mems tohoku 検索

Smart Sensor System for Robotic Applications

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Sendai, Japan

Micro Electro Mechanical Systems Lab
Tanaka Shuji Laboratory

μSIC MicroSystemIntegrationCenter

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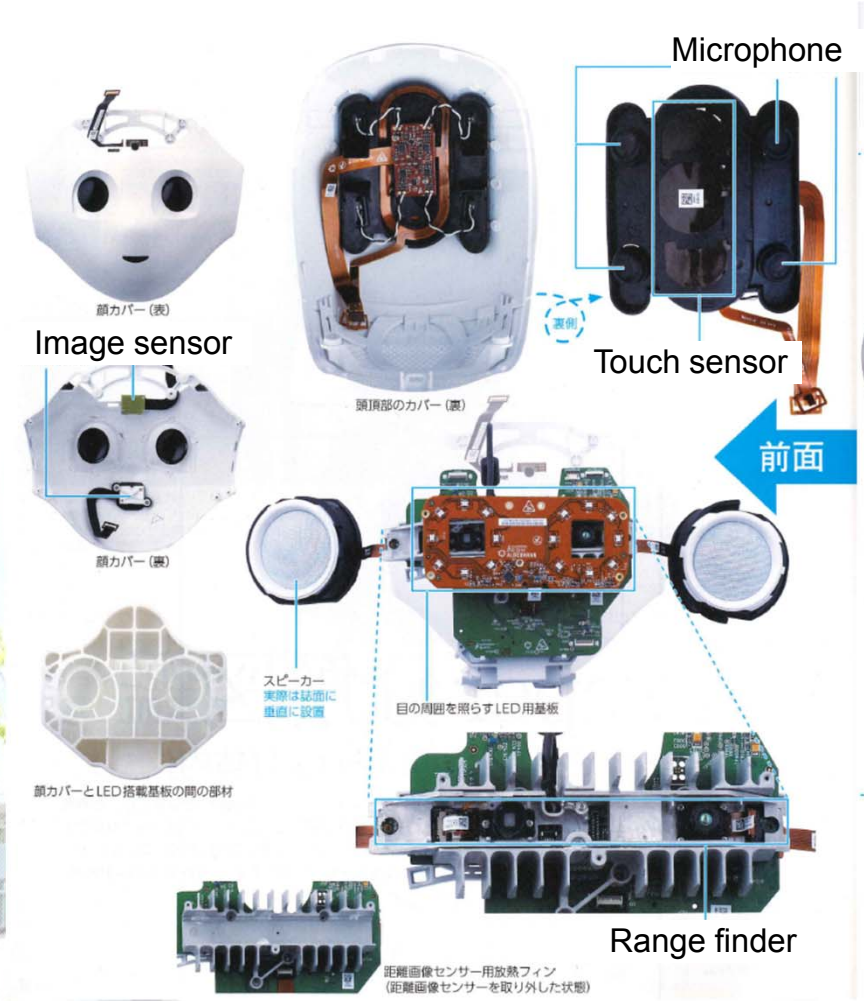
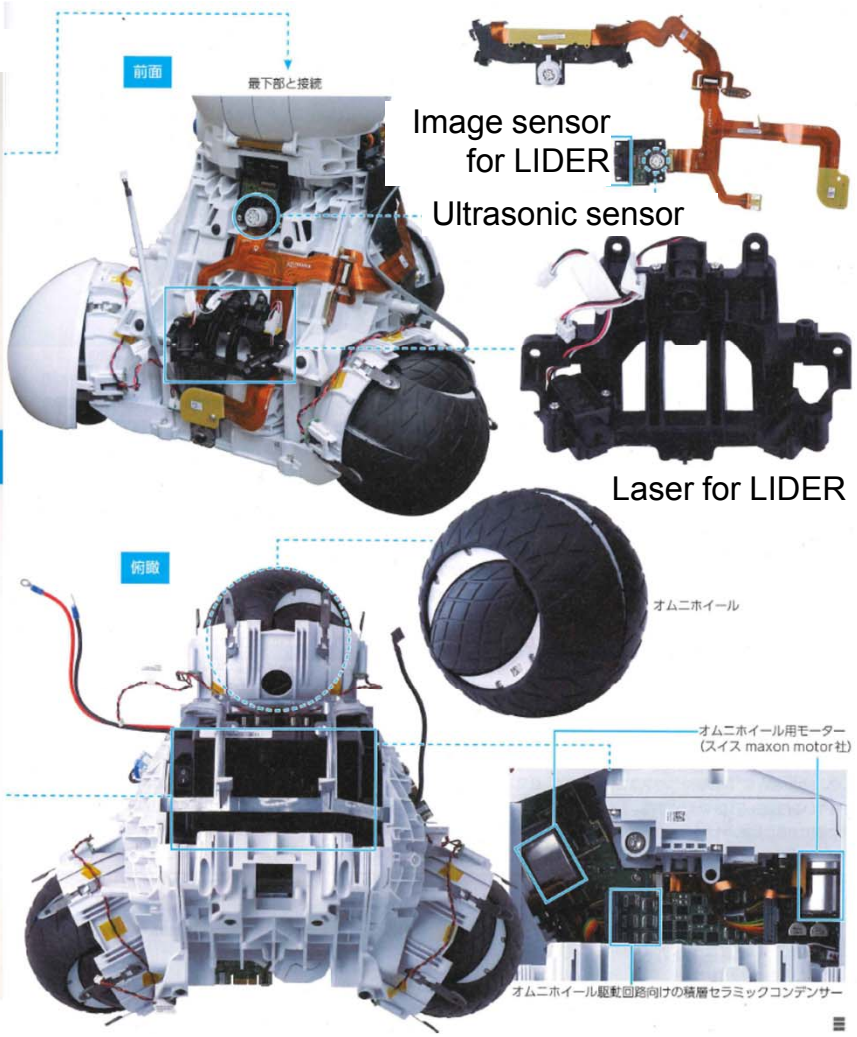
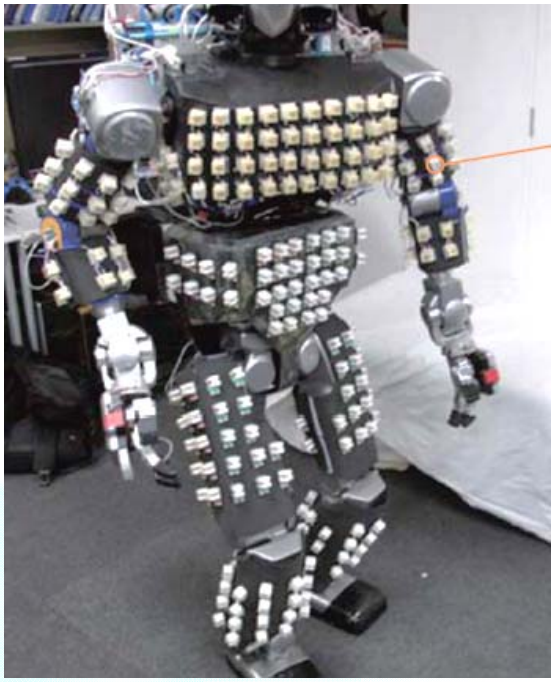
Sensors in Softbank's "Pepper"



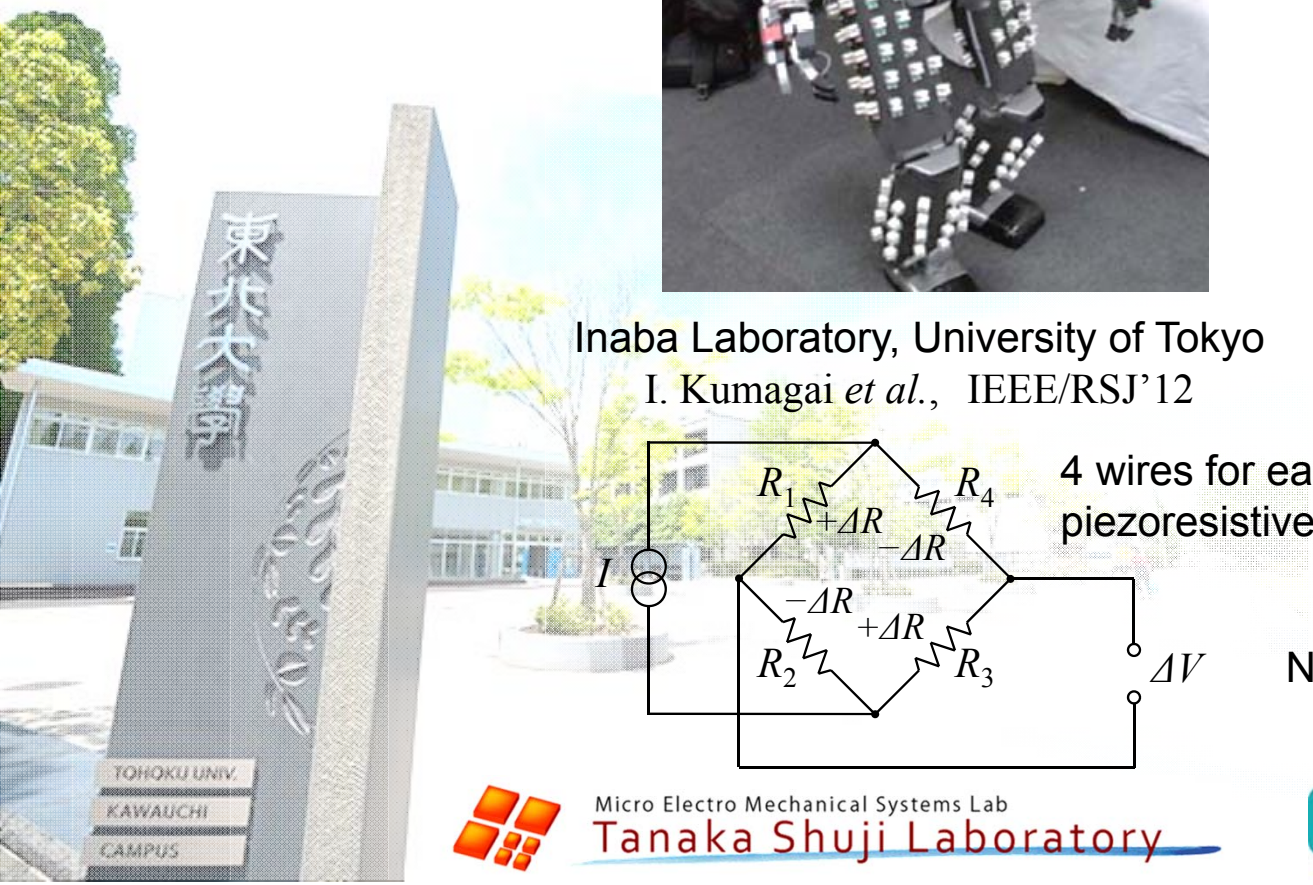


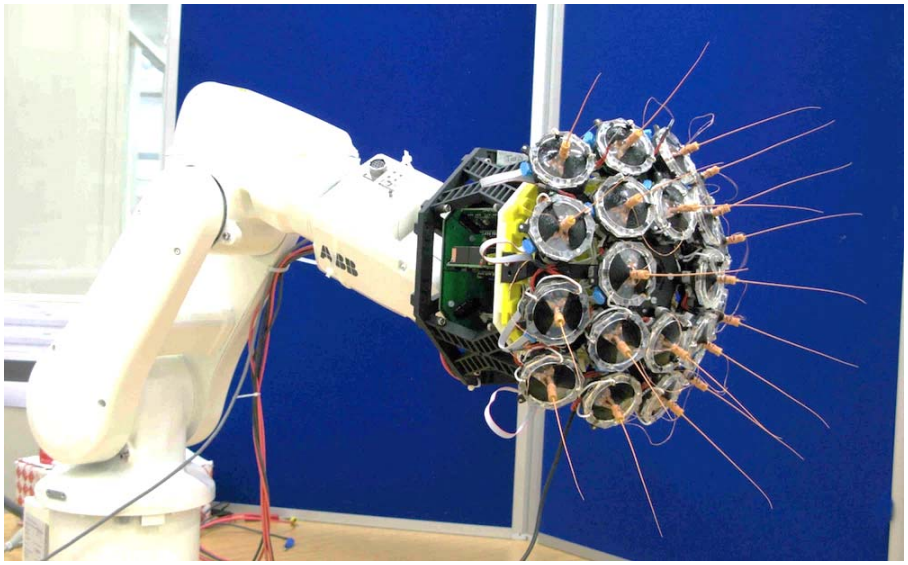
日経エレクトロニクス, 2015.10, Softbank Pepper

Abundance of Sensors on Robots



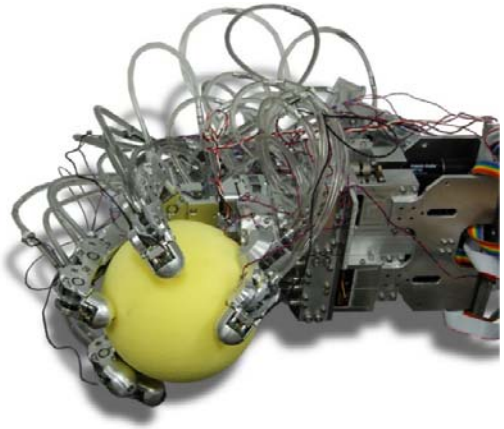
Inaba Laboratory, University of Tokyo
I. Kumagai *et al.*, IEEE/RSJ'12





