

2017 International Topical Meeting on Microwave Photonics (MWP 2017)

**Beijing, China
23 – 26 October 2017**



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Technical Program

Monday, 23 October 2017

Workshop 1: Integrated microwave photonics

Session Chair: José Capmany

Room 301

- **8:30-8:50**
Invited Speaker: Jianping Yao
Affiliation: University of Ottawa, Canada
Title: Recent advances in Silicon Integrated Microwave PhotonicsN/A
- **8:50-9:10**
Invited Speaker: John Bowers, and Tin Komljenovic
Affiliation: University of California, Santa Barbara (UCSB), USA
Title: Recent advances in Hybrid Integrated MWPN/A
- **9:10-9:30**
Invited Speaker: Chris Roeloffzen, and Martijn Heck
Affiliation: LioniX International, The Netherlands
Title: Recent advances in Si₄N₃ Integrated Microwave PhotonicsN/A
- **9:30-9:50**
Invited Speaker: Pascual Muñoz, and Ruben Alemany
Affiliation: Universidad Politecnica de Valencia (UPV), Spain
Title: Recent advances in InP Integrated Microwave PhotonicsN/A
- **9:50-10:10**
Invited Speaker: Benjamin Eggleton
Affiliation: CUDOS - University of Sydney, Australia
Title: Recent advances in chalcogenide based Integrated Microwave PhotonicsN/A

Coffee Break: 10:10-10:30

- **10:30-10:50**
Invited Speaker: Ming Li

Affiliation: Institute of Semiconductors, CAS, China
Title: Integrated optical signal processing.....N/A

● **10:50-11:10**

Invited Speaker: Antonello Vanucci

Affiliation: Linkra, Italy

Title: Packaging for MWP PICs.....N/A

● **11:10-11:30**

Invited Speaker: Guillermo Carpintero

Affiliation: Universidad Carlos III de Madrid (UC3M), Spain

Title: Integrated microwave photonics.....N/A

● **11:30-11:50**

Invited Speaker: Andreas stöhr

Affiliation: University of Duisburg, Germany

Title: Integrated Microwave Photonics for very high frequency operation.....N/A

Workshop 2: Microwave photonics for 5G

Session Chair: Yitang Dai
Room 301

13:30-13:50

Invited Speaker: Liam Barry

Affiliation: Dublin City University, Ireland

Title: Integrated PON and CRAN design for 5G communications.....N/A

● **13:50-14:10**

Invited Speaker: Roberto Sabella

Affiliation: Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT), Italy

Title: Architectural considerations for the design of 5G Front and backhaul networks.....N/A

14:10-14:30

Invited Speaker: Nathan Gomes

Affiliation: University of Kent, UK

Title: MWP photonic transmission techniques and components for future 5G communications.....N/A

- **14:30-14:50**
Invited Speaker: Zizeng Cao
 Affiliation: Technische Universiteit Eindhoven, The Netherlands
 Title: Optical mm-wave beam steering for 5G: integrated circuits and fiber systems.....N/A
- **14:50-15:10**
Invited Speaker: Shilong Pan
 Affiliation: Nanjing University of Aeronautics and Astronautics, China
 Title: Photonics-based Reconfigurable Array Antenna for 5G communications.....N/A

Coffee Break: 15:10-15:30

Workshop 3: Microwave photonics instrumentation

Session Chair: Ming Li
Room 301

- **15:30-15:50**
Invited Speaker: Stavros Iezekiele
 Affiliation: University of Cyprus, Cyprus
 Title: Introduction to Microwave Photonic Vector Network Analysis.....N/A
- **15:50-16:10**
Invited Speaker: Lute Maleki
 Affiliation: OE Waves, USA
 Title: High quality OEOs for MWP instrumentation.....N/A
- **16:10-16:30**
Invited Speaker: Asghari, Hossein
 Affiliation: Loyola Marymount University, USA
 Title: RougeWave Scope and its application in ultrafast optical measurement.....N/A
- **16:30-16:50**
Invited Speaker: Antonella Bogoni

Affiliation: Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT), Italy

Title: Photonic Radars and their application to remote instrumentation and measurement.....N/A

