APOS2018 Technical Program

	28-May Mon	29-May Tue	30-May Wed	31-May Thu	
9:00					9:00
	Opening Ceremony	Specialty Optical Fibers for Sensing 1	Novel Concepts for Photonic Sensing	Imaging Technologies for Sensing	
10:00	Plenary Talk (Y. Ozeki)	Break	Break	Break	10:00
11:00	Short Break Biological and Biomedical Sensing	Physical Sensing Technologies	Photonic Device Technologies for Sensing 2	Post Deadline Papers	11:00
12:00	Lunch	Lunch	Lunch	Closing Ceremony Lunch	12:00
13:00	Distributed Sensing and Applications 1	Technologies for Civil and Construction Engineering	Distributed Sensing and Applications 2		13:00
14:00					14:00
15:00	Poster 1 & Break	Poster 2 & Break	Poster 3 & Break		15:00
16:00					16:00
17:00	Photonic Device Technologies for Sensing 1	Grating Technologies for Sensing 1	Grating Technologies for Sensing 2 Group Photo		17:00
18:00	Reception		Bus Transfer		18:00
19:00			Banquet		19:00
20:00					20:00

Monday (May 28, 2018) 9:30 - 9:45

Opening Ceremony

Monday (May 28, 2018) 9:45 - 10:35

Plenary Talk

Molecular imaging of cells and tissues by multicolor stimulated raman scattering microscopy

Yasuyuki Ozeki

Department of Electrical Engineering and Information Systems, The University of Tokyo

Imaging of biological cells and tissues with subcellular spatial resolution is important in biology and medicine for exploring the dynamics of cells and for diagnosing the structure of tissues. Among various optical imaging modalities, laser microscopy with fluorescent staining is a powerful tool for this purpose but suffered from the limited applicability and cytotoxicity of staining process. Stimulated Raman scattering (SRS) microscopy allows for high-speed, multicolor imaging based on molecular vibrational contrast, offering alternative opportunities of laser microscopy. In this talk, I'll introduce the principle and applications of SRS microscopy and its recent technical advances for stain-free, multicolor, high-speed imaging of cells and tissues.

Monday (May 28, 2018) 10:35 - 10:45

Short Break

Monday (May 28, 2018) 10:45 - 12:00

Biological and Biomedical Sensing

10:45 **Invited 1**

Biological and biomedical sensing: challenges and rewards of multidisciplinary projects

Frédérique Vanholsbeeck

The Dodd-Walls Centre for Photonic and Quantum Technologies, Department of Physics, New Zealand

At the biophotonics group at The University of Auckland, our research projects focus on different imaging modalities such as fluorescence quantification using an all-fibre real time spectroscopic optical probe, and optical coherence tomography imaging. Our fluorescence work aims at detecting, enumerating and monitoring bacteria for the food industry. As for OCT, we have been using it as optical biopsies with a particular focus on detection of early signs of non-communicable diseases such as osteoarthritis, skin cancer and age related macular degeneration. During this talk, I will use some of our recent results on these topics to draw conclusions on the many rewards and challenges we face when working on these multidisciplinary projects.

11:15 **Mon_1**

Highly sensitive fiber-coupled optofluidic immunosensors for early cancer diagnosis

Lili Liang, Long Jin, Yang Ran, Jun Ma, Bai-Ou Guan

Jinan University

We present a fiber-coupled optofluidic immunosensor for the detection of p53 protein at a detection limit 0.11 fg/mL. Serum test shows its feasibility in complex biological environment, which is favorable for diagnostic applications.

11:30 **Mon_2**

Smart epidural needle

Benito Carotenuto[1], Armando Ricciardi[1], Alberto Micco[1], Ezio Amorizzo[2], Marco Mercieri[2], Antonello Cutolo[1], Andrea Cusano[1]

[1]Optoelectronics Group, Engineering Department, University of Sannio, Italy,
[2]Pain Medicine Unit, Sant'Andrea Hospital, "Sapienza" University, Italy

We report on a novel smart needle based on optical fiber sensor technology which assists physicians in identifying epidural space during regional anesthesia. The potential of the device is demonstrated through an in vivo study.

11:45 **Mon_3**

A novel single fiber optical tweezers for selective trapping and transporting

Yu Zhang[1], Yan Li[1], Xiaoyun Tang[1], Yaxun Zhang[1], Zhihai Liu[1, 2], Libo Yuan[1, 3]

[1]Key Lab of In-fiber Integrated Optics, Ministry Education of China, Harbin Engineering University,
[2]National Demonstration Center for Experimental Physics Education, Harbin Engineering University,
[3]Photonics Research Center, Guilin University of Electronics Technology

We propose and demonstrate a single fiber optical tweezers based on a hollow annular-core fiber (HACF), which is available for cells selective trapping and transporting in the fiber hollow structure, the natural fluidic channel.

Monday (May 28, 2018) 12:00 - 13:00

Lunch

Monday (May 28, 2018) 13:00 - 14:30

Distributed Sensing and Applications 1

13:00 **Invited 2**

Ultra-fast distributed Brillouin optical fiber sensing for dynamic strain measurement

Dengwang Zhou, Benzhang Wang, Yongkang Dong

National Key Laboratory of Science and Technology on Tunable Laser, Harbin Institute of Technology, China

The key operation of traditional Brillouin optical time-domain analysis (BOTDA) is the frequency-sweeping process to get the distributed Brillouin gain spectrum (BGS) whose central frequency (i.e. Brillouin frequency shift, BFS) has a linear relationship with the environmental information (e.g. temperature or strain) over the sensing fiber. However, this time-consuming process has limited the sampling rate of BOTDA. In this paper, we summarize several fast BOTDA systems for dynamic strain measurement which is developed by our team and refers to frequency-agile technique, slope-assisted methods and optical chirp chain technique.

13:30 **Mon_4**

Inter-modal crosstalk manipulation for Brillouin gain measurement based few-mode fiber sensors

Hiroshi Takahashi, Kunihiro Toge, Tomokazu Oda, Tetsuya Manabe

NTT Corporation

This paper focuses on Brillouin gain measurement based few-mode fiber sensors using crosstalk manipulation by launching 2nd-probe beam. With this technique, we demonstrate the accurate measurement of Brillouin gain with reduced effects of inter-modal crosstalk.

13:45 **Mon_5**

A cost-effective long-range Raman distributed temperature sensor based on dual-source scheme and RZ Simplex coding

Gaoyu Dai, Xinyu Fan, Zuyuan He

State Key Laboratory of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong University, Shanghai, China

We proposed a cost-effective fiber-optic Raman distributed temperature sensor based on dual-source scheme and return-to-zero Simplex coding over 50 km. The spatial resolution and temperature resolution are 10 m and 1.8 degree respectively.

14:00 **Mon_6**

Non-constant Brillouin amplification for phase-sensitive optical time domain reflectometry

Haijun He[1], Li-Yang Shao[2]
[1]Southwest Jiaotong University, [2]Southern University of Science and Technology

Non-constant Brillouin amplification based on pulse width modulation pump has been proposed to compensate the inherent transmission attenuation for the backscattered Rayleigh light. With this method, 9-dB attenuation along 25 km fiber has been compensated excellently.

14:15 **Mon_7**

Distributed salinity sensor using a PI-coated polarization-maintaining photonic crystal fiber based on Brillouin dynamic grating

Lei Teng, Yongkang Dong, Jialiang Yan, Dengwang Zhou, Taofei Jiang
Harbin Institute of Technology

We propose a distributed salinity sensor with BDG using a polyimide-coated PM-PCF based on the birefringence measurement induced by the coating swelling. The salinity sensitivity is 141 MHz/mol•L^{-1} for the thickness of 20 μm.

Monday (May 28, 2018) 14:30 - 16:30

Monday Poster

Mon_P1

Air hole assisted photonic crystal fiber for discrimination of chemical vapor and temperature

Jong-Cheol Shin[1], Ju Il Hwang[1], Sang Bae Lee[2], Young-Geun Han[1]
[1]Hanyang University, [2]Korea Institute of Science and Technology

An In-line reflection type interferometer based on a polarization-maintaining photonic crystal fiber (PM-PCF) two large circular air holes is investigated for simultaneous measurement of chemical vapor and temperature.

Mon_P2

Ratiometric optical fiber acetone sensor based on CdSe/ZnS QDs and AFC embedded in EC martix

Cheng-Shane Chu, Wei-Ren Chen
Ming Chi University of Technology

This paper presents a ratiometric optical acetone sensor that comprises an optical fiber coated at one end with CdSe/ZnS quantum dots (QDs) and 7-amino-4-trifluoromethyl coumarin (AFC) embedded in ethyl cellulose (EC) matrix.

Mon_P3

Optical wavelength dependence of strain sensitivity of perfluorinated plastic optical fiber Bragg grating

Ryo Ishikawa[1], Heeyoung Lee[1], Amédée Lacraz[2], Antreas Theodosiou[2], Kyriacos Kalli[2], Yosuke Mizuno[1], Kentaro Nakamura[1]
[1]Tokyo Institute of Technology, [2]Cyprus University of Technology

We measure the strain dependence of multiple Bragg wavelengths of a fiber Bragg grating inscribed in a perfluorinated graded-index plastic optical fiber, and prove that the fractional strain sensitivity is actually dependent on optical wavelength.