"Bellabot"
Bristol Robotics Laboratory & Sheffield Robotics

4 wires for each piezoresistive sensor



Nakamura Laboratory, University of Tokyo

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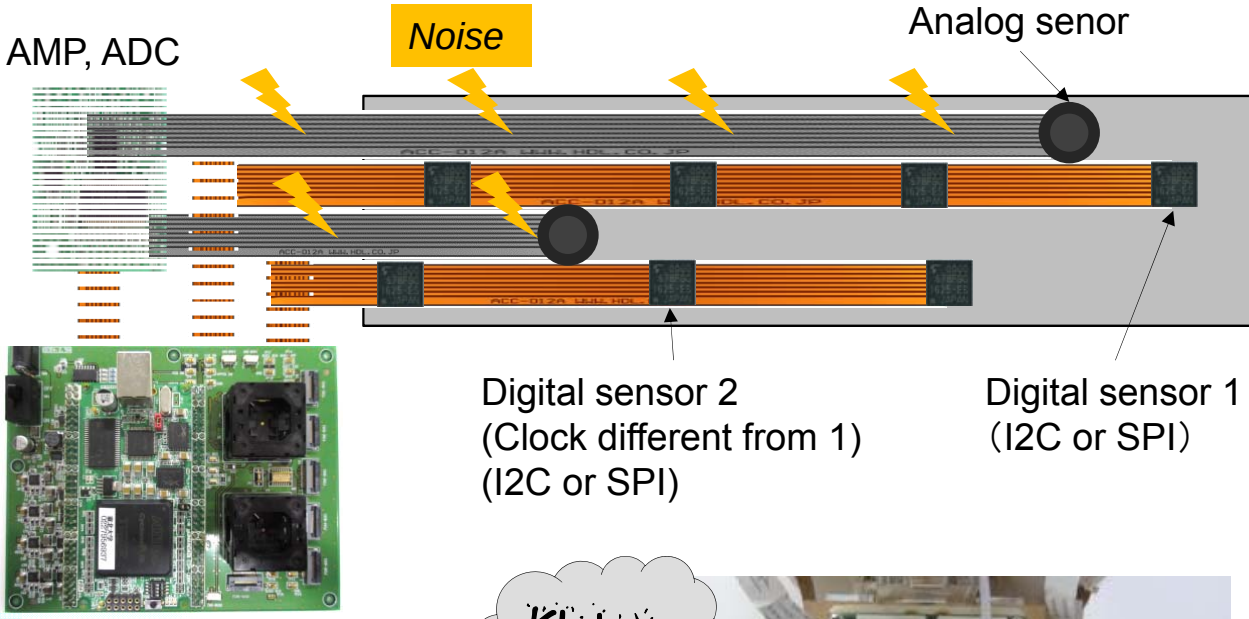
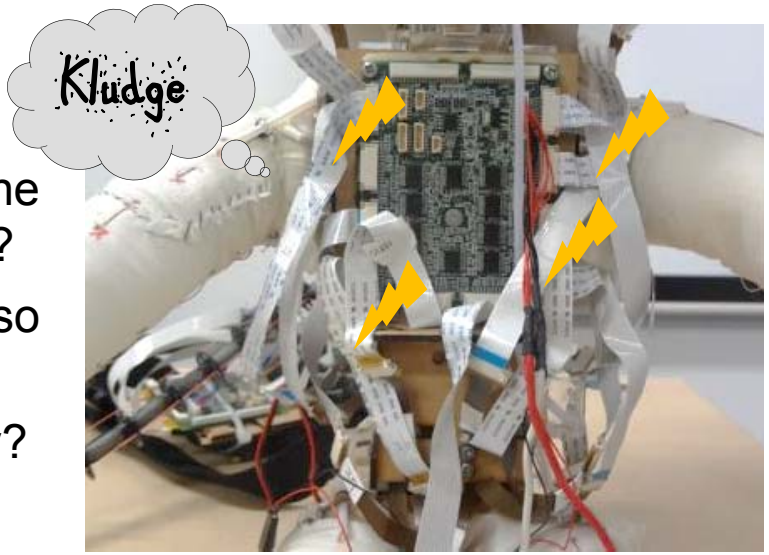
Can we smartly install many sensors in robots?

Conventional method

- ✓ Low density
- ✓ Busy wires
- ✓ Inconsistent interface
- ✓ Low performance especially for analog sensors



Relay node



Can we install different sensors in the same manner on a common bus network?

We need to install a lot of sensors, but also expect fast response. Is it possible?

Can we configure each sensor separately?

→ **Sensor platform LSI**

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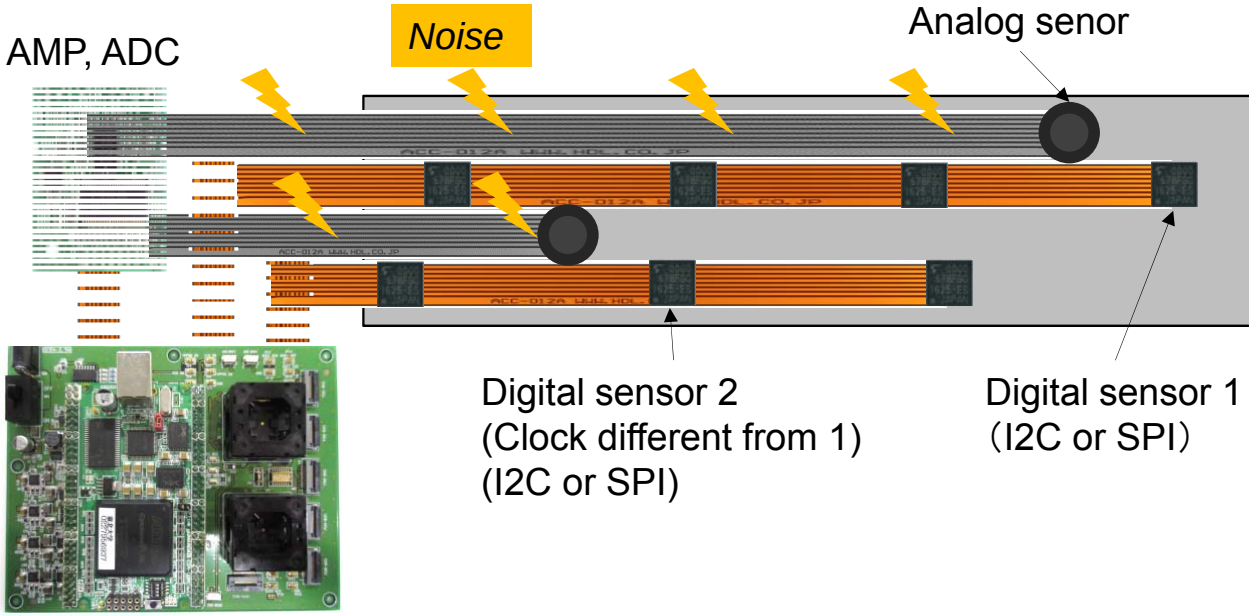
Sensors

Connected to Bus via Platform LSI

Conventional method

- ✓ Low density
- ✓ Busy wires
- ✓ Inconsistent interface
- ✓ Low performance especially for analog sensors

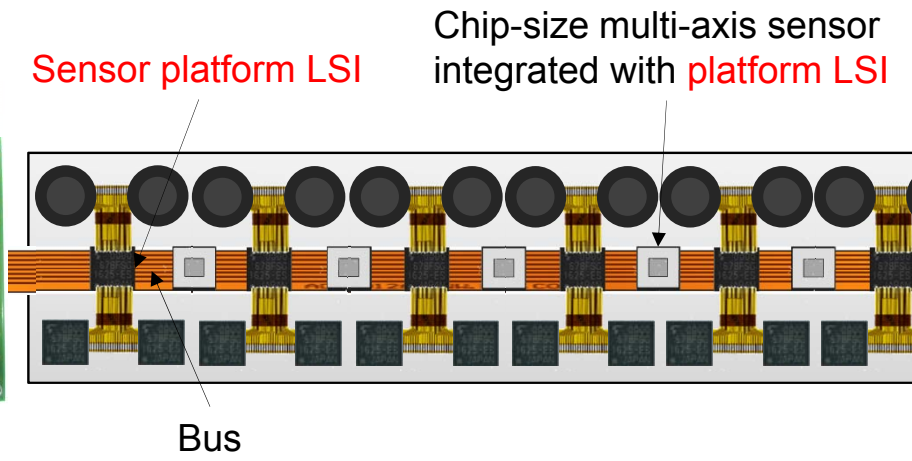


Relay node

Platform LSI

- ✓ High density
- ✓ Minimum wires
- ✓ Consistent interface
- ✓ High performance
- ✓ Event driven

Relay node



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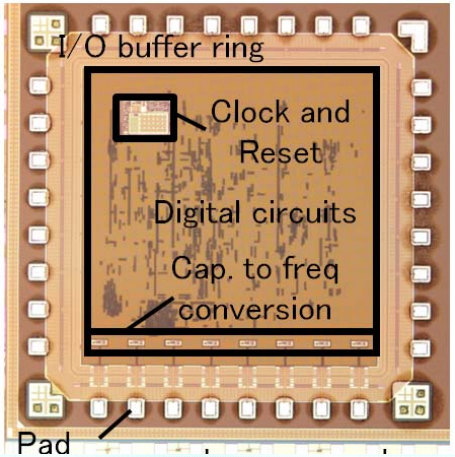
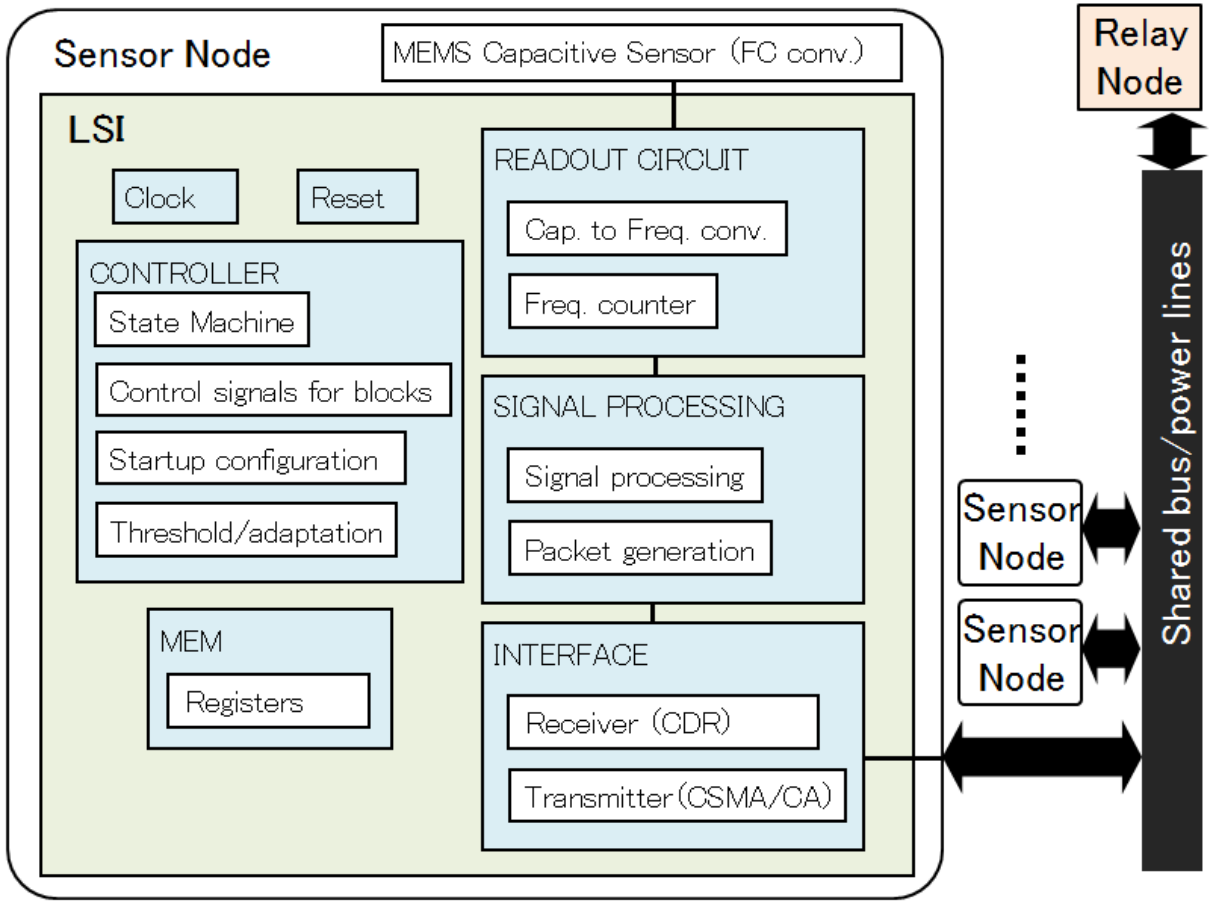
Sensor Platform

LSI “HIROSE”



室山 真徳 准教授
Assoc. Prof. M. Muroyama



RS485 compatible with original protocol
Capacitive + resistive sensors 4 + 8 ch, Temperature sensor
Power: 1.2 V for digital and 3.3 V for I/O, OTP memory

Collaboration with Toyota Motor and Toyota Central R&D Labs.

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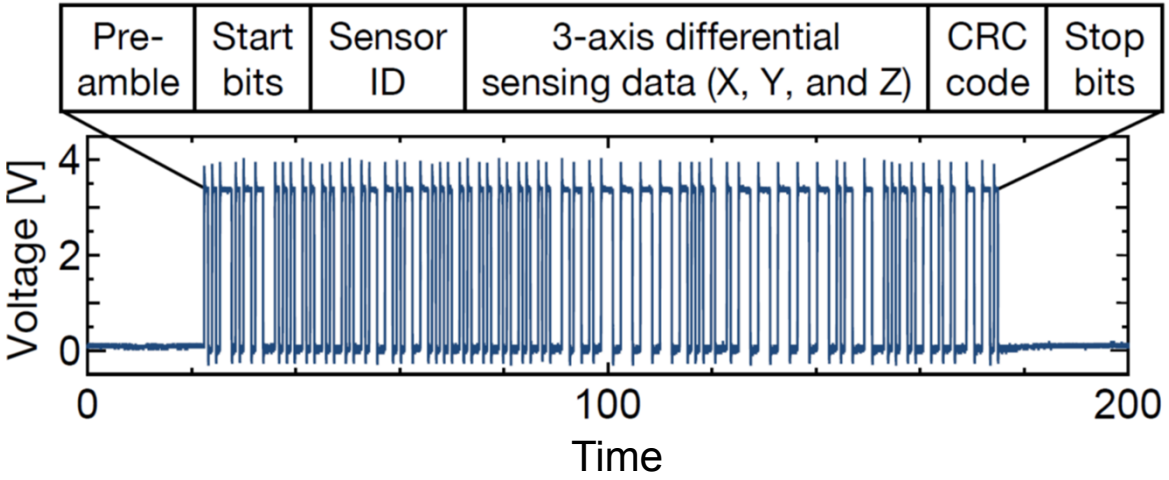
HIROSE on Bus Networks

FPGA-based relay node



Collaboration with Toyota Motor and Toyota Central R&D Labs

Each platform LSI works asynchronously.