● **16:50-17:10**

Invited Speaker: Nikos.Karafolas

Affiliation: European Space Agency (ESA), The Netherlands

Title: How can MWP be employed in on-board satellite instrumentation?.....N/A

● **17:10-17:30**

Invited Speaker: Avinoam Zadok, and Luc Thevenaz

Affiliation: Bar-Ilan University, Israel

Title: Fiber opto-mechanics: oscillators, crosstalk and sensors.....N/A

● **17:30-17:50**

Invited Speaker: Thomas Schneider

Affiliation: Technische Universität Braunschweig, Germany

Title: Stimulated Brillouin scattering for microwave and optical signal processing.....N/A

● **17:50-18:10**

Invited Speaker: François DEBORGIES

Affiliation: European Space Agency-European Space Research and Technology Centre (ESA-ESTEC), The Netherlands

Title: MWP for space applications.....N/A

● **18:10-18:30**

Invited Speaker: Jinlong Yu

Affiliation: Tianjin University, China

Title: High quality OEOs for distance measurement.....N/A

● **18:30-18:50**

Invited Speaker: Wei Li

Affiliation: Institute of Semiconductors, CAS, China

Title: Optical vector network analyzer.....N/A

YOFC **Workshop 4** on microwave photonic applications of specialty fibers

Room 302

Organizer: Yangtze (Optical Fibre and Cable, China)

Session Chair: Songnian Fu, Weijun Tong

- **13:30-13:55**
Invited Speaker: Qingqing Qi
Affiliation: FiberHome Telecommunication Technologies Co., Ltd, China
Title: Development and Test of Dynamic-Bend-Resistant Fiber Cable for FAST Program.....N/A
- **13:55-14:20**
Invited Speaker: Xin Zhong and Tao Zhou
Affiliation: Southwest China Research Institute of Electronic Equipment, China
Title: The Applications of Dispersion Fibers in Microwave Photonic Signal Generation and Processing.....N/A
- **14:20-14:45**
Invited Speaker: Ming Tang
Affiliation: Huazhong University of Science and Technology, China
Title: ROF Transmission and Processing over Multi-Core Fibers.....N/A
- **14:45-15:10**
Invited Speaker: Guifang Li
Affiliation: University of Central Florida, USA
Title: Few-Mode Fibers for Microwave Transmission and Processing.....N/A

Coffee Break: 15:10-15:30

Session Chair: Jianqiang Li, Weijun Tong

- **15:30-15:55**
Invited Speaker: Richard Penty
Affiliation: University of Cambridge, UK
Title: Methods for Transmitting MIMO Radio Signals over Fibre.....N/A
- **15:55-16:20**
Invited Speaker: Maria Morant and Roberto Llorente
Affiliation: Universitat Politècnica de València, Spain
Title: 5G Large-Count MIMO Fronthaul Systems based on Multicore Microwave Photonics.....N/A

- **16:20-16:45**
Invited Speaker: Sergi Garcia, and Ivana Gasulla
Affiliation: Universitat Politecnica de Valencia, Spain
Title: Exploiting the space dimension for reconfigurable optical fiber delay lines.....N/A
- **16:45-17:10**
Invited Speaker: Xinben Zhang
Affiliation: Yangtze Optical Fibre and Cable Co., Ltd, China
Title: Advances in Specialty Fibers at YOFC.....N/A
- **17:10-17:20**
Closing Remarks for YOFC Workshop

Industry Forum on Component, T&M and System application for Microwave Photonics

Room 303

Session Chair:

Invited Speaker: X. Steve Yao (Founder & CTO, General Photonics)

Invited Speaker: Tao Zhou (Chief Scientist, Southwest China Research Institute of Electronic Equipment)

Invited Speaker: Wentao Wang (Senior VP, Luster LightTech Corp)

- **13:30-13:50**
Invited Speaker: X. Steve Yao, (Founder & CTO, Director; Photonics Information Innovation Center)
Affiliation: General Photonics, USA; Hebei University, China
Topics: Microwave Photonics in Real World Applications
- **13:50-14:10**
Invited Speaker: Andreas Gerhard Steffan, (Senior Engineering Manager)
Affiliation: Finisar, Germany
Topics: High-Power Photodiodes for Analogue Applications
- **14:10-14:30**
Invited Speaker: K V Reddy, (Founder and President)
Affiliation: Pritel, Inc., USA

Topics: Applications of Mode-Locked Lasers in Microwave Photonics

- **14:30-14:50**

Invited Speaker: Thomas Lee, (VP Marketing)

