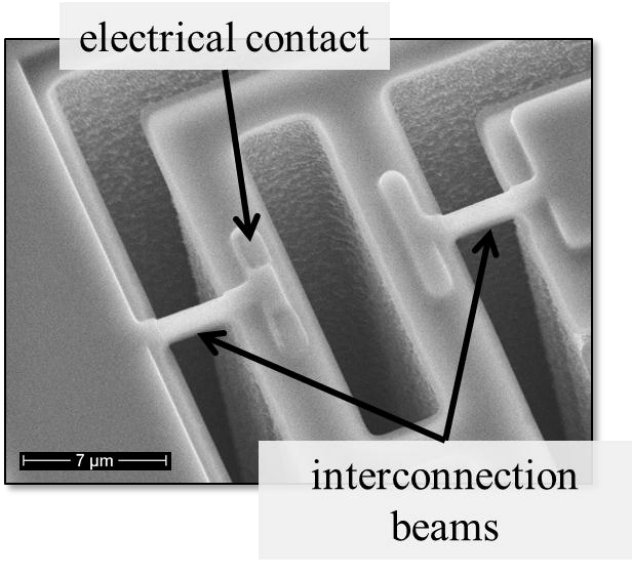
Acceleration, Inclination or Vibration Sensing

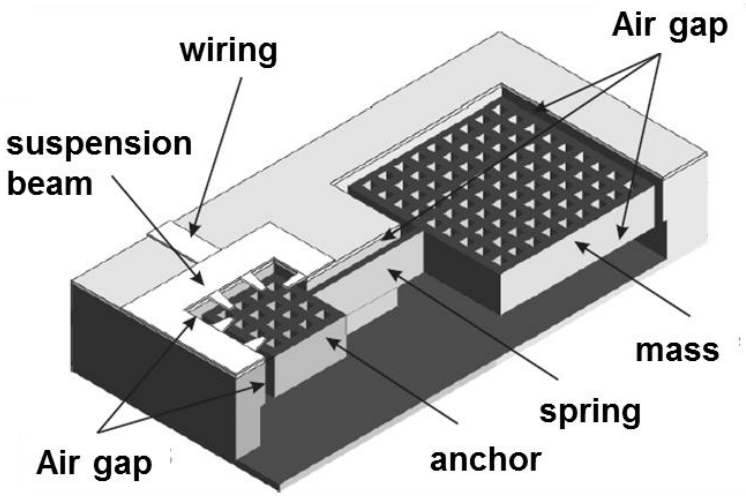


Figures: *Overview and detailed view of micromechanical structures fabricated by AIM technology*

AIM technology



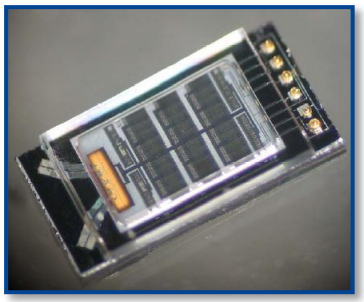


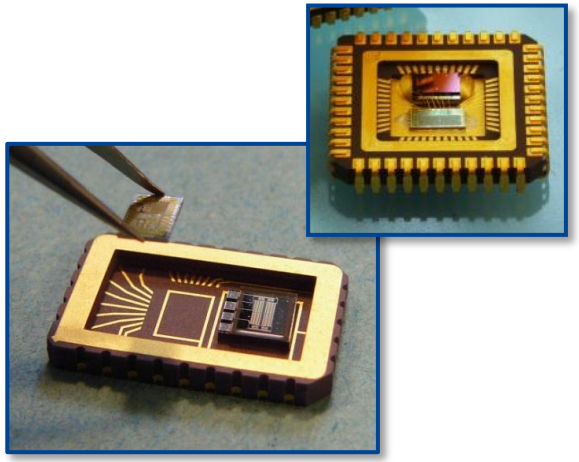


Figures: *Process flow and detailed view of the AIM specific interconnection beams*

Applications

Devices: AIM technology is used to fabricate sensors and actuators → typically devices are Inertial MEMS and RF MEMS



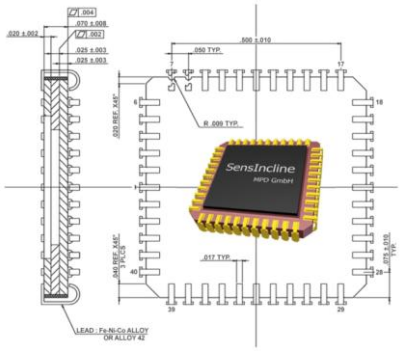


High Precision Inclination Sensors:

(resolution 0,0013° for a measurement range of ±30°)

Measuring Range: ± 0.5g (± 30°)
Noise of sensor system → Resolution: 0.0012-0.0014°

≈ 37 aF → ≈ 44 pm mechanical deflection of the transducer element



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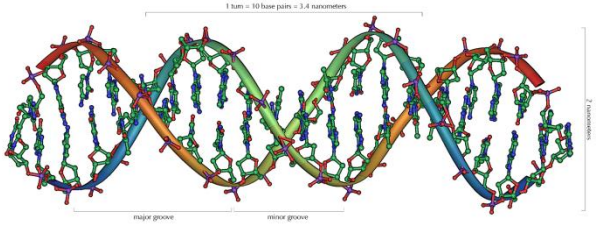

DNA double helix with 2000 pm in diameter

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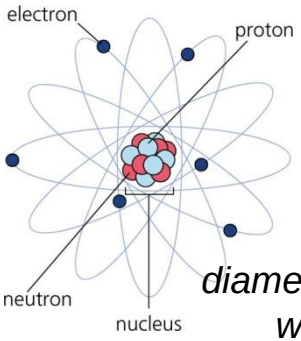