Mon_P4

Temperature-insensitive in-fiber Fabry-Perot interferometer for vibration sensing

Haihu Yu, Zhuozhao Luo, Jian Ma, Ying Wang, Xin Gui, Yu Zheng
National Engineering Laboratory for Fiber Optic Sensing Technology, Wuhan University of Technology

A temperature-insensitive Fabry-Perot interferometric sensor based on a Kagomé photonic crystal fiber is fabricated. The sensor can accurately measure the vibration frequency from 1 Hz to 5000 Hz and have a temperature insensitive characteristic.

Mon_P5
Distributed vibration sensing based on chirped weak fiber Bragg grating array

Chengli Li, Kun Yang, Jianguan Tang, Zhihui Mei, Minghong Yang
National Engineering Laboratory for Fiber Optic Sensing Technology (NEL-FOST)

Abstract: A distributed sensing system based on chirped weak fiber Bragg grating array merged Michelson interferometer and φ-OTDR technology can demodulate Phase, amplitude, frequency response and location information of the vibration signal at the same time.

Mon_P6
Correlational measurement of Brillouin frequency shift by using frequency combs with different frequencies

Yusuke Sagisaka[1], Fumihiko Ito[1], Hiroshi Takahashi[2], Tetsuya Manabe[2]
[1]Shimane University, [2]NTT Corporation

We propose a new method for high spatial resolution and short range measurement of Brillouin frequency shifts by using coherent pulse trains (frequency combs) with two different frequencies. Experiment for proof-of-concept is conducted.

Mon_P7
Internal strain monitoring using FBG sensor for steel/CFRP hybrid structure

Genki Mieda[1], Hitoshi Nakamura[2], Yosuke Mizuno[3], Kentaro Nakamura[3], Takahiro Matsui[4], Yutaka Ochi[4], Yukihiro Matsumoto[1]
[1]Toyohashi University of Technology, Japan, [2]Tokyo Metropolitan University, Japan, [3]Tokyo Institute of Technology, Japan, [4]Toray Industries, Japan

This study demonstrates internal strain monitoring using FBG for steel/CFRP hybrid structure. FBG is successfully embedded inside CFRP by VaRTM, and it is confirmed that the strain obtained by FBG is corresponding to FEA results.

Mon_P8
A novel optical fiber Fabry-Perot inclinometer based on white light interferometry

Peng Cui[1], Ying Song[1], Wentao Zhang[2], Dongmei Li[3], Yifei Ma[4], Fang Li[2]
[1]School of Traffic and Transportation, Shijiazhuang Tiedao University,
[2]State Key Laboratory of Transducer Technology, Institute of Semiconductors, Chinese Academy of Sciences,
[3]Institute of Semiconductors, Chinese Academy of Sciences,
[4]School of Precision Instruments and Optoelectronics Engneering, Tianjin University

In this paper, a simple, compact and high sensitivity fiber-optic inclinometer based on white-light interferometric measurement is proposed. Experimental results show that a high sensitivity of 4.670 nm/″ can be achieved.

Mon_P9
Data mining and analysis in optical fiber acoustic sensors for accurate recognition of weak gas pipeline leakages

Lin Cheng, Huijuan Wu, Xiangrong Liu, Yunjiang Rao
University of Electronic Science and Technology of China

Data mining and association analysis is used in optical fiber acoustic sensors for the first time to automatically discover the hidden relationship between the features of mass data and target event types in the database.

Mon_P10
Strain distribution monitoring for a high-aspect-ratio wing in a wind-tunnel test by using optical frequency domain reflectometry and a long-length FBG

Daichi Wada, Masato Tamayama, Midori Maki
Japan Aerospace Exploration Agency

We conducted a wind tunnel test for a high-aspect-ratio 3.6 m wing model equipped with an optical fiber distributed sensing technique. We successfully observed the correlation between the wing maneuvers and the strain profiles.

Mon_P11
A giant interferometric fiber optic gyroscope: design and realization

Yulin Li, Rongya Luo, Fang Ben, Dong He, Sheng Deng, Fangyuan Chen, Chao Peng, Zhengbin Li
State Key Laboratory of Advanced Optical Communication Systems and Networks, Peking University

A giant interferometric fiber optic gyroscope with a 15-km-long single-mode fiber coil utilizing high-order eigen frequency modulation method is designed and demonstrated, whose angular random walk is 5.2 $\times 10^{-5}$ °/$h^{1/2}$.

Mon_P12
High precision 3-dimensional indoor localization with single light source and image sensor

Bo Lin[1], Heqing Huang[1], Lihui Feng[2], Long Zhang[1]
[1]China Academy of Electronics and Information Technology, [2]Beijing Institute of Technology

A visible light positioning algorithm with single light source and an image sensor is proposed and proved in experiment, which can achieve centimeter-accuracy 3-dimensional indoor positioning in experiment for various applications.

Mon_P13
Single fiber optical tweezers for trapping and axial-position adjustment based on graded-index multimode fiber

Zhihai Liu[1, 2], Tong Wang[1], Xiaoyun Tang[1], Yaxun Zhang[1], Yu Zhang[1], Libo Yuan[1, 3]
[1]Key Lab of In-fiber Integrated Optics, Ministry Education of China, Harbin Engineering University,
[2]National Demonstration Center for Experimental Physics Education, Harbin Engineering University,
[3]Photonics Research Center, Guilin University of Electronics Technology

We propose and demonstrate a single fiber optical tweezers for trapping and axial-position adjustment based on graded-index multimode fiber, by utilizing fiber grinding polishing technology and multiple mode groups couple principles.

Mon_P14
Scattering effect on skin surface intensity distribution in optical system of hyperspectral slit-light sensor

Shota Miyazawa[1], Tomonori Yuasa[1], Kaustav Das[1], Takaaki Maeda[2], Hideki Funamizu[1], Yoshihisa Aizu[1]
[1]Muroran Institute of Technology, [2]Kushiro National College of Technology

We propose a hyperspectral slit-light sensor and investigate intensity distribution with scattering change in skin phantom. Results demonstrate that light in the longer wavelength well contributes the intensity distribution change due to scattering variation.

Mon_P15
Modeling of Au circular aperture arrays on a Bragg fiber endface for refractive index sensing

Gongli Xiao[1, 3], Hongyan Yang[2]
[1]Guang xi Key Laboratory of Precision Navigation Technology and Application Guilin University of Electronic Technology ,
[2]School of Electronic Engineering and Automation Guilin University of Electronic Technology,
[3]Guangxi Experiment Center of Information Science

The proposed Bragg fiber endface refractive index sensor is compact and has the potential to be used in biomedical applications, having a better sensitivity of (156±5) nm per refractive index unit (RIU).

Mon_P16
Single-longitudinal-mode fiber laser based on the microfiber knot resonators

Ao Yang, Fan Shi, Jinqiu Zheng, Teng Wang, Xianglong Zeng
Shanghai University

We experimentally demonstrate the single wavelength erbium-doped fiber lasers with single-longitudinal-mode based on microfiber knot resonators (MKR). A MKR possess broad free spectral range. It is sensitive to the refractive index of the surrounding medium.

Mon_P17
Performance verification on weave type for smart textiles using hetero-core optical fiber

Yuya Koyama, Michko Nishiyama, Kazuhiro Watanabe
Soka University

We fabricated two types of smart textile by weaving a hetero-core optical fiber sensor into textiles. The sensing performance was investigated for bending and stretching the textiles.

Mon_P18
Tunable add-drop filter based on mode conversion in a microsphere resonator coupling with microfiber coupler

Ke Liu, Yang He, Teng Wang, Xianglong Zeng
Shanghai University

A tunable filter was experimentally demonstrated using microfiber coupler in microsphere resonator. An enhanced higher-order mode (LP11) was observed which proves the mode conversion of the microspheres. This makes the filter more practical in application.

Mon_P19
High sensitivity temperature sensor based on no-core fiber with PMMA coating

Yaofei Chen[1], Yunhan Luo[1], Jiangli Dong[1], Zhe Chen[1], Qun Han[2], Tiegen Liu[2]
[1]Jinan University, China, [2]Tianjin University, China

A high sensitivity temperature sensor based on no-core fiber with PMMA coating is proposed. The sensitivity increases with the increase of coating length. The maximum sensitivity of -2.29 nm/°C was achieved in our experiments.

Mon_P20
Distributed analysis of high-frequency localized acoustic sources by means of OFDR

Leonardo Marcon, Andrea Galtarossa, Luca Palmieri
Department of Information Engineering - University of Padova

A data analysis algorithm for distributed acoustic sensing based on the phase analysis of OFDR traces is proposed and experimentally tested. The algorithm allows to sense high-frequency signals with sharp spatial resolution.

Mon_P21
Haptic perception for evaluating viscoelastic property based on a fiber optic mechanoreceptor embedded in a pseudo-finger

Hiroshi Yamazaki, Michiko Nishiyama, Kazuhiro Watanabe
Soka University

Haptic impressions based on viscoelastic natures of objects was quantified using a hetero-core fiber optic mechanoreceptor embedded in a soft pseudo-finger, by analyzing stress relaxation curves during pressing motion.

Mon_P22
Automatic segment assembly system for shield tunneling machine using multiple imaging and laser displacement sensors

Zhiyang Wu[1], Shuang Wang[1], Yong Yang[2], Jinshi Zhang[1], Jie Zhou[1], Tiegen Liu[1]
[1]Tianjin University, China, [2]Hangzhou Tuxi Science and Technology Co., Ltd., China

To achieve the automation of segment assembly of shield machine, we propose a new method that uses multiple imaging sensors and laser displacement sensors to acquire the segments date associated with the operation.