Affiliation: SHF Communication Technologies AG, Germany

Topics: Adapting a 64Gbps Multi-channel BPG and DAC for High Speed Arbitrary Waveform Generation

Coffee Break: 15:00-15:30

- **15:30-15:50**

Invited Speaker: Tao Zhou, (Chief Scientist)

Affiliation: Southwest China Research Institute of Electronic Equipment, China

Topics: Development Trend of Microwave Photonic Technology and Photonic Integrated devices

- **15:50-16:10**

Invited Speaker: Kai Wang, (Director assistant, Microwave Photonics Department)

Affiliation: East China Research Institute, China

Topics: Microwave Photonics and Applications in the Radar Field

- **16:10-16:30**

Invited Speaker: Feng Chen, (Support Manager)

Affiliation: Rohde & Schwarz, China

Topics: Test solutions on uW, mmW and THz Applications

- **16:30-16:50**

Invited Speaker: Yongpeng Zhao, (Director)

Affiliation: Luster LightTech Corp, China

Topics: Microwave Photonic Device, Technology and Applications

- **16:50-17:10**

Panel discussion

Moderator:Invited Speaker: Steve Yao, Invited Speaker: Tao Zhou,

Invited Speaker: Wentao Wang

Monday, 23 October 2017

Session 1 & Session 2

Room 302

Session 1: Integrated Devices

Session chair: Minghua Chen

Mo1.1 8:30~8:45

Title: Experimental Demonstration of Amplified Feedback DFB Laser Based on the Reconstruction Equivalent Chirp Technique.....1

- **Jilin Zheng, Tao Pu, Jin Li**, (PLA University of Science and Technology, P.R. China); **Zhike Zhang, Yu Liu**, (Institute of Semiconductors, Chinese Academy of Sciences, P.R. China); **Guowang Zhao, Yuechun Shi, Jun Lu, Xiangfei Chen**, (Nanjing University, P.R. China); **Yunshan Zhang, Lianyan Li**, (Nanjing University of posts and Telecommunications, P.R. China); **Xing Zhang**, (Changchun Institute of Optics and Fine Mechanics and Physics, P.R. China).

Abstract: An amplified feedback DFB laser with extended modulation bandwidth is experimentally demonstrated in this paper. All the three sections of laser cavity, including DFB section, phase section and amplified feedback section, have the same active layer, which can avoid the butt-joint re-growth process. The gratings in both DFB section and amplified feedback section are fabricated by the Reconstruction Equivalent Chirp technique, which can significantly decrease the difficulties in realizing precise grating structure. An enhanced -3 dB bandwidth of 19 GHz is achieved by means of a normal low-frequency wafer. 30 MSymbol/s 16-QAM signal with 15 GHz carrier are transmitted via 10 km radio-over-fiber link using the as-fabricated directly modulated DFB laser, and the average error vector magnitude of the whole link is 4.38%.

Mo1.2 8:45~9:00

Title: FBGs based multicore fiber curvature sensor interrogation using microwave photonics filtering techniques.....5

- **Di Zheng, Yanhao Ma**, (School of Information Science & Technology, Southwest Jiaotong University, Chengdu, China); **Di Zheng, Javier Madrigal, David Barrera, Salvador Sales, Jose Capmany**, (ITEAM Research Institute Universitat Politècnica de València, Valencia, Spain)

Abstract: A high-resolution and temperature-insensitive interrogation scheme for fiber Bragg grating (FBG) based multicore fiber curvature sensor using microwave photonics filtering techniques is proposed and verified by experimental demonstration. The principle of operation exploited for curvature interrogation is based on monitoring the notch frequency shift of a two-tap microwave photonics filter (MPF), which is formed by combining two reflected sample signals from the two FBGs inscribed in multicore fiber (MCF) and a dispersion device. The proposed interrogation scheme with the sensitivity of 92 MHz/m-1 is achieved, whilst it is naturally insensitive to any temperature variations.

