MEMS evolution towards smaller and more standardized devices

International Symposium on Smart Integrated Systems

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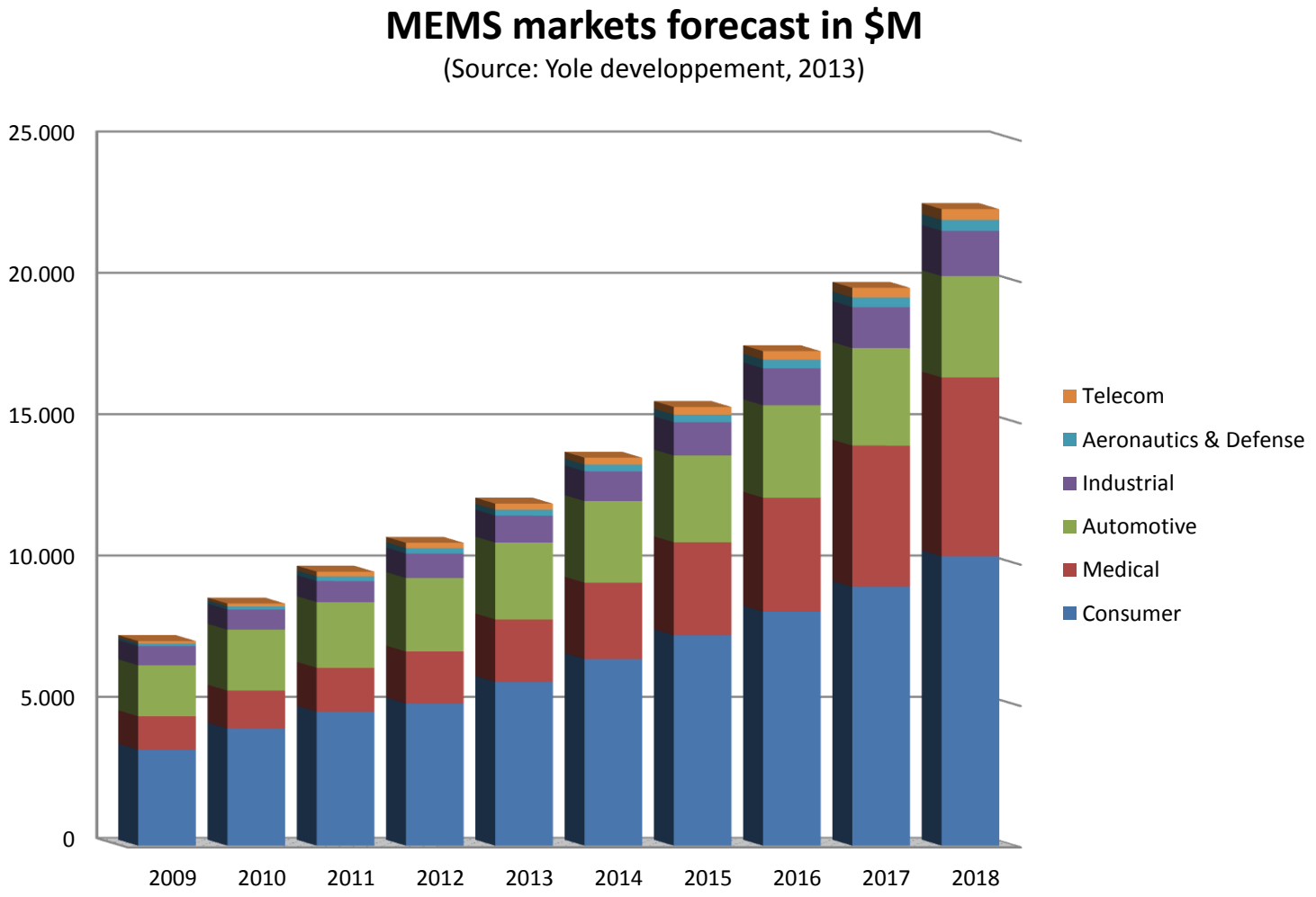
MEMS: a billions dollars industry



Why going from MEMS to NEMS ?

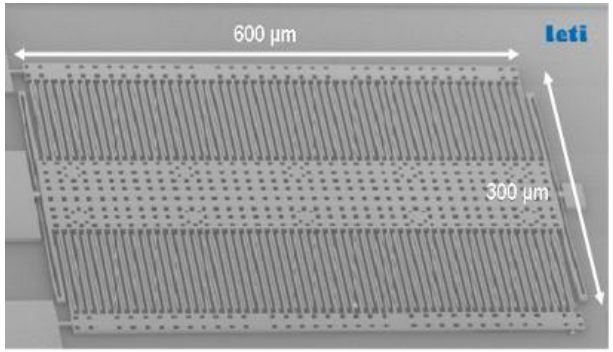
Large volume markets (Automotive/Consumer) → Strong pressure on prices → Smaller devices

Consumer markets → More integration → The multi axis sensor

Mobile phones, gaming, tablets, e-books, digital cameras, camcorders, HDD protection, laptop, Personal media Players,set-up boxes, GPS, sport equipments…

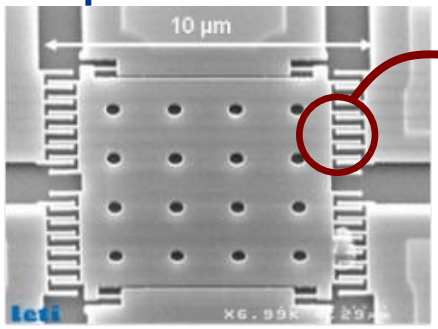
- 3 axis accelerometer
- 3axis gyrometer
- 3axis magnetometer
- 1 P sensor

500 µm

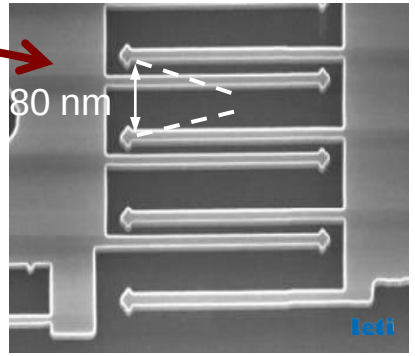


MEMS accelerometer

10 µm



Source LETI – MIMOSA project

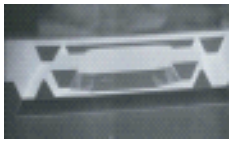


- Typical sizes : ~10 nm – 100 nm (X, Y, Z)
- Used material : silicon structured by microelectronic tools

Miniaturization issues

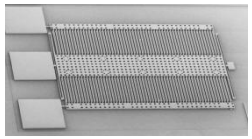
Electromagnetic detection

New design →



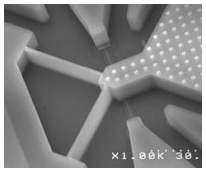
Piezo or electrostatic out of plane detection