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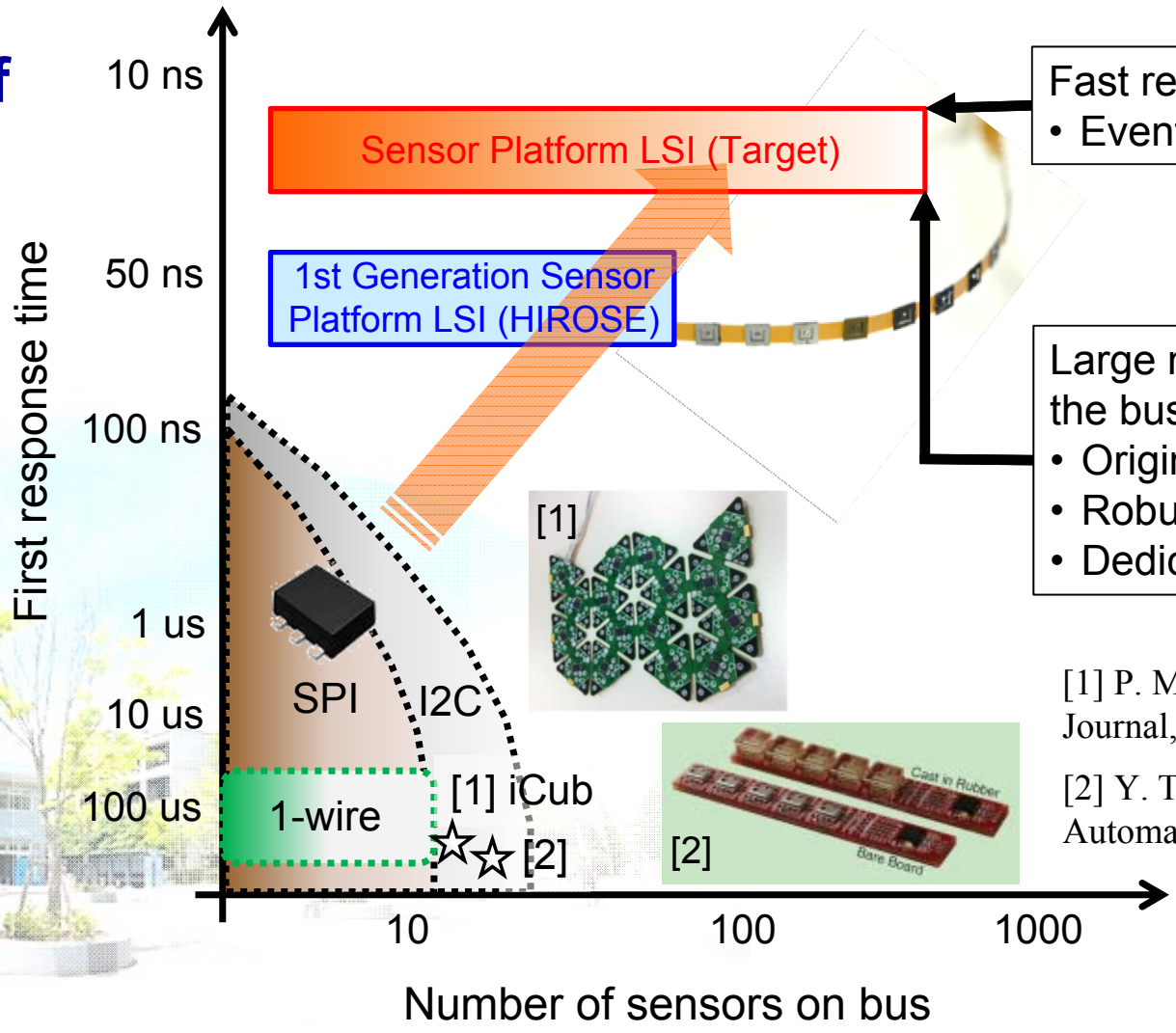
Comparison of Sensor Bus Networks



Fast response by
- Event driven mode

Large number of sensors on the bus by
- Original protocol
- Robust clock data recovery
- Dedicated transmission line

[1]

[2]

[1] P. Maiolino *et al.*, IEEE Sensors Journal, Vol. 13, No. 10, 2013

[2] Y. Tenzer *et al.*, IEEE Robotics & Automation Magazine, pp.89-95, 2014

Demonstration of Event-Driven Operation

Please watch the student's finger(s) and the oscilloscope.
Only when the sensor is pushed, a packet appears on the oscilloscope.

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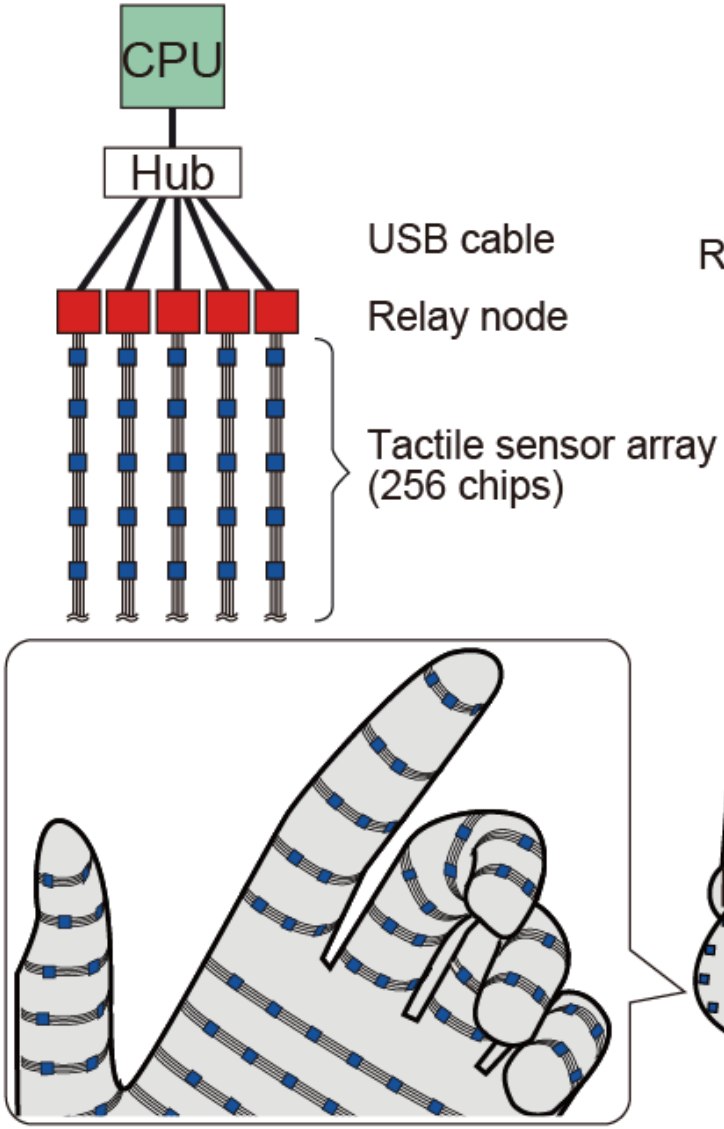
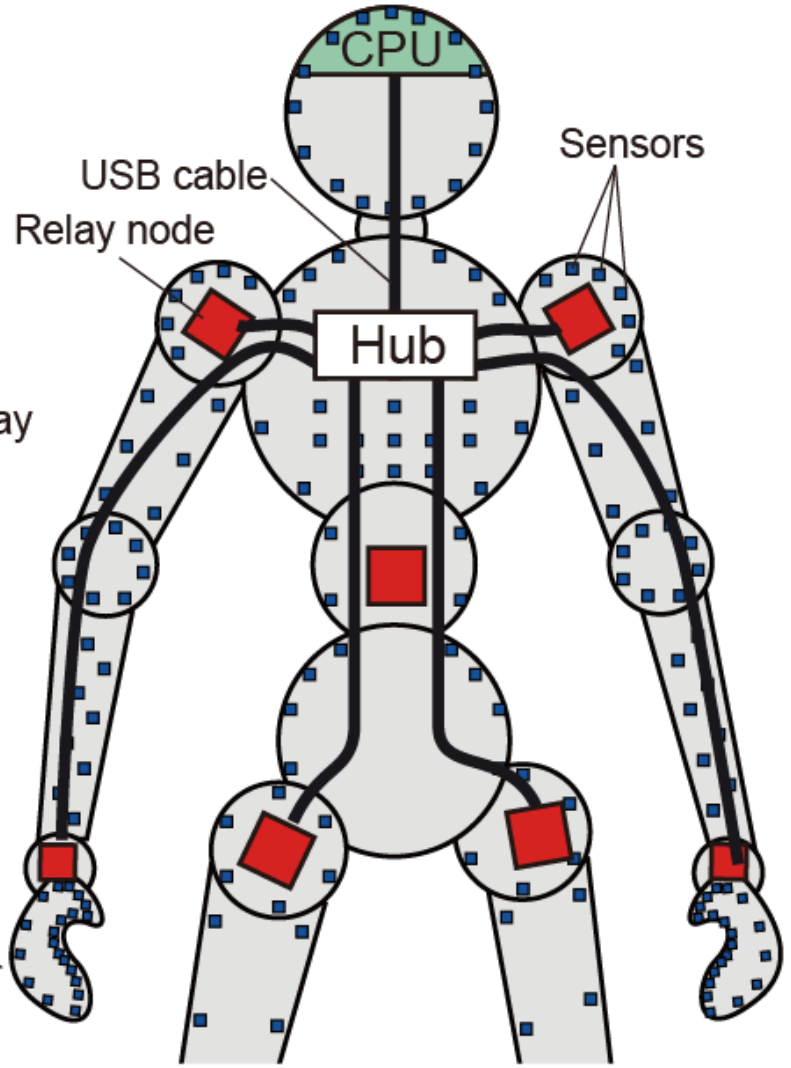
Tactile Sensor Network Covers Robot Surface





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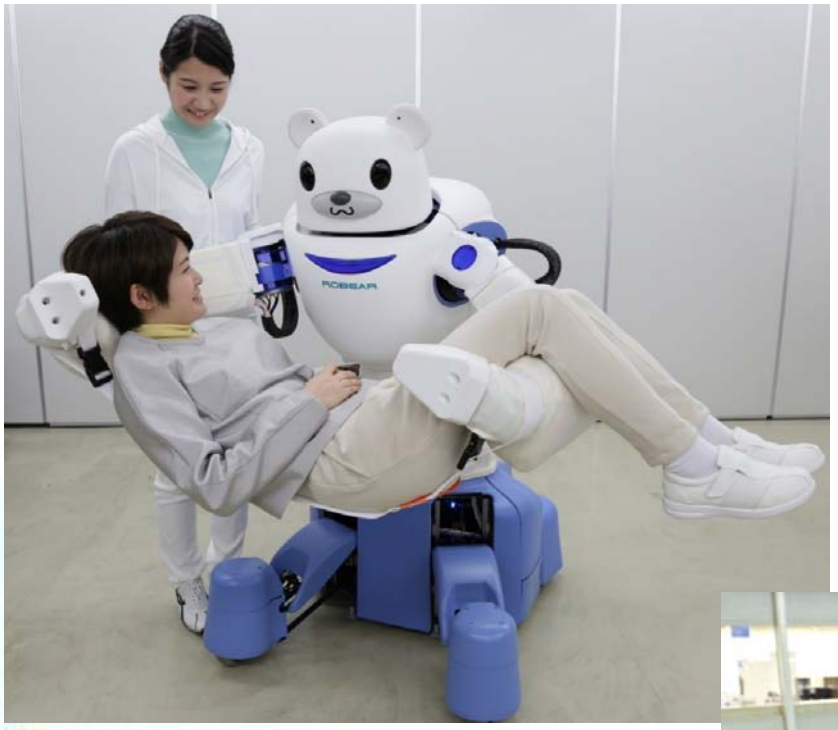
Robots Working with Human



“ROBEAR” (Riken)

Mental commit robot “PARO”
http://www.paro.jp/

“NEXTAGE”
(Kawada Robotics)

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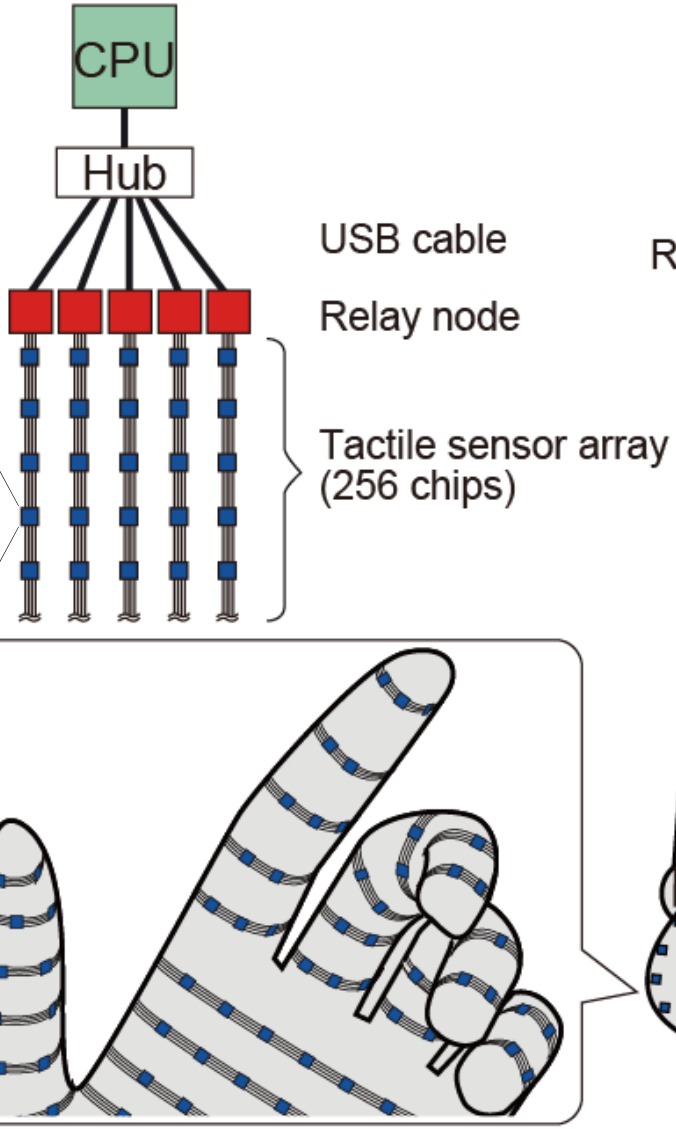
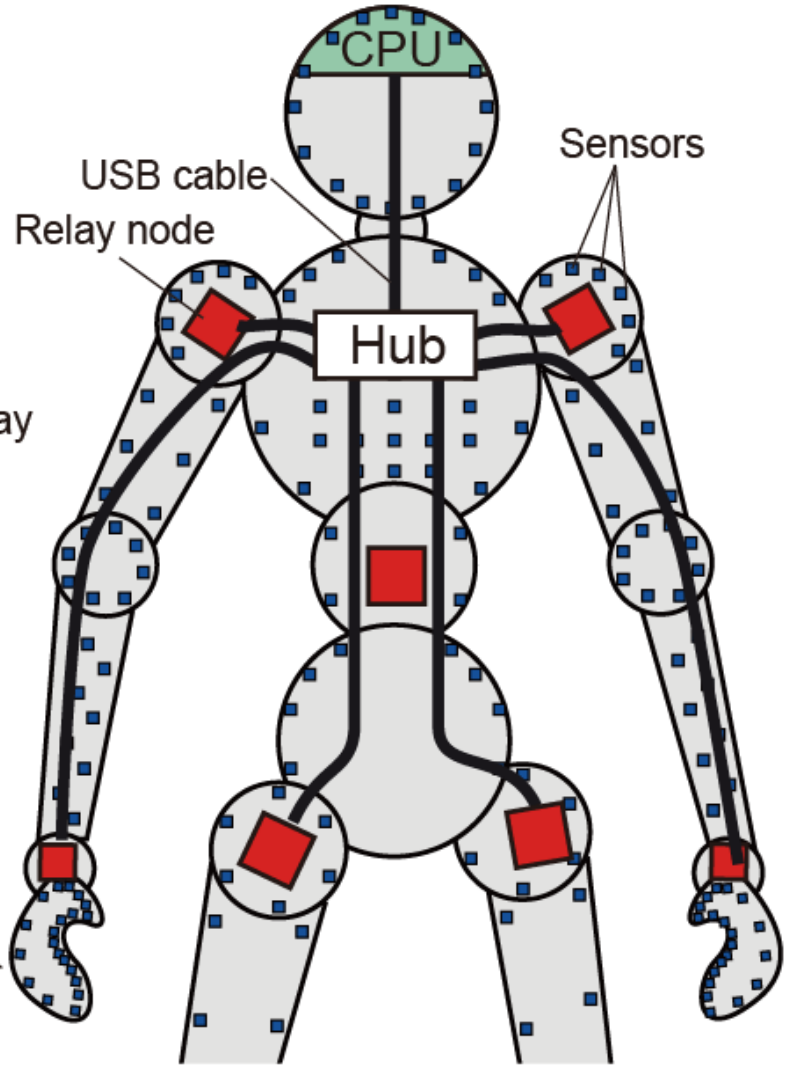
Tactile Sensor Network Covers Robot Surface