Mo1.3 9:00~9:15

Title: On-wafer RF characterization of integrated silicon photonic transceivers with self-calibration method.....8

- **S. J. Zhang, H. Wang, X. H. Zou, Y. Liu** (*State Key Laboratory of Electronic Thin Films and Integrated Devices, School of Optoelectronic Information, University of Electronic Science and Technology of China (UESTC), Chengdu 610054, P. R. China*); **S. J. Zhang, C. Zhang, J. D. Peters, J. E. Bowers**, (*Department of Electrical and Computer Engineering, University of California at Santa Barbara (UCSB), SantaBarbara, CA 93106, USA*)

Abstract: An on-wafer and self-calibrated scheme is proposed and demonstrated for self-referenced microwave characterization of a silicon integrated optical transceiver. The proposed self-calibration method enables on-wafer selective extraction of microwave characteristic parameters of high-speed modulators and photodiodes in the integrated optical transceiver, without the need for extra electrical-to-optical or optical-toelectrical calibration.

Mo1.4 9:15~9:30

Title: Design and Characterization of a Photonic Integrated Circuit for Beam Forming in 5G Wireless Networks.....11

- **Giovanni Serafino, Claudio Porzi, Scuola Superiore Sant'Anna, (Italy); Vito Sorianello, Paolo Ghelfi, (CNIT, Italy); Antonio D'Errico, Ericsson, (Italy); Sergio Pinna, Scuola Superiore Sant'Anna, (Italy) ; Marzio Puleri , (ERICSSON, Italy) ; Marco Romagnoli , Antonella Bogoni , (CNIT, Italy)**

Abstract: We present the design and experimental characterization of a silicon-on-insulator photonic integrated circuit to be used as building block in photonics-based beamforming networks for 5G wireless systems. The integrated module controls the phase of the millimeter-wave signals transmitted and received by an antenna element in a phased-array antenna. It comprises an optical de-interleaver for carrier-sideband separation, a microring resonator (MRR) -based phase-shifter (PS) and a carrier depletion-based MRR electro-optic modulator. The photonic de-interleaver enables flexible operation with different RF frequencies. The PS exploits two thermally-tunable cascaded MRRs that allow continuous shifting of the carrier phase over more than 400 degrees. The device is proved allowing a precise beamforming control with a power consumption of few tens of mWs per antenna element.

Mo1.5 9:30~9:45

Title: A Silicon Photonic Integrated Frequency-Tunable Microwave Photonic Bandpass Filter.....15

- **Weifeng Zhang, Jianping Yao, (University of Ottawa, Canada)**

Abstract: We report a fully integrated microwave photonic passband filter on a silicon photonic chip. The on-chip integrated microwave photonic filter (IMPF) consists of a high-speed phase modulator (PM), a thermally tunable high-Q micro-disk resonator (MDR), and a high-speed photo-detector (PD). The bandpass filtering function of the IMPF is implemented based on phase modulation and phase-modulation to intensity-modulation conversion, to translate the spectral response of an optical filter, which is the MDR in the IMPF, to the spectral response of a microwave filter. By injecting a CW light from a laser diode (LD) to the PM, a passband IMPF with a broad tuning

range is demonstrated. Thanks to the ultra-narrow notch of the MDR, a passband IMPF with a 3-dB bandwidth of 2.3 GHz is realized. By thermally tuning the MDR, the center frequency of the IMPF is tuned from 7 to 25 GHz, achieving a tuning range of 18 GHz at a power consumption of 1.58 mW. This successful implementation of an IMPF marks a significant step forward in full integration of microwave photonic systems on a single chip and opens up avenues toward real applications of microwave photonic filters.

Mo1.6 9:45~10:00

Title: RF photonic Frontend on a Chip.....19

- **Longtao Xu**, (*University of Massachusetts Dartmouth, USA*); **Ding Ding**, (*Beijing University of Posts and Telecommunications, USA*); **Shilei Jin**, (*University of Massachusetts Dartmouth, USA*); **Yifei Li**, (*University of Mass. Dartmouth, USA*)

Abstract: We present the concept, design, fabrication and preliminary measurement results of a RF photonic frontend on a photonic IC chip. The RF photonic frontend employs linear optical phase modulation and linear phase demodulation by an ACP-OPLL. The link achieves frequency down-conversion by optical sampling. The preliminary results demonstrated down conversion SFDR of 108.1dB-HZ^{2/3} with 1GHz RF and 50MHz IF input.