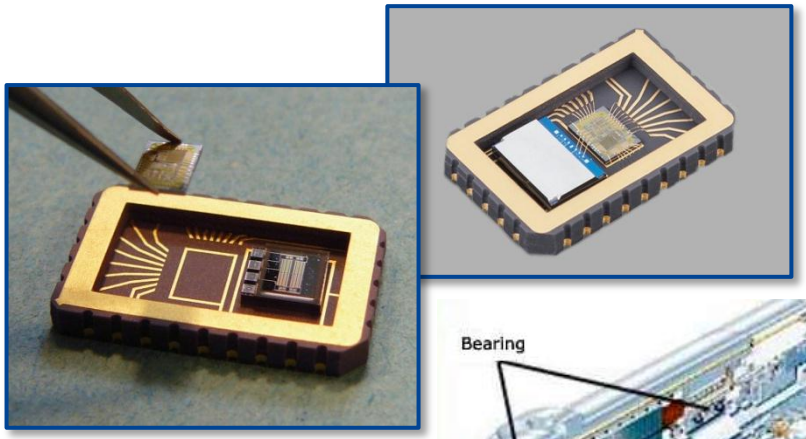
diameter of a C-atom with 154 pm

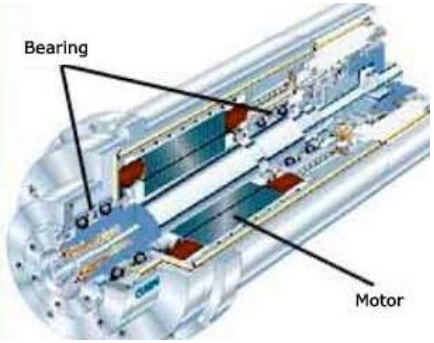
Applications

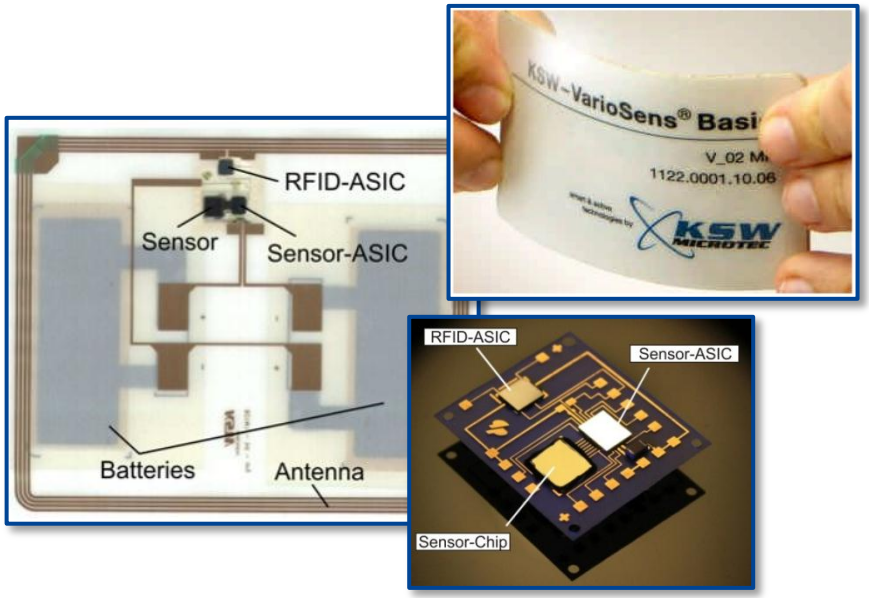
First Sensor

Vibration Sensors:

for Condition Monitoring
(frequency range 2,5 KHz,
measurement range ±50 g)







Smart RFID Sensors:

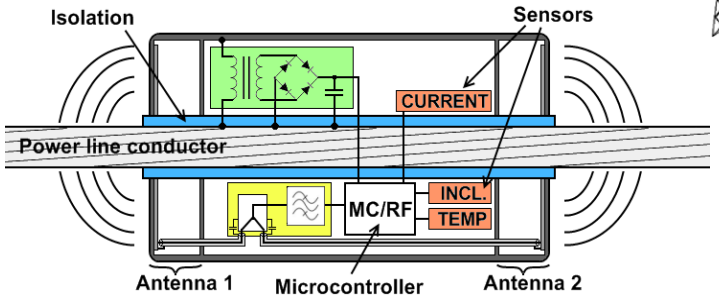
(data-logger for
temperature, inclination
and shock in chip card-
format)