Integrated sensor





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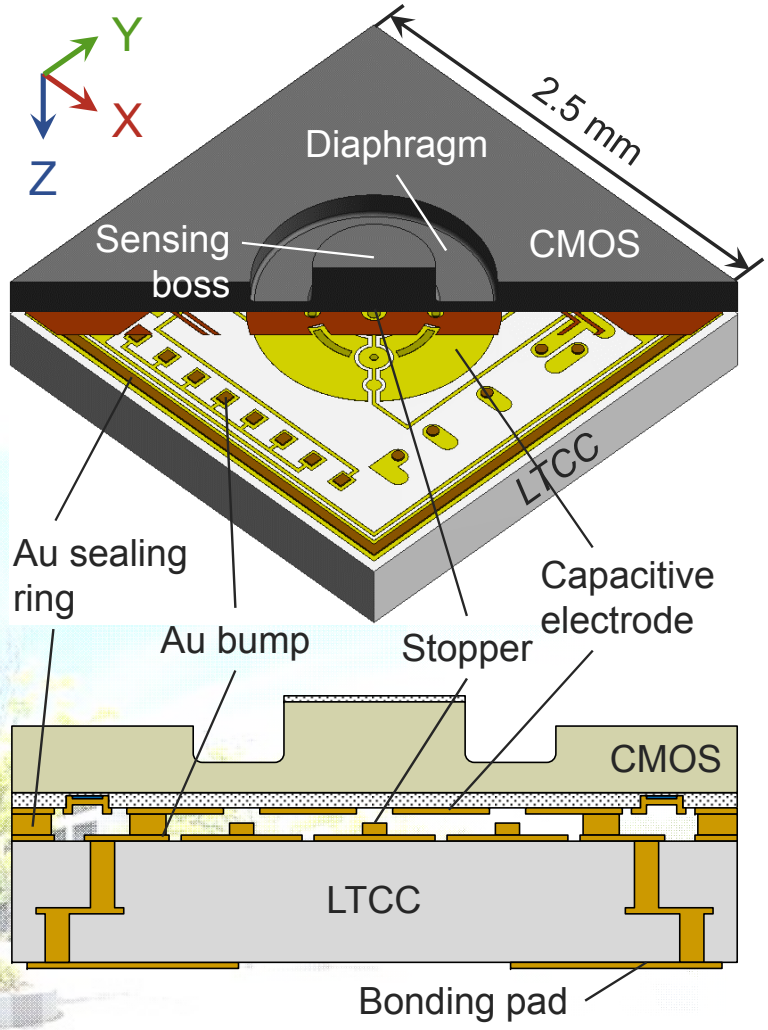
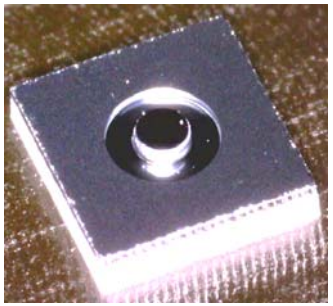
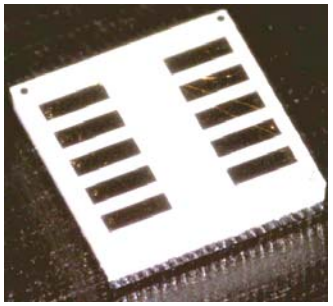
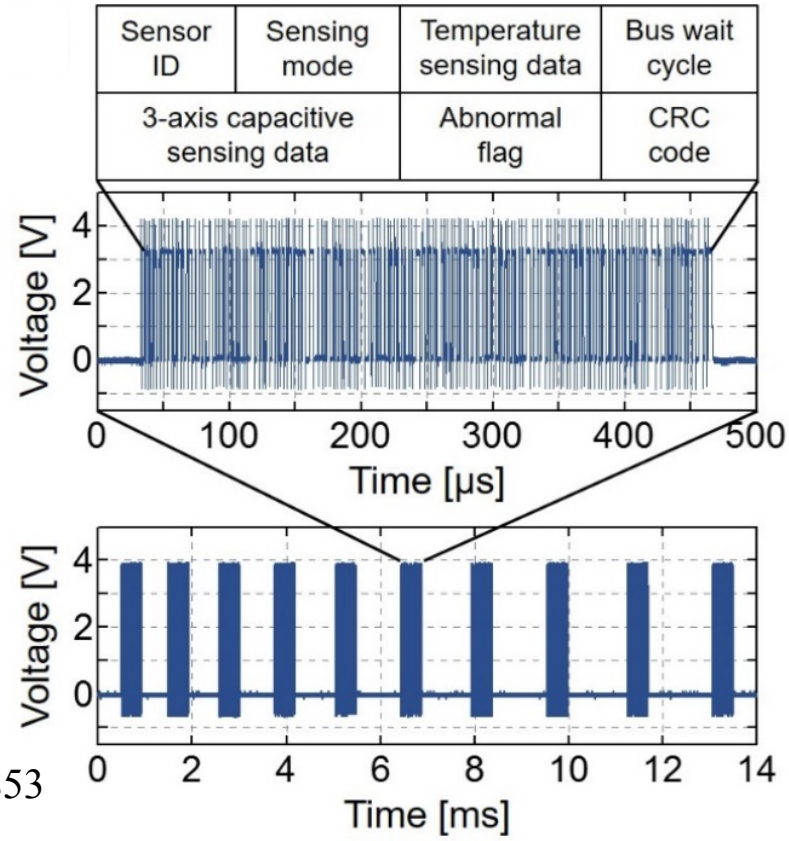
Integrated Finger Sensor (3 Axis Force and Temperature)









Sho Asano *et al.*, IEEE MEMS 2016, pp. 850-853

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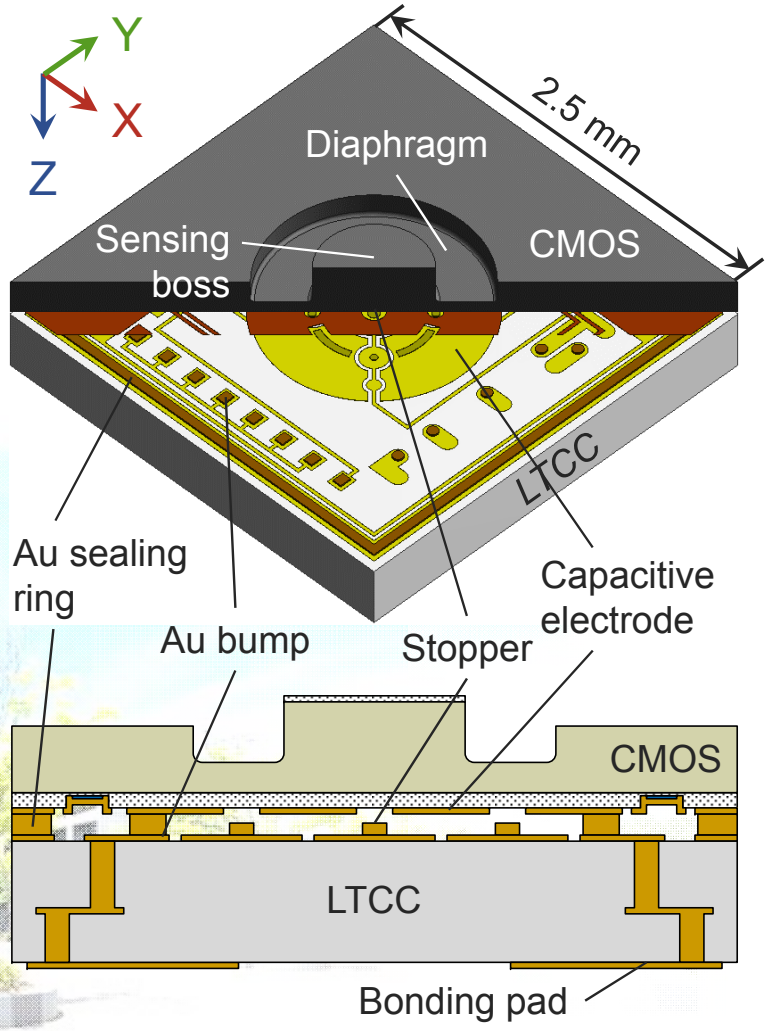

Integrated finger sensors on a robotic hand

Sho Asano *et al.*, IEEE MEMS 2016, pp. 850-853

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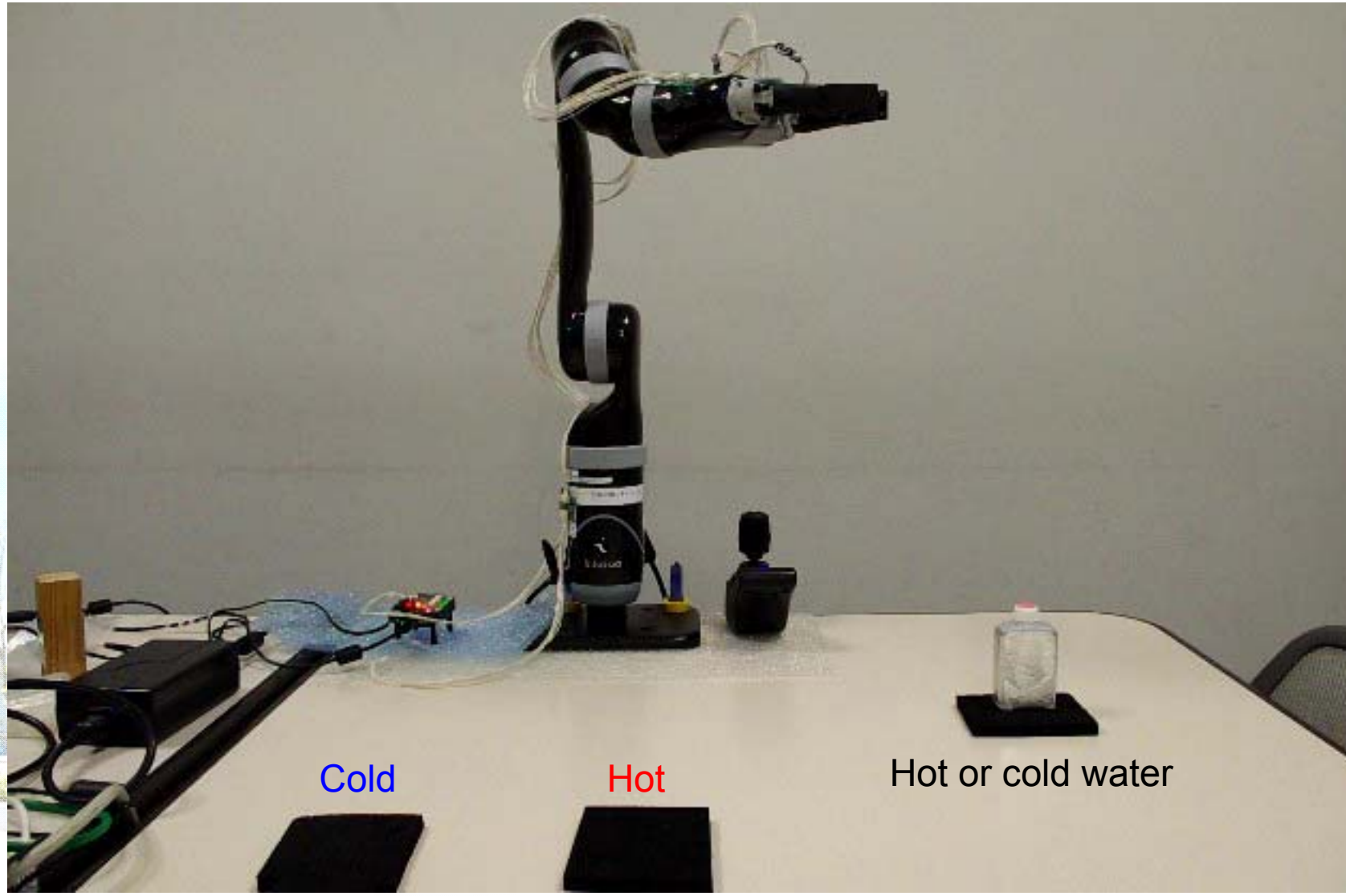
Demonstration of Finger Sensor on Robot



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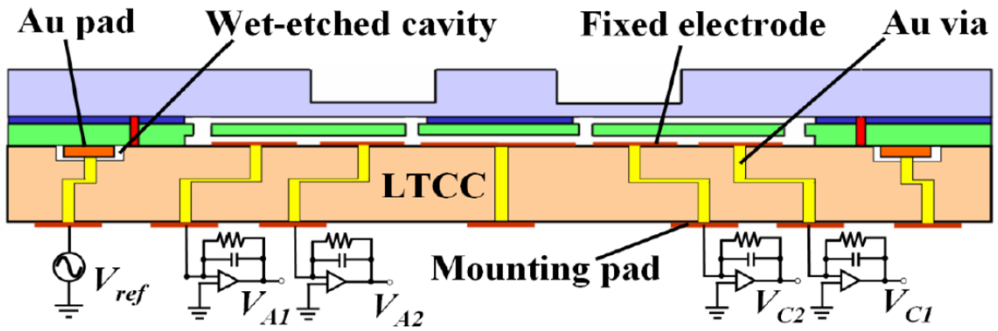
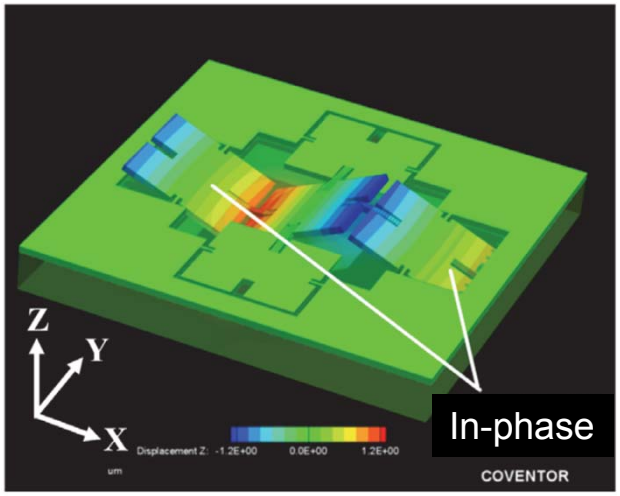
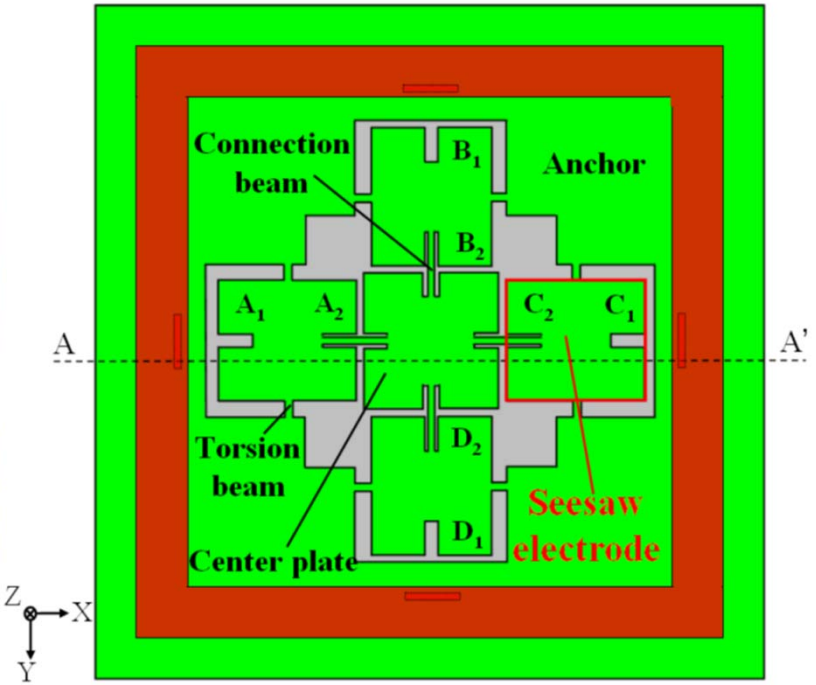
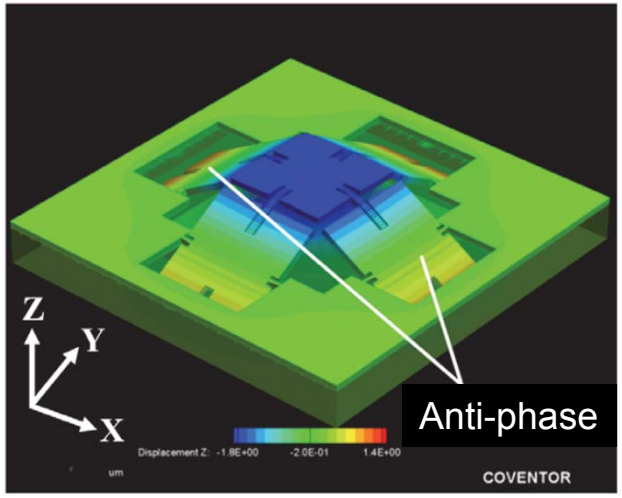
Fully Differential 3 Axis Tactile Sensor (Toyota)