New design →

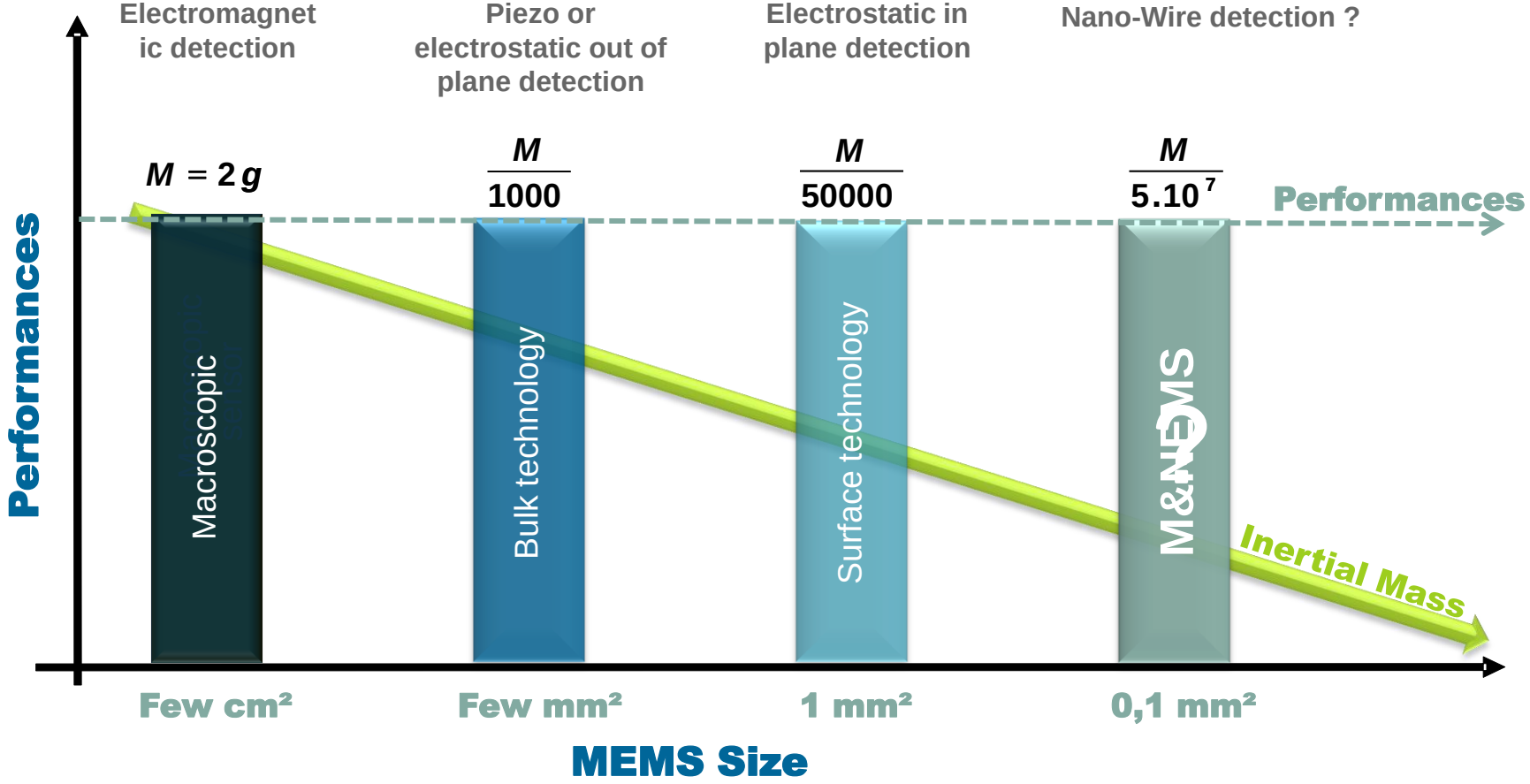


Electrostatic in plane detection

New design →



Nano-Wire detection ?



M&NEMS principle

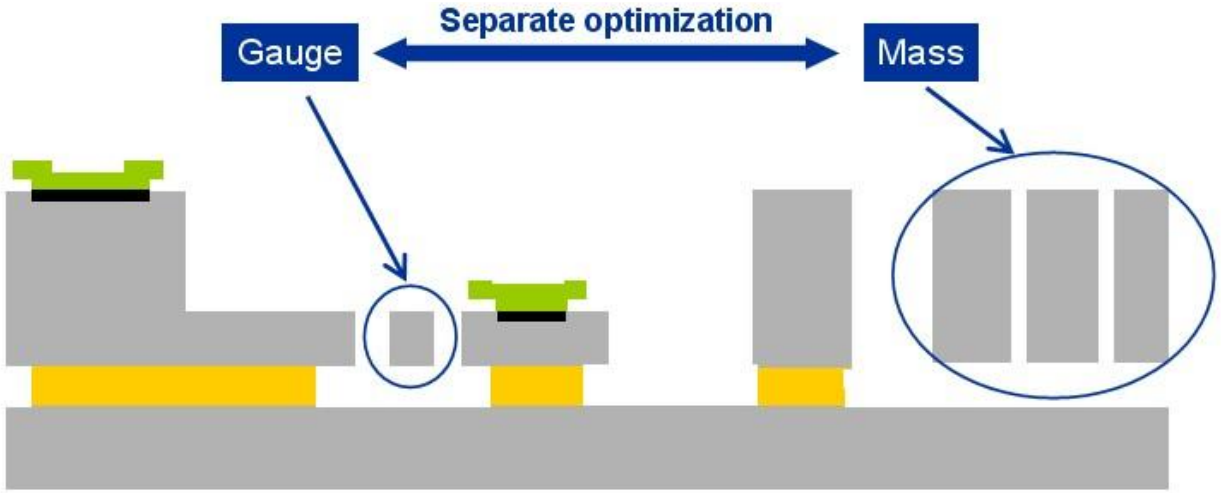
Mix on a same device two different thicknesses

- A thick layer for the proof mass (MEMS)
- A thin layer for the gauge (“NEMS part”, compatible with DUV litho).

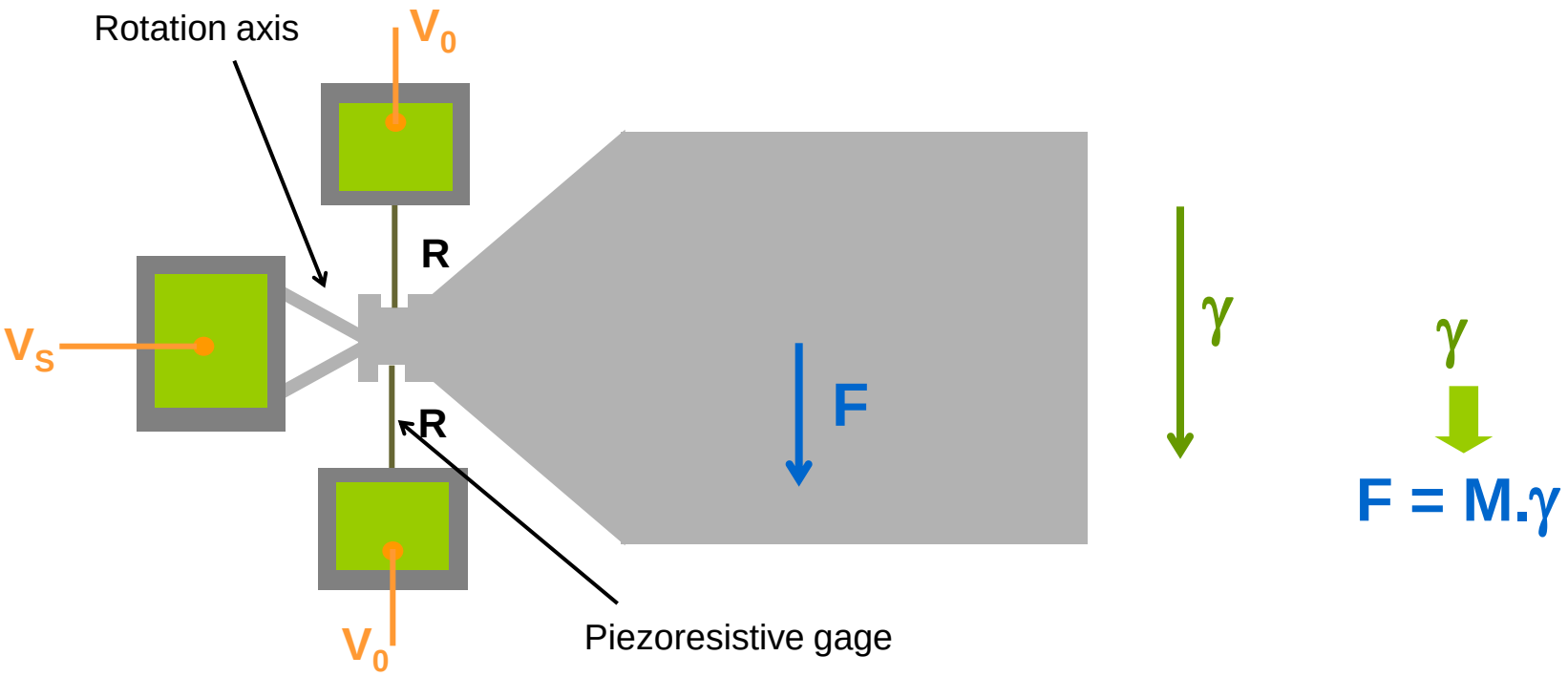
Highly efficient transduction: stress concentration (design lever + size effect)