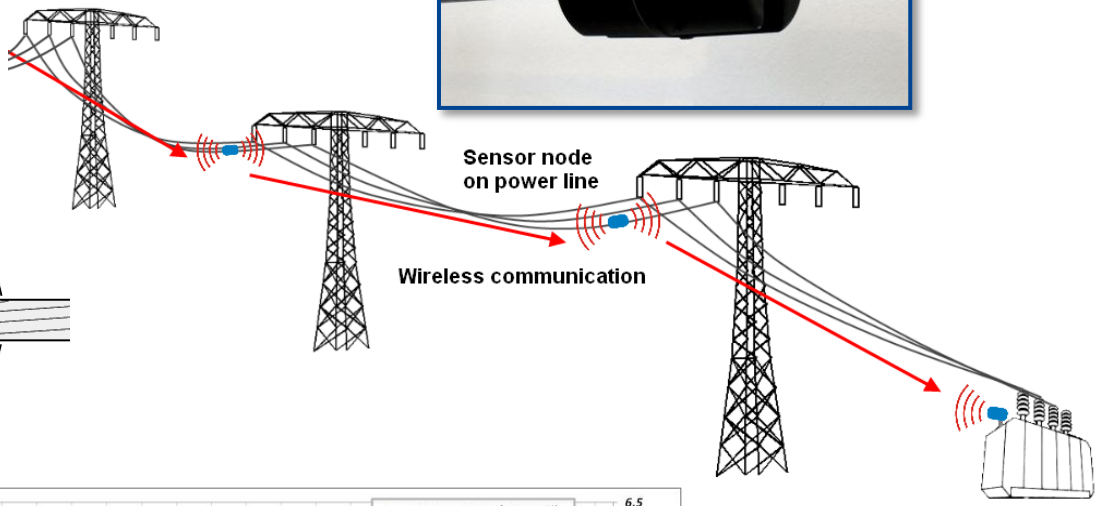
Applications

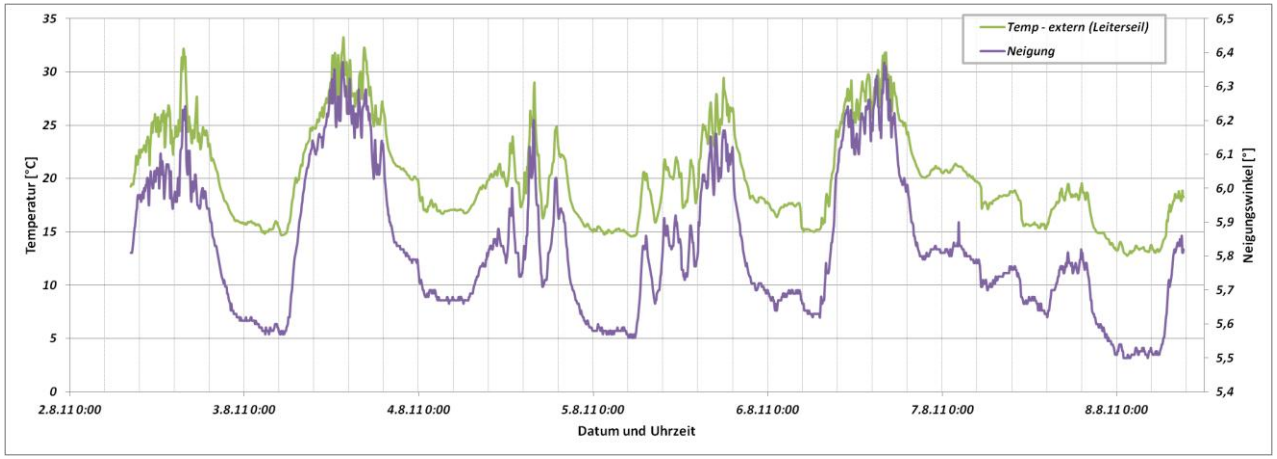
Inclination Sensors:

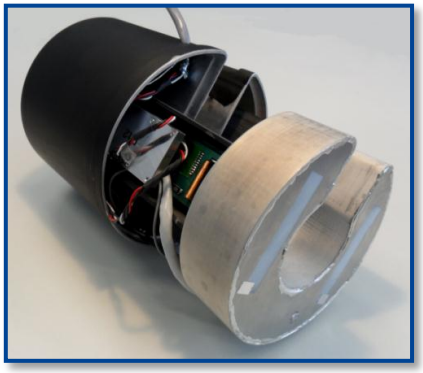
+/- 10 ° Inclination of power line

+/- 50 ° twist of power line









Example – monitoring of power lines

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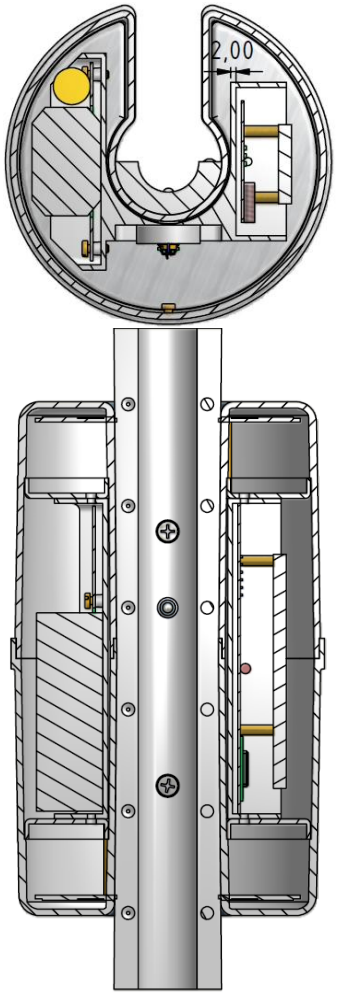
Goal of the project:

- Autonomous sensor network for monitoring of power lines
- Power load optimization of high-voltage power lines

VDI|VDE|IT

Bundesministerium für Bildung und Forschung



Specifications:

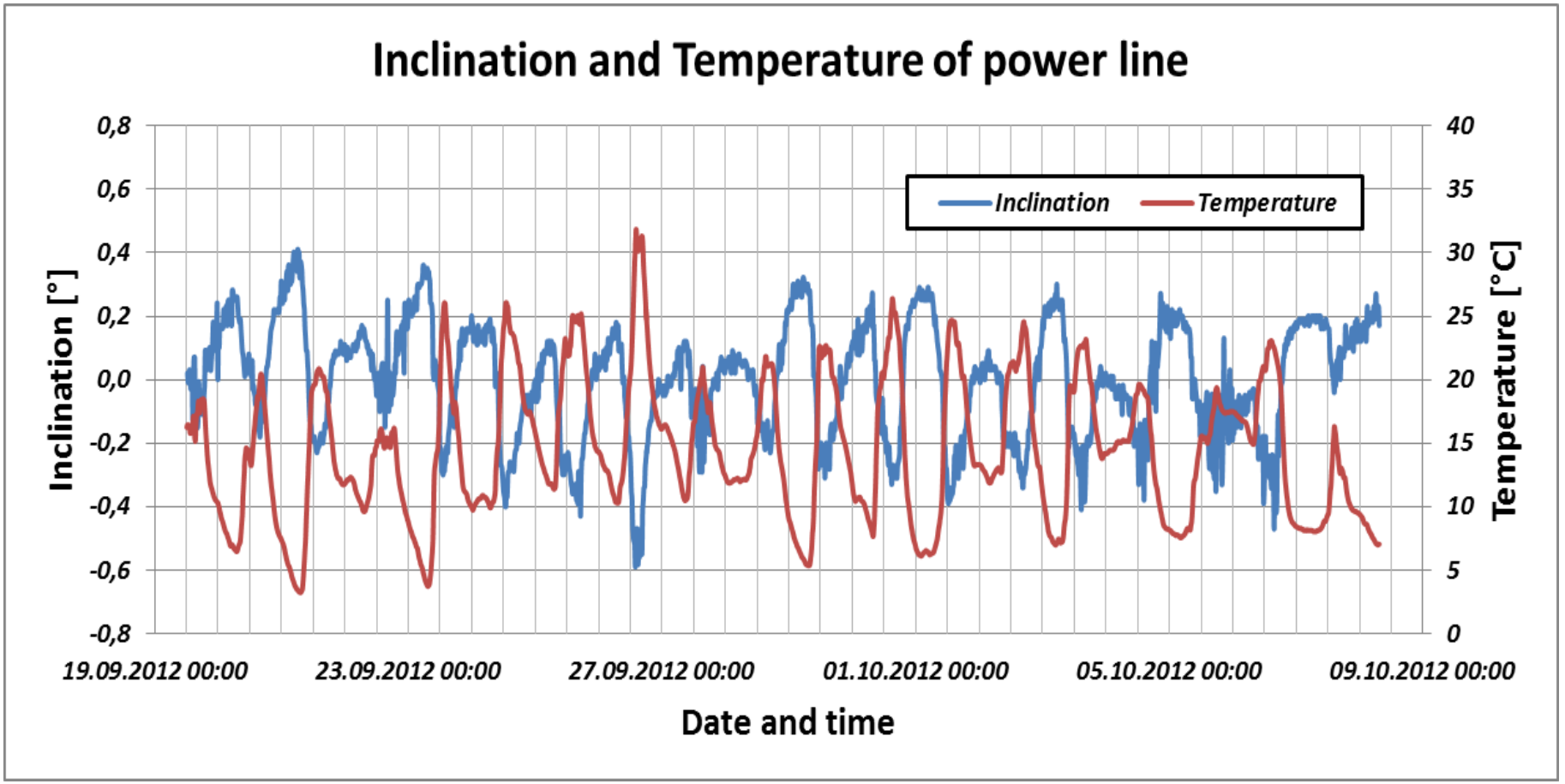
- Suitable for 110kV, 220kV and 380 kV
- Data acquisition every 15 minutes
- Measurement values per power line section: temperature, angle, torsion, vibration detection, current flow, short-circuit and high-voltage detection
- Geographic localization of each eGrain using unique ID's
- Autonomous power supply
- Automatically detects operating conditions such as isolation mode
- Redundant communication system

Project "Astrose": Funded by the German federal ministry of education and research

Example – monitoring of power lines

Figures: *photographs of the Astrose-eGrains*

Example – monitoring of power lines



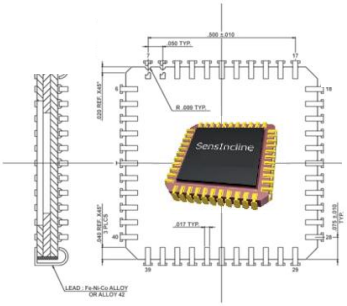
- Inclination data of the sensor node is shifted by a specific offset
- Correlation between inclination and temperature of power lines

SensIncline

First Sensor

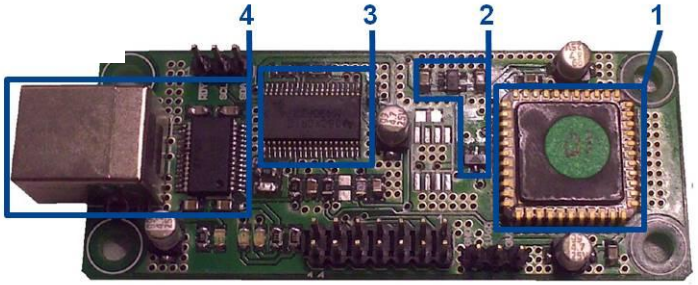
Applications

- Geoengineering
- Navigation
- Security systems
- Platform control and stabilization
- Instrumentation, Robotics
- Tilt sensing, Leveling