Mon_P23
High-resolution optical fiber temperature sensor system using linear cross-correlation fiber interferometer

Takahiro Ohmae, Atsuki Ishiguro, Toshiki Nakamura, Tetsuya Matsuyama, Kenji Wada
Osaka Prefecture University

A high-resolution fiber temperature sensor system including the sensor of an 80-m single-mode fiber and the signal-detector of a linear cross-correlation fiber interferometer was constructed, whose temperature resolution was estimated to be 1.0×10^{-3} °C.

Mon_P24
Second generation point-by-point fs-laser-written fiber Bragg gratings with extremely low loss and low polarization dependence

Xin Gong[1], Margarethe Kampling[1], Hatem Dachraoui[1], Roman Flehr[2]
[1]FemtoFiberTec GmbH, [2]Loptek GmbH & Co.KG

FemtoFiberTec now provides the second generation of isotropic femtosecond point-by-point written FBGs with near zero polarization dependence in central wavelength and extremely low scattering loss. This allows extremely precise static measurements and flexible sensor arrangement.

Mon_P25
In vitro cell imaging by using green fluorescent black phosphorus nanosheets

Su-Jin Song[1], Yong Cheol Shin[2], Moon Sung Kang[1], Yu Bin Lee[1], Heejung Seo[1], Hyun Uk Lee[3], Bongju Kim[4], Dong-Wook Han[1]
[1]Department of Cogno-Mechatronics Engineering, College of Nanoscience & Nanotechnology, Pusan National University, Busan 46241, Republic of Korea,
[2]Research Center for Energy Convergence Technology, Pusan National University, Busan 46241, Republic of Korea,
[3]Advanced Nano-Surface Research Group, Korea Basic Science Institute (KBSI), Daejeon 34133, Republic of Korea,
[4]Dental Life Science Research Institute, Seoul National University Dental Hospital, Seoul 03080, Republic of Korea

In the present study, the cell imaging potential of BP nanosheets was evaluated, and their cytotoxicity was examined. Our results suggest that the BP nanosheets can be promising candidates for biomedical imaging applications.

Mon_P26
Yb-doped dissipative solitons fiber laser passively mode locked by few-layer bismuthene via evanescent field interaction

Xiaohui Li
Shaanxi Normal University

We report on the all-fiber Yb-doped mode-locked fiber laser based on bismuthene absorber. Dissipative soliton up to 21.74 MHz are generated at a center wavelength of 1034.4 nm, with a pulse width of 23.03 ps.

Mon_P27
Fiber optic temperature sensor based on polymer coating on side-polished single mode optical fibers

Umesh Sampath, Daegil Kim, Minho Song
Chonbuk National University

A fiber-optic temperature sensor with a side-polished fiber (SPF) covered with a polymer resin is proposed. The temperature sensing is based on significant interaction between the propagating light and polymer resin via strong evanescent field of the SPF.

Mon_P28
Monitoring Australian utility poles

John Canning, Kevin Cook
University of Technology Sydney

Utility power poles span the Australian landscape and are particularly important for ensuring power to remote communities. A feasibility assessment for using fibre Bragg gratings to assess utility poles is presented.

Mon_P29
Self-selector unipolar resistive switching behavior on Ni/Al_2O_3/p-AlGaN memory structures

Min Ju Yun[1], Kyeong Heon Kim[1, 2], Hee-Dong Kim[1]
[1]Sejong University, [2]University of Michigan

Self-selector-based unipolar resistive switching (RS) behavior is demonstrated in Al_2O_3-based resistive random access memory (RRAM) devices by employing wide bandgap compound semiconductors, such as p-AlGaN, as a bottom electrode (BE).

Mon_P30
Electrical and optical properties of SWNT TCEs on p-AlGaN via the microwave treatment

Min Ju Yun[1], Kyeong Heon Kim[1, 2], Hee-Dong Kim[1]
[1]Sejong University, [2]University of Michigan

A microwave treatment (MWT) ef-fect of single-wall carbon nanotube (SWNT) based trans-parent conductive electrodes (TCEs) on a p-AlGaN for ultraviolet light-emitting devices is presented.

Monday (May 28, 2018) 16:30 - 17:45

Photonic Device Technologies for Sensing 1

16:30 **Invited 3**
Terahertz molecule-specific sensing platform and applications

Minah Seo
Sensor System Research Center, Korea Institute of Science and Technology (KIST), South Korea

We developed ultrasensitive terahertz (0.2-2.5 THz) sensing system with nano scale metamaterials for detection of various biochemical materials even in very low concentration level. Ultrasensitive terahertz sensing platform can be used for discrimination of various types of viruses and quantification of small molecules. It is also useful for investigation of electro-optical properties of surface of semiconductors.

17:00 **Mon_8**
Fiber-optic refractive index sensing with bimetallic Au@Pt nanoparticles based on localized surface plasmon resonance

Qing Huang, Yong Wang, Wenjie Zhu, Tianting Lai, Jiankun Peng, Minghong Yang
Wuhan University of Technology

Spherical Au@Pt nanoparticles with rough surface were successfully synthesized and immobilized on the sensing section surface of hetero-core structured fiber optic by electrostatic interaction method to conduct refractive index measurements.

17:15 **Mon_9**
Integrated all-silicon waveguide photodetector for silicon photonics based system-on-chip sensor unit

Haike Zhu, Kazuhiro Goi, Norihiro Ishikura, Koji Omichi
Fujikura Ltd.

We introduce the silicon photonics based system-on-chip sensor unit for wireless sensor system. As a key element, we mainly discuss all-silicon waveguide photodetector, which can be used as optical power monitor for optical sensing.

17:30 **Mon_10**
Power scaling of HOMs from an all-fiber system based on WDM-MSC

Yiping Huang, Fan Shi, Teng Wang, Xianglong Zeng
Shanghai University

Power scaling of HOMs have been demonstrated by using homemade WDM-MSC. Slope efficiency of 57% is achieved in few-mode fiber laser. About 7 dB power gain is obtained by few-mode pump.

Monday (May 28, 2018) 17:45 - 20:00

Reception

Tuesday (May 29, 2018) 9:00 - 10:15

Specialty Optical Fibers for Sensing 1

9:00 **Invited 4**

From the catastrophic fuse effect to low-cost optical fiber sensors: SMF and POF applications

Paulo André[1], M. Fátima Domingues[2,3], Carlos Marques[2,3], Nélia Alberto[2], Cátia Leitão[2,3], Cátia Tavares[2], Arnaldo Gomes Leal-Junior[4], Anselmo Frizera[4], Maria José Pontes[4], Paulo Antunes[2,3]

[1]Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Instituto Superior Técnico, University of Lisbon, Portugal, [2]Instituto de Telecomunicações, Aveiro, Portugal,
[3]Physics Department & I3N, University of Aveiro, Portugal,
[4]Graduate Program of Electrical Engineering of Federal University of Espírito Santo, Brazil

The consumption of optical fiber sensors is a growing market with expected revenue of $5.98 billion by 2026. In this paper we review new cost-effective methods to produce Fabry-Perot micro-cavities by recycling fiber previously damaged by the fused effect. The application of the sensing elements to monitor refractive index, hydrostatic pressure, relative humidity, strain, high temperature and vertical loads is also assessed. Moreover, the possibility of using fuse polymer optical fiber for the production of sensing devices is evaluated.

9:30 **Tue_1**

An ultra-sensitive vector curvature sensor based on an integrated triple-core fiber interferometer

Shaoxian Zhang[1], Ai Zhou[3], Yujia Zhang[1], Yang Ouyang[3], Libo Yuan[2]

[1]Harbin Engineering University, [2]Guilin University of Electronics Technology, [3]Wuhan University of Technology

An ultra-sensitive vector curvature sensor based on an integrated triple-core fiber interferometer is proposed and the curvature sensitivities at the two opposite bending directions along the cores' connection are -30 nm/m^{-1} and 39 nm/m^{-1}, respectively.

9:45 **Tue_2**

Fiber optic magnetic field sensor utilizing DFB fiber laser and Terfenol-D material

Wentao Zhang[1], Rui Ma[1, 2], Wenzhu Huang[1], Dongmie Li[1], Yifei Ma[3], Fang Li[1]

[1]Institute of Semiconductors, Chinese Academy of Sciences,
[2]College of Materials Science and Opto-Electronic Technology, University of Chinese Academy of Sciences,
[3]School of Precision Instruments and Optoelectronics Engneering, Tianjin University

A fiber laser sensor, bonded with Terfenol-D material, can measure static magnetic field through sweep acoustic wave. The experimental results show that the sensor exhibits excellent linearity and directivity in response to static magnetic field.

10:00 **Tue_3**

Magneto-optical fiber sensor based on high birefringence photonic crystal fiber selectively filled with magnetic fluid

Weiheng Wang, Yinping Miao, Hongmin Zhang, Xiaoping Yang

Tianjin University of Technology

A magnetic field optical fiber sensor based on high-birefringence photonic crystal fiber selectively filled with magnetic fluid is proposed. The experiment results show a high linear sensitivity of 16.8 pm/Oe.

Tuesday (May 29, 2018) 10:15 - 10:45

Break

Tuesday (May 29, 2018) 10:45 - 12:00

Physical Sensing Technologies

10:45 **Invited 5**

3D printing and photonics

Kevin Cook, John Canning

Interdisciplinary Photonics Laboratories, School of Electrical & Data Engineering, University of Technology Sydney (UTS) & School of Chemistry, The University of Sydney, Australia

Recent progress in the field of 3D-printed photonic devices and their tremendous potential in sensing applications is reviewed. This truly disruptive technology has led to the realization of polymer optical fibres made from 3D-printed preforms, planar rib waveguides, lens arrays and prisms, all precursors for coming 3D printing of silica and other components.