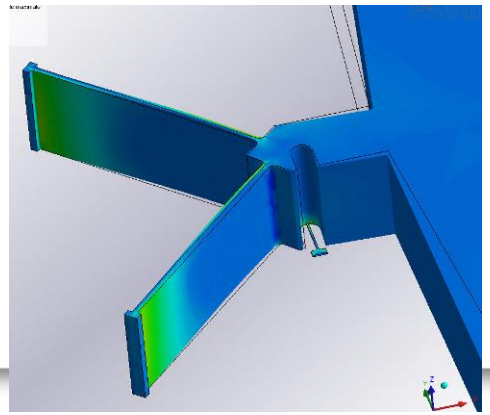
Optimization of the ratio performance/die area.

Area gain x3-5 for same perfs

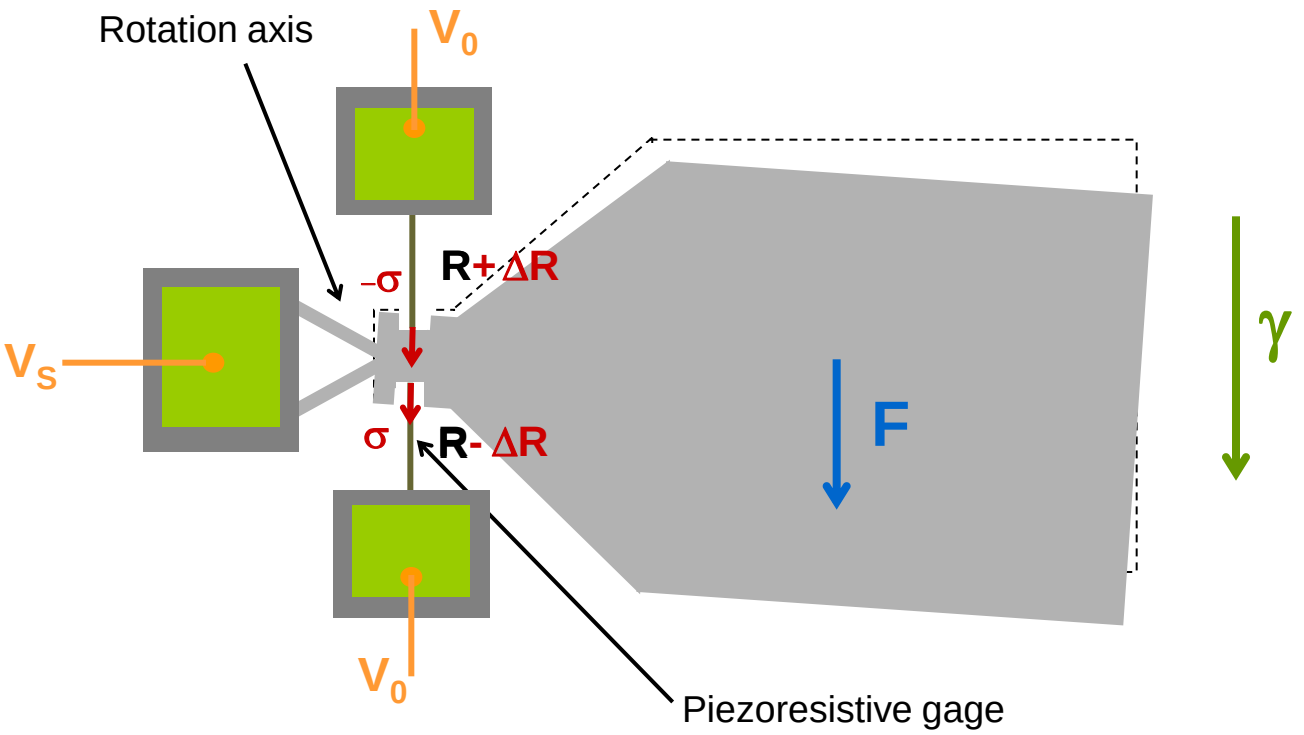


Principle

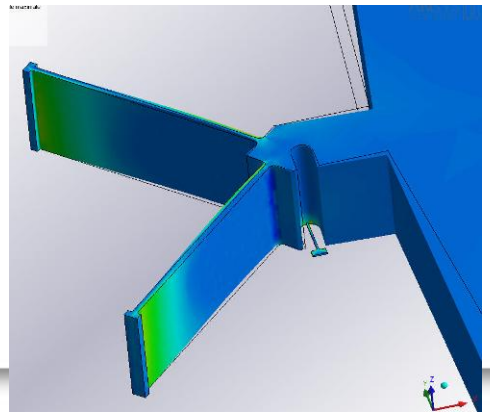




Principle



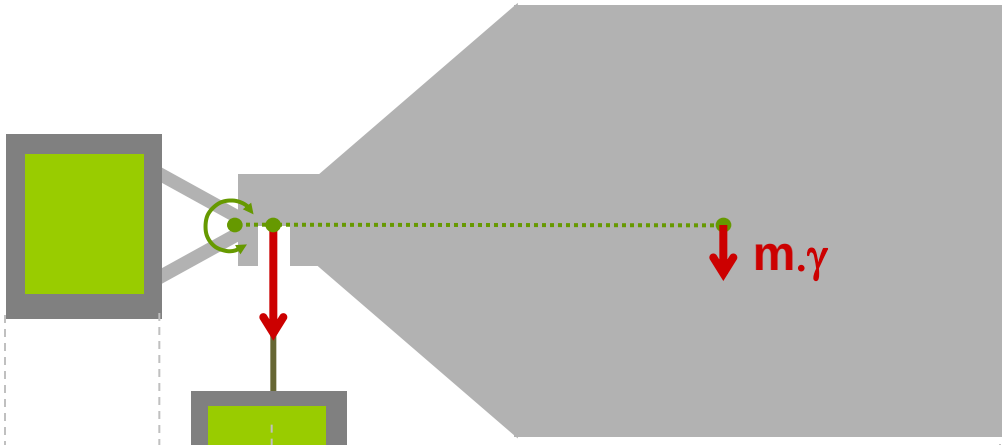
$$\gamma \rightarrow F = M.\gamma \rightarrow \sigma \rightarrow \frac{\Delta R}{R} = \pi\sigma$$



S = 50 mV/V full scale
(σ_{max}= 100MPa)

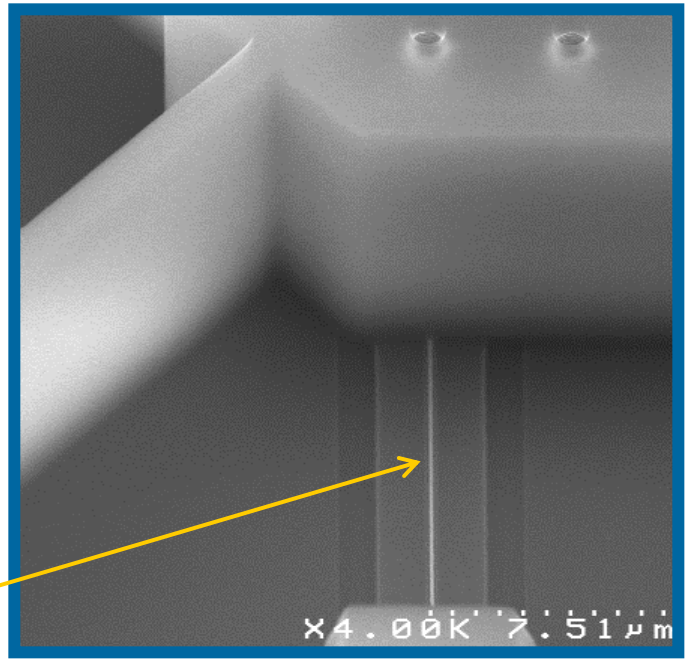
In-plane measurement

Top view



Cross section view

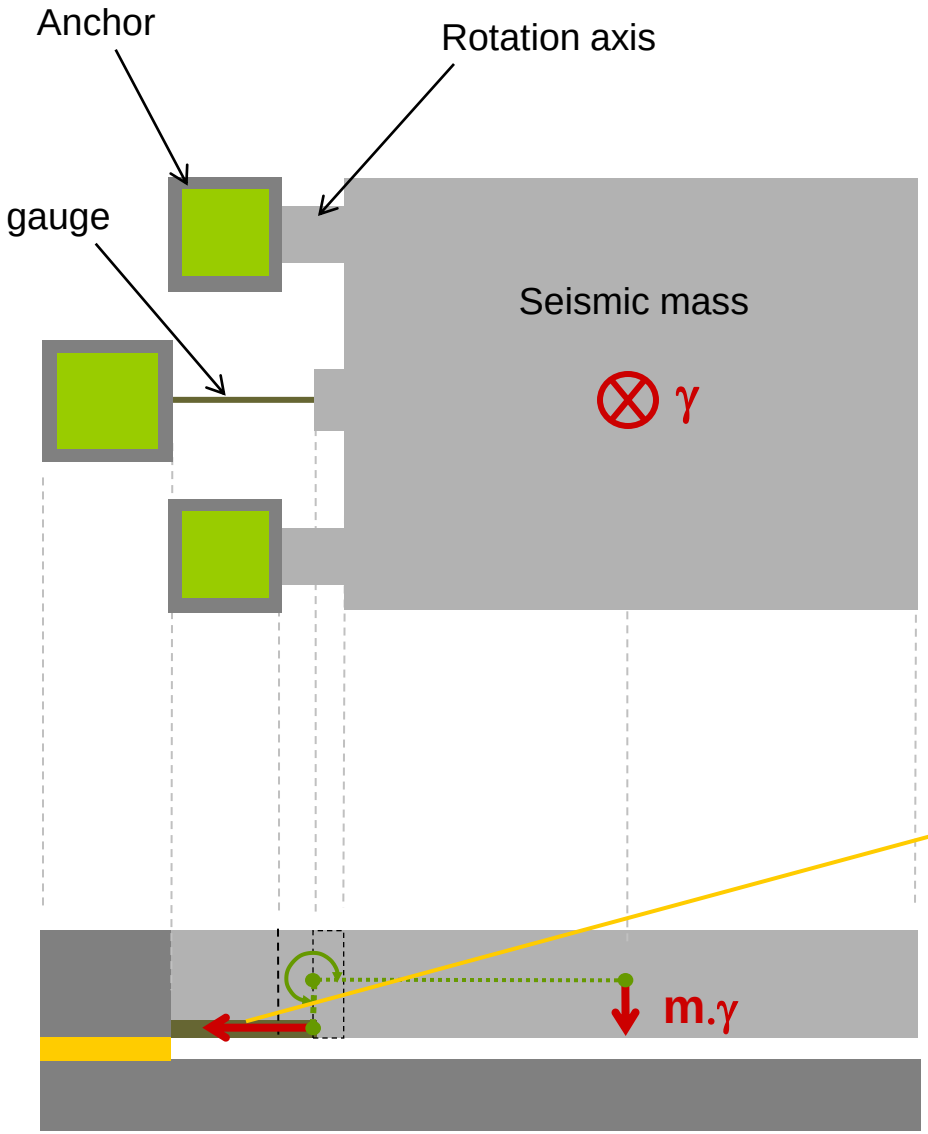
- Stress magnification induced by design lever effect



- Stress magnification induced by the Nano-gauge

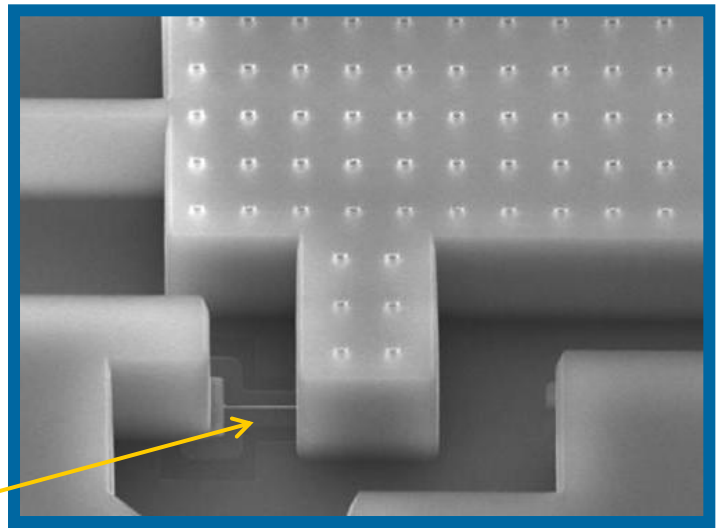
Total Magnification : x3000

Out of plane measurement



2 different thicknesses

Out-of-plane detection

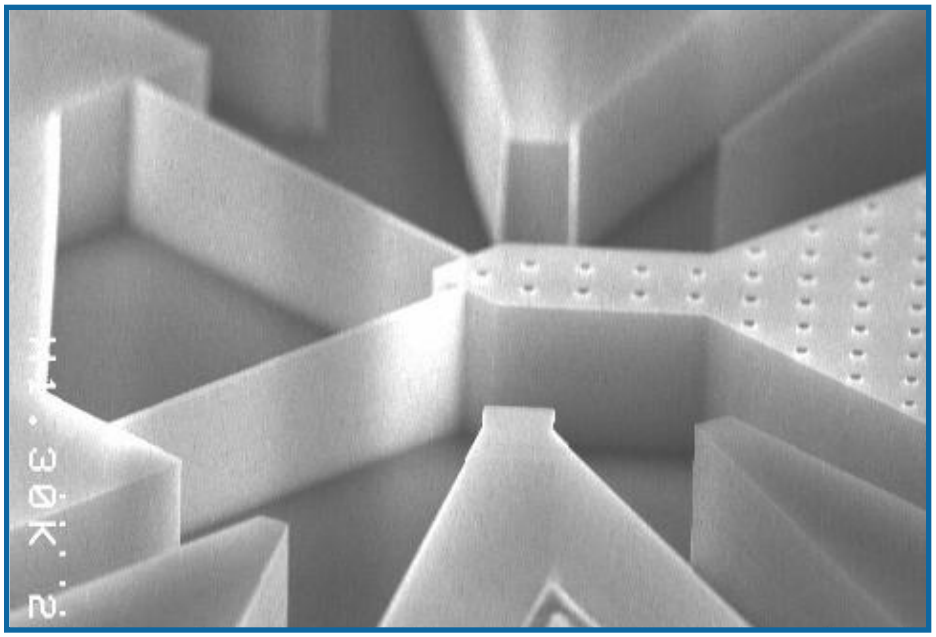


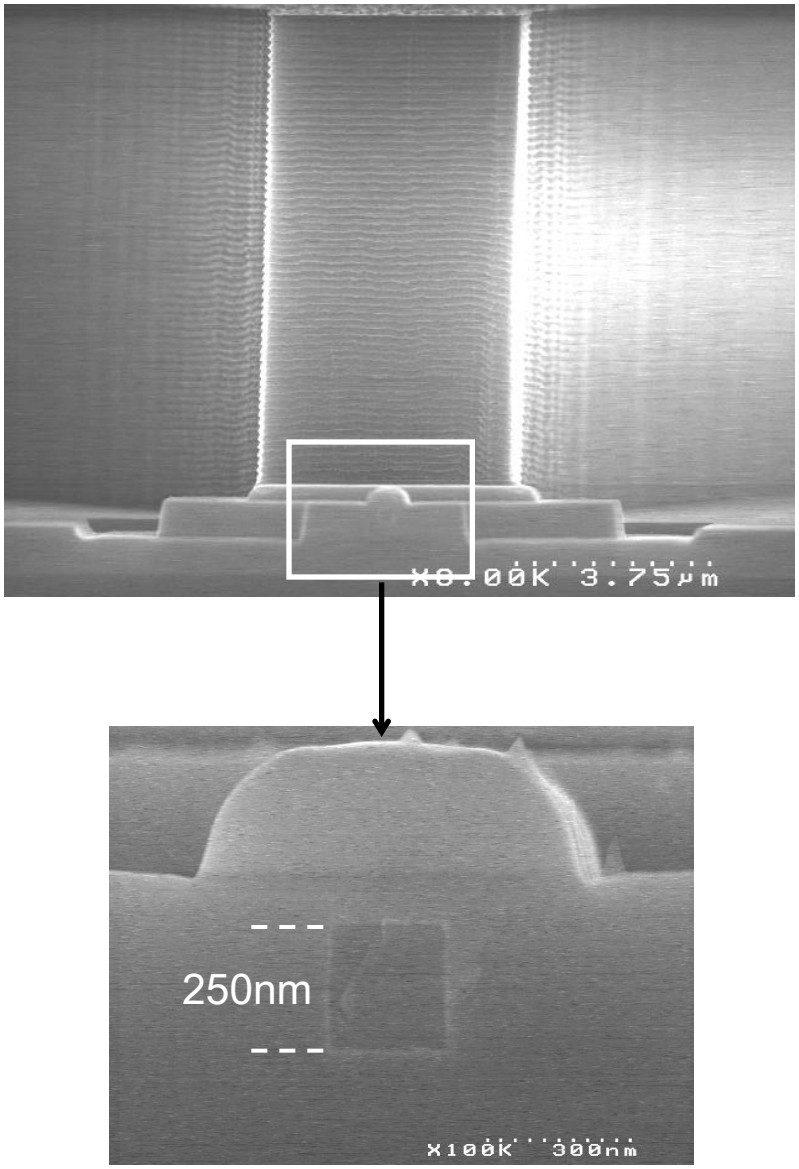
- Stress magnification induced by design lever effect & nano-gauge

Total Magnification : x1000

M&NEMS accelerometer demonstrator

- Proof of concept design and fabrication of accelerometer have been achieved
- Typical dimensions of the sensitive element ≈ 0.1mm² / axis





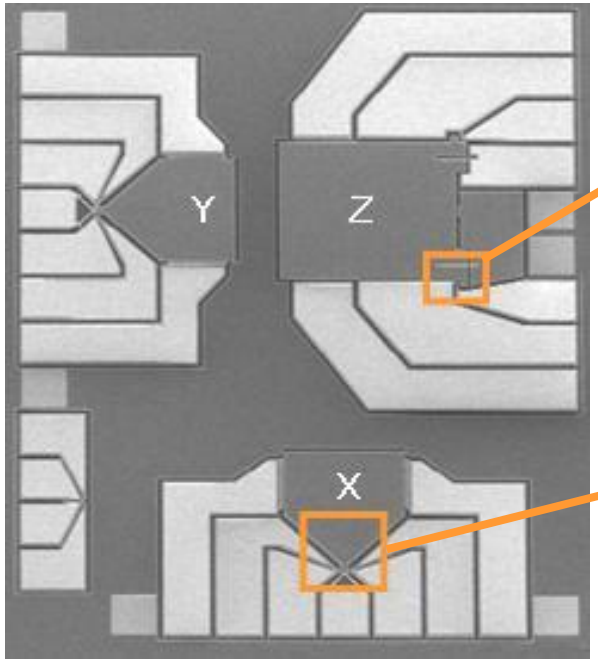
M&NEMS: **3-axis accelerometer**

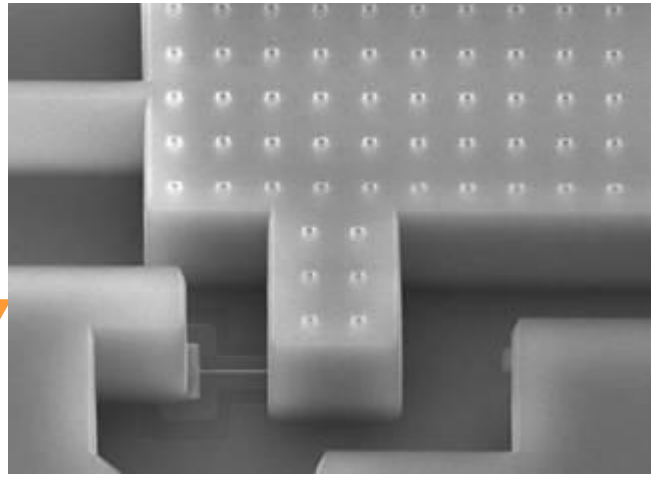
3-axis Accelerometer
3-axis Gyroscope
3-axis Magnetometer
Pressure sensor

Main characteristics

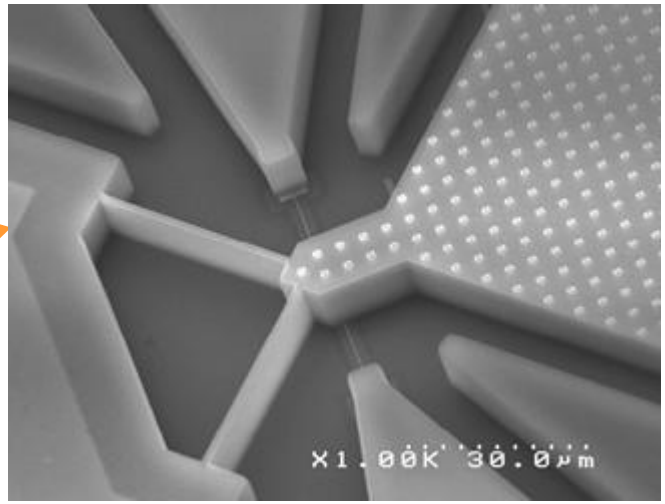
(first demonstrator designed with consumer specs)

- Typical size of 3-axis chip: 1mm²
- Range: 10 or 50G
- Dynamic range: 5000
- Linearity deviation < 0.3%





Focus on the nano-gauge of the Z-axis accelerometer



Focus on the nano-gauge of the X-axis accelerometer

M&NEMS: **3-axis gyroscope**

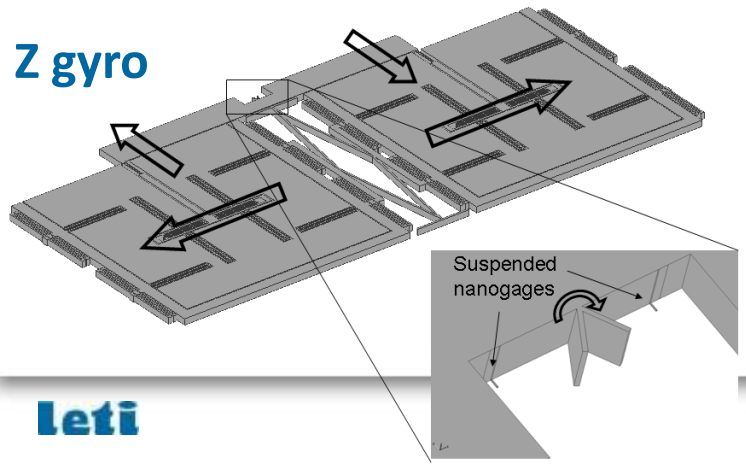
Main characteristics

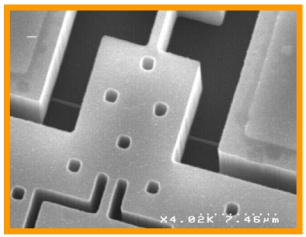
(first demonstrator designed with consumer specs)

- Typical size of 3-axis chip < 3mm² (2mm² for the electromechanical part)
- Resolution: 0.02° /s/√Hz (limited by readout electronics noise)

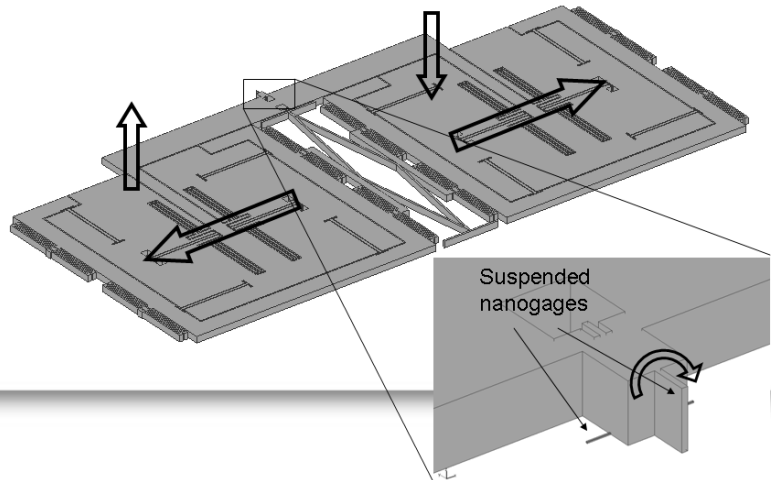
- Piezoresistive (differential) detection based on nano-gauges
- The high-sensitivity open-loop detection scheme enables working with **high mismatch (1kHz) between drive and sense** resonance frequencies (20kHz)
- **Possible to operate under rough vacuum** (no need of getter)

Z gyro





X/Y gyro

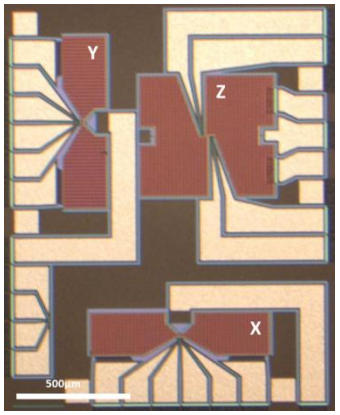


M&NEMS: **3-axis magnetometer**

Main characteristics

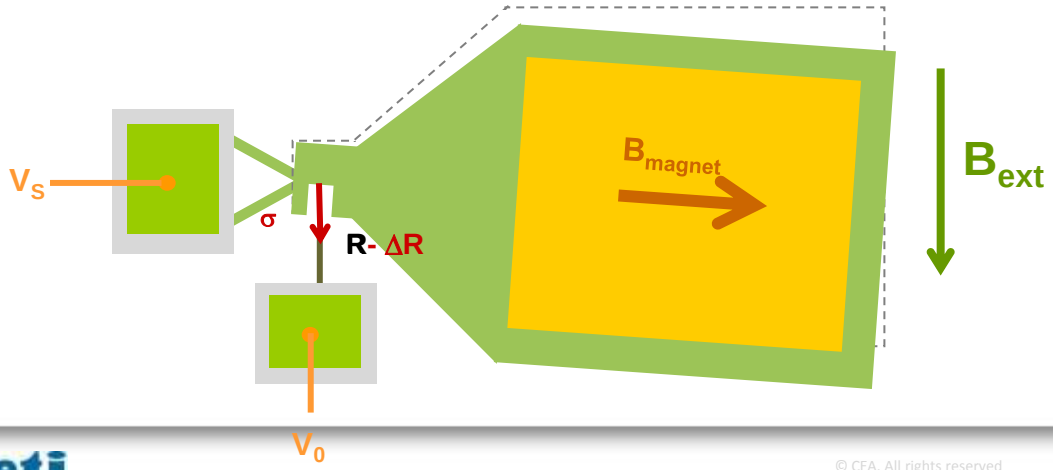
(first demonstrator designed with consumer specs)

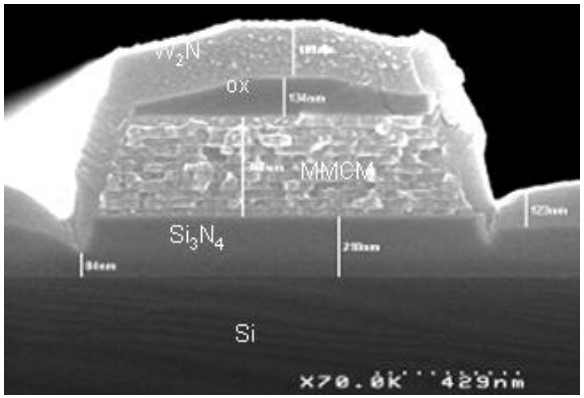
- Typical size of 3-axis chip: 1mm²
- Low power consumption (integrated permanent magnet)
- Resolution: 100 nT/√Hz
- Linearity range 4.5mT



- **Permanent magnet layer** deposited on top of the moving part. The magnet tends to align along the external magnetic field

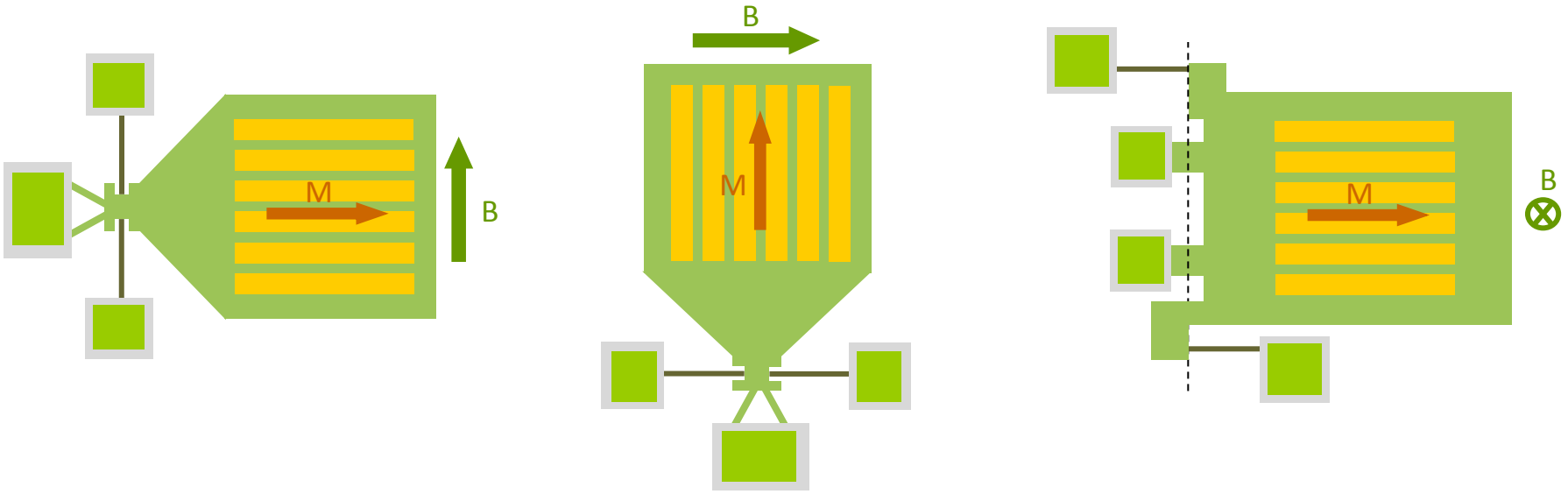
→ induced torque detected by piezoresistive nano-gauges





M&NEMS: **3-axis magnetometer**

3-axis magnetometer on the same chip with the same process
thanks to multi-directional permanent magnet technology



- Magnetic stack = Coupled ferromagnetic / anti-ferro (F/AF) multilayer
- Deposition **in one single step** of a magnetic stack having **2 magnetic orientations** (patented concept) obtained by using **magnetic shape-anisotropy** for self-alignment during annealing step

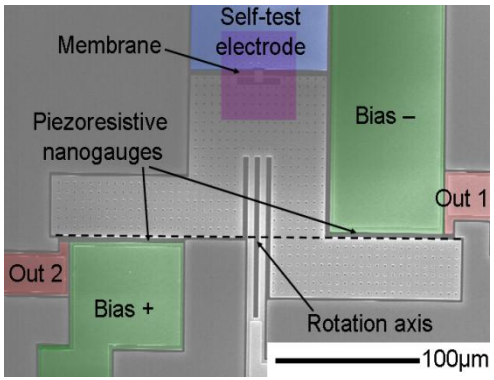
M&NEMS: **pressure sensor**

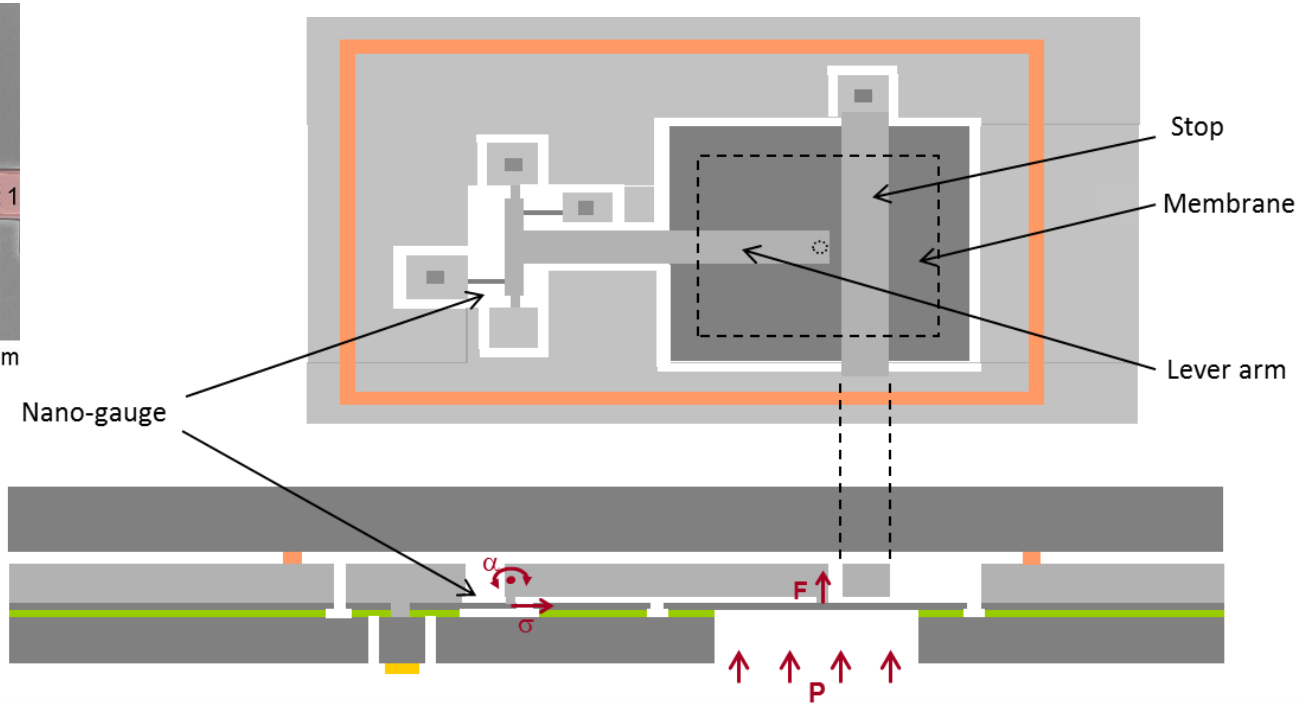
3-axis Accelerometer
3-axis Gyroscope
3-axis Magnetometer

Main characteristics

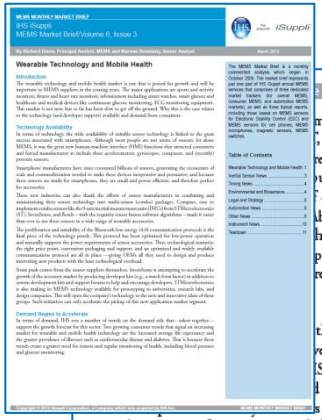
(first demonstrator designed with consumer specs)

- Die size: 0.25mm² (mech. footprint 0.02mm²), range: 1 Bar, resolution: 1Pa
- **High efficiency** due to the lever effect (performances / miniaturization)
- **Reliability:** Over-pressure protection, protected gauges from ext. environment
- **Possible co-integration with inertial sensors**





M&NEMS in MEMS business journals



more specifically focused on mobile
, a 'Tricorder' style multifunctional
es heart rate, blood oxygenation,
ulse transit time), and is targeted the
devices are Alivecor and Cardionet
bbott CGM and C8 MediSensor
hese latter two categories are aimed
problems such as hypertension , and
rease patient comfort.

the wearable technology and mobile
ver, this does not mean that there
S predicts strong—but not hockey
l wellness and fitness devices. The
s (and similar products) will depend on the success of companies to help the transit towards true lifestyle products. That is, to make products fashionable (like jewelry), smaller, or even inconspicuous and hidden within existing products, such as the aforementioned Valencell's PerformTek earphones.