Coffee Break: 10:00~10:15

Session 2: Signal Generation

Session chair: Xihua Zou

Mo2.1 10:15~10:30

Title: Linear Frequency-Modulated Waveform Generation Based on a Tunable Optoelectronic Oscillator.....22

- **Pei Zhou**, (*NUAA, P.R. China*); **Fangzheng Zhang**, (*Nanjing University of Aeronautics & Astronautics, P.R. China*); **Qingshui Guo**, (*NUAA, P.R. China*); **Shilong Pan**, (*Nanjing University of Aeronautics & Astronautics, P.R. China*)

Abstract: A new scheme for generating linear frequency-modulated (LFM) microwave waveforms is proposed and demonstrated based on a tunable optoelectronic oscillator (OEO) with an optically injected semiconductor laser. Frequency tunability of the OEO is achieved by controlling injection strength of the injection light. When the sweep period of output frequency matches with the cavity round-trip time, the signal quality of generated LFM waveform is significantly improved by the high Q optoelectronic oscillation. In the experiment, LFM signal with a sweep range as large as 7 GHz, a sweep rate reaching 0.18 GHz/ns, and a time-bandwidth product (TBWP) up to 2804.2 is generated. An improvement of the frequency comb contrast by 43 dB is also achieved in the spectrum. The proposed LFM waveform generator features large bandwidth, fast sweeping rate, and high spectral purity, which may find wide applications in future radar systems.

Mo2.2 10:30~10:45

Title: Coherent Frequency Tuneable THz Wireless Signal Generation Using an Op-

tical Phase Lock Loop System.....26

- **Haymen Shams, Katarzyna Balakier**, (University College London, United Kingdom); **Martyn Fice, Lalitha Ponnampalam, Chris Graham**, (University College London, United Kingdom); **Frédéric Van Dijk, Alcatel Thales (III-V Lab, France); Cyril Renaud, Alwyn Seeds**, (University College London, United Kingdom)

Abstract: We demonstrate experimentally, for the first time, the photonic generation of a continuous tunable THz wireless signal based on using an optical phase lock loop (OPLL) sub-system and optical frequency comb generator (OFCG). The OPLL is employed to select one line from the optical comb and shift it by the desired frequency offset allowing for the frequency tuneability of THz carrier signal. The selected optical tone from the OPLL is heterodyne mixed with another selected optical line of the optical comb to generate a stabilized THz frequency carrier with a low phase noise. Full system operation is demonstrated by transmitting wirelessly a THz signal modulated with 10 Gbaud QPSK data. The system performance is evaluated for four selected THz carrier frequencies obtained by tuning the laser included in the OPLL. This configuration is a promising architecture that would allow a THz carrier to be flexibly generated at the central office with high frequency stability and low phase noise.

Mo2.3 10:45~11:00

Title: All-Optical Random Sequence Generation For Compressive Sensing Detection of RF Signals.....30

- **Chaitanya Mididoddi, Eamonn J Ahmad, Chao Wang**, (University of Kent, United Kingdom, Great Britain)

Abstract: Photonic compressive sensing is a promising data compression method and has been successfully applied in high-speed RF signal detection with greatly reduced requirement for receiver bandwidth. A key challenge is due to the electronic bottleneck in high-speed random sequence mixing. In this work, we propose and experimentally demonstrated for the first time all-optical random pattern generation and mixing for compressive sensing detection of RF signals. The technique is based on photonic time stretch involving cascaded Mach-Zehnder Interferometers (MZIs) for spectral domain random mixing. In a proof-of-concept experiment, successful detection of 1 GHz RF signal with 10% compression ratio using only 50 MHz detection bandwidth has been demonstrated.

Mo2.4 11:00~11:15

Title: Highly linear silicon Mach-Zehnder modulators with optimized phase-shifter.....34

- **Sheng Yu, Yadong Liu**, (Institute of Semiconductors, Chinese Academy of Sciences, P.R. China); **Tao Chu**, (Zhejiang University, P.R. China)

Abstract: We have experimentally demonstrated that the linearity of a silicon Mach-Zehnder modulator (MZM) could be improved by optimizing its phase-shifter length (PSL). Through the optimization of the PSL, the third order intermodulation distortion of the silicon MZM could be 16.7 dB lower than that of a commercial LiNbO₃ MZM. The spurious free dynamic range of the link with the silicon MZM could be 4.1 dB higher than that with the LiNbO₃ MZM.