11:15 **Tue_4**

Multimodal-interference-based strain sensing using plastic optical fibers: response to partially applied strain

Sonoko Hagiwara, Tomohito Kawa, Heeyoung Lee, Yosuke Mizuno, Kentaro Nakamura

Tokyo Institute of Technology

Strain sensors based on multimodal interference in multimode fibers (MMFs) have been extensively developed. In this work, using a plastic optical fiber as an MMF, we investigate operation with partially applied strain.

11:30 **Tue_5**

Additive random sampling in distributed fiber vibration sensing: theoretical model and signal reconstruction

Jingdong Zhang[1], Hua Zheng[1], Tao Zhu[1], Yongzhong Bai[2], Dingrong Qu[2], Feng Qiu[2]

[1]*Key Laboratory of Optoelectronic Technology & Systems (Ministry of Education), Chongqing University,*

[2]*State Key Laboratory of Safety and Control for Chemicals, SINOPEC Research Institute of Safety Engineering*

A sub-Nyquist additive random sampling based distributed fiber vibration sensing system is proposed. The sampling theoretical model is established, and a sparse vibration signal with bandwidth exceeding 150 kHz is sampled and reconstruction in 10 km sensing fiber.

11:45 **Tue_6**

Dynamic displacement measurement using fiber interferometer with phase modulated reference light—experimental demonstration of tolerance to signal intensity fluctuation

Shinya Takemae, Koki Tsuchiya, Kohei Ueda, Yosuke Tanaka

Tokyo University of Agriculture and Technology

We demonstrate dynamic displacement measurement for vibration with an amplitude of tens of nanometer using an interferometer with high-frequency phase modulation. We experimentally confirm that this method is tolerant to intensity fluctuation of interference signal.

Tuesday (May 29, 2018) 12:00 - 13:00

Lunch

Tuesday (May 29, 2018) 13:00 - 14:30

Technologies for Civil and Construction Engineering

13:00 **Invited 6**

Applications of fiber optic sensors in geophysics and seismology

Wentao Zhang[1, 2], Wenzhu Huang[1, 2], Li Li[3], Wenyi Liu[4]

[1]State Key Laboratory of Transducer Technology, Institute of Semiconductors, Chinese Academy of Sciences, China,
[2]College of Materials Science and Opto-Electronic Technology, University of Chinese Academy of Sciences, China,
[3]Institute of Geophysics, China Earthquake Administration, China,
[4]Second monitoring center, China Earthquake Administration, China

With the development of high-resolution fiber Bragg grating (FBG) signal interrogation technique, it highly promotes the applications of fiber optic sensors in the fields of geophysical exploration, seismic observation and crust deformation measurement. This paper introduces the research status of high-resolution FBG sensing technique and focuses on the cord devices and key techniques, including high-fineness FBG based resonant cavity, low-noise narrow-linewidth tunable laser and high-resolution broadband FBG wavelength demodulation technique. The field trail results of FBG resonant seismometer, strainmeter and temperature sensor are also given and discussed.

13:30 **Tue_7**

The use of BOTDA/R methods to monitor the behavior of the settlement profile in a large-scale civil construction application

Bastian Braeuer, Michael Cheng, Hylton White

International Earth Sciences IESE Ltd

This paper presents the method and results of measuring strain and calculating the settlement profile in a large scale civil construction application using BOTDA/R technology.

13:45 **Tue_8**

Field trail of high resolution fiber optic strainmeter and temperature sensor

Wentao Zhang[1, 2], Wenzhu Huang[1, 2], Yingbo Luo[1], Li Li[3], Wenyi Liu[4], Fang Li[1, 2], Dongliang Lu[5], Li Wang[5], Li Liu[5], Fangyu Tao[5]

[1]Institute of Semiconductors, Chinese Academy of Sciences,
[2]College of Materials Science and Opto-Electronic Technology, University of Chinese Academy of Sciences,
[3]Institute of Geophysics, China Earthquake Administration, [4]Second monitoring center, China Earthquake Administration,
[5]Jinzhai Seismic Station, Anhui Earthquake Agency

High resolution strainmeter and temperature sensor based on FBG resonators are proposed for earthquake precursory observation. The field trail shows a strain resolution of 0.94 nε and a temperature resolution of 0.11 mK.

14:00 **Tue_9**

Health monitoring of composite structure based on slope-assisted Brillouin optical correlation-domain reflectometry

Heeyoung Lee[1], Yutaka Ochi[2], Takahiro Matsui[2], Yukihiro Matsumoto[3], Yosuke Tanaka[4], Hitoshi Nakamura[5], Yosuke Mizuno[1], Kentaro Nakamura[1]

[1]Tokyo Institute of Technology, [2]Toray Industries, Inc., [3]Toyohashi University of Technology,
[4]Tokyo University of Agriculture and Technology, [5]Tokyo Metropolitan University

We present an example of structural diagnosis of slope-assisted Brillouin optical correlation-domain reflectometry toward practical applications. After measuring the strain distributions along optical-fiber-embedded composite structure, we show that fiber breakage can also be detected.

14:15 **Tue_10**

Downhole test of three-component fiber laser seismic sensor system

Zhihui Sun

Laser Institute, Qilu University of Technology (Shandong Academy of Sciences)

We are presenting downhole test results for a 3C fiber laser geophone and comparing its performance with coil geophones. The 3C fiber laser geophone has advantages of higher sensitivity , wide bandwidth and better resolution.

Tuesday (May 29, 2018) 14:30 - 16:30

Tuesday Poster

Tue_P1
Anti-hydrogen loss of optical fiber pressure sensor for permanent dynamic downwell monitoring

Yingying Wang[1], Gangding Peng[2], Minghong Yang[3], Chang Wang[1], Jiasheng Ni[1]
[1]Laser Institute of Shandong Academy of Sciences, [2]University of New South Wales, [3]Wuhan University of Technology

A kind of carbon-coated pressure sensor based on Fabry-Perot is present to ensure the long-term stability of the sensors in harsh environment downhole for permanent monitoring, the hydrogen induced loss particularly.

Tue_P2
Random distributed feedback Er-doped fiber laser based on the disordered FBG array

Yihan Qiu[1], Yuheng Tong[1], Linyu Wu[1], Siyue Zeng[1], Zhengying Li[1, 2]
[1]School of Information Engineering, Wuhan University of Technology,
[2]National Engineering Laboratory for Fiber Optic Sensing Technology, Wuhan University of Technology

A random distributed feedback Er-doped fiber laser based on a disordered fiber Bragg grating array is proposed, which performs a single-mode operation. Based on the structure, a dual-wavelength random distributed feedback fiber laser is realized.

Tue_P3
Loss reduction of hybrid photonic crystal fiber ring resonator and application for resonant fiber optic gyro

Yi Lin[1], Hanzhao Li[1], Huilian Ma[1], Zhonghe Jin[1], Lin Ma[2]
[1]School of Aeronautics and Astronautics, Zhejiang University,
[2]State Key Lab of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong University

A hybrid ring resonator with the photonic crystal fiber and the polarization-maintaining fiber having better matched mode field diameters is fabricated and achieves a finesse of 11 and a loss of 2.29 dB.

Tue_P4
Enhanced performance of optical fiber hydrogen sensor based on self-referenced method and Pt/WO_3 film

Yuhuan Qin, Jixiang Dai, Gaopeng Wang, Feng Xiang, Minghong Yang
National Engineering Laboratory for Fiber Optic Sensing Technologies, Wuhan University of Technology

The optical fiber hydrogen sensor based on self-referenced method and Pt/WO_3 film was studied to improve hydrogen sensitive performance. The experimental results demonstrate the resolution of the hydrogen sensor can reach to 3 ppm.

Tue_P5
Mach-Zehnder interferometer for refractive index sensor with etched multi-core fiber

Bin Dai, Xiang Shen, Xiongwei Hu, Jinyan Li
Huazhong University of Science and Technology, Wuhan

We have demonstrated a refractive index fiber sensor worked as a Mach-zehnder interferometer with etched multi-core fiber fused between single mode fiber.

Tue_P6
Potential of strain-insensitive temperature sensing using Brillouin scattering in slimmed plastic optical fibers

Natsuki Matsutani, Heeyoung Lee, Yousuke Mizuno, Kentaro Nakamura
Tokyo Institute of Technology

We investigate the dependence of the Brillouin frequency shift on large strain in slimmed perfluorinated graded-index plastic optical fibers. The independent of the strain in the range indicates the possibility of strain-insensitive temperature sensing.

Tue_P7
Photoacoustic computed tomography with a curved fiber laser ultrasound sensor

Xue Bai, Jun Ma, Long Jin, Yizhi Liang, Bai-Ou Guan
Jinan University

We have showcased the development of PACT using a focused fiber-laser-based sensor which offers a sensitivity enhancement by a factor of ~ 5.5, an effective vision width of 1.1 cm, and a spatial resolution of ~ 70 μm.

Tue_P8
Application of optical fiber sensing technology in reciprocating compressor crosshead bearing temperature on-line monitoring system

Fang Liu, Xinglin Tong, Cui Zhang, Chengwei Deng, Pengfei Wang, Zhiyuan Zheng, Qiao Xiong
Wuhan University of Technology

This proposed system is based on FBG and wireless transmitters, which are used to bidirectionally transmit light signal to avoid line winding. The experiment shows that the temperature can be demodulated in the reciprocating movement.