Y. Hata (Toyota CRL) *et al.*, IEEE MEMS 2014, pp. 709-712

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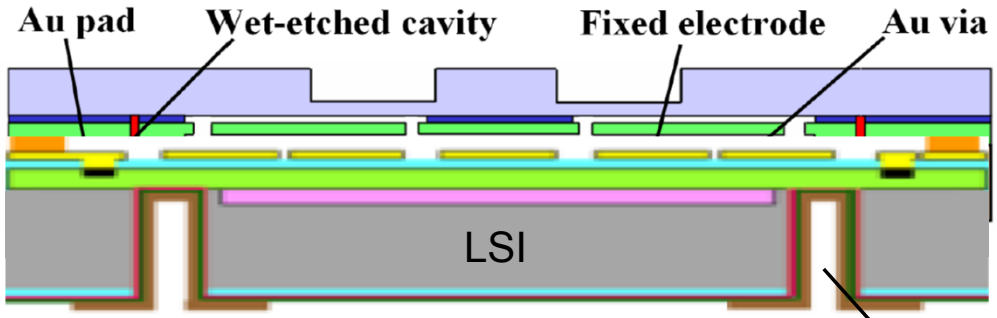
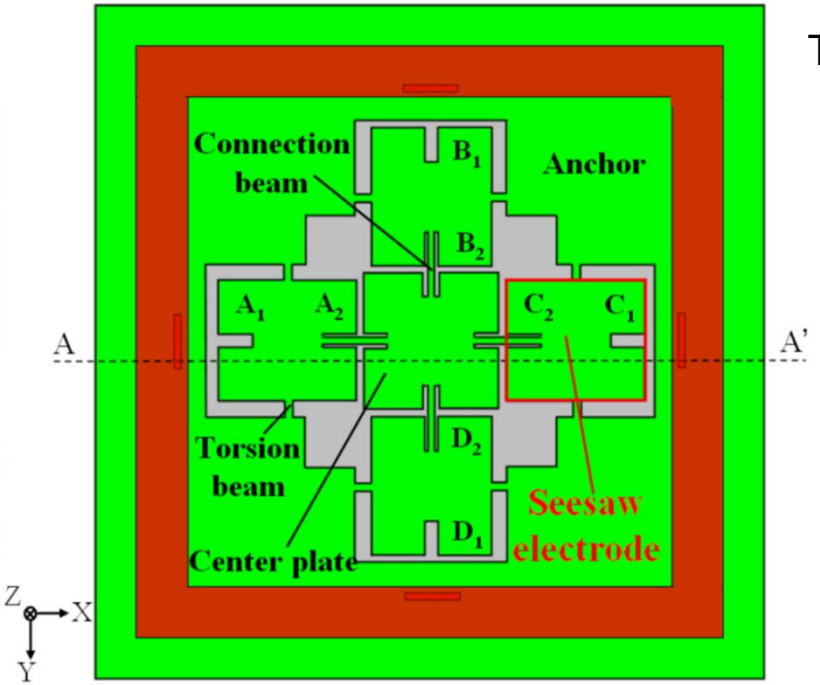
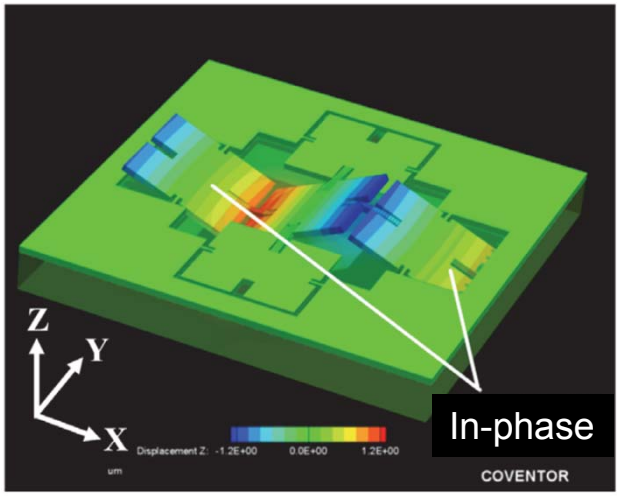
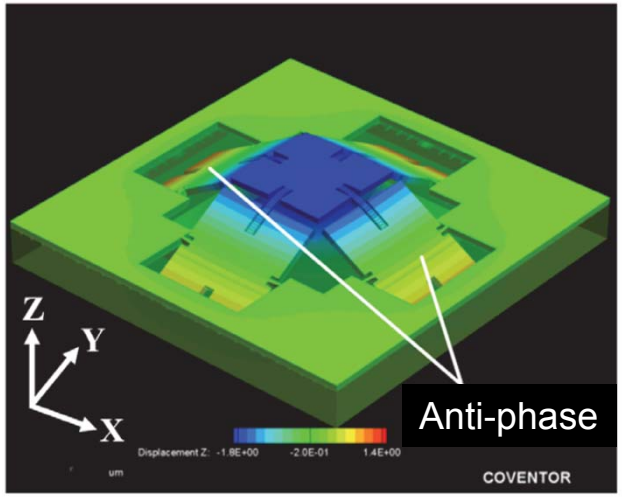
Fully Differential 3 Axis Tactile Sensor (Toyota)









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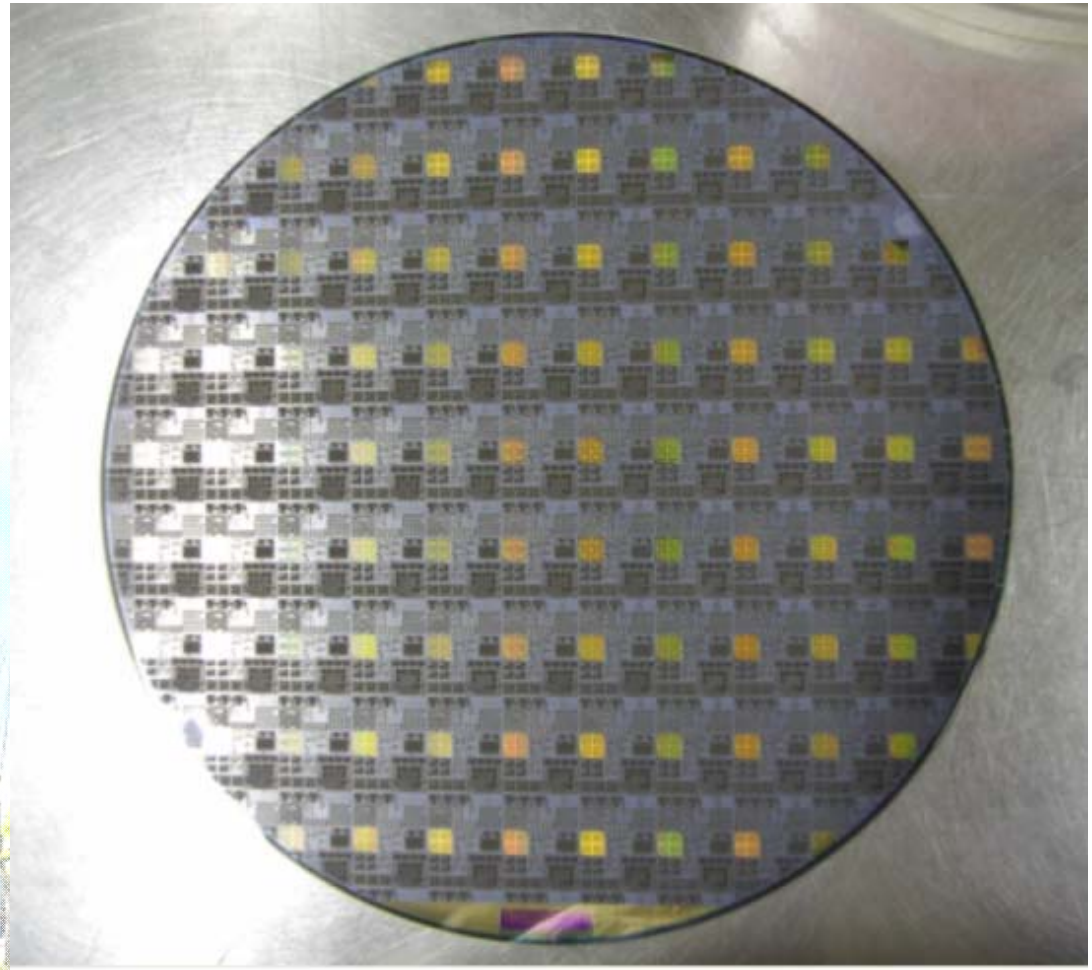
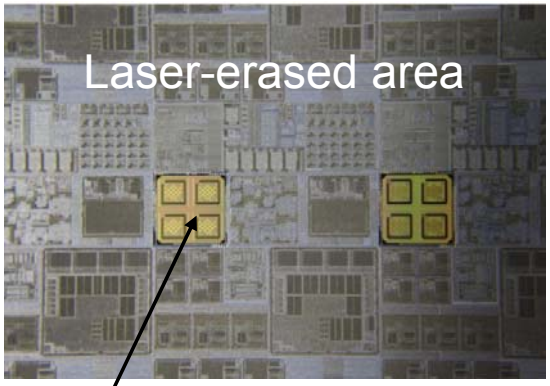
TSV in Multi Project Wafer for Integrated MEMS



TSMC 0.18 μm multi-project wafer (MPW)



Cut-down 4 inch wafer

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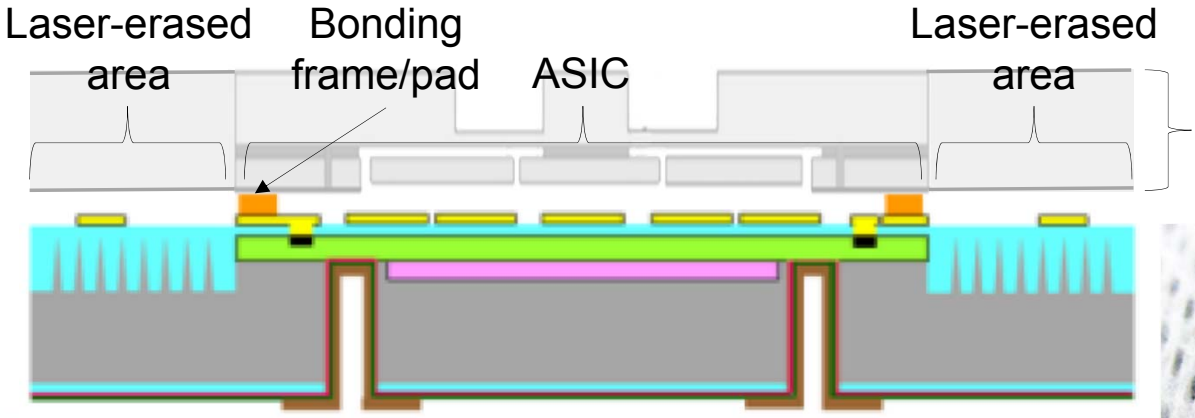

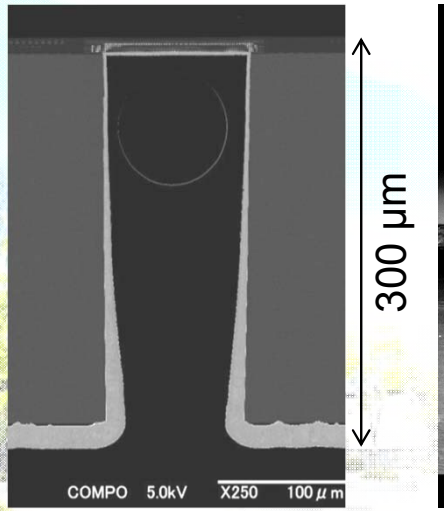

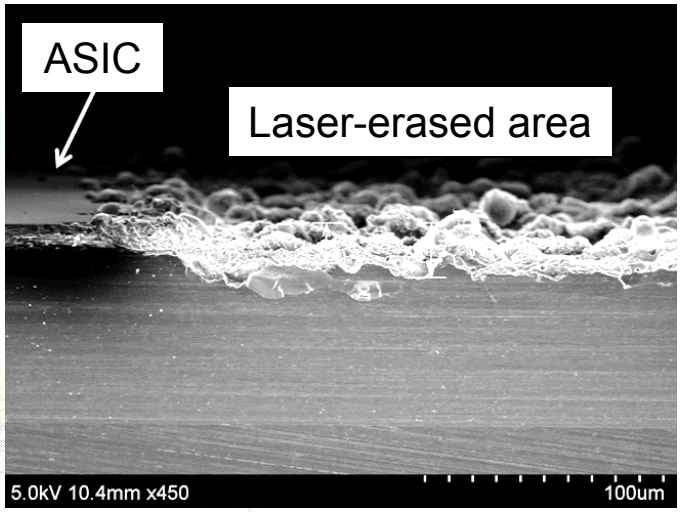

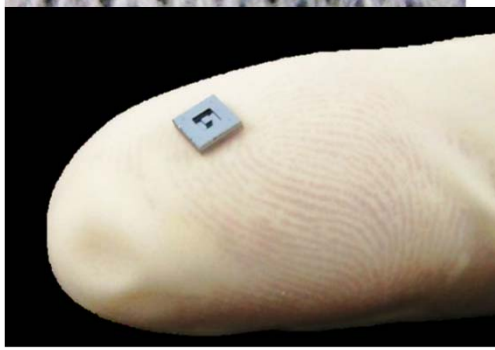

Yukio Suzuki *et al.*, IEEE MEMS 2017
The 3-axis tactile sensor this integration platform will be presented in Transducers 2017.