Mo2.5 11:15~11:30

Title: A Radio Astronomy L-Band Phased Array Feed System using RF over Fiber Distribution.....37

• **Ron Beresford, (CSIRO, Australia)**

Abstract: This is an overview of the system level RF design for the second generation architecture used in the Australian Square Kilometre Array Pathfinder (ASKAP) design enhancement (ADE). ADE is a distributed antenna system (DAS) of 36 reflector antennas each 12m in diameter. Each antenna has a planar Phased Array Feed (PAF) at the prime focus. The PAF contains 188 broadband 700-1800MHz receptors. Inside a PAF the radioastronomy (RA) signals are amplified, band selected and converted to 188 individual broadband RF over (singlemode optical) fiber (RFoF) lightwaves. The entire ADE array has 6840 RFoF links, this includes transmission line delay metrology for each reflector. The longest RFoF span is 6km. Optical to RF demodulation of the RF sky signal at the central site Digital Signal Processing (DSP) shielded building is direct sampled in 12bit analog to digital convertors (ADCs). Digital beamforming provides 36 pencil beams, each of 384MHz bandwidth. The scale of ADE represents a leap forward in applied RF and photonic techniques to enable a simpler, lower cost, more modular, EMC compliant, phased array receiver architecture. ADE will provide unprecedented high speed sky surveys with an instantaneous wide-field of view (30deg² at 1420MHz) capability for a new generation of radio astronomers.

Tuesday, 24 October 2017

Room: Auditorium(三楼报告厅)

Opening: 8:30~8:40

Session: Plenary I

8:40~9:20 Prof. Ke Wu

Title: Ultra-Broadband and Ultra-Fast Technology - Calling for Cooperative Integrated Electronics and Photonics.....N/A

Abstract: Current and future wireless and wireline system evolutions, in the spirit of connectivity being “anywhere, anytime, anyone and anything”, advocate for a cooperative and joint development platform of integrated electronics and photonics. This presentation will address and review scientific and engineering issues of high-frequency and high-speed electronics and photonics in connection with fundamental physical hurdles of the much-anticipated ultra-broadband analog and ultra-fast digital applications. In particular, two revolutionary schemes will be highly sought after in the future: first, THz-over-fiber (ToF) which would enable the networking of THz bandwidth communication and sensing; and second, pico-second interconnects which would realize massive chip-to-chip data transfer with high signal integrity. To transform these two technological dreams into reality, critical components and techniques will be required. To this end, an emerging concept of mode-selective transmission line will be exposed and detailed with its physical mechanism for low-loss and low-dispersion super-wideband and ultra-fast signal transmissions over the DC-THz spectrum. Early theoretical and experimental results have created new excitement for the future of electronics and photonics.

9:20~10:00 Prof. Chih-Lin I

Title: 5G RAN's Revolutionary Transformation.....N/A

Abstract: The ambitious 5G vision leads to an evolutionary revolution of RAN technologies and, directly or indirectly, spread to the transport industry. As a Chinese old saying goes, food and fodder should go ahead of troops and horses, which marks the importance of logistics. In the context of 5G, this could be translated to that transport network is more important than ever. In this talk, first, we will bring the audience our vision, achievements, and on-going effort on 5G RAN transformation towards a Soft, Smart and open-Source RAN. Furthermore, the critical requirements imposed on underlined transport will be introduced, accompanied by potential solutions as well as our latest achievements in the area of NGFI, from requirements, architecture to PoC development. CMCC sees great potential in MWP, an interdisciplinary field that combines microwave engineering and photonics, especially its applications in the areas that can revolutionize the future RAN architecture and implementation, such as fronthaul, backhaul and cloud RoF networks, etc. CMCC has led and impacted the work of MWP community for the past 5 years through our work on NGFI (xHaul). In the future, we believe the ownership model of enabling network sharing and the business model of integrated optical-wireless access systems will be instrumental in realizing a successful 5G.

Coffee Break: 10:00~10:15

Session 3: Integrated Chips and Components **(BSPA session 1)**

Session chair: Iezekiel Stavros, and Yifei Li

Tu1.1 10:15~10:45 (Invited)

- **Luc Augustin**, (SMART photonics, the Netherlands)

Title: InP based platform for MWP.....N/A

Tu1.2 10:45~11:00

Title: Integrated RF-Photonic Delay Lines using Reconfigurable Photonic Waveguide Meshes.....41

- **Daniel Pérez, Ivana Gasulla, Jose Capmany**, (*Universidad Politecnica de Valencia, Spain*); **Lee Crudgington, David Thomson, Ali Khokhar, Ke Li, Wei Cao, Goran Z Mashanovich**, (*University of Southampton, United Kingdom*)

Abstract: In this paper we demonstrate the implementation of optical delay lines on a programmable hexagonal waveguide mesh integrated in Silicon on Insulator (SOI). This building block enables the synthesis of reconfigurable discrete-time filters and beamforming networks.

Tu1.3 11:00~11:15

Title: Lens-assisted Quasi-Optical THz Transmitter employing Antenna-integrated Triple Transit Region Photodiodes.....45

- **Vitaly Rymanov, Peng Lu**, (*University of Duisburg-Essen, Germany*; *Sebastian Dülme, Universität Duisburg-Essen, Germany*); **Andreas Stöhr**, (*University of Duisburg-Essen, Germany*)

Abstract: In this paper, a compact lens-assisted quasi-optical THz transmitter, using a 2x2 mm² planar log-periodic toothed antenna / bow-tie antenna (LPTA/BTA) integrated InP-based waveguide triple transit region (TTR) photodiode chip and an extended highly-resistive silicon (HR-Si) quasi-optical lens, is developed and presented for directive THz beam forming. In order to decrease the optical propagation loss in the passive optical waveguide section (<1 dB), as well as enable the THz range capability of the integrated TTR-photodiode by optimized impedance matching to the antenna feed and increase the THz beam directivity (>25 dBi) of the developed LPTA/BTA-integrated THz photomixer, different numerical analyses are carried out with respect to the optical waveguide and the RF antenna characteristics, considering the integrated HR-Si quasi-optics. Experimentally, THz operation up to a frequency of about 300 GHz is demonstrated for the fabricated lens-assisted quasi-optical THz transmitters.

Tu1.4 11:15~11:30

Title: Integrated Optical Beamforming Network for Millimeter Wave Communications.....49

- **Yuan Liu, Fengqiao Sang, Brandon Isaac, Jonathan Klamkin, (University of California, Santa Barbara, USA); Sergio Pinna, Scuola Superiore Sant'Anna, Italy; Jean Kalkavage, Eric Adles, Thomas Clark, (The Johns Hopkins University Applied Physics Laboratory, USA)**

Abstract: An optical ring resonator (ORR) based 1×4 integrated optical beamforming network (OBFN) targeting mmW is reported. The optimized true time delay response of a 3-ORR delay line with a bandwidth of 8.7 GHz was achieved over tuning range of 172.4 ps, which corresponds to a 31π phase shift for a 90 GHz signal. A 3 Gbps OOK NRZ data signal was transmitted through the delay line to verify the overall performance. A 49-degree beamsteering angle equivalent OBFN delay response was achieved for a 90 GHz half-wavelength dipole antenna array. Using heterodyne upconversion technology and a single delay path, 41 GHz mmW signal with 3 Gbps OOK NRZ data modulation was generated and delayed.

Tu1.5 11:30~11:45

Title: Large Capacity Terahertz Tag Using Photonic Crystal Slabs.....53

- **Yusuke Kujime, Masayuki Fujita, Tadao Nagatsuma, (Osaka University, Japan)**

Abstract: The Internet of Everything (IoE) has attracted a great deal of interest. To realize the IoE concept, information tags which directly attach to objects are one of the keys to date. However, in terms of security or their uniqueness issues, today's information tags are still not satisfactory. Here, we propose the use of large capacity terahertz (THz) tags; by utilizing both frequency and spatial domains. This approach is expected to reduce our security concerns towards future IoE applications. In place of usual small capacity THz tag techniques, we introduced a new approach by large capacity THz tags using two dimensional (2D) photonic-crystal slabs in a matrix. As a result, we successfully demonstrated a THz tag of 48 bits/cm² at 600-GHz band. In conclusion, we anticipate that this work will contribute to the further development of the capacity enhancement of the THz tag: over 128 bits/cm² suitable for various IoE applications.

Tu1.6 11:45~12:00

Title: Sub-20-dB Noise Figure and Positive Link Gain in a Chip-based Si₃N₄ Microwave Photonic Filter.....57

- **Yang Liu, (University of Sydney, Australia); David Marpaung, (University of Sydney & Centre for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS), Australia); Amol Choudhary, (CUDOS/University of Sydney, Australia); Jason Hotten, Benjamin Eggleton, (University of Sydney, Australia)**

Abstract: We present a microwave photonic notch filter based on a Si₃N₄ photonic chip, with a noise figure of less than 20 dB, a positive link gain and an ultra-deep rejection beyond 50 dB in the stopband. This level of performance is achieved by using on-chip resonators' unique phase responses, and thorough optimizations of the photonic link.

Lunch: 12:00~13:30

Session 4: MWP devices (BSPA session 2)

Session chair: Antonella Bogoni and Hiroshi Murata

Tu2.1 13:30~14:00 (Invited)

- **Xiaoke Yi**, (University of Sydney, Australia)

Title: Integrated Microwave Photonic Signal Processor.....61

Tu2.2 14:00~14:15

Title: Tunable Single Passband Microwave Photonic Filter using a Cascaded Pair of Microring Resonators.....65

- **Shijie Song, Xiaoke Yi, Suen Chew, Linh Nguyen, Robert Minasian**, (University of Sydney, Australia)

Abstract: We propose and demonstrate a novel integration based technique employing a cascaded pair of silicon-on-insulator (SOI) microring resonators to achieve a tunable single passband filter. The use of a double microring structure provides an all-integration approach to eliminate the usual selectivity dependence of the radio frequency (RF) response on the shape of a single ring resonator. Instead, the selectivity of the RF filter is enhanced by controlling the relative difference between the bandwidths of the two optical ring resonators which directly maps to the resulting bandwidth of the RF passband. Experimental results show the realization of a tunable single passband filter with out-of-band rejection ratio around 20 dB. The RF filter is demonstrated with a tuning capability from 6 GHz to 17 GHz without altering the optical carrier frequency, while maintaining the filter bandwidth below 1.9 GHz. Moreover, the shape factor was also kept within 1.78 with a variation of only ± 0.05 throughout the entire tuning range, thus successfully accomplishing shape invariant tuning of the single passband without compromising the filter rejection bandwidth.

Tu2.3 14:15~14:30

Title: On-Chip Selectable-Frequency Comb Generation by Passive Harmonic Mode Locking.....69

- **Mu-Chieh Lo, Robinson Guzmán**, (Universidad Carlos III de Madrid, Spain; Carlos Gordon, Universidad Técnica de Ambato, Ecuador); **Muhsin Ali and Guillermo Carpintero**, (Universidad Carlos III de Madrid, Spain)

Abstract: A monolithic integrated 2.8-mm colliding-pulse mode-locked laser is demonstrated to emit optical combs with switchable mode spacing for millimeter-wave generation. By selecting the DC-bias condition, the laser is forced to operate in harmonic mode locking regimes. Optical frequency combs with mode spacing of 2nd (30 GHz), 3rd (45 GHz), 4th (60 GHz) and 6th (90 GHz) harmonics are presented. The autocorrelation trace of 2nd harmonic exhibits a 1.03-ps pulsewidth. The beat note of 4th harmonic has an RF linewidth of 520 kHz.

Tu2.4 14:30~14:45

Title: Photonic Generation of Linear Frequency Modulated Terahertz Pulses in the 350 GHz Band with beyond 40 GHz Bandwidth.....73

- **Hangkai Zhang, Jia Shi, Xianbin Yu, (Zhejiang University, P.R. China)**

Abstract: A simple photonic scheme for generation of linear frequency modulated (LFM) THz pulses with large bandwidth is experimentally demonstrated based on optical interferometer. We successfully generate linearly chirped THz pulses centered at 350 GHz, and featuring a bandwidth in excess of 40 GHz. The tunability of the THz center frequency is also investigated in the experiment. The time bandwidth product (TBWP) of the generated THz pulses is up to 360, which will have a potential in implementing high resolution radar sensing and imaging.

Tu2.5 14:45~15:00

Title: Dispersion-Free Wavelength-to-Time Mapping Method for Optical Arbitrary Waveform Generation.....77

- **Xinyi Zhu, Hao, Sun Wei, Li Ning-Hua Zhu, Ming Li, (University of Chinese Academy of Sciences & Institute of Semiconductors)**

Abstract: A novel approach to generate arbitrary waveforms based on spectrum-shaping and wavelength-to-time mapping without any dispersive element is proposed and investigated. The generation of a variety of waveforms, including Gaussian, square, and other specific waveforms, is demonstrated experimentally. The arbitrary waveform generator features superior advantages such as low power loss, simple structure, and high reconfiguration.