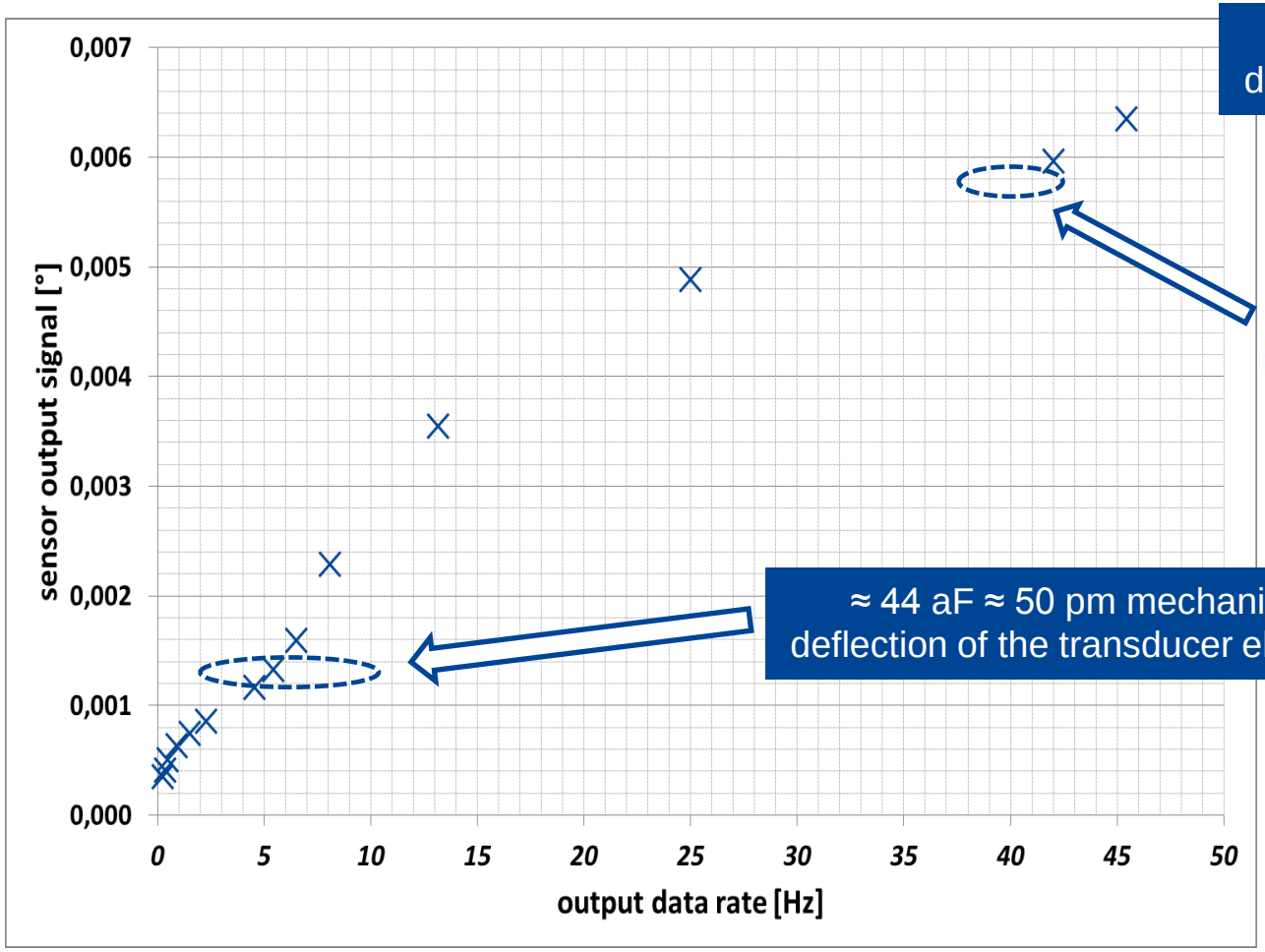


Features

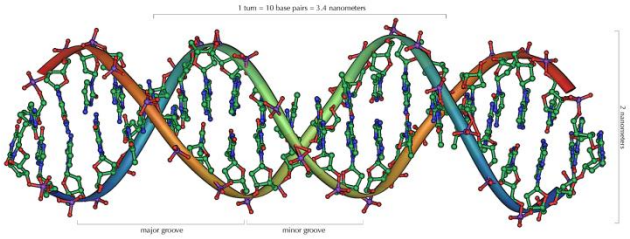
- Dual axis acceleration measurement (x and y)
- Measuring Range ±30°(linear)
- Excellent stability over temperature
- Digital I²C -Interface
- Single supply +3.3V
- Shock survival 2000g
- Over damped frequency response
- Hermetically sealed package