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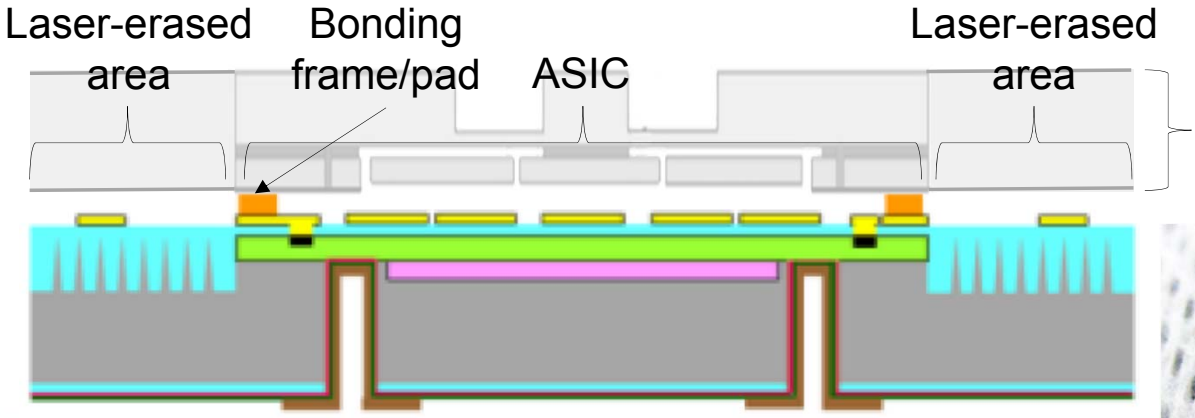

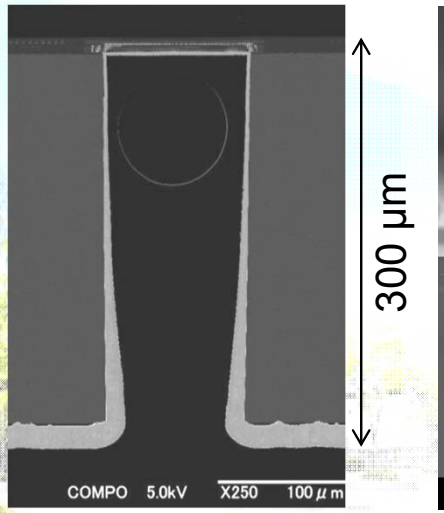

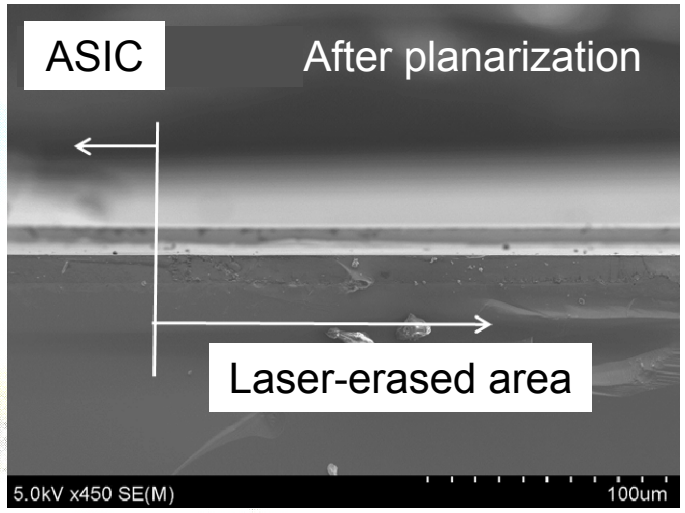

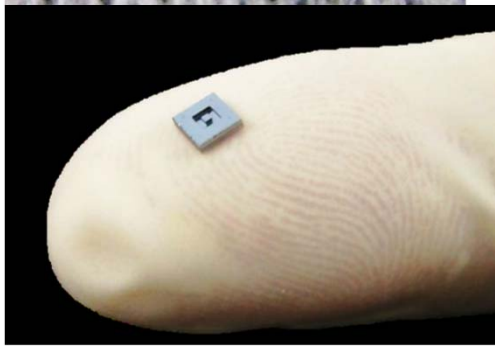

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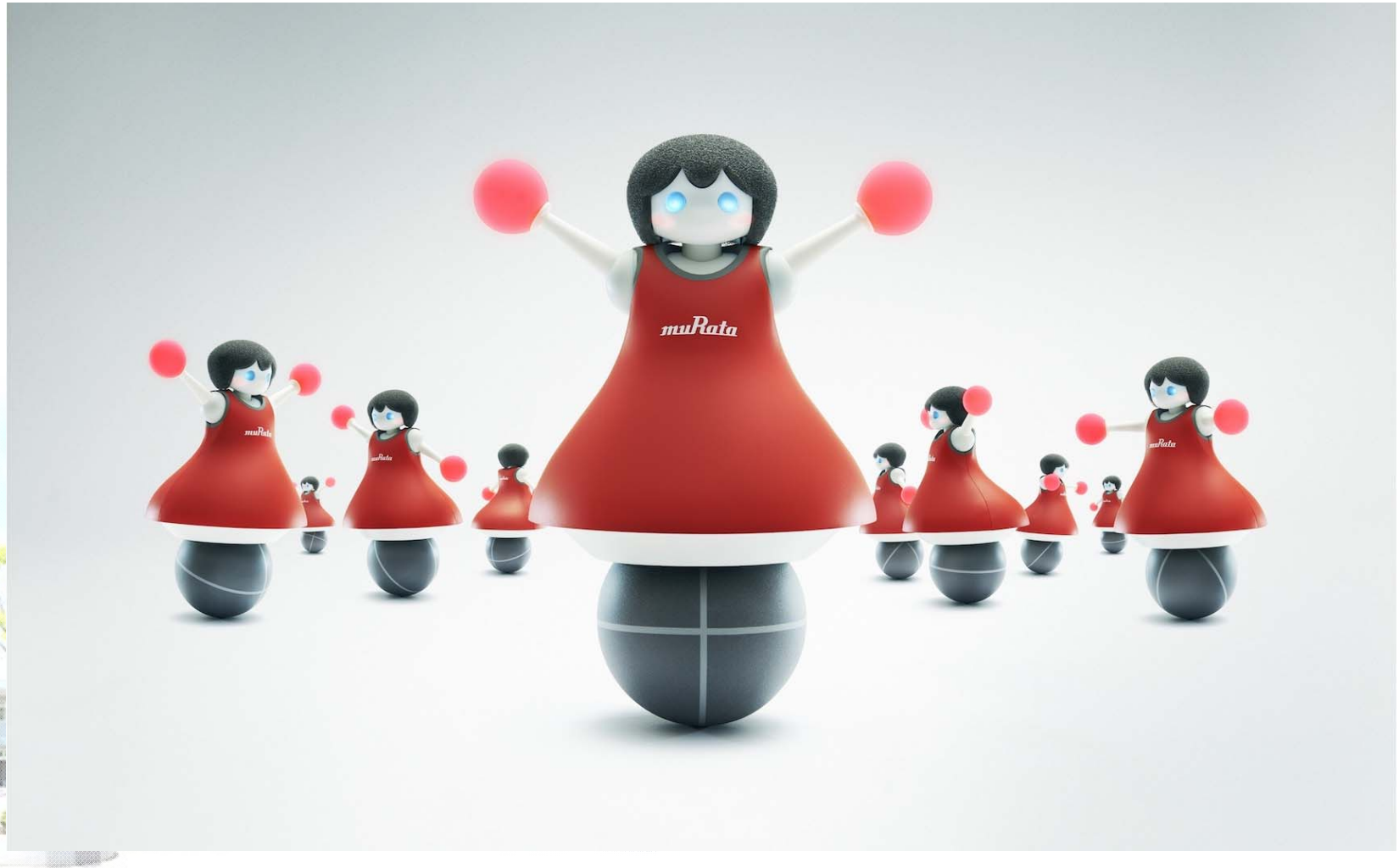
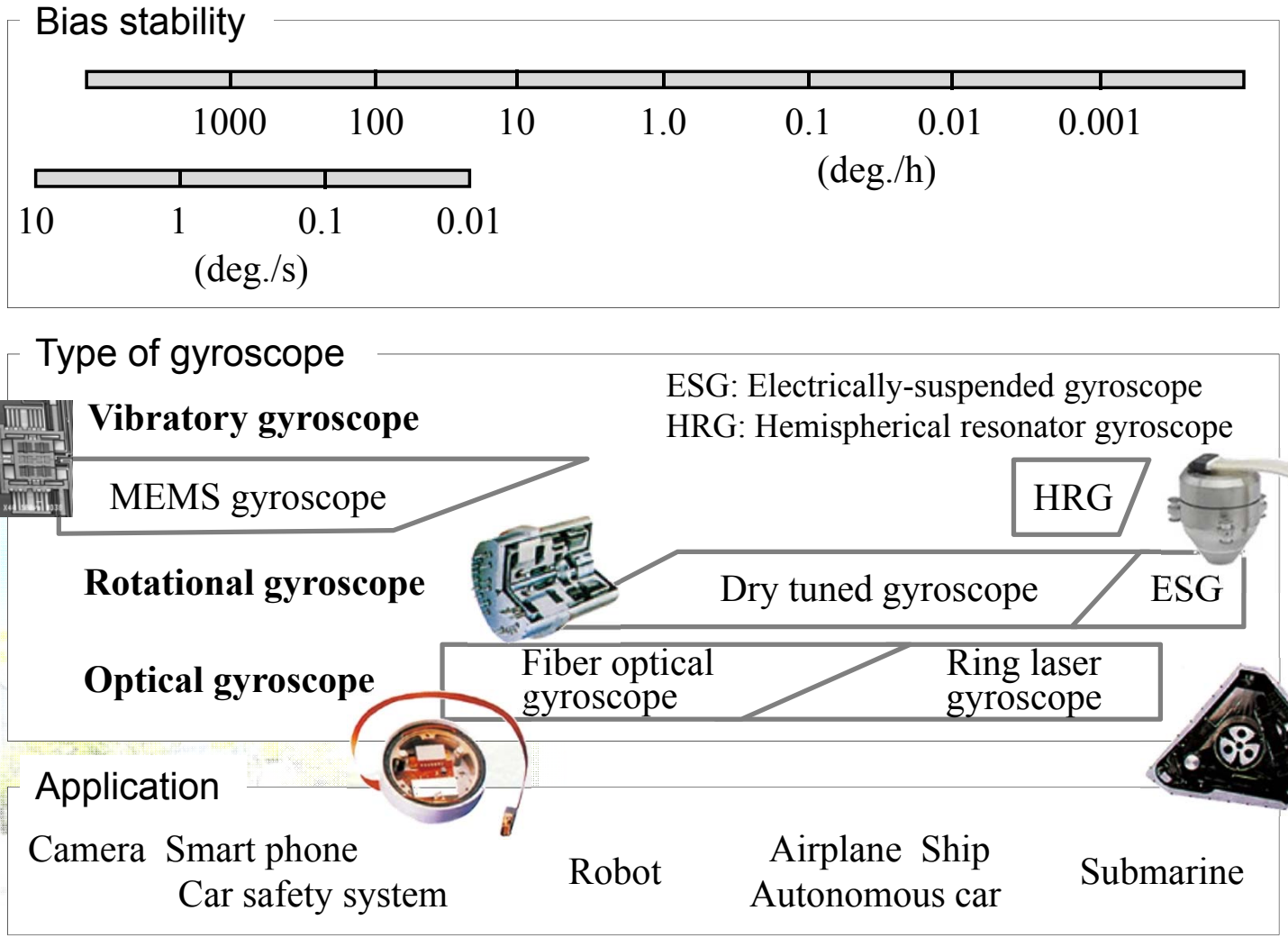
MEMS

Gyroscope in Robot



Murata Cheerleaders (Murata Manufacturing)

Performance of Gyroscopes



DTG, FOG, RLGの図：多摩川精機　HRGの図：Northrop Grumman

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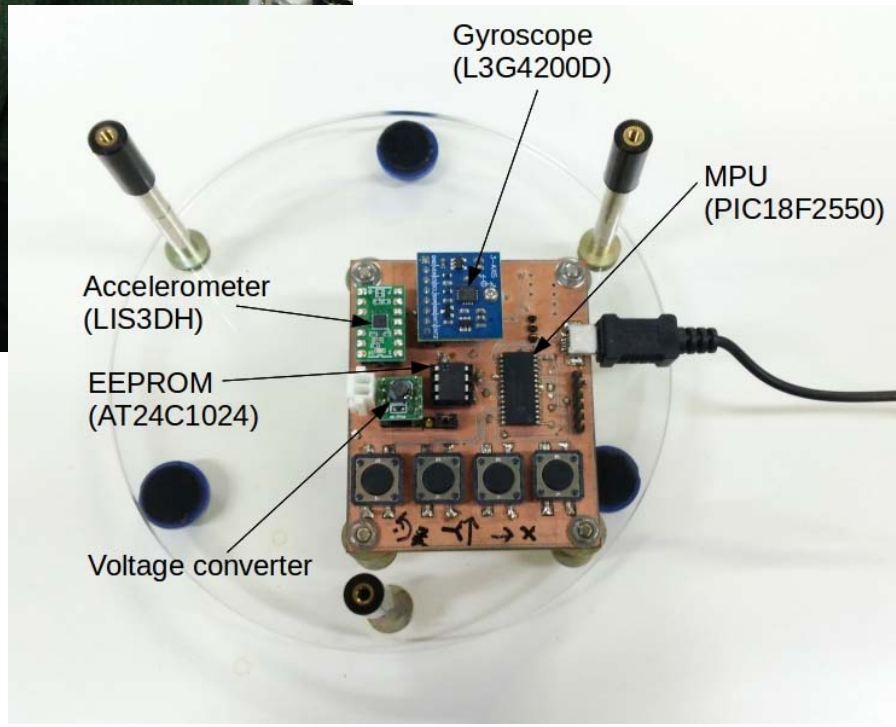
Class for Junior on Inertial Measurement