Tue_P9
Twin source driven closed-loop fiber optic gyroscope

Fuling Yang, Yuanhong Yang, Han Yan, Xin Liu
BeiHang University

A closed-loop fiber optic gyroscope (FOG) driven by two sources was proposed. The experimental results show that the noise of the FOG was depressed effectively and about 4 times improvement of bias stability was achieved.

Tue_P10
Lightweight design and performance of FBG acceleration sensor

You Wang, Yutang Dai, Yun Wang, Shengli Dai, Lei Liang, Minghong Yang
Wuhan University of Technology

Using sequential quadratic programming (SQP) method, a lightweight and exquisite low-frequency FBG acceleration sensor is designed. The performance of the fabricated sensor is tested by calibration experiment on shaking table.

Tue_P11
Waveguiding analysis of birefringence-reduced polymeric optical fiber using dichroic dye

Takamichi Tozaki[1], Rei Furukawa[1], Daichi Mizorogi[1], Kentaro Yano[2]
[1]University of Electro-Communications, [2]Hayashibara co., ltd.

Waveguiding analysis was performed by doping dichroic dyes to polymeric optical fibers with birefringence-reduced core. Solubility of the dye in various solvents including monomer was investigated.

Tue_P12
Comparison of optical fibre high temperature sensors

Stephen C. Warren-Smith[1], Linh V. Nguyen[1], Dale Otten[2], Erik P. Schartner[1], Zheng Yu[1], David G. Lancaster[2], Heike Ebendorff-Heidepriem[1]
[1]The University of Adelaide, [2]University of South Australia

We present a comparison of four different grating-based optical fibre high temperature sensors. Sensors based on pure-silica fibres show good stability up to 900°C.

Tue_P13
Efficient data compression in distributed optical fiber vibration sensing for railway monitoring in noisy environments

Xiao Zhang, Huijuan Wu, Yi Zheng, Haoyu Qiu, Yunjiang Rao
University of Electronic Science and Technology of China

A sparse representation method by using Shearlet transform combined with efficient signal-noise separation is proposed to compress the temporal-spatial signal matrix obtained from the distributed optical fiber vibration sensor in railway monitoring in noisy environments.

Tue_P14
Analysis of BGS observation condition dependence of ring circumferential strain measurement error

Kento Nishimura, Hiroshi Naruse
Mie University

For strain measurements around a ring that compare a model of Brillouin gain spectrum to observations, the effects of the observation angle, section, and frequency on measurement errors are clarified through simulations.

Tue_P15
Research of a fiber-optic hydroacoustic sensor based on Fizeau interferometry of chirped ultra-weak fiber Bragg gratings

Qiannan Xu[1, 2], Ciming Zhou[1], Dian Fan[1], Yandong Pang[1, 2], Yi Li[1, 3], Chenguang Zhao[1, 4]
[1]National Engineering Laboratory for Fiber Optic Sensing Technology,Wuhan University of Technology,
[2]School of Information Engineering ,Wuhan University of Technology, [3]School of Science,Wuhan University of Technology,
[4]School of Mechanical and electronic engineering ,Wuhan University of Technology

We demonstrated a fiber-optic hydroacoustic sensing system by using digital arc tangent and PGC combined algorithm, whose sensing range is from 500 to 3000 Hz with an acoustic phase sensitivity of -153.03dB (re rad/μpa)

Tue_P16
A fiber-optic long-period-grating temperature sensor using a vertical-cavity surface-emitting laser

Satoshi Arahira, Nobutoshi Hamada, Toru Mizunami
Kyushu Institute of Technology, Japan

A long-period fiber grating sensor was developed using a vertical-cavity surface-emitting laser as a narrowband light source. The grating period was varied with the tilted mask method. Temperature sensing in 100-150 degrees centigrade was performed.

Tue_P17
Recycling of polymer optical fibers damaged by fuse effect: dynamic mechanical analysis for sensing applications

Arnaldo Gomes Leal-Junior[1], Anselmo Frizera[1], Maria José Pontes[1], Paulo Antunes[2, 3], Nélia Alberto[2], Maria Fátima Domingues[2, 3], Heeyoung Lee[4], Ryo Ishikawa[4], Yosuke Mizuno[4], Kentaro Nakamura[4], Paulo André[5], Carlos Marques[2, 3]
[1]Federal University of Espírito Santo, [2]Instituto de Telecomunicações-Aveiro, [3]University of Aveiro, [4]Tokyo Institute of Technology, [5]University of Lisbon

Recently, optical fiber fuse has been observed in polymer optical fibers (POFs). In this work, we evaluate the dynamical mechanical properties of the fused POFs for their sensing applications of temperature, humidity, etc.

Tue_P18
A high sensitivity fiber laser microphone

Yingbo Luo[1], Wentao Zhang[1, 2], Fang Li[1, 2]
[1]Institute of Semiconductors, Chinese Academy of Sciences,
[2]College of Materials Science and Opto-Electronic Technology, University of Chinese Academy of Sciences

A novel fiber laser microphone is presented. Due to the ultra-narrow line width of the fiber laser and interferometric demodulation method, the FLM shows a low noise level and high acoustic sensitvity.

Tue_P19
Characteristics of wavelength modulation of a laser diode for optical fiber sensing using wavelength sweep

Atsushi Wada, Satoshi Tanaka, Nobuaki Takahashi
National Defense Academy

An inexpensive laser diode (LD) can be utilized as a light source to detect narrow transmission peaks of a Fabry-Perot interferometer. Experimental investigation of dynamic characteristics of a wavelength of LD is reported.

Tue_P20
Slope-assisted BOCDR using low-bending-loss fiber

Tianyi Ma, Heeyoung Lee, Yosuke Mizuno, Kentaro Nakamura
Tokyo Institute of Technology

We demonstrate the improved measurement stability of slope-assisted Brillouin optical correlation-domain reflectometry using a low-bending-loss fiber. After fundamental characterizations, we present distributed strain/temperature measurement results, which are shown to be insusceptible to locally applied loss.

Tue_P21
Analysis of core eccentricity on the long period grating in eccentric core fiber

Ai Zhou[1], Xiaofeng Xu[1], Xiaowei Ouyang[1], Jianxia Liu[2], Fang Liu[1], Weibing Gan[1]
[1]Wuhan University of Technology, China, [2]Hubei university of science and technology, China

The effect of core eccentricity on the property of eccentric core fiber LPFG is investigated. Results indicate that the core eccentricity significantly affect which cladding modes coupled to the core mode.

Tue_P22
Ultra-high sensitive acoustic sensor based on distributed microstructured optical fiber (DMOF) and hollow cylinder transducer

Hao Li, Fan Ai, Jingyi Wang, Wei Zhang, Zhikun Xing, Zhijun Yan, Deming Liu, Qizhen Sun
Huazhong University of Science and Technology

An ultra-high sensitive acoustic sensor based on distributed microstructured optical fiber (DMOF) and hollow cylinder transducer is proposed, demonstrating a flat phase sensitivity over -112 dB (re rad/μPa) and a peak sensitivity up to -83.7 dB.

Tue_P23
Intensity modulated directional torsion sensor based on optical fiber modal interferometer in single mode fiber

Qinjiang Fu, Guolu Yin, Chuancan Liang, Lei Lu, Tao Zhu
Chongqing University

An intensity modulated torsion sensor was reported in range of ±50 rad/m. The ability of distinguishing torsion direction stems from the reversal between dips and peaks when twisting in CCW and CW direction.

Tue_P24
Correction of delay time in high-speed fiber Bragg grating interrogation system with wavelength swept laser

Tatsuya Yamaguchi, Yukitaka Shinoda
Nihon University

We demonstrate correction of delay time in a high-speed fiber Bragg grating (FBG) interrogation system with a wavelength swept laser.

Tue_P25
Evaluation of the curing process of ultraviolet curable adhesive by using both digital holography and UV-Vis spectroscopy

Mohamad Haidar Bin Aziz, Masayuki Yokota
Shimane University

A technique to study the curing process of UV curable adhesive using digital holography and UV-Vis spectroscopy method is presented. Correlation between these methods can be used to estimate curing time of adhesive is suggested.

Tue_P26
Optic fibre sensor for detection of gaseous ammonia by methylammonium lead halide perovskite

Shuai Ruan, Quantao Sun, Heike Ebendorff-Heidepriem, Yinlan Ruan
University of Adelaide

Photoluminescence of methylammonium lead halide was observed to be fast quenched by gaseous ammonia. This was utilised to create a reversible ammonia sensor with high sensitivity and prompt response using a functionalized optical fibre tip.

Tue_P27
The correlation analysis of the excess relative intensity noise in depolarized interferometric fiber optic gyroscope

Yulin Li, Fang Ben, Rongya Luo, Chao Peng, Zhengbin Li
State Key Laboratory of Advanced Optical Communication Systems and Networks, Peking University

The correlation of excess relative intensity noise (RIN) limited by the depolarizer in a depolarized interferometric fiber optic gyroscope is theoretically analyzed and experimentally verified, which corresponds to the excess RIN suppression efficiency.

Tue_P28
Distributed fiber optic sensing with Rayleigh backscattering (TW-COTDR) for rainfall-induced strain changes in a landslide

Tetsuya Kogure, Yudai Okuda
Shimane University

Fiber optic sensing with Rayleigh backscattering produced a clear-cut vertical profile of strain changes along a borehole in a landslide. Visualization of unknown deformation of mudstone layer below a slip plane has been achieved.