In terms of the growth of the Healthcare and Medical category, the obstacles amount to ease of use, reliability, and competitive pricing in order to maximize penetration. These factors will be important overcoming patient compliance hurdles in home monitoring situations (Telehealth), which has held back the growth of this market until now.

Conclusions

Wearable technology is an exciting new area for technological innovation and consumer service. These are applications that are only possible (due to the wide availability of sensors), but will eventually amount to revenue opportunities for sensor manufacturers.

Inertial Sensor News

Tronics Commercializes LETI's Miniaturized MEMS Process

Tronics has launched a project to industrialize M&NEMS (Micro and Nano Electro-Mechanical Systems) technology from Grenoble based CEA-LETI. Based on piezoresistive nanowires rather than capacitive detection, Tronics claims M&NEMS offers a new level of device performance and chip size, which would especially suit combo sensors currently being used in motion sensing applications. In two years time, the goal is for the partnership to develop 6-, 9-, and higher-DOF inertial devices using M&NEMS technology. In addition to investments from Tronics and its partners, a big part of the project's cost is stems from a €6.5 million ($8.3 million) grant from the French Ministry of Industry. As part of the project, ASIC suppliers are contributing expertise to a design for a motion sensor chipset that fully leverages M&NEMS, while the French motion company Movea is lending data fusion expertise. LETI and Tronics already have a long history of collaboration.

IHS Comment:

IHS believes this M&NEMS technology has game changing potential for combo sensors (source Motion Sensors in Handsets and Tablets special report). Today, 6-axis compass modules and 9-axis IMUs are judged to be still too large for mainstream products. Handset OEMs still prefer to purchase small discrete magnetometers, which are easier to place on the PCB and mitigate potential EMI issues. In theory, the M&NEMS process enables much smaller 9-axis IMUs, and this eventuality would significantly boost the adoption of 9-axis IMUs.

That said, the motion sensor market for consumer applications is well underway, making it very difficult for newcomers to gain significant traction. Such a radically new approach could however change the playing field, and allow newcomers to join the fray! Note that the partnership with Tronics is not exclusive, leaving LETI to potentially cooperate with other semiconductor or sensor companies.

STMicroelectronics Releases 3-Axis Accelerometer with MCU

STMicroelectronics has announced its LIS331EB iNEMO-A, a miniature smart sensor that combines a 3-axis accelerometer with an embedded microcontroller in a 3 x 3 x 1 mm LGA package. The package includes an ARM Cortex-M0 processor to act as a sensor hub which supports inputs from 3-axis gyroscopes and magnetometers, as well as a pressure sensor to provide a '10-axis' sensor fusion solution. It is targeting wearable sensor applications, motion-activated user interfaces in handheld devices, and augmented reality.

Kionix KXCNL Accelerometer

Kionix has introduced its first accelerometer with integrated dual user-programmable state machines. The KXCNL can simultaneously run two applications at the chip level and this leads to power savings as it removes processing load from the applications processor. This also enables users to implement a range of recognition algorithms including free-fall, tap/double-tap, and step recognition—some of which are supplied by Kionix.

InvenSense and ST IMUs Used in Basketballs

InvenSense's 3-axis gyroscope (TG-3200) has been used by InfoMotion Sports Technologies in its 94Fifty sensor basketball skill analysis product. STMicroelectronics' 9-axis IMU (MPU-9150) is also scheduled to be used in a consumer targeted 94Fifty in Q3 2013. These products are designed to accurately measure performance characteristics and transmit this information to a computer or smartphone in real time.

SOURCE: 94fifty

94Fifty Basketball with InvenSense's Motion Sensors

"M&NEMS technology has game changing potential for combo sensors"

"Sensor market for consumer applications is well underway, making it very difficult for newcomers to gain significant traction. **Such a radically new approach could however change the playing field, and allow newcomers to join the fray! "**

MEMS Market Brief - IHS iSuppli - March 2013

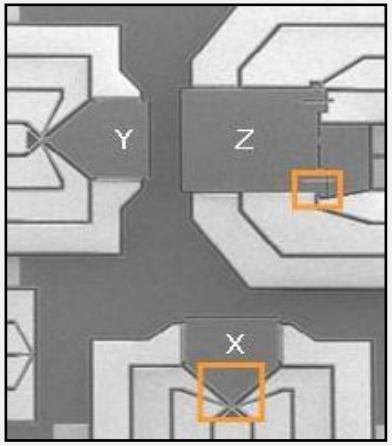
M&NEMS: a multi-axis, multi-sensor platform with increasing maturity

A generic platform for sensor fusion (protected by more than 20 LETI patents)

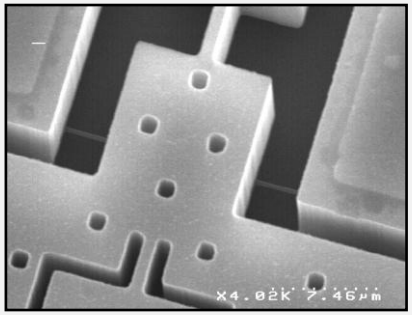
- Advantages: Miniaturization, generic processes, common readout electronics
- **Well known and robust piezoresisitive detection, unsensitive to parasitics**
- A & G: 6 mask levels (without packaging) / CMOS compatible fabrication
- **First (ongoing) industrial transfer (non-exclusive licensing) to Tronics (9-axis)**

tronics
ENVISION MEMS | DELIVER MEMS

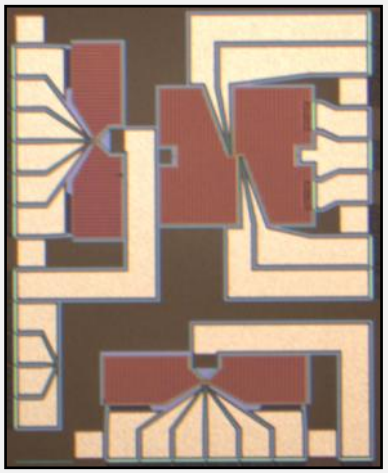
3axis accelerometer



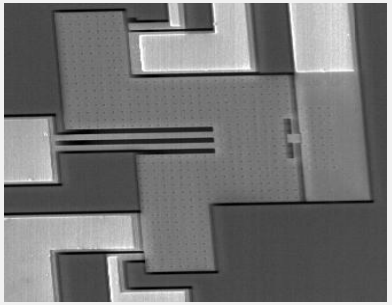
3axis gyroscope



3axis magnetometer



Pressure sensor



Microphone

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