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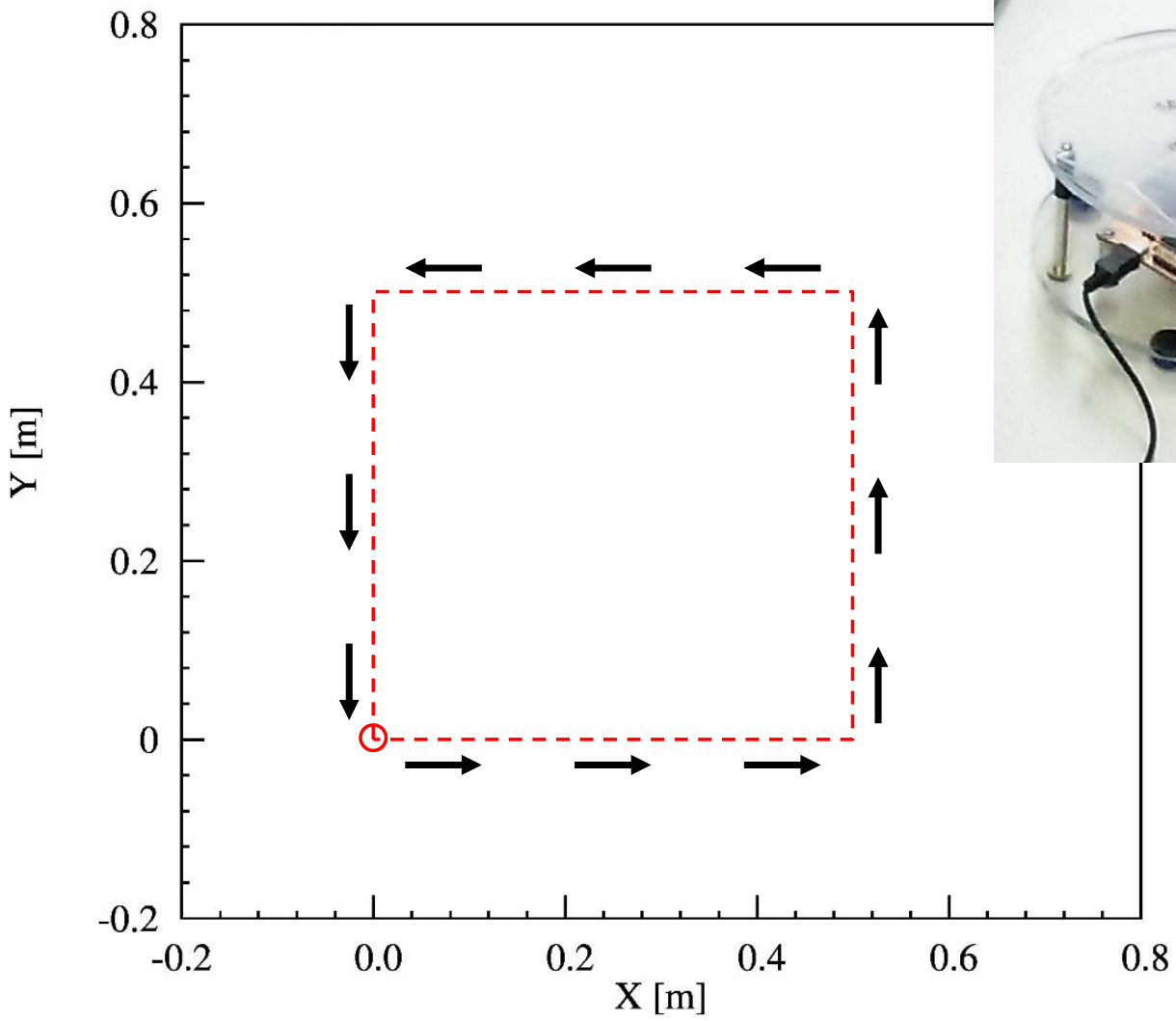

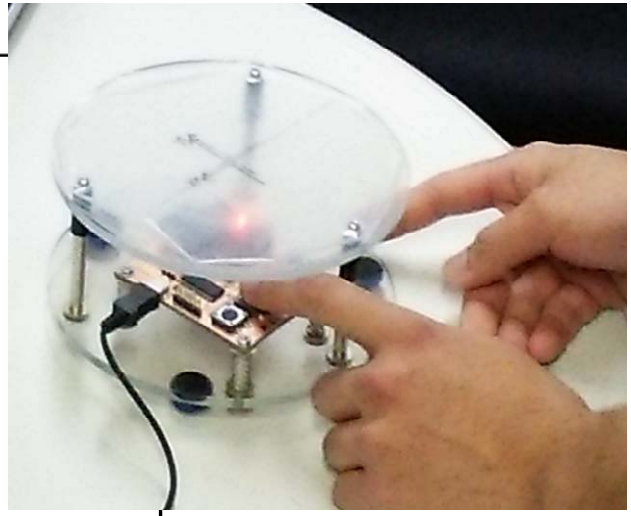

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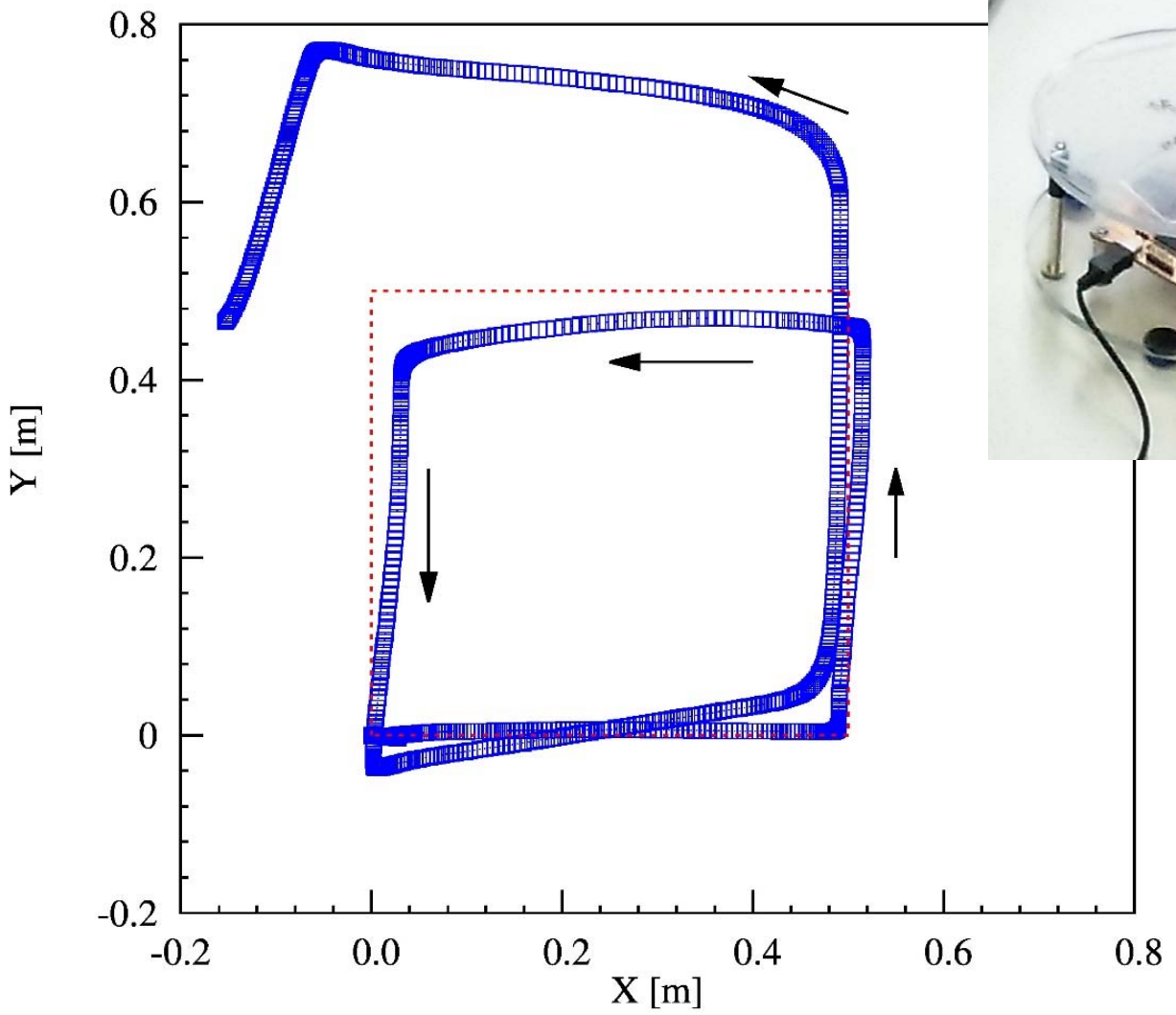
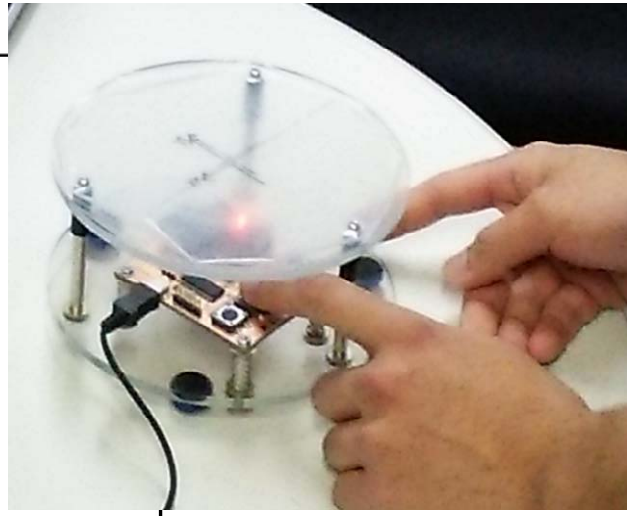
Trajectory Measured by MEMS Inertial Sensors





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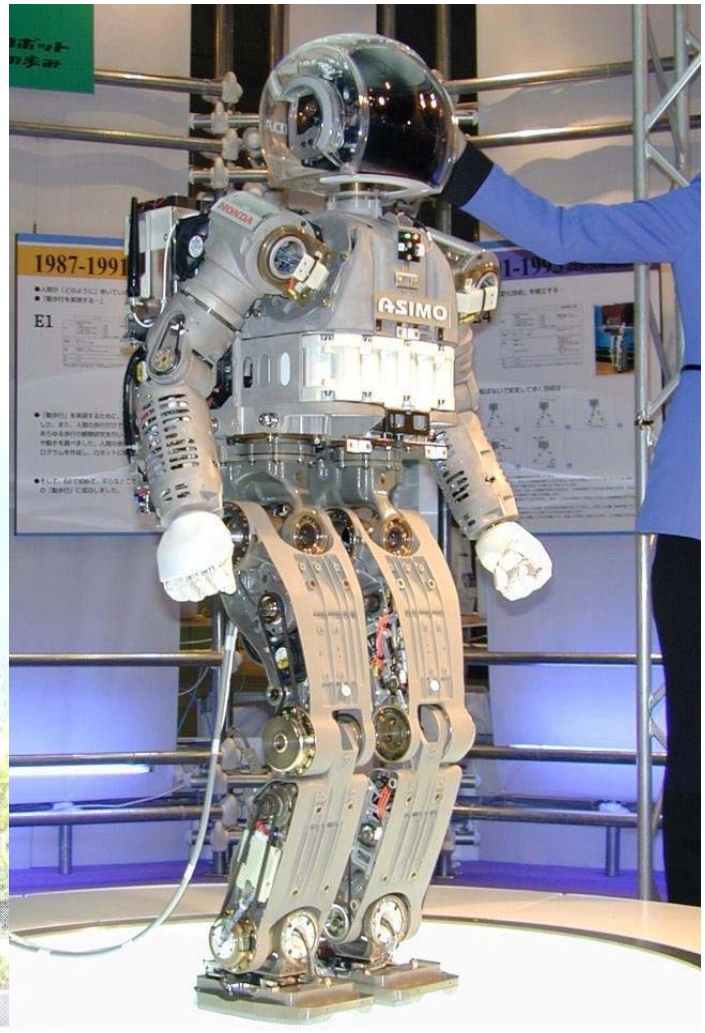
Applications Requiring High Performance Gyroscope



Asimo (Honda Motor)

Autonomous car (Nissan Motor)

Autopilot indoor drone (DARPA)

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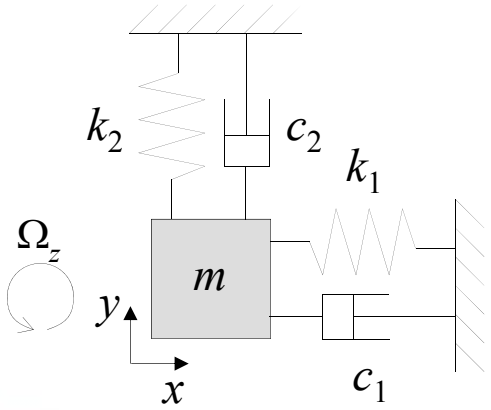
Whole Angle Gyroscope: Foucault Pendulum

http://photozou.jp/photo/show/181646/64768929

Principle of Whole Angle Gyroscope



$$\begin{cases} \ddot{x} + \frac{c_1}{m}\dot{x} + [\frac{k_1}{m} - \Omega_z^2]x = 2\,\Omega_z\dot{y} \\ \ddot{y} + \frac{c_2}{m}\dot{y} + [\frac{k_2}{m} - \Omega_z^2]y = -\,2\,\Omega_z\dot{x} \end{cases}$$

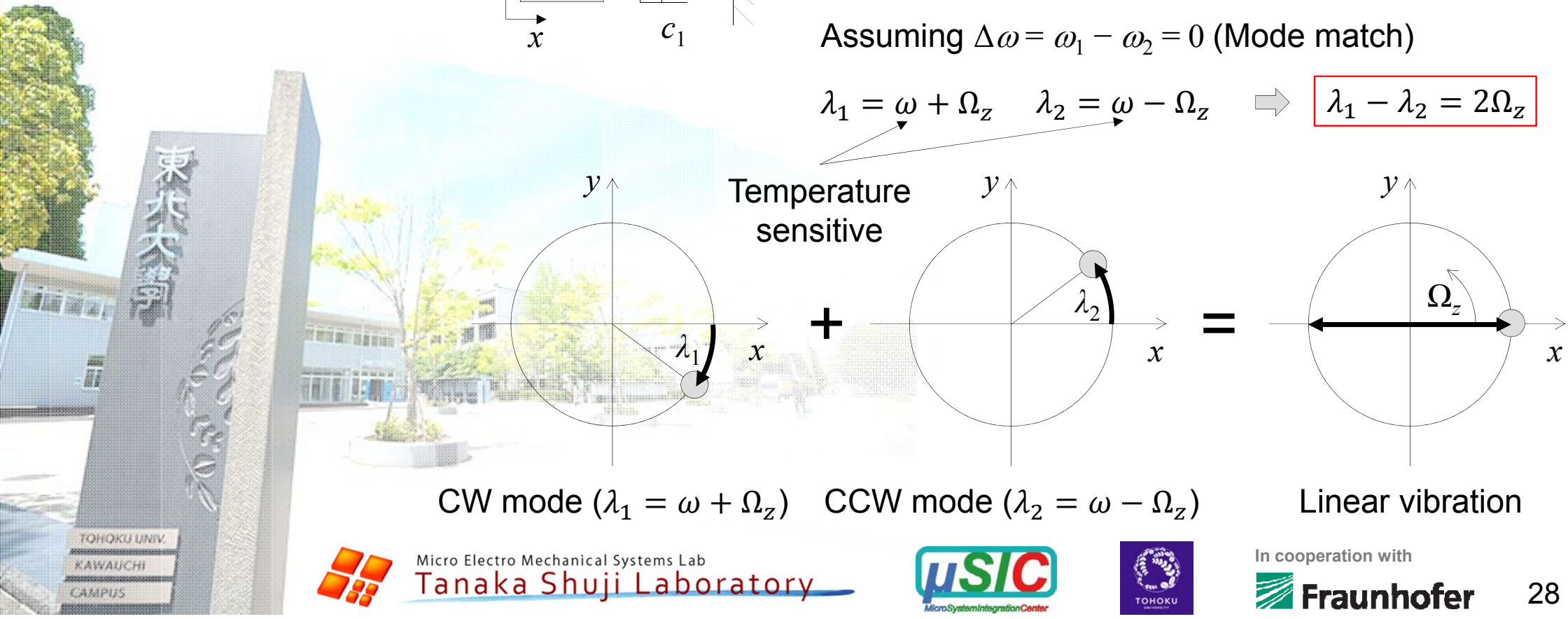
Coriolis force

$$\lambda^2 = (\omega^2 + \Omega_z^2 + \frac{\Delta\omega}{4}) \pm \sqrt{\Delta\omega^2(\omega^2 + \Omega_z^2) + 4\omega^2\Omega_z^2}$$