Tue_P29
Bending characteristics of Ta_2O_5 thin-film-coated hetero-core single-mode fiber optic sensor with large fiber insertion of 3 mm

Michiko Nishiyama, Shoichi Kubodera, Kazuhiro Watanabe
Soka University

Bending loss of a hetero-core fiber sensor with Ta_2O_5 thin film coating was tested. Coating the Ta_2O_5 thin film on the hetero-core fiber sensor, the oscillatory change in loss with bending decreased.

Tuesday (May 29, 2018) 16:30 - 17:30

Grating Technologies for Sensing 1

16:30 **Tue_11**
High speed vibration demodulation of Mach-Zehnder interference based on pulse modulation

Wang Honghai[2], Wang Jinming[1], Wang Jiaqi[1], Yang Qian[1], Li Zhengying[1]
[1]*School of Information Engineering, Wuhan University of Technology,*
[2]*National Engineering Laboratory for Fiber Optic Sensing Technology, Wuhan University of Technology*

Based on Mach-Zehnder interference, we use the pulse to modulate broadband light source to achieve the high-speed vibration demodulation of the large-capacity identical-weak Fiber Bragg Gratings (FBGs) array.

16:45 **Tue_12**
Development of novel type transparent/scattering filter for 260 / 280 nm with simple PDMS composition

Junfeng Zhu[1], Keisuke Nakakubo[1], Yuya Mikami[1], Hiroaki Yoshioka[1], Kinichi Motita[2], Yuji Oki[1]
[1]*Kyushu University,* [2]*Ushio Inc.*

The index matching of the scattering particles of CaF_2 and matrix of polydimethylsiloxane can make the material transparent just on specified wavelength. It is due to the different index dispersions around the UV wavelength region.

17:00 **Tue_13**
PI coated FBG sensor with femtosecond laser ablated microstructure for the detection of relative humidity

Shengli Dai, Peng Chen, Yutang Dai, Mingbi Li, Lei Liang
Wuhan University of Technology

Relative humidity sensors utilizing expansion strain of polyimide film on FBG is proposed and demonstrated. The FBG's cladding is micro-machined into a spiral type microstructure aided by femtosecond laser, resulting in dramatic improvement of sensitivity.

17:15 **Tue_14**

Linear-response fiber-optic anemometer based on single walled carbon nanotube coated tilted fiber Bragg grating

Fang Wang, Hui Zhi Duan, Yang Zhang, Shi meng Chen, Zhen guo Jing, Zhen lin Wu, Yun Liu, Da peng Zhou, Wei Peng

Dalian University of Technology

A linear-response and simple optical fiber hot-wire anemometer based on SWCNTs coatedTFBG is proposed. In the experiments, the sensitivity of the system is as high as 7.425 dBm/(m/s) and the R^2=0.9927.

Wednesday (May 30, 2018) 9:00 - 10:15

Novel Concepts for Photonic Sensing

9:00 **Invited 7**

Variable-focus lens using ultrasound vibration

Daisuke Koyama

Faculty of Science and Engineering, Doshisha University, Japan

Variable-focus lenses using ultrasound vibration were introduced. The lens profile can be changed by the acoustic radiation force, which is a static force acting to an interface between two different media. The focal point can be controlled by the input voltage to the ultrasound piezoelectric transducer, and the high-speed focus control can be realized. The lens array that has variable focal length and lens pitch can be fabricated by switching the resonance vibration mode. A technique to control the orientation of liquid crystals using ultrasound vibration is useful in developing optical devices.

9:30 **Wed_1**

Measurement of dose distributions using a 1-dimensional phantom dosimeter for Co-60 radiotherapy

Hyun Young Shin

Chung-Ang University

The purpose of this study is to develop a method for measuring transverse and longitudinal dose distribution of Co-60 gamma-rays using a 1-dimensional phantom dosimeter.

9:45 **Wed_2**

Photon density wave spectroscopy for sensing in highly concentrated biotechnical processes

Nabarun Polley, Thomas Schiewe, Oliver Reich, Roland Hass

University of Potsdam

The ability of Photon Density Wave (PDW) spectroscopy to quantify absorption and reduced scattering coefficient independently, in-line, calibration-free, and as function-of-time has been utilized to monitor enzymatic milk coagulation and baker's yeast fermentation in bioreactors

10:00 **Wed_3**

Fiber-optic cascaded forward Brillouin scattering seeded by backward SBS: conceptual proposal and experimental verifications

Neisei Hayashi[1], Yosuke Mizuno[2], Kentaro Nakamura[2], Sze Yun Set[1], Shinji Yamashita[1]

[1]The University of Tokyo, [2]Tokyo Institute of Technology

We propose a novel principle for generating the cascaded forward Brillouin scattering (CFBS) using a counter-propagating pump-probe technique. The basic concept of this principle is the use of backward SBS as the seed of CFBS.

Wednesday (May 30, 2018) 10:15 - 10:45

Break

Wednesday (May 30, 2018) 10:45 - 11:45

Photonic Device Technologies for Sensing 2

10:45 **Wed_4**

Proper selection of ASE noise suppression techniques for a probe pulse in fine resolution optical fiber sensing

Yu Yamasaki, Daiki Ishihara, Tsuyoshi Konishi
Osaka University

We examine two representative ASE noise suppression approaches in terms of their probe pulse width dependent performances in order to more properly use these different approaches for fine resolution optical fiber sensing applications.

11:00 **Wed_5**

Seismic detection using opto-mechanical lab-on-fiber sensors

Marco Pisco[1], Francesco Antonio Bruno[1], Danilo Galluzzo[2], Lucia Nardone[2], Grzegorz Gruca[3], Niek Rijnveld[3], Francesca Bianco[2], Antonello Cutolo[1], Andrea Cusano[1]
[1]University of Sannio Eng.Department, [2]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Vesuviano INGV, [3]OPTICS11

We propose a Lab on fiber sensor for seismic surveillance applications. During the trials, this sensor accurately sensed and registered the ground acceleration associated with the seismic sequence that struck central Italy on 2016.

11:15 **Wed_6**

Highly sensitive optical sensing scheme using erbium-doped fiber ring circuit

Hiroji Masuda, Kokoro Kitamura
Shimane University

We have achieved a significant improvement in the optical power variation using a novel optical ring circuit equipped with an erbium-doped fiber as a gain medium, which operates under the laser oscillation condition.

11:30 **Wed_7**

Atomic spin precession determination based on acoustic-optic amplitude modulation in all-optical magnetometers

Han Yao, Hong Zhang, Danyue Ma, Junpeng Zhao, Ming Ding
Beihang University

A detection method was proposed based on acoustic-optic modulation, improving the atomic magnetometer sensitivity by 61 times @30 Hz from balanced polarimetry method. AOM may benefit compact magnetometers for small size and low power consumption.

Wednesday (May 30, 2018) 11:45 - 13:00

Lunch

Wednesday (May 30, 2018) 13:00 - 14:15

Distributed Sensing and Applications 2

13:00 **Invited 8**

Distributed analysis of media outside optical fibers using forward stimulated Brillouin scattering

Gil Bashan, Hilel Hagai Diamandi, Yosef London, Yair Antman, Eyal Preter, Avi Zadok
Faculty of Engineering and Institute for Nano-Technology and Advanced Materials, Bar-Ilan University, Israel

A new concept for the distributed analysis of liquid media outside the cladding of standard, unmodified optical fiber is proposed and demonstrated. The measurement protocol relies on a forward stimulated Brillouin scattering process that is driven by two co-propagating optical field components. The exchange of optical power between the two fields is mapped through spectrally-selective analysis of Rayleigh back-scatter. Measurements are performed over 3 km of fiber with a spatial resolution of 100 m. The results successfully distinguish between air, ethanol and water outside the fiber cladding.

13:30 **Wed_8**

Measurement of cross-sectional Brillouin gain in few-mode fiber by pulsed pump-probe BOTDA with image sensor

Tomokazu Oda, Hiroshi Takahashi, Kunihiro Toge, Tetsuya Manabe
NTT Access Network Service Systems Laboratories

We measure cross-sectional Brillouin gain in FMF by employing pulsed pump-probe BOTDA with CCD. We confirm that cross-sectional Brillouin gain corresponds to the relation of the electric field distributions of the pump and probe beams.

13:45 **Wed_9**

Ultra-long-distance distributed optical fiber sensing based on hybrid of Brillouin and Rayleigh scattering

Yun Fu, Zinan Wang, Richeng Zhu, Naitian Xue, Jialin Jiang, Chongyu Lu, Bin Zhang, Le Yang, David Atubga, Yunjiang Rao
University of Electronic Science and Technology of China

A 150.62 km hybrid DOFS system, which integrates BOTDA (spatial resolution is 9 m, uncertainty is ±0.82 MHz) and Φ-OTDR (spatial resolution is 30 m), is designed and demonstrated for the first time.

14:00 **Wed_10**

Hardware-adaptive algorithm for phase-noise-compensated optical frequency domain reflectometry

Zhaopeng Zhang, Xinyu Fan, Zuyuan He
Shanghai Jiao Tong University, China

We demonstrate an algorithm for phase-noise-compensated optical frequency domain reflectometry (PNC-OFDR), which mainly depends on the multiply operation and is hardware-adaptive. The proof-of-concept experiment shows a 7-cm spatial resolution over 100-km fiber link.