SensIncline – Resolution

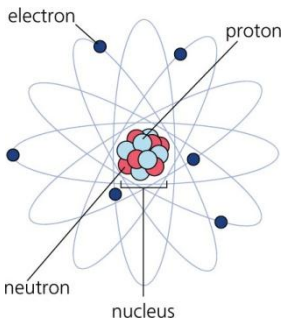


≈ 165 aF ≈ 200 pm mechanical deflection of the transducer element



DNA double helix with 2000 pm in diameter

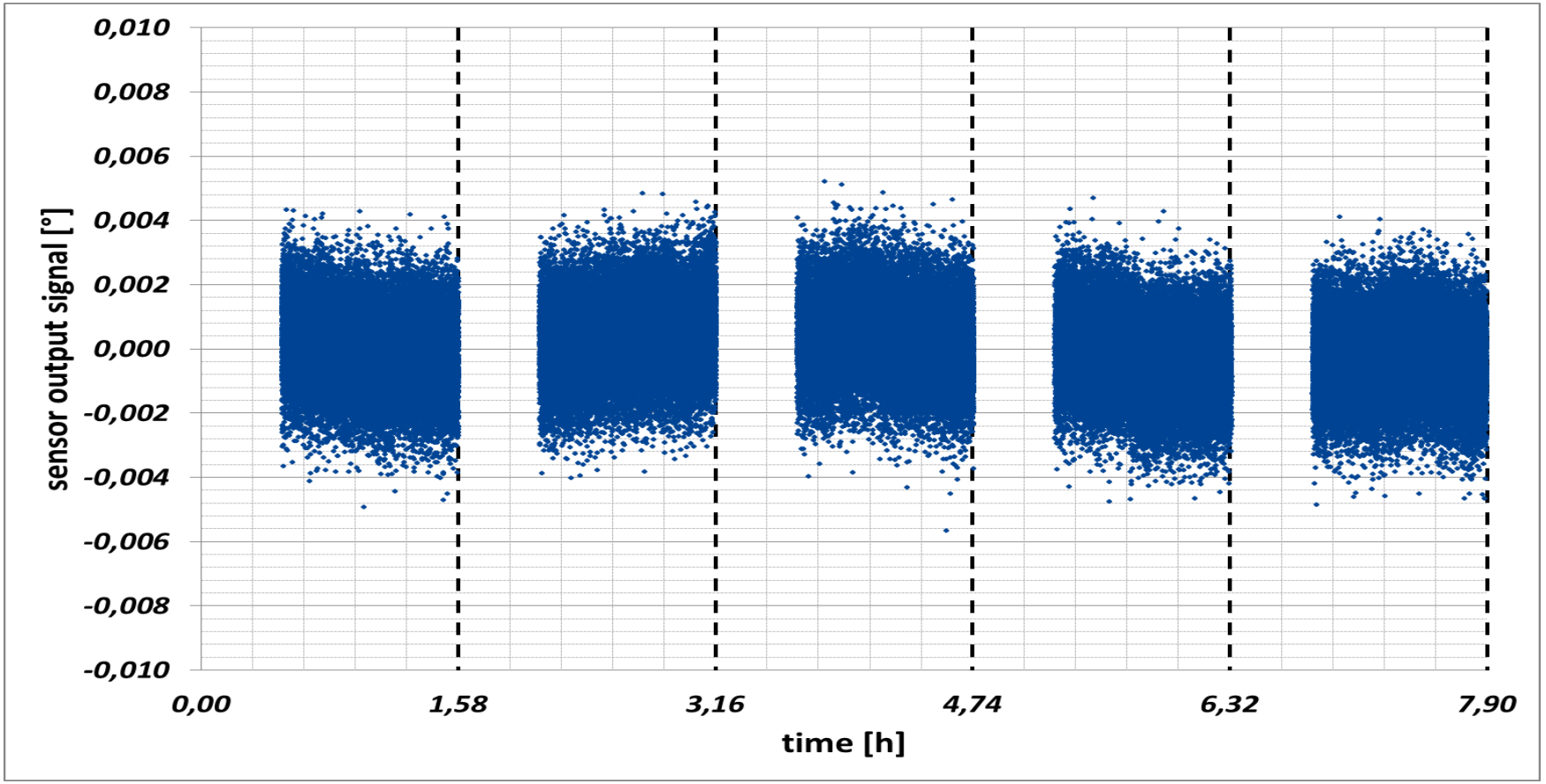
≈ 44 aF ≈ 50 pm mechanical deflection of the transducer element



diameter of a C-atom with 154 pm

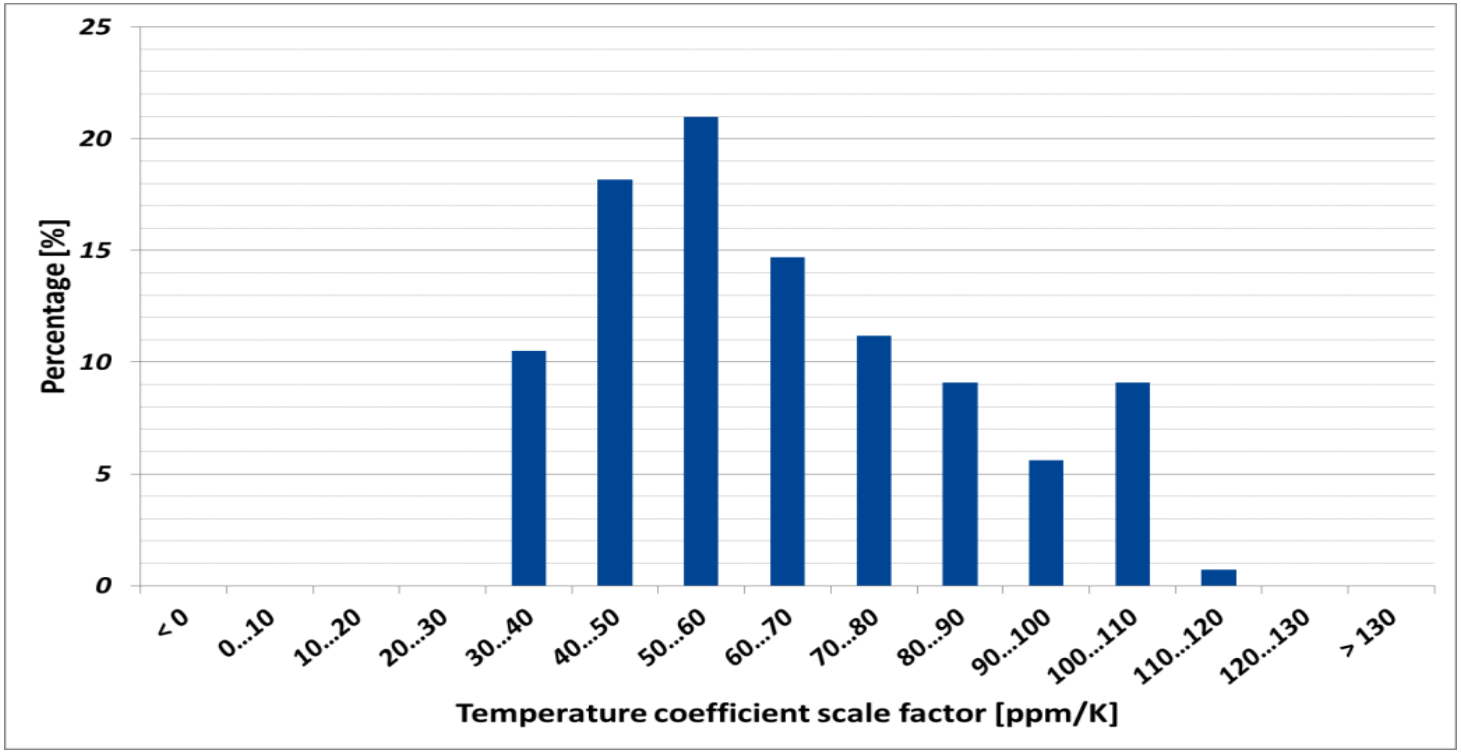
- Resolution 0.00055° (2“ bzw. 10 µm/m) @ bandwidth 1 Hz