Assuming $\Delta\omega = \omega_1 - \omega_2 = 0$ (Mode match)

$\lambda_1 = \omega + \Omega_z \quad \lambda_2 = \omega - \Omega_z$ ⇒ $\lambda_1 - \lambda_2 = 2\Omega_z$

Temperature sensitive



CW mode ($\lambda_1 = \omega + \Omega_z$) CCW mode ($\lambda_2 = \omega - \Omega_z$) Linear vibration

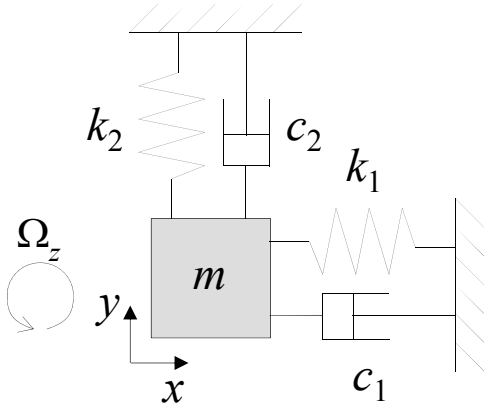
Features and Challenges of Whole Angle MEMS Gyroscope

Features

- Direct angle output − Low drift
- Stable scale factor
- Temperature insensitive

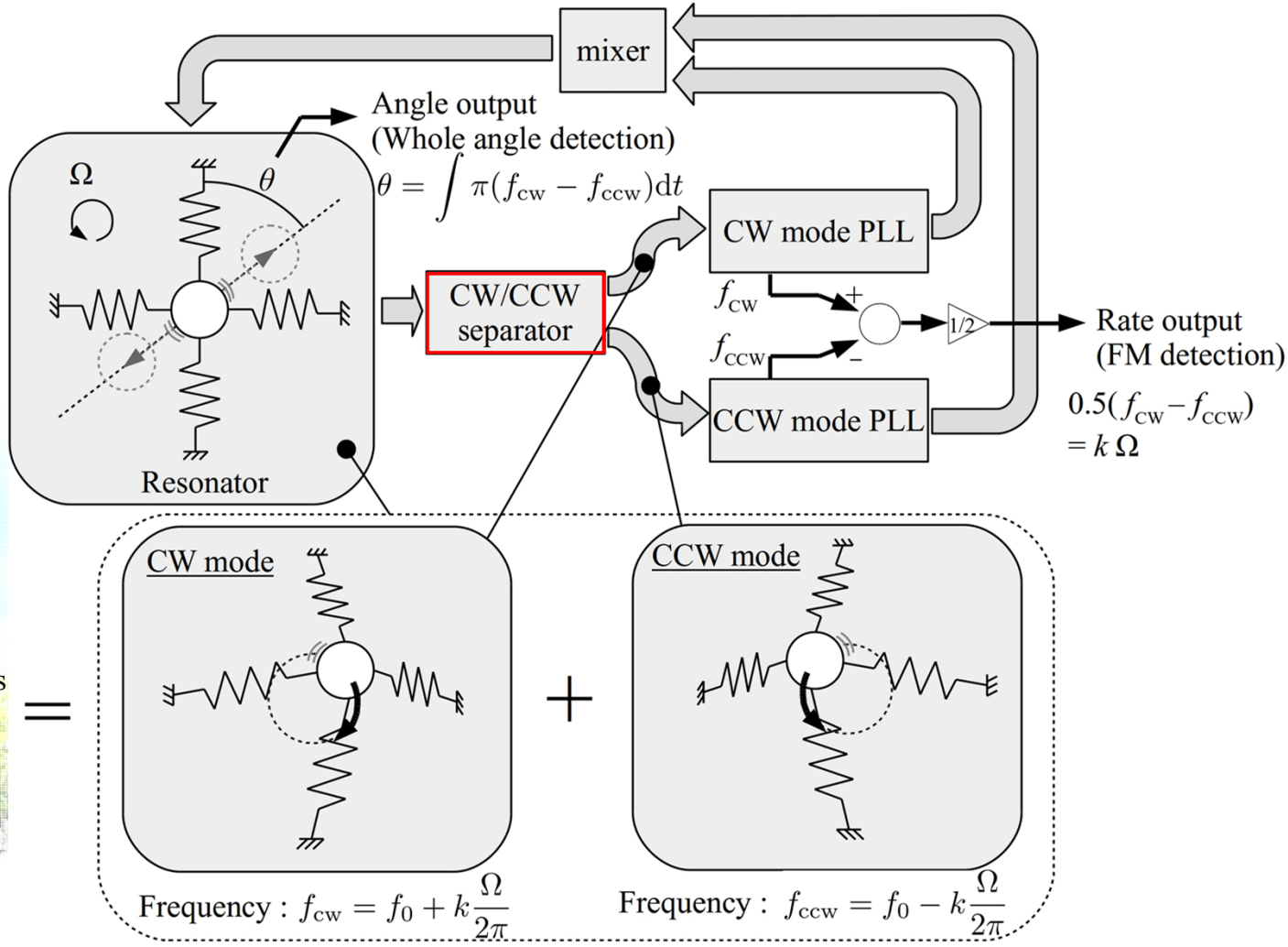
Challenges

- Symmetric 2-DOF MEMS resonator
  - Minimized frequency mismatch
  - Minimized Q mismatch
- In-run compensation of Q mismatch (under development)
- Oscillation of linear (free) vibration



Control system of Whole Angle Gyroscope with Mode Separator

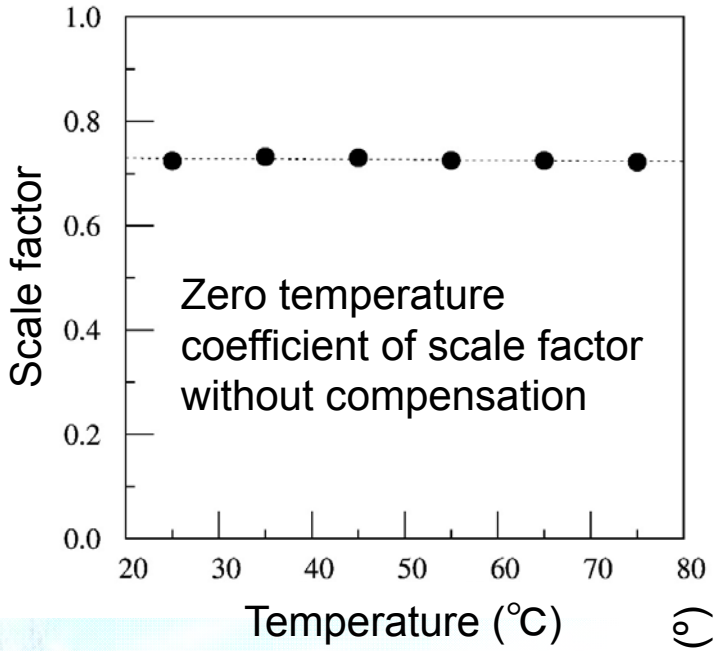
Silicon Sensing Systems



T. Tsukamoto, S. Tanaka, IEEE MEMS 2017, IEEE Inertial 2017

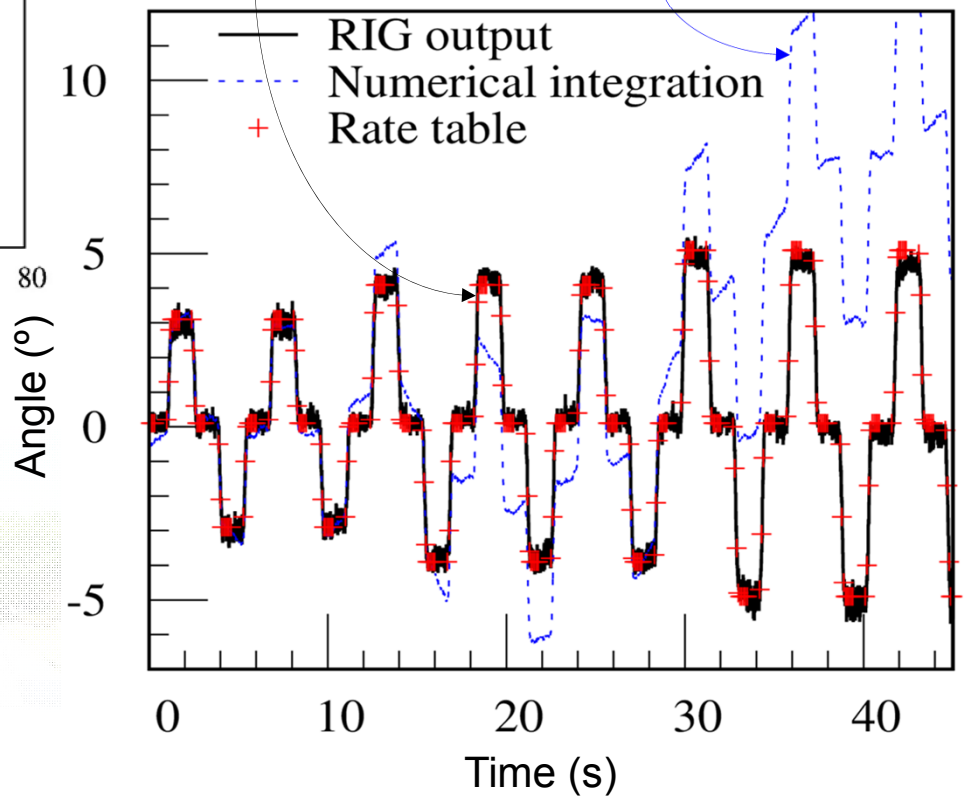
Demonstration of Whole Angle Gyroscope

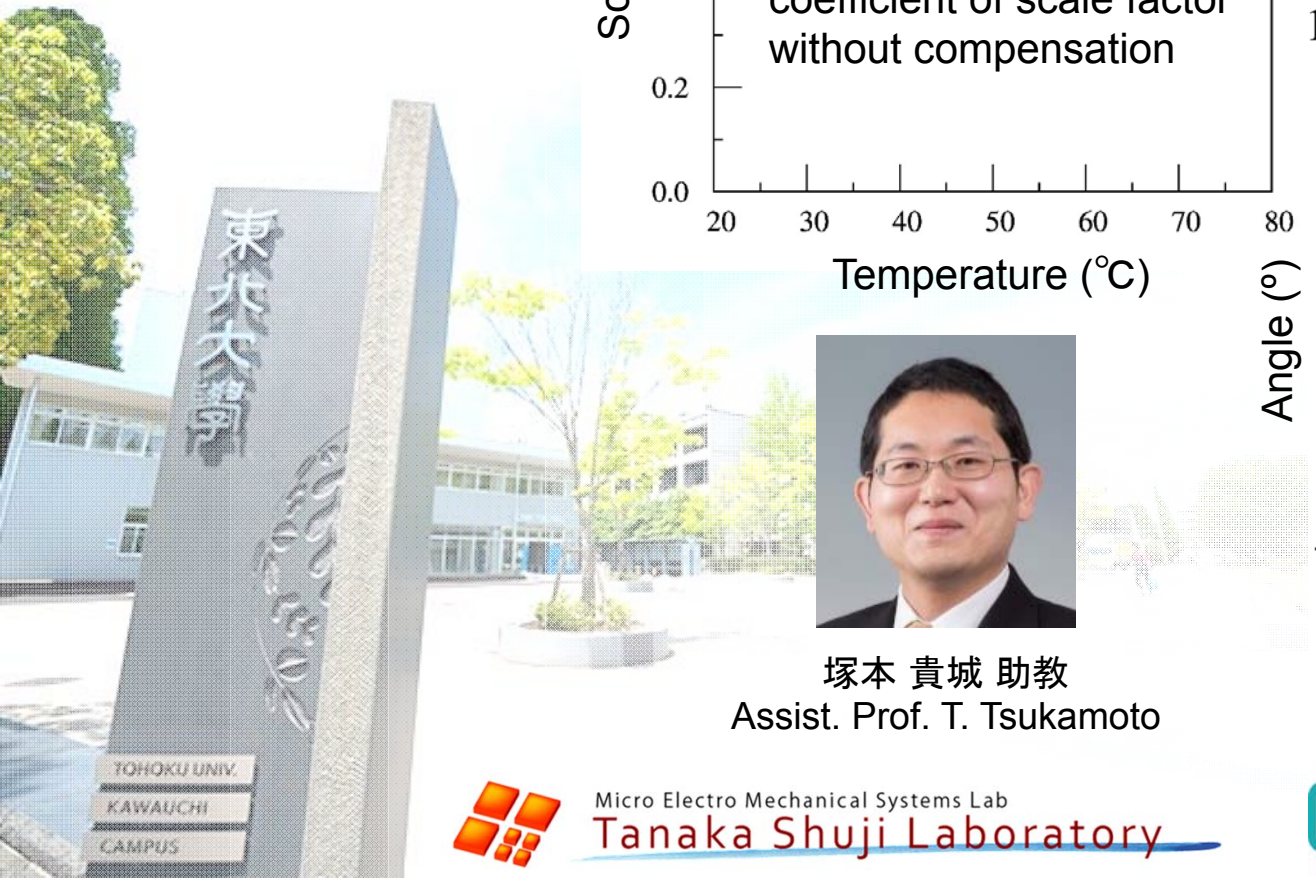
IEEE MEMS 2017, IEEE Inertial 2017



This work (WAG)
No error from rate table angle

Integration of angular rate measured by high performance MEMS gyro





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Assist. Prof. T. Tsukamoto

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Summary and Message

- The sensor platform LSI enables you to install a lot of sensors in a smarter way.
- The sensor platform LSI will be released as an ASSP. Potential users are welcome.

- The integrated tactile sensors using the platform LSI are ready for use.
- The wafer-level MEMS-LSI integration platform is now available for our customers.

- The whole angle MEMS gyroscope was demonstrated using our original control system.
- This control system is applicable to any types of symmetric gyroscope dies. Partners are welcome.

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Research menu in 2017

- Sensor systems for human-friendly robots
- Frequency control devices (SAW and BAW devices)
- Advanced inertial sensors
- Acoustic sensors
- Integrated biosensors
- Piezoelectric thin films and devices (Epitaxial PZT on Si)
- Heterointegration and wafer-level packaging technology
- MEMS process tools (ALD, wafer bonder etc.)