Wednesday (May 30, 2018) 14:15 - 16:15

Wednesday Poster

Wed_P1

High density distributed crack tip sensing system using dense ultra-short FBG sensors

Wang Fan[1], Wang Jiaqi[1], Gui Xin[2], Wang Changjia[1], Zhou Zude[1], Li Zhengying[1,2]
[1]*School of Information Engineering, Wuhan University of Technology,*
[2]*National Engineering Laboratory for Fiber Optic Sensing Technology, Wuhan University of Technology*

We developed a dense ultra-short Fiber Bragg Grating array for high-spatial resolution distributed sensing in crack tip detection. The experimental results consistent with the theoretical analysis. The 1.5 mm spatial resolution was successfully realized.

Wed_P2
Adiabatically tapered birefringent optical fibers depending on their waist diameter for detection of ambient index

Jong-Cheol Shin, Seungmin Lee, Ju Il Hwang, Kwang Wook Yoo, Young-Geun Han
Hanyang University

The fiber-optic ambient index sensor using a Sagnac loop interferometer with an adiabatically tapered polarization-maintaining fiber is investigated. The ambient index sensitivity of the adiabatically tapered PMF-based Sagnac interferometer strongly depends on the waist diameter.

Wed_P3
Common path swept-source OCT interferometer using eccentric-core fiber

Qiao Xiong, Xinglin Tong, Cui Zhang, Chengwei Deng, Pengfei Wang, Zhiyuan Zheng, Fang Liu
Wuhan University of Technology

A common-path interferometer using eccentric-core fiber (ECF) for Swept-Source Optical Coherence Tomography (SS-OCT) is presented and demonstrated. It improves performance of image reconstruction about different depth biological sample.

Wed_P4
A large-scale fiber Bragg grating array demodulator with wavelength- and time-division multiplexing method

Lei Dong[1], Yi Min Xu[1], Hong Hai Wang[1], Shan Jiang[2], De Sheng Jiang[1], Zheng Ying Li[1], Yao Bin Qi[1]
[1]Wuhan University of Technology, [2]FLOES Co., Ltd.

A 8 channels FBG demodulator which can parallel process 4 of them in 500 ms with 10,000 gratings on a single channel. The demodulator realized 1 m location accuracy and 10 km-level coverage per channel.

Wed_P5
Brillouin frequency shift resolution improvement in PSP-BOTDR based on bipolar Golay code

Mohd Saiful Dzulkefly Zan[1, 2], Yuki Masui[1], Tsuneo Horiguchi[1]
[1]Shibaura Institute of Technology, [2]Universiti Kebangsaan Malaysia

We propose coding PSP-BOTDR with bipolar Golay code. With 1- to 16 bit-codes, the BFS resolution improved linearly from 2.06 to 1.34 MHz. We also achieved 20 cm spatial resolution along 350-m fiber.

Wed_P6
Temperature dependence measurement in polarization maintaining optical fiber using Pound-Drever-Hall technique

Tomoyuki Uehara[1, 2], Kenichiro Tsuji[1]
[1]National Defense Academy of Japan, [2]University of Florida

We measured the change in optical path length of optical fiber in a fiber ring resonator by the frequency shift measurement of its resonance using Pound-Drever-Hall technique.

Wed_P7
The photonics IoT and health

John Canning[1, 2], Sandra Ast[2], Mojtaba Golzan[1]
[1]University of Technology Sydney, [2]Australian Sensing and Identification Systems

A general view of the photonics internet-of-things (Iot) is presented, focusing on examples around the role photonics and the internet play in medical industries.

Wed_P8
3D-printed photonic ribs: a new platform for devices, sensors and more

Padraic James Flanagan[1, 2, 3], John Canning[1, 2], Kevin Cook[1, 2]
[1]University of Technology Sydney, [2]The University of Sydney, [3]Trinity College Dublin

A novel approach to the 3D-printing of rib-like features with dimensions well below the xy-resolution specifications of a cheap desktop printer is described.

Wed_P9
Measurement of third-order dispersion coefficient by 2 THz-bandwidth coherence-recovered linear optical sampling

Takuto Kano[1], Naoto Kono[1], Fumihiko Ito[1], Daisuke Iida[2], Tetsuya Manabe[2]
[1]Shimane University, [2] NTT Corporation

Higher-order dispersions of optical fibers were measured by linear optical sampling with a dynamic range of several tens dB over 2 THz-bandwidth. The results show that the spectral phases are well fitted by third-order polynomials.

Wed_P10
Magnetic field sensor using Cu-coated DFB fiber laser

Chaojiang Hao[2], Ying Song[2], Wentao Zhang[1], Yifei Ma[3], Fang Li[1], Dongmei Li[1]
[1]Institute of Semiconductors, Chinese Academy of Sciences,
[2]School of Traffic and Transportation, Shijiazhuang Tiedao University,
[3]School of Precision Instruments and Optoelectronics Engneering, Tianjin University

Distributed feedback Bragg fiber laser (DFB-FL) with Cu-coating is used as the sensing element to measure the static magnetic field. Experiments show that a resolution of 0.05 μT/Hz1/2 is achieved using PGC demodulation method.

Wed_P11
Noise reduction for Brillouin gain spectrum observations using nonnegative matrix factorization

Takuya Fujimoto[1], Hiroshi Naruse[1], Takanori Nishino[2]
[1]Mie University, [2]Meijo University

We propose a novel noise reduction method for Brillouin gain spectrum data that uses nonnegative matrix factorization. Simulations confirm that the method reduces noise.

Wed_P12
Sensors applications of polymer optical fibers submitted to the fuse effect

Arnaldo Gomes Leal-Junior[1], Anselmo Frizera[1], Heeyoung Lee[2], Yosuke Mizuno[2], Cátia Leitão[3], Fátima Domingues[3], Paulo Antunes[3], Kentaro Nakamura[2], Paulo André[4], Carlos Marques[3], Maria José Pontes[1]
[1]Telecommunications Laboratory (LABTEL), Graduate Program of Electrical Engineering of Federal University of Espírito Santo, Brazil,
[2]Institute of Innovative Research, Tokyo Institute of Technology, Japan,
[3]Instituto de Telecomunicações and Physics Department & I3N, University of Aveiro, Portugal,
[4]Instituto de Telecomunicações and Department of Electrical and Computer Engineering, Instituto Superior Técnico, University of Lisbon, Portugal

This paper presents the application of polymer optical fibres submitted to the catastrophic fuse effect as sensors for strain, transverse force and angle based on the intensity variation-based principle.

Wed_P13
A single fiber optical tweezers for trapping low refractive index microparticles based on Bessel beam

Xiaoyun Tang[1], Yu Zhang[1], Yaxun Zhang[1], Zhihai Liu[1, 2], Libo Yuan[1, 3]
[1]Key Lab of In-fiber Integrated Optics, Ministry Education of China, Harbin Engineering University,
[2]National Demonstration Center for Experimental Physics Education, Harbin Engineering University,
[3]Photonics Research Center, Guilin University of Electronics Technology

We proposed and experimentally demonstrated a 3D dark traps for low refractive index particles using a single optical fiber Bessel beam, which generated by multi-mode interference and focused by a high refractive index glass microsphere.

Wed_P14
Analytical study of the operational spatial resolution of long length FBG based OFDR

Mengshi Zhu, Hideaki Murayama
The University of Tokyo

We introduced a numerical model to estimate the operational spatial resolution of FBG based OFDR. Quantitatively, we showed the influence of sliding window in typical signal processing methods and the modified theoretical equation.

Wed_P15
Au aperture arrays-dielectric hybrid structure on an optical fiber endface for refractive index sensing

Hongyan Yang[1], Liuxia Wei[1], Houquan Liu[1], Chengcheng Feng[1], Xingchao Liu[2], Chuanxin Teng[1], Libo Yuan[1], Xianmin Xiong[1]
[1]Guilin University of Electronic Technology, [2]181st Hospital of Chinese People's Liberation Army

The hybrid structure Bragg fiber endface refractive index sensor is compact and has the potential to be used in biomedical applications, having a better negative sensitivity of (-45±1) nm per refractive index unit (RIU).

Wed_P16
Array strain sensor based on fiber grating for monitoring pipeline

Hui Wang, Hui Feng Wu, Lei Liang, Chen Liang, Ru Quan Xu
Wuhan University of Technology

We present a fiber grating array sensor for pipeline monitoring. Sensors are exploited to monitor changes in stress and strain on outer wall of pipe to improve analysis of pipe interior wall and operating conditions.

Wed_P17
Dynamic strain measurements based on F-BOTDA and pump frequency modulation

Hua Zheng[1], Jingdong Zhang[1], Tao Zhu[1], Yongzhong Bai[2], Dingrong Qu[2], Xianbin Huang[2], Feng Qiu[2]
[1]Chongqing University, [2]SINOPEC Research Institute of Safety Engineering

A fast Brillouin optical time-domain analysis based on pump pulse frequency modulation is presented and demonstrated, in which the bandwidth requirement of AWG is significantly reduced without any expense of acquiring speed.

Wed_P18
Simultaneous measurement of strain and temperature using cascaded dual side-hole fiber and single-mode fiber Bragg gratings

Ai Zhou, Yang Ouyang, Xiaofeng Xu, Fang Liu, Weibing Gan
Wuhan University of Technology

A simultaneous strain and temperature sensor based on cascaded FBGs in SMF and side-hole fiber (DSHF) is proposed. The sensitivities of the DSHF- and SMF-based FBGs 1.01 pm/με, 10.7 pm/°C, 0.83 pm/με and 10.5 pm/°C.