SensIncline – Bias stability



- 5x 32000 samples (including 30 min break) → **no drift** during measuring time of 8 h
- Range sensor output signal ± 0.0040° = Noise 0.0011°… 0.0014°

SensIncline – Temperature behavior



- Temperature coefficients of scale factor is based on measurements **without temperature compensation**
- Scale factor: maximum 45…115 ppm/K → caused by Young's modulus of silicon → blanket correction of the output signal in dependence of temperature leads to a scale factor temperature coefficient of ± 50 ppm/K

Outlook

- Industrial Applications: 5.0-10”
- Geodesy: 0.5-1.0”

$$TNEA = \sqrt{BNEA^2 + CNEA^2}$$

→ Decreasing of total noise

→ Large capacitive change per mass displacement

→ Low Brownian noise

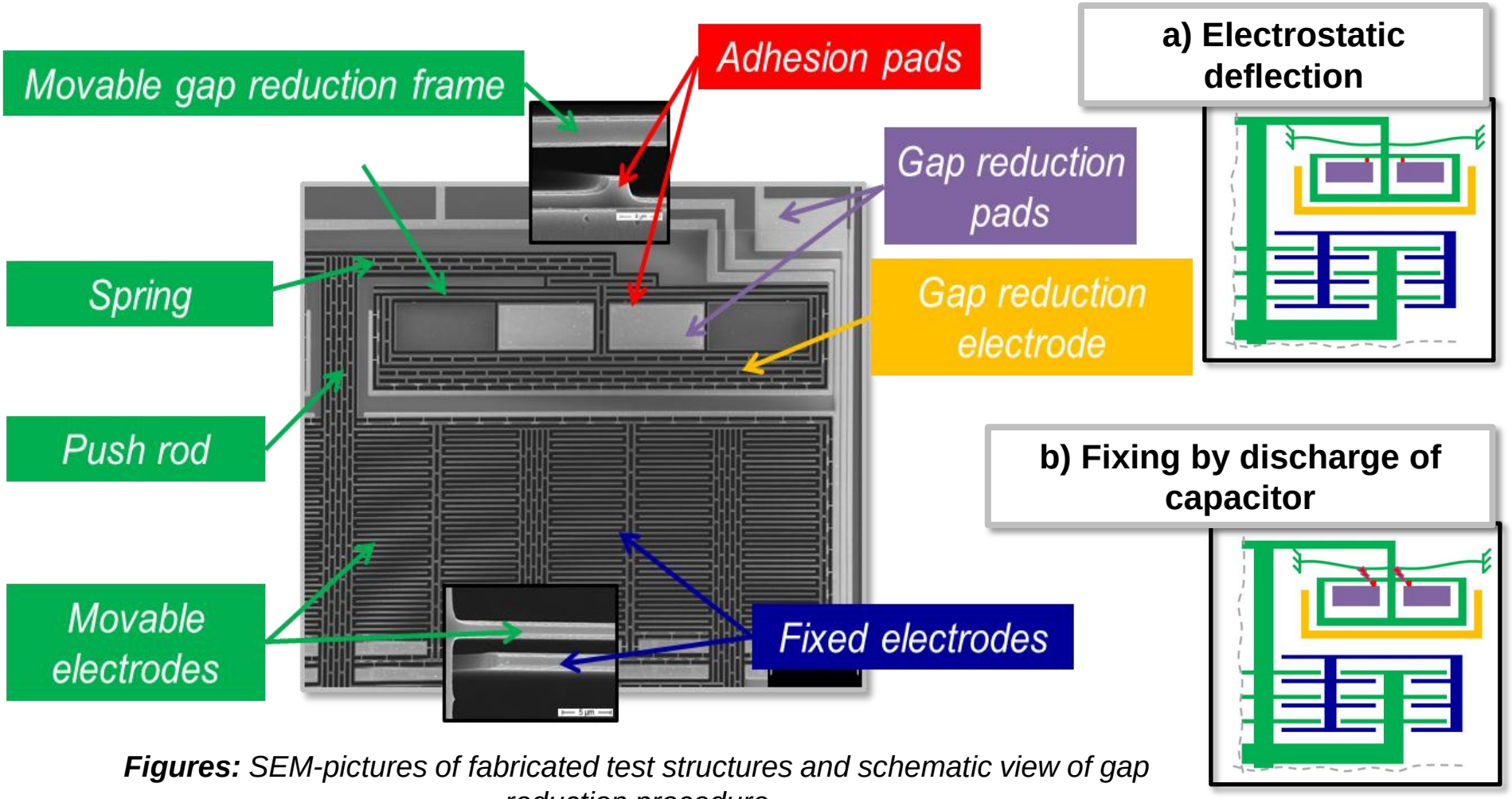
$$BNEA = \sqrt{\frac{4k_B T \omega_0}{mQ}}$$

- Vertical comb electrodes with high aspect ratios are commonly used
- Fabrication restrictions limit the minimum size of trenches between the electrodes

$$\frac{\partial C}{\partial x} = \left(\frac{\varepsilon_0 \cdot \varepsilon_r \cdot A}{(d-x)^2} - \frac{\varepsilon_0 \cdot \varepsilon_r \cdot A}{(d+x)^2} \right)$$

➔ Post process gap reduction procedure

Outlook – post process gap reduction



Figures: *SEM-pictures of fabricated test structures and schematic view of gap reduction procedure*

