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The 11th IEEE International Symposium on Inertial Sensors & Systems

Hiroshima, Japan || March 25-28, 2024

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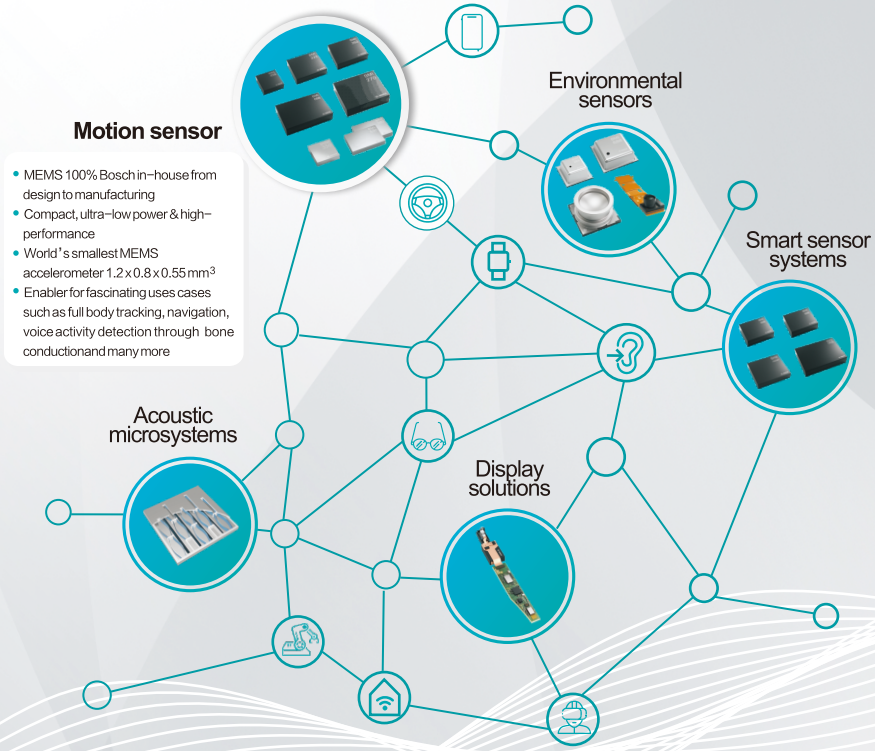

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Welcome Message

Dear Colleagues and Friends,

A heartfelt welcome to the 11th IEEE International Symposium on Inertial Sensors and Systems (IEEE INERTIAL'24) at the Grand Prince Hotel Hiroshima, Japan! We are delighted to have you join us for this momentous event. Notably, this conference marks a historic milestone as the first in-person IEEE INERTIAL conference held in Asia. This year's conference holds a special significance as the Grand Prince Hotel Hiroshima was originally planned to host the 2020 conference, which, regrettably, had to be canceled due to the unprecedented challenges posed by the COVID-19 pandemic.

This year's event continues our established tradition, started in 2014 in Laguna Beach, CA, USA of informal international meetings discussing the latest developments in the area of modern inertial sensors and emerging applications enabled by inertial sensors.

The IEEE INERTIAL is sponsored by the IEEE Sensors Council, overseen by the Technical Committee of Inertial Sensors and Systems (TCISS), and is the only IEEE event exclusively dedicated to inertial sensors and systems technology. Inertial technology is ubiquitous and its adoption continues to advance, thanks to the strong pull from the market that signals a strong and continuous growth in the year to come.

This year, we are excited to introduce two publication options for your contributions. You may choose (Option-A) to have your work published as a regular proceeding paper or (Option-B) as an "IEEE Sensors Letters" journal paper. We believe this dual-option approach provides flexibility and caters to the diverse preferences of our esteemed contributors.

The symposium is the go-to event of all inertial, giving the unique opportunity to connect with leaders in the field, and providing an informal atmosphere of focused international technical collaboration between industry, academia and research agencies and institutions. We aim for the breadth and depth of research and development topics, combined with the quality of invited and contributed technical presentations. This is what makes INERTIAL a 'must attend' event each year.

Our ambition remains committed in establishing IEEE as the premier forum for reporting the latest research, development, and commercialization results in modern inertial sensors technology. Throughout the conference, you will have the opportunity to hear from world experts on the latest advancements, innovative designs, and emerging applications.

The technical program spans four days, including tutorials, and maintains our commitment to a single-track conference with high-quality oral/ poster presentations and exhibitions. This year the organizing committee has made an effort to enrich the discussion with a diverse constellation of distinguished invited speakers and keynotes that will take us on a journey from the ancestral seafarer non-inertial

Welcome Message (cont.)

navigation techniques used by the Polynesians to the use of inertial technology for space exploration and quantum inertial sensors development.

The digest of technical papers for the 2024 IEEE Inertial Sensors will offer in-depth insights into the latest research presented during the symposium, with most papers available on IEEE Xplore after the event.

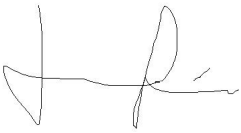
As we convene for IEEE INERTIAL'24, we extend our gratitude to the Oversight Committee, the Technical Program Committee of Inertial Sensors and Systems, the Technical Program Committee and the many experts who dedicated their time to evaluate submissions exceeding an average of 4 reviewers per paper in a single-blind review process. Special thanks to the IEEE Sensors Council for their sponsorship, and our patrons, exhibitors, and administrative support teams for their invaluable contributions.

Finally, we thank all speakers, presenters, and attendees for making the 2024 IEEE Inertial Sensors Symposium such a unique event. We hope that you find IEEE INERTIAL'24 professionally stimulating and enjoyable, and of course, we are looking forward to seeing you back next year for IEEE INERTIAL'25.

Welcome to IEEE-INERTIAL2024!

Sincerely,

Takashiro Tsukamoto
General Co-Chair
IEEE INERTIAL 2024



Joan Giner
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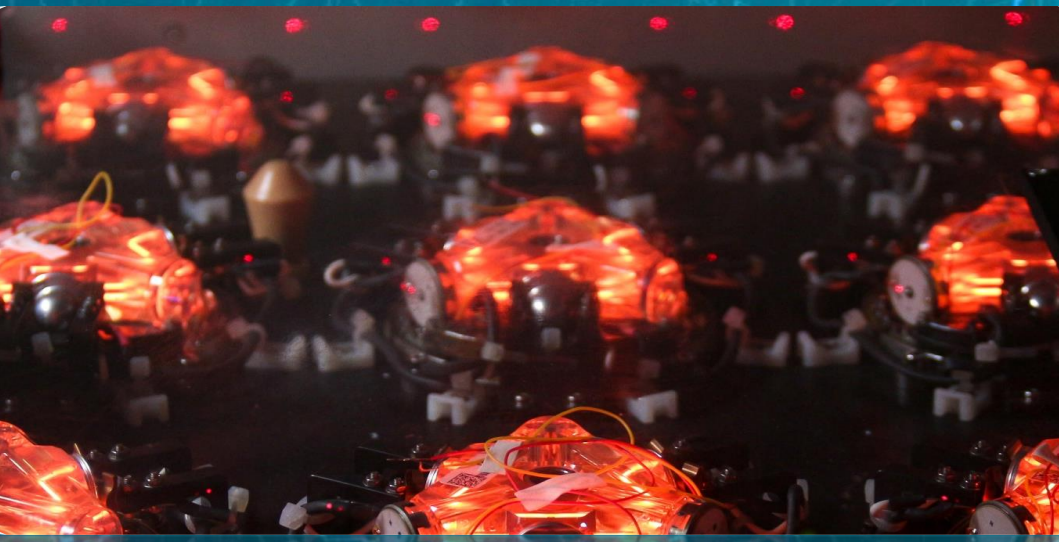

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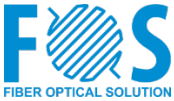

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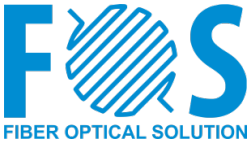

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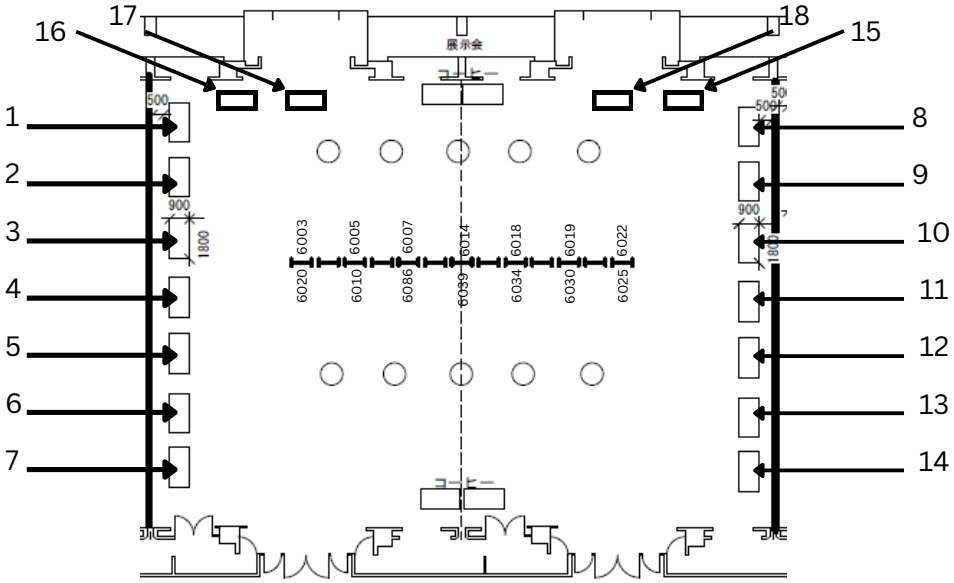
Poster Session I



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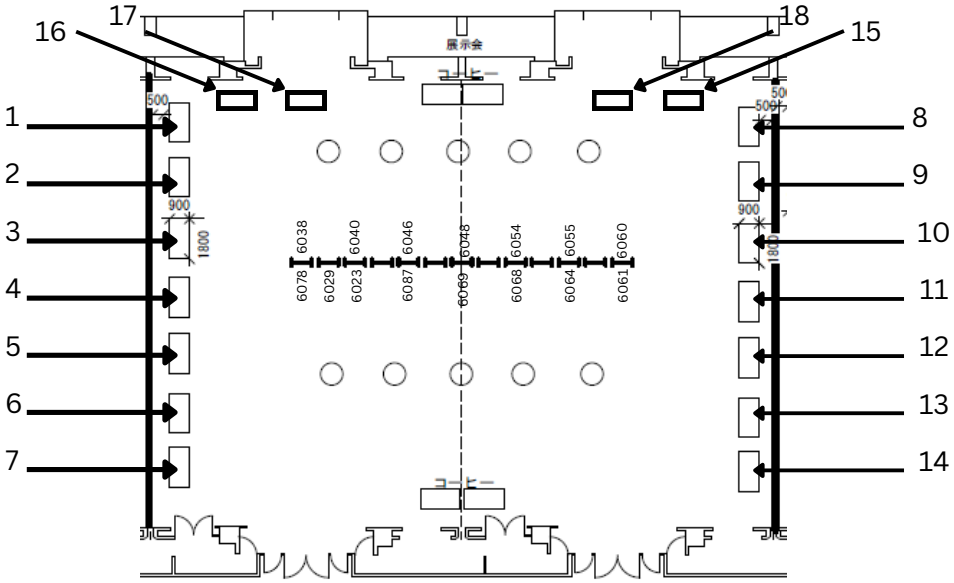
Poster Session II



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Tutorials

Monday, March 25th | 09:30 - 11:30 JST

Towards Chip-integrated Sagnac Gyroscopes

Room: Setouchi I
Instructor: Kerry Vahala, *Caltech, USA*

Abstract: Modern optical gyroscopes use long coiled optical fiber paths (fiber optic gyroscopes [1]) or resonant recirculation (ring laser gyroscopes [2]) to greatly enhance the Sagnac effect for rotation measurement. In recent years, the possibility of chip-based optical gyroscopes has garnered considerable attention. Such optical gyrocopes could enjoy the advantages of integration and scalable manufacturing, and would offer rugged designs for operation in challenging environments [3]. Compact or chip-based ring laser gyroscopes [4–6], passive resonant gyroscopes [7–10], and interferometric gyroscopes [11] have been reported. Here we first review some of the enabling technologies of chip-integrated designs, overview recent results, and then focus on a chip-based laser gyroscope that has been used to measure the Earth's rotation [6]. We conclude by considering prospects for boosting device performance based on recent measurements of optical loss in CMOS compatible dielectrics [12]. **[Read More]**

Monday, March 25th | 13:00 – 15:00 JST

Exploring the Mechanical Design of MEMS Gyroscopes: A Focus on the AM Mode split Architecture

Room: Setouchi I
Instructor: Gabriele Gattere, *STMicroelectronics, Switzerland*

Abstract: MEMS gyroscopes have become an integral part of many electronic devices, including smartphones, gaming controllers, and navigation systems. The AM mode split architecture is a widely used design for MEMS gyroscopes due to its high sensitivity and low noise. This architecture involves splitting the drive and sense modes with a frequency difference, which allows for better control of the mechanical resonances and improves the overall performance of the gyroscope.

This tutorial will provide an in-depth analysis of the mechanical aspects of MEMS gyroscopes, with a particular focus on the AM mode split architecture. It will cover the design principles, optimization techniques, and performance evaluation of MEMS gyroscopes. The tutorial will also discuss the challenges associated with the AM mode split architecture, such as sensor stability and spurious mode coupling, and outline possible solutions to address these challenges.

The presentation will be beneficial for researchers, engineers, and students who are interested in the design and optimization of MEMS gyroscopes using the AM mode split architecture. It will provide a comprehensive understanding of the mechanical aspects of MEMS gyroscopes and equip the attendees with the necessary knowledge and skills.

Tutorials (cont.)

Monday, March 25th | 15:30 – 17:30 JST

MEMS inertial Sensors and Their Application to Navigation

Room: Setouchi I
Instructor: Yasushi Tomizawa, *Toshiba, Japan*

Abstract: In recent years, efforts to create new businesses by incorporating location information of objects into IoT services as a new added value have been gaining momentum. This has created a need for technology to precisely measure the position and posture of objects for a variety of applications, such as position measurement of workers and unmanned vehicles in warehouses and factories, precise posture control of drones for infrastructure inspection and unmanned agricultural operations, and automatic operation of mobility vehicles.

GPS, which is commonly used for object positioning, lacks robustness to the environment, as it is extremely inaccurate or impossible to measure indoors, behind buildings, under bridges, and in tunnels, where satellite signals do not reach. Inertial navigation technology using inertial measurement units (IMUs), which are already widely used in the maritime, aerospace, satellite, and defense industries, is attracting attention as an alternative positioning technology. However, the size of the typical IMUs used in these applications is quite large (several 10 cm square) and extremely expensive (several hundred thousand dollars for high-end IMUs), so there is a mismatch between the size and price range that would be required for new market applications. The dynamic range (DR) of the measurement is also insufficient, especially for measuring objects that move violently in the air, such as drones.

Against this background, research and development is actively conducted to realize an ultra-compact, ultra-high-precision, ultra-wide DR, yet relatively inexpensive IMU using MEMS (Micro Electro-Mechanical Systems) technology. Toshiba is engaged in research and development of MEMS inertial sensors that, in principle, can achieve both high accuracy and wide DR, such as the Rate Integrating Gyroscope (RIG), which uses the Foucault pendulum principle to directly detect angle instead of angular velocity, and the Differential Resonant Accelerometer (DRA), which detects acceleration by the difference between the resonance frequencies of two resonant beams. In this tutorial, we will introduce the recent R&D trends toward higher accuracy and wider DR of MEMS inertial sensors, including these efforts above, as well as the application of these sensors to positioning for mobility.

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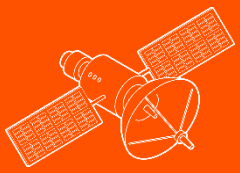

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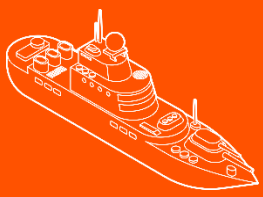

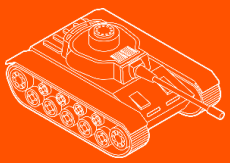

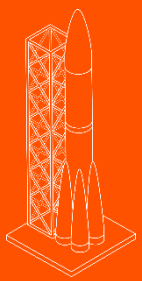

Keynotes

Tuesday, March 26th | 08:45 – 09:25 JST

The Last Navigator

Room: Setouchi I
Steve Thomas, *Emmy Award-winning TV Host, USA*

Abstract: Imagine navigating at sea using only the rising and setting points of the stars, the direction and intersection of ocean swells, and the flight paths of birds — no charts, compass, or instruments of any kind, just the sea's own signs of land.

Steve Thomas is best known as the two-time Emmy Award winning host of PBS's "This Old House," the History Channel's "Save Our History," and Discovery's "Renovation Nation." The other track in his life has been ocean voyaging and navigation. After college he crewed on a racing yacht out to Hawaii, was first-mate of a 103 foot schooner and other vessels in the Mediterranean, and then sailed a 43 foot sloop from England to San Francisco via the Panama Canal, Galapagos, Marquesas and Hawaii.

In 1983 and 1984 he undertook an ambitious project to study traditional Oceanic "Star Path" navigation on the remote Micronesian island of Satawal with Mau Piailug, last of the fully initiated Star Path Navigators, or Ppalu. Over the course of two years of fieldwork he learned Satawalese and was trained in secret navigational lore not taught to another Westerner. **[Read More]**

Keynotes (cont.)

Tuesday, March 26th | 11:25 - 12:05 JST

Progress in the Development of Space Inertial Sensor for TianQin Project

Room: Setouchi I
Ze-Bing Zhou, *Huazhong University of Science and Technology, China*

Abstract: TianQin is a Chinese space-borne gravitational wave detector proposed in 2014, and aims to detect gravitational waves in the frequency range 10^{-4} ~ 1 Hz, with three earth orbiting satellites with an orbital radius of about 10^5 km forming an equilateral triangle with side length 1.7×10^5 km. The test mass of inertial sensor is used as an inertial reference to provide measurement endpoints and reference points for intersatellite laser interferometry, and the residual acceleration noise in the direction of the sensitive axis (intersatellite link) must be not exceed 10^{-15} $(m/s^2)/\sqrt{Hz}$ within the detection band for TianQin. In this talk, we will give the requirement analysis for TianQin inertial sensor, and current progress, such as the design and manufacture of the test mass, the capacitance sensing and electrostatic control, the charge management, and the performance test with torsion pendulum on the ground and flight validation.

Wednesday, March 27th | 08:45 - 09:25 JST

Quantum Inertial: Rising from the Trough of Disillusionment

Room: Setouchi I
John Burke, *Office of the Undersecretary of Defense (OUSD) (R&E) (S&T), USA*

Abstract: Years before we started up the Gartner hype cycle for quantum computing, the inertial community endured another quantum hype cycle: “cold atom interferometers”. We will look back at where the hype came from and the technical challenges to making progress. The trough of disillusionment bottomed out around five years ago or around the time that Frank Narducci, Adam Black, and I wrote our review paper, in part about these technical challenges. One pandemic later, however, practical progress is being made. The presentation will cover recent technical progress including an upcoming space flight experiment of a system with real-world relevance. Finally, we discuss technical and non-technical lessons learned.

Keynotes (cont.)

Thursday, March 28th | 08:45 - 09:25 JST

Inertial Sensor Applications for Satellites and a Luna Lander

Room: Setouchi I
Shin-ichiro Sakai, *Japan Aerospace Exploration Agency (JAXA), Japan*

Abstract: Space applications for inertial sensors will be discussed based on actual space missions. Attitude control is one of the key functions for artificial satellites, and gyroscopes play a key role. Appropriate gyros are selected to meet the mission requirements and resource constraint from various types, such as mechanical gyros, vibrating structure gyros, MEMS gyros and fiber optical gyros.

The output of gyroscope is used as angular velocity information and to propagate satellite's attitude, and some absolute attitude sensors, such as star trackers, are combined for the correction. Similar configuration appears in the guidance, navigation and control system for luna or planet landers. SLIM (Smart Lander for Investigating Moon) is a small lunar lander to demonstrate precise landing technology, developed by Japan Aerospace Exploration Agency (JAXA), launched on 2023/9/7. To achieve very precise 100m landing ellipses, navigation accuracy is essentially important. Lander position is propagated using onboard accelerometer, and corrected with vision-based navigation system at several timing. In this presentation, we will also discuss about which features of the inertial sensors are important for these types of applications.

Invited Speakers

Tuesday, March 26th | 14:00 – 14:40 JST

Technical Challenges and Possible Solutions for Development of CMOS-MEMS and Piezoelectric MEMS Accelerometers

Room: Setouchi I
Sheng-Shian Li, *Institute of NanoEngineering and MicroSystems, Department of Power Mechanical Engineering, National Tsing Hua University, Taiwan*

Abstract: A technical presentation on the development of CMOS-MEMS and piezoelectric MEMS accelerometers, including design, modeling, simulation, fabrication, and testing, will be delivered. A special focus lies on the challenges we encountered during the development phase, such as in (i) device level: design trade-off, thin-film residual stress, fabrication imperfection/variation, etc.; (ii) interfaced circuit level: biasing issue, dc drift on high impedance node, low-corner frequency and bandwidth, etc.; (iii) sensing module level: packaging issues, spurious resonance from PCB/packaging, non-uniform frequency response, calibration, etc. Some potential approaches will be elaborated to address the aforementioned technical challenges. Finally, I will briefly introduce the applications of our developed MEMS vibration sensing module (accelerometer) in it's *a*-site and *b*-site verifications.

Wednesday, March 27th | 11:10 – 11:40 JST

Quantum sensors for long-duration navigation without GNSS

Room: Setouchi I
Patrick Everitt, *Q-CTRL, Australia*

Abstract: Q-CTRL is Australia's first VC-backed quantum technology company. In this talk, we present results and demonstrations of Q-CTRLs deployable quantum inertial sensors and recent improvements to their robustness and performance using quantum control, including a sensitivity increase of 23x when undergoing laser fluctuations corresponding to platform dynamics of order 1g.

Invited Spekaers (cont.)

Wednesday, March 27th | 14:10 – 14:40 JST

Vibrating Beam MEMS Accelerometers for Gravimetry and Inertial Navigation

Room: Setouchi I
Ashwin A. Seshia, *University of Cambridge, Silicon Microgravity Ltd., UK*

Abstract: MEMS vibrating beam accelerometers operate on the principle of tracking shifts in the resonant frequencies of one or more micromachined vibrating elements coupled to a proof mass in response to changes in external acceleration. The resonant MEMS transduction approach offers scale-invariant mechanical sensitivity, extended mechanical bandwidth and dynamic range, and highly stable tracking of inertial forces. The development of highly accurate MEMS vibrating beam accelerometers (VBAs) has seen significant progress in recent years with application to the fields of gravimetry and inertial navigation. This talk will present the development of a first-of-its-kind resonant MEMS gravimeter with a resolution of less than 5 microGal and an emerging class of silicon MEMS VBAs for inertial navigation with performance benchmarking favorably with respect to the state-of-the-art.

Thursday, March 28th | 11:15 – 11:45 JST

Technologies for High Performance MEMS IMU Sensors

Room: Setouchi I
Anssi Blomqvist, *Murata Electronics Oy, Finland*

Abstract: Many applications in mobility and industrial machinery markets require reliable and robust IMU's which maintain low noise and high accuracy operation in harsh environments. To reach high volume business required for MEMS, targets should be achieved with low-cost and compact solutions. This talk will provide some insight in Murata's unique MEMS technology and innovative 3-axis sensor concepts behind new High Performance 6 Degrees of Freedom Sensor product.

MONDAY, MARCH 25, 2024

TIME	SESSION
8:30 - 9:30	Tutorial Registration
9:30 - 11:30	Tutorial: Towards Chip-Integrated Sagnac Gyroscopes
11:30 - 13:00	Lunch
13:00 - 15:00	Tutorial: Exploring the Mechanical Design of MEMS Gyroscopes: A Focus on the AM Mode Split Architecture
15:00 - 15:30	Coffee Break
15:30 - 17:30	Tutorial: MEMS inertial Sensors and Their Application to Navigation
18:00 - 20:00	Ideal Aerosmith Welcome Reception

TUESDAY, MARCH 26, 2024

TIME	SESSION
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8:45 - 9:25	Keynote: The Last Navigator
9:25 - 10:25	Sensor Compensation & Self Calibration
10:25 - 10:55	Exhibitors Lightning Round
10:55 - 11:25	Coffee Break & Exhibits
11:25 - 12:05	Keynote: Progress in the Development of Space Inertial Sensors for the TianQin Project
12:05 - 12:45	Optical Sensors
12:45 - 14:10	IAI Lunch
14:10 - 14:40	Invited: Technical Challenges & Possible Solutions for Development of CMOS-MEMS and Piezoelectric MEMS Accelerometers
14:40 - 15:40	Packaging & Stress Mitigation
15:40 - 16:10	Posters Lightning Round
16:10 - 16:25	Wrap up
16:25 - 16:55	Coffee Break & Exhibits
16:55 - 18:00	Poster Session One
18:00 - 19:30	Sponsor Appreciation Social

WEDNESDAY, MARCH 27, 2024

TIME	SESSION
7:30 - 8:30	Registration
8:30 - 8:45	Opening Remarks
8:45 - 9:25	Keynote: Quantum Inertial: Rising from the Trough of Disillusionment
9:25 - 9:55	Invited: Quantum sensors for long-duration navigation without GNSS
9:55 - 10:55	Quantum/Atomic Sensors
10:55 - 11:25	Coffee Break & Exhibits
11:25 - 11:45	INERTIAL 2025 Announcement
11:45 - 12:45	Sensor Phenomena
12:45 - 14:10	Lunch
14:10 - 14:40	Invited: Vibrating Beam MEMS Accelerometers for Gravimetry and Inertial Navigation
14:40 - 15:40	Advanced System Architectures
15:40 - 16:10	Posters Lightning Round
16:10 - 16:25	Wrap up
16:25 - 16:55	Coffee Break & Exhibits
16:55 - 18:00	Poster Session Two
18:30 - 20:30	Gala Dinner

THURSDAY, MARCH 28, 2024

TIME	SESSION
7:30 - 8:30	Registration
8:30 - 8:45	Opening Remarks
8:45 - 9:25	Keynote: Inertial Sensor Applications for Satellites and a Lunar Lander
9:25 - 10:25	Test & Calibration
10:25 - 10:55	Coffee Break & Exhibits
10:55 - 11:25	Invited: Technologies for High Performance MEMS IMU Sensors
11:25 - 12:45	MEMS Sensors
12:45 - 14:10	Lunch
14:10 - 15:10	Late News
15:10 - 15:40	Closing Remarks/Award Ceremony

Technical Program: 25 March 2024

**All times appear in Japan Standard Time (JST) GMT+9)*

8:30 – 9:30
Registration
Room: Setouchi Foyer

9:30 – 11:30
Tutorial: Towards Chip-integrated Sagnac Gyroscopes
Kerry Vahala, *Caltech*
Room: Setouchi I
Session Chair: Tamio Ikehashi, Waseda University, Japan

11:30 – 13:00
Lunch
Room: Setouchi III

13:00 – 15:00
Tutorial: Exploring the Mechanical Design of MEMS Gyroscopes: A Focus on the AM Mode Split Architecture
Gabriele Gattere, *STMicroelectronics*
Room: Setouchi I
Session Chair: Tamio Ikehashi, Waseda University, Japan

15:00 – 15:30
Coffee Break
Room: Setouchi Foyer

15:30 – 17:30
Tutorial: MEMS Inertial Sensors and Their Application to Navigation
Yasushi TOMIZAWA, *Toshiba*
Room: Setouchi I
Session Chair: Tamio Ikehashi, Waseda University, Japan

18:00 – 20:00
Ideal Aerosmith Welcome Reception
Room: Suite Des Fleurs
**Open to everyone*

IDEAL AEROSMITH

All times appear in Japan Standard Time (JST) GMT+9)

7:30 – 8:30
Registration
Room: Setouchi Foyer

8:30 – 8:45
Opening Remarks
Room: Setouchi I

8:45 – 9:25
Keynote: The Last Navigator
Steve Thomas, *Emmy Award-winning TV Host of This Old House, Renovation Nation, & Save Our History*
Room: Setouchi I
Session Chair: Joan Giner, Bosch Sensortec

9:25 – 10:25
A1L-A: Sensor Compensation & Self Calibration
Room: Setouchi I
Session Chair: Paola Carulli, STMicroelectronics

9:25
6044: North Finding IMU with Electromagnetic MEMS Gyroscope and Mode Reversal Technique
Ryuta Araki, Ryohei Uchino, Takafumi Moriguchi
Sumitomo Precision Products Co., Ltd., Japan

9:45
6024: Vibration Rectification Error Reduction in MEMS Vibrating Beam Accelerometers by Using the F-Squared Method
Theo Miani{1}, Lokesh Gurung{1}, Guillermo Sobreviela-Falces{1}, Douglas Young{1}, Colin Baker{1}, Ashwin Seshia{2}
{1}Silicon Microgravity Ltd, United Kingdom; {2}University of Cambridge, United Kingdom

10:05
6006: Auxiliary Gyroscope Approach for Balanced Performance via Gyro Self-Calibration
John Liu
Jet Propulsion Laboratory, United States

10:25 – 10:55
Exhibitor Lightning Round
Room: Setouchi I
Session Chair: Diego Serrano, Panasonic

10:55 – 11:25
Coffee Break & Exhibits
Room: Setouchi II

11:25 – 12:05
Keynote: Progress in the Development of Space Inertial Sensor for TianQin Project
Ze-Bing Zhou. *Huazhong University of Science and Technology*
Room: Setouchi I
Session Chair: Zhipeng Ma, Zhejiang University

12:05 – 12:45
A2L-A: Optical Sensors
Room: Setouchi I
Session Chair: Edward Ohad Zohar, Smart Systems Pte Ltd.

12:05
6065: Optical Fiber Displacement Sensor Array with Reduced Sampling Rate for Gravitational Reference Sensor
Junhui Wu, Zhilin Xu, Yi Shi, Qi Xia, Yurong Liang, Zebing Zhou
Huazhong University of Science and Technology, China

12:25
Sensors Letters Paper
6080: Detection Schemes for Two-Mode Squeezed Fiber Optic Sagnac Interferometry
Patrick Tritschler{1}, Torsten Ohms{1}, Peter Degenfeld-Schonburg{2}, Fabian Zschocke{2}, André Zimmermann{3}
{1}Bosch Sensortec GmbH, Germany; {2}Robert Bosch GmbH, Germany; {3}University of Stuttgart, Germany

12:45 – 14:10
IAI Lunch Break
Room: Setouchi III

14:10 – 15:40
A3L-A: Packaging & Stress Mitigation
Room: Setouchi I
Session Chair: Joan Giner, Bosch Sensortec

14:10
Invited: Technical Challenges and Possible Solutions for Development of CMOS-MEMS and Piezoelectric MEMS Accelerometers
Sheng-Shian Li, Institute of NanoEngineering and MicroSystems, Department of Power Mechanical Engineering, National Tsing Hua University, Hsinchu

14:40
6043: Improving the Temperature Stability of MEMS Gyroscope Bias with On-Chip Stress Sensors
Derin Erkan, Erdinc Tatar
Bilkent University, Turkey

15:00
Sensors Letters Paper
6073: Facile Packaging for Fiber-Shaped Flexible MEMS Thermal Accelerometer
Muhammad Salman Al Farisi, Yang Wang, Yoshihiro Hasegawa, Mitsuhiro Shikida
Hiroshima City University, Japan

15:20
Sensors Letters Paper
6079: Investigating the Effects of Stress on Die Deformation and on Cross-Axis Offset Drift in Mode-Split MEMS Gyroscopes
Wolfram Mayer{2}, Burkhard Kuhlmann{1}, Tobias Hiller{3}, Thorsten Balslink{3}, Ulrich Kunz{3}, André Zimmermann{4}
{1}Bosch Sensortec GmbH, Germany; {2}Bosch Sensortec GmbH, University of Stuttgart, Germany; {3}Robert Bosch GmbH, Germany; {4}University of Stuttgart, Germany

15:40 – 16:10
Poster Lightning Round I
Room: Setouchi I
Session Chair: Giacomo Langfelder, Politecnico di Milano

16:10 – 16:25
Wrap Up
Room: Setouchi I

16:25 – 16:55
Coffee Break & Exhibits
Room: Setouchi II

16:55 – 18:00
A4P-B: Poster Session I
Room: Setouchi II
Session Chair: Giacomo Langfelder, Politecnico di Milano

6003: Symbolic Simulation of Sensor Trimming Algorithms Using Affine Arithmetic
Alexandra Küster{1}, Rainer Dorsch{1}, Christian Haubelt{2}
{1}Bosch Sensortec GmbH, Germany; {2}University of Rostock, Germany

6005: GNSS-Denied Pedestrian Navigation Using Machine Learning Aided Gait Recognition
Minhdao Nguyen, Roger Sengphanith, Jeffrey Onners
Naval Information Warfare Center Pacific, United States

6007: Active Probe Card for Multi-Parameter Fast Characterization of MEMS Gyroscope at Wafer-Level
Yang Zhao, Qin Shi, Guoming Xia, Jinyang Huang, Anping Qiu
Nanjing University of Science and Technology, China

6014: A Mode-Localized Resonant Accelerometer Based on a Novel Micro-Lever Coupler Resistant to Manufacture Process Defects
Bowen Wang{3}, Kunfeng Wang{3}, Zheng Wang{1}, Xingyin Xiong{2}, Zhaoyang Zhai{3}, Wuhao Yang{2}, Xudong Zou{4}
{1}QiLu Aerospace Information Research Institute, China; {2}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CAS, China; {3}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CA

6018: Robust High-G Microaccelerometers with Mechanical Low-Pass Filters and Electrical ROIC
Yebin Choi{3}, Minho Seok{3}, Song-I Cheon{3}, Minkyu Je{3}, Young-Ho Cho{4}, Sehwan Song{2}, Sang-Hee Yoon{2}, Kilyug Kim{1}, Won-Young Uhm{1}, Junyong Jang{1}, Yongjun Cho{1}, Myung-Suk Jung{1}
{1}Agency for Defense Development, Korea; {2}Inha University, Korea; {3}Korea Advanced Institution of Science and Technology, Korea; {4}Korea Advanced Institution of Science and Technology & Nextreme Inc., Korea

6019: On the Optimal Measurement Time in North-Finding Procedures Using Maytagging
Bernard Vau, Mehdi Bussutil, Colin Stevens, Romain Daudigny
Exail, France

6022: A Low Noise Full Digital Phase-Locked Loop with Feedthrough Suppression Technology for Resonant Accelerometer
Bingchen Zhu{3}, Liangbo Ma{2}, Xingyin Xiong{1}, Xudong Zou{3}
{1}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CAS, China; {2}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CAS, UCAS, China; {3}State Key Laboratory of Transducer Tec

6025: Characterization of a Passive 3×3 Fiber Optic Gyroscope for Cryogenic Applications at Liquid Nitrogen Temperatures
Frank Windeck, Martin Tajmar
Technische Universität Dresden, Germany

6030: Mode-Matched Disk Resonator Gyroscope in (100) Single Crystal Silicon with Shock Resistance
Zhaoyang Zhai{2}, Xingyin Xiong{1}, Liangbo Ma{2}, Wuhao Yang{1}, Bowen Wang{2}, Zhenxiang Qi{2}, Xudong Zou{3}
{1}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CAS, China; {2}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CAS, UCAS, China; {3}State Key Laboratory of Transducer Tec

6034: High-Performance Navigation Grade Resonant Beam MEMS Accelerometers
Lokesh Gurung{1}, Theo Miani{1}, Guillermo Sobreviela-Falces{1}, Douglas Young{1}, Colin Baker{1}, Ashwin Seshia{2}
{1}Silicon Microgravity Ltd, United Kingdom; {2}University of Cambridge, United Kingdom

6039: Technology Platform for High Performance MEMS Inertial & Vibration Sensors
Beatrice Wenk, Joël Collet, Vincent Gaff
Tronics Microsystems, France

6086: Simulation-Based Approach in Design of Low Stress Bowl-Shaped Micro Hemispherical Resonators
Yinan Zhang{2}, Bin Zhou{2}, Ruixue Zhang{2}, Haoyu Gu{1}, Qi Wei{2}, Rong Zhang{2}
{1}Suzhou Raysen Microsystem Technology Co., Ltd, China; {2}Tsinghua University, China

6010: Frequency-Comb-Like Behavior in a Resonant MEMS Accelerometer Subject to Blue Sideband Excitation
Jingqian Xi{1}, Jiao Xu{1}, Ziqian Zhang{1}, Erion Uka{5}, Huafeng Liu{1}, Jianlin Chen{2}, Chen Wang{3}, Michael Kraft{3}, Pui-In Mak{4}, Yuan Wang{4}, Chun Zhao{5}
{1}Huazhong University of Science and Technology, China; {2}Shanghai University, SIMIT, China; {3}University of Leuven, Belgium; {4}University of Macau, China; {5}University of York, United Kingdom

6020: Bridging Piezoelectric and Electrostatic Effects: A Novel Pitch/Roll Gyroscope
Zhenxiang Qi{3}, Zhaoyang Zhai{3}, Bowen Wang{3}, Wuhao Yang{2}, Xingyin Xiong{2}, Zheng Wang{1}, Haoqi Lv{3}, Xiaorui Bie{2}, Xudong Zou{4}
{1}QiLu Aerospace Information Research Institute, China; {2}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CAS, China; {3}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CA

18:00 – 19:30
Patron & Exhibitor Appreciation Social/ Open Posters
Room: Setouchi II

*Open to everyone

All times appear in Japan Standard Time (JST) GMT+9)

7:30 – 8:30
Registration
Room: Setouchi Foyer

8:30 – 8:45
Opening Remarks & IEEE Sensors Council President Address
Room: Setouchi I

8:45 – 9:25
Keynote: Quantum Inertial: Rising from the Trough of Disillusionment
John Burke, *Office of the Undersecretary of Defense (OUSD (R&E)) (S&T)*
Room: Setouchi I
Session Chair: Diego Emilio Serrano, Panasonic

9:25 – 10:55
B1L-A: Quantum/Atomic Sensors
Room: Setouchi I
Session Chair: Susannah Jones, Defence Science and Technology Laboratory

9:25
Invited: Quantum Sensors for Long-Duration Navigation Without GNSS
Patrick Everitt, Q-CTRL

9:55
6041: A Dual Atomic Interferometric Inertial Sensor Utilizing Transversely Cooled Atomic Beams
Weichen Jia, Peiqiang Yan, Shengzhe Wang, Yanying Feng
Tsinghua University, China

10:15
6051: A Quantum Matterwave Vortex Gyroscope
Ryan Husband, Samuel Legge, Simon Haine, Ryan Thomas, John Close
Australian National University, Australia; Australian National University, Canada

10:35
6058: Real-Time Scale-Factor Calibration for Cold-Atom Gyroscope Based on Point-Source Interferometry
Nikolaos Dedes{2}, David Harvey{1}, Tim Freegarde{2}
{1}Thales UK, United Kingdom; {2}University of Southampton, United Kingdom

10:55 – 11:25
Coffee Break & Exhibits
Room: Setouchi II

11:25 – 11:45
INERTIAL 2025 Announcement
Room: Setouchi I
Session Chair: Joan Giner, INERTIAL 2025 General Chair

11:45 – 12:45
B2L-A: Sensor Phenomena
Room: Setouchi I
Session Chair: Sheng-Shian Li, National Tsing Hua University

11:45
6009: Angle White Noise in Vibratory Rate Gyroscopes
Diego Emilio Serrano
Panasonic Massachusetts Laboratory, United States

12:05
6070: On Temperature Effects in a MEMS Ring Gyroscope
Mehran Hosseini Pishrobat, Derin Erkan, Erdinc Tatar
Bilkent University, Turkey

12:25
Sensors Letters Paper
6077: Split Is Not Dead: A Case Study on the Performance Gap Between MEMS Automotive-Grade Gyroscopes and High-End Applications
Marco De Pace{2}, Paolo Frigerio{2}, Carlo Valzasina{3}, Luca Falorni{3}, Pietro Peliti{1}, Valentina Zega{2}, Giacomo Langfelder{2}
{1}Northorp Grumman Italia, Italy; {2}Politecnico di Milano, Italy; {3}STMicroelectronics, Italy

12:45 – 14:10
Lunch
Room: Setouchi III

14:10 – 15:40
B3L-A: Advanced System Architectures
Room: Setouchi I
Session Chair: Marius Gheorghe, Ideal Aerosmith

14:10
Invited: Vibrating Beam MEMS Accelerometers for Gravimetry and Inertial Navigation
Ashwin A. Seshia, University of Cambridge and Silicon Microgravity Ltd.

14:40
6021: Upgrading a Gyroscope from a Lab-Based Setup Into a Pre-Industrial Demo: Challenges and Lessons Learned
Andrea Buffoli{2}, Philippe Robert{1}, Giacomo Langfelder{2}
{1}CEA-Leti, France; {2}Politecnico di Milano, Italy

15:00
Sensors Letters Paper
6072: AutoML for On-Sensor Tiny Machine Learning
Mahesh Chowdhary, Derek Lilienthal, Swapnil Sayan Saha, Krishna Chaitanya Palle Hayagreeva
STMicroelectronics, United States

15:20
Sensors Letters Paper
6075: The Extended Kalman Filter with Reduced Computation Time for Pedestrian Dead Reckoning
Shunsei Yamagishi, Lei Jing
University of Aizu, Japan

15:40 – 16:10
Poster Lightning Round II
Room: Setouchi I
Session Chair: Zhipeng Ma, Zhejiang University

16:10 – 16:25
Wrap Up
Room: Setouchi I

16:25 – 16:55
Coffee Break & Exhibits
Room: Setouchi II

16:55 – 18:00
B4P-B: Poster Session II
Room: Setouchi II
Session Chair: Zhipeng Ma, Zhejiang University

6038: A High Sensitivity MEMS Gravimeter with Electrically Tunable Stiffness
Chengzhi Yi, Jun Wu, Tamio Ikehashi
Waseda University, Japan

6040: Theoretical Analysis of (100) Silicon Ring Gyroscope with Chamfered Rectangle Springs
Ayumu Takahashi, Shuya Okayama, Amit Banerjee, Jun Hirotani, Toshiyuki Tsuchiya
Kyoto University, Japan

6046: Enhancement of Frequency and Amplitude Stability in a Bulk Acoustic Wave Resonator Based on Amplitude Saturation
Zhaoyang Zhai{3}, Xingyin Xiong{2}, Liangbo Ma{3}, Zheng Wang{1}, Bowen Wang{3}, Zhenxiang Qi{3}, Xudong Zou{4}
{1}QiLu Aerospace Information Research Institute, China; {2}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CAS, China; {3}State Key Laboratory of Transducer Technology, Aerospace Information Research Institute, CA

6048: Navigation Grade Lowest CSWaP Single Proof Mass MEMS 3-Axis Accelerometer
Robert Boysel, Louis Ross
MEI Micro, Inc., United States

6054: Stress Reduction by Indirect Bonding Configuration
Shih-Wei Lee, Chao-Shiun Wang
Sensortek Technology Cooperation, Taiwan

6055: MEMS Underwater Acoustic Vector Sensor Operating in Near Neutral Buoyancy Configuration
Justin Ivancic, Jeffrey Catterlin, Fabio Alves
Naval Postgraduate School, United States

6060: The GYTRIX Quartz Crystal Axisymmetric MEMS GYRO: Preliminary Measurements
Jean Guérard, Maxime Duquesnoy, Olivier Le Traon, Pierre Lavenus, Amandine Andrieux Ledier, Raphael Levy, Jeremy Bonhomme
ONERA, Université Paris-Saclay, France

6061: Single Crystal Lithium Niobate Cylindrical Resonator for High-Performance Miniature Piezoelectric Gyroscope
Kenji Morita{1}, Toshiyuki Tsuchiya{1}, Kazutaka Araya{3}, Tsunehiko Imamura{3}, Masanori Yachi{2}
{1}Kyoto University, Japan; {2}Tamagawa Mobile Equipment Company Ltd., Japan; {3}Tamagawa Seiki Company Ltd., Japan

6064: Nano-G Optical Fiber Accelerometer with Double-Leaf Spring Structure
Yi Shi, Hongbo Duan, Xiaoyun Wang, Zhilin Xu, Qizhen Sun, Yurong Liang, Zebing Zhou
Huazhong University of Science and Technology, China

6068: A CNN-LSTM Model for IMU-Based Energy Expenditure Estimation Under Various Walking Conditions
Chang June Lee, June Keun Lee
Hankyong National University, Korea

6069: Map-Based Inertial Navigation for GNSS-Free and Safe Train Localization
Pierre d'Harcourt{1}, Jean-Philippe Michel{1}, Laurent Poletti{1}, Sophie Glevarec{1}, Juliette Marais{2}
{1}Exail, France; {2}Gustave Eiffel University, France

6087: Real Time Mismatch Monitoring Using Software Defined Frequency Modulation and Rate Integrating Gyroscope
Takashiro Tsukamoto{1}, Fumito Miyazaki{2}, Yasushi Tomizawa{2}, Shuji Tanaka{1}
{1}Tohoku University, Japan; {2}Toshiba Corporation, Japan

6023: Nonlinearity Identification of an Integrated Packaged Micro Gyro Operated in a Closed Loop Mode
Naftaly Krakover{1}, Yaron Zimmerman{1}, Ronen Maimon{1}, Eldad Yichie{1}, Danny A. Kassie{1}, Slava Krylov{2}
{1}Rafael Advanced Defense Systems, Israel; {2}Tel Aviv University, Israel

6029: High Q-Factor and Mode-Matching Disk Ring Gyroscope Using (100) Single Crystal Silicon
Tiantian Wang{3}, Congchen Wang{3}, Junying Yang{3}, Jianlin Chen{3}, Fang Chen{1}, Tao Wu{4}, Nan Wang{2}
{1}Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, China; {2}Shanghai University, Shanghai Key Laboratory of Chips and Systems for Intelligent Connected Vehicle, China; {3}Shanghai University, SIMIT, China; {4}Sh

6078: Strength Differences of Lateral, Top and Bottom Surface in Monocrystalline Silicon Micromachining
Sara Cozzi{1}, Roberto Martini{2}, Francesco Coppo{2}, Giacomo Langfelder{1}, Edoardo Belloni{2}, Stefano Dellea{2}, Luca Coronato{2}
{1}Politecnico di Milano, Italy; {2}TDK-InvenSense Italy S.r.l., Italy

Technical Program: 27 March 2024

18:30 – 20:30
Gala Dinner Cruise
Hiroshima Harbor: Moto Ujina Pier 2

**All times appear in Japan Standard Time (JST) GMT+9)*

7:30 – 8:30
Registration
Room: Setouchi Foyer

8:30 – 8:45
Opening Remarks
Room: Setouchi I

8:45 – 9:25
Keynote: Inertial Sensor Applications for Satellites and a Luna Lander
Shin-ichiro Sakai, *Japan Aerospace Exploration Agency (JAXA)*
Room: Setouchi I
Session Chair: Takashiro Tsukamoto, Tohoku University

9:25 – 10:25
C1L-A: Test & Calibartion
Room: Setouchi I
Session Chair: Erdinc Tatar, Bilkent Üniversitesi

9:25
6013: Improvements to Calibration Modeling of a Tri-Axial Accelerometer Using Response Surface Methods
Kenneth Toro{2}, Jonathon Ponder{1}, Peter Parker{2}
{1}NASA Glenn Research Center, United States; {2}NASA Langley Research Center, United States

9:45
6026: Computation of Inertial Signals on Rotational Testbeds
Jason Bingham, Michael Walker II
Sandia National Laboratories, United States

10:05
Sensors Letters Paper
6074: Disentangling Triaxial Sensor Nonorthogonalities and Installation Errors
Marius Gheorghe, John Neal
Ideal Aerosmith Inc., United States

10:25 – 10:55
Coffee Break & Exhibits
Room: Setouchi II

10:55 – 12:45
C2L-A: MEMS Sensors
Room: Setouchi I
Session Chair: Ryuta Araki, Sumitomo Precision Products

10:55
Invited: Technologies for High Performance MEMS IMU Sensors
Anssi Blomqvist, Murata Electronics Oy, Vantaa, Finland

11:25
6042: Advancement in the MEMS Gyroscope from a Vibrating Tuning Fork to a Tuned Ring with Comb Electrodes
Roman Forke{2}, Takashiro Tsukamoto{3}, Alexey Shaporin{2}, Sebastian Weidlich{1}, Daniel Bülz{2}, Susann Hahn{1}, Shuji Tanaka{3}, Karla Hiller{1}
{1}Chemnitz University of Technology, Germany; {2}Fraunhofer Institute for Electronic Nano Systems ENAS, Germany; {3}Tohoku University, Japan

11:45
6062: Passive Quadrature Reduction in Vibratory MEMS BAW Gyroscopes
Amir Rahafrooz, Diego Emilio Serrano, Kieran Nunan, Ryan Hennessy, Duane Younkin, Ijaz Jafri
Panasonic Massachusetts Laboratory, United States

12:05
6063: High Sensitivity Mode-Localized Ring Resonator with Tunable Sensitivity
Takashiro Tsukamoto{3}, Roman Forke{2}, Sebastian Weidlich{1}, Daniel Bülz{2}, Alexey Shaporin{2}, Karla Hiller{1}, Shuji Tanaka{3}
{1}Chemnitz University of Technology, Germany; {2}Fraunhofer Institute for Electronic Nano Systems ENAS, Germany; {3}Tohoku University, Japan

12:25
Sensors Letters Paper
6076: Combining Lissajous Frequency Modulation with 250-nm Piezoresistive Sensing in MEMS Gyroscope: Theoretical Advantages and Practical Challenges
Matteo Gianollo{2}, Marco Gadola{2}, Giada Bettini{2}, Christian Padovani{2}, Philippe Robert{1}, Giacomo Langfelder{2}
{1}CEA-Leti, France; {2}Politecnico di Milano, Italy

12:45 – 14:10
Lunch
Room: Setouchi III

14:10 – 15:10
C3L-A: Late News
Room: Setouchi I
Session Chair: Xudong Zou, University of Chinese Academy of Sciences

14:10
6082: Demonstration of Multi-Axis Sensitivity and Temperature Compensation for a Physically Tightly-Coupled MEMS IMU Integrating a Mode-Matched Gyroscope and Two Differential Resonant Accelerometers
Fumito Miyazaki, Tazuko Tomioka, Jumpei Ogawa, Daiki Ono, Kei Masunishi, Kengo Uchida, Hideaki Murase, Etsuji Ogawa, Fumitaka Ishibashi, Yasushi Tomizawa
Toshiba Corporation, Japan

14:30
6085: Precision Mode-Matching Gyroscope Using In-Run Adjustment of Spring Azimuth
Keitaro Ito, Shota Harada, Yusuke Kawai, Hiroyuki Wado
MIRISE Technologies Corporation, Japan

14:50
6081: Molded Foaming 3D MEMS Vapor Cell for Weak Magnetic Detection
Ziji Wang, Ruochen Tie, Jintang Shang
Southeast University, China

15:10 – 15:40
Closing Remarks/Award Cermony
Room: Setouchi I