Wed_P19
Highly sensitive temperature sensor based on cascaded hollow core fiber Mach-Zehnder interferometer with vernier effect

Ai Zhou[1], Yujia Zhao[1], Shaoxian Zhang[3], Libo Yuan[2]
[1]Wuhan University of Technology, [2]Guilin University of Electronics Technology, [3]Harbin Engineering University

We present a highly sensitive temperature sensor based on cascaded hollow core fiber MZIs with vernier effect. The sensitivities are respectively -334.3 pm/°C and 370.7 pm/°C when MZI1 and MZI2 are separately heated.

Wed_P20
DAS-VSP data analysis and application in Turpan-Hami Basin

Zhidong Cai[1, 2], Gang Yu[1], Chong Wang[1], Hongtao Liu[1], Ce Chen[1]
[1]BGP Inc., CNPC, Hebei, China, [2]China University of Geoscience, Beijing, China

The DAS has better adaptability in the complex environment. The research presents an application method of DAS-VSP and analyzes the effect based on an actual test in complex geologic structure of western China.

Wed_P21
Highly sensitive acoustic detection by use of cascaded chirped long period fiber gratings

Hayato Takeyama, Satoshi Tanaka, Atsushi Wada, Nobuaki Takahashi
National Defense Academy

Cascaded chirped long period fiber gratings (C-CLPG) are fabricated for use in acoustic sensing. In the experiment, the highly sensitive longitudinal elastic wave detection is demonstrated by employing C-CLPG with longer separation length.

Wed_P22
A novel surface plasmon resonance sensor based on one-dimensional photonic crystal

Xin Xiong, Yunhan Luo, Yaofei Chen, Jiangli Dong, Wenguo Zhu, Wentao Qiu, Huihui Lu, Jianhui Yu, Heyuan Guan, Jun Zhang, Zhe Che
Jinan University

We propose and demonstrate a novel SPR sensor based on one-dimensional photonic crystal. The improved FOM compared to the conventional SPR sensor would lead to a better resolution in bio- and chemical sensing.

Wed_P23
Tunable refractive index sensor using guided mode resonance based on phase change material

Chulsoo Choi, Jangwoon Sung, Byoungho Lee
Seoul National University

We numerically demonstrate guided mode resonance (GMR) based refractive index sensor that has tunable capabilities, using phase change material. We achieve sensitivity equal to 667 nm/ RIU for amorphous phase, and 134 nm /RIU for crystalline phase.

Wed_P24
Highly sensitive temperature sensor based on a balloon-shaped bent single mode fibre structure

Ke Tian[1], Gerald Farrell[2], Xianfan Wang[1], Pengfei Wang[1, 3]
[1]Key Laboratory of In-fiber Integrated Optics of Ministry of Education, College of Science, Harbin Engineering University,
[2]Photonics Research Centre, Dublin Institute of Technology,
[3]Key Laboratory of Optoelectronic Devices and Systems of Ministry of Education and Guangdong Province, College of Optoelectronic Engineering, Shenzhen University

A highly sensitive fibre optic temperature sensor (-2285 pm/°C over the temperature range of 21.2–32.2°C) based on a balloon-shaped bent single-mode (BSBS) fibre structure with its original polymer coating is demonstrated.

Wed_P25
Micro-meter repeatability in distance measurement using tunable laser source

He Li, Yuyao Zhai, Dian Chen, Qingwen Liu, Zuyuan He
State Key laboratory of Advanced Optical Communication System and Networks, Shanghai Jiao Tong University

A frequency-modulated continuous-wave LiDAR system is demonstrated, with a repeatability of less than 35 μm in distance measurement from 0.1 m to 1 m. The proposed sensor technique would find applications in high-precision distance measurements.

Wed_P26
Design and research of 3D grating shape sensor

Huifeng Wu
Wuhan University of Technology

Designing highly sensitive grating shape sensors by using memory wires and gratings.On any cross-section of the memory wire, there are sticked-up three different wavelength grating,which separately apart 120 °

Wednesday (May 30, 2018) 16:15 - 17:15

Grating Technologies for Sensing 2

16:15 **Wed_11**

Highly integrated all-fiber FP/FBG sensor for accurate measurement of high pressure under high temperature

Zeng Ling Ran[1], Ting Ting Yang[1], Xiu He[1], Zhen Dong Xie[1], Shuang Zhang[1], Wen Fei Liu[1], Ya Xin Wang[1], Yun Jiang Rao[1], Xue Guang Qiao[2], Zheng Xi He[3], Peng He[3]

[1]University of Electronic Science & Technology of China, [2]Department of Physics, Northwest University, [3]Nuclear Power Institute of China

A highly integrated fiber-optic sensor, consisting of a short FBG inscribed by 800 nm femtosecond laser and a micro FP fabricated by 157 nm laser, is developed to achieve accurate measurement of high pressure under high temperature.

16:30 **Wed_12**

Multimode fiber Bragg grating in suspended core fiber with a single peak for high temperature sensing

Linh Viet Nguyen[1], Stephen Christopher Warren-Smith[1], Dale Otten[2], Erik Schartner[1], Zheng Yu[1], David Lancaster[2], Heike Ebendorff-Heidepriem[1]

[1]The University of Adelaide, [2]University of South Australia

This work presents a technique to suppress undesired peaks from a fiber Bragg grating (FBG) inscribed in a few-moded all-silica suspended core fiber (SCF) for multiplexed high temperature sensing.

16:45 **Wed_13**

Time-resolved measurement of co-directional mode coupling spectra in two-mode fibers for multipoint sensing

Naoto Kono[1], Fumihiko Ito[1], Satoshi Tanaka[2]

[1]Shimane University, [2]National Defense Academy

A novel multipoint sensing technique is demonstrated which uses co-directional mode coupling between two propagation modes in polarization maintaining fiber, by using high-speed complex impulse response measurement realized by coherence-recovered linear optical sampling.

17:00 **Wed_14**

Fiber optic gyro with special photonic crystal fibers

Kuiyan Song, Fuling Yang, Yuanhong Yang

Beihang University

An interferometer photonic crystal fiber gyroscope with solid core polarization maintaining photonic crystal fiber (PM-PCF) was proposed and developed. The bias drift is about 0.001°/h, and the scale error is 1.53 ppm with ~1000 m PM-PCF.

Wednesday (May 30, 2018) 17:15 - 17:30

Group Photo

Wednesday (May 30, 2018) 17:30 - 18:00

Bus Transfer

Wednesday (May 30, 2018) 18:00 - 21:00

Banquet

Thursday (May 31, 2018) 9:00 - 10:15

Imaging Technologies for Sensing

9:00 **Invited 9**

Photoacoustic and ultrasound imaging with fiber-laser-based sensors

Long Jin, Yizhi Liang, Jun Ma, Bai-Ou Guan

Guangdong Provincial Key Laboratory of Fiber Optic Sensing and Communications, Institute of Photonics Technology, Jinan University

Ultrasound detection is a fundamental technique for biomedical imaging and underwater applications. The implementation of fiber optic ultrasound sensors has long been a great challenge due to the weak response. We have developed highly sensitive ultrasound sensors based on small-sized fiber lasers. Incident ultrasound waves exert pressures on the sensor, drive harmonic vibrations of the fiber, and induce responses in the frequency shift of the beating signal between the two orthogonal polarization lasing modes. A bare sensor with a fiber diameter at 60 microns presents a noise-equivalent pressure (NEP) of 40 Pa over a 50-MHz bandwidth. The detection frequency can be adjusted by changing the transverse diameter of the sensor. The present sensors have been applied in photoacoustic microscopy and ultrasound pulse-echo imaging.

9:30 **Thu_1**

A time-resolved near-infrared spectroscopy based on CMOS image sensor

De Xing Lioe[1], Zhonghui Liu[1], Min-Woong Seo[1], Masatsugu Niwayama[1], Masashi Hakamata[1], Keita Yasutomi[1], Keiichiro Kagawa[1], Yasuko Fukushi[2], Seiji Yamamoto[2], Shoji Kawahito[1]

[1]Shizuoka University, [2]Hamamatsu University School of Medicine

A prototype time-resolved near-infrared spectroscopy using a four-tap lock-in pixel CMOS image sensor based on lateral electric field charge modulation has been developed. Experiments observing the blood oxygenation of a rat is performed.

9:45 **Thu_2**

Develop a high energy efficiency swept source optical frequency comb for tomography

Tuan Cong Truong[1], Tuan Quoc Banh[1, 2], Tatsutoshi Shioda[1]

[1]Graduate School of Science and Engineering, Saitama University, [2]Sevensix Inc.

We develop a high energy efficiency, high repetition rate and low-cost swept source optical frequency comb. In which a wavelength is scanned with step of hundreds GHz in frequency domain and a ns step in time-domain.

10:00 **Thu_3**

Dual-frequency phase-sensitive optical time domain reflectometry based on image matching algorithm

Dexin Ba, Long Wang, Yue Pan, Yue Li, Zhigang Fan, Yongkang Dong

Harbin Insitute of Technology

A Φ-OTDR based on image matching algorithm is proposed and experimentally demonstrated. It improves the temporal resolution by six times compared with the dual-frequency Φ-OTDR based on one-dimensional cross-covariance.

Thursday (May 31, 2018) 10:15 - 10:45

Break

Thursday (May 31, 2018) 10:45 - 11:45

Post Deadline Papers

10:45 **PDP_1**

11:00 **PDP_2**

11:15 **PDP_3**

11:30 **PDP_4**

Thursday (May 31, 2018) 11:45 - 12:00

Closing Ceremony

Thursday (May 31, 2018) 12:00 - 13:00

Lunch