Outlook – post process gap reduction

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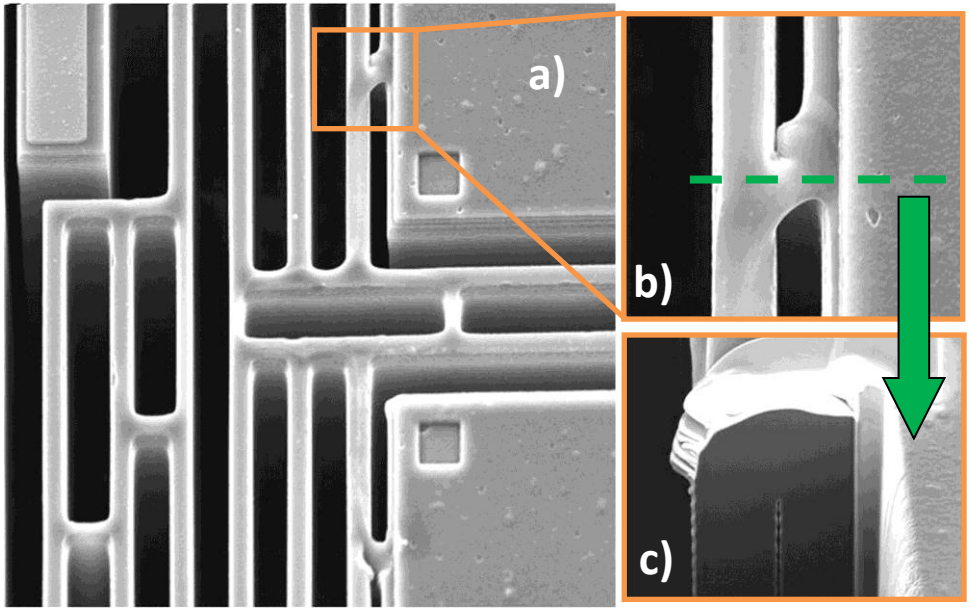
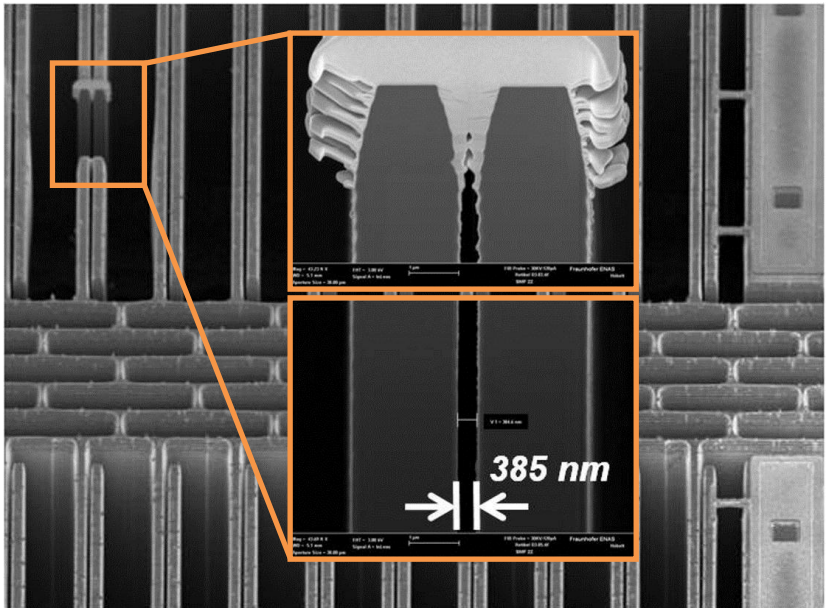
FIB preparation after gap reduction procedure has been performed



Figures: *SEM photograph of a gap reduction area after the gap reduction sequence has been done a) including a top view of a micro welding pad b) and a cross section of a micro welding pad after FIB preparation c)*



Figures: *SEM photographs after FIB preparation (overview of comb electrodes and detailed view of an electrode pair)*

Summary

- There is a market for high precision MEMS solutions
- First Sensor offers a technology platform to fabricate inclinometer for geoengineering or navigation systems
- Example: Sensing inclination is a new approach for monitoring and power load optimization of power lines
- The performance of the sensor type “SensIncline” was presented
- Research and Development for future optimization of the noise level performance was shown

First Sensor

Thank you, for your attention…

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First Sensor

Die First Sensor AG ist ein wachstumsstarkes deutsches Technologieunternehmen, das sich auf die maßgeschneiderte Entwicklung und Herstellung individueller Sensorlösungen spezialisiert hat. First Sensor erfüllt die Anforderungen weltweiter Kunden an höchste Präzision, Individualität und Beständigkeit.

Applikationsübergreifendes Know-how aus den Technologiefeldern Optoelektronik und MEMS-Sensorik, Mikrosystemtechnik sowie Hybridelektronik ist integraler Bestandteil von First Sensor Bauteil-, Modul- und Systemlösungen. Produkte für die Märkte Life Science, Industrial, Security, Mobility und Aerospace entwickelt und fertigt First Sensor am Stammsitz Berlin sowie in den nationalen und internationalen Tochtergesellschaften. Die eigene Produktion in Reinräumen bis zur Klasse 100 garantiert höchste Qualitätsstandards für individuelle Losgrößen von einem bis zu mehreren Millionen Stück pro Jahr.

Durch das Engagement der weltweit mehr als 700 Mitarbeiter, erwartet First Sensor im laufenden Geschäftsjahr 2011 einen Umsatz von über EUR 65 Millionen. First Sensor wurde 1991 in Berlin gegründet und ist seit 1999 an der Frankfurter Wertpapierbörse gelistet [Prime Standard I WKN: 720190 I ISIN DE0007201907 I SIS].

Informationen und aktuelle Kennzahlen unter www.first-sensor.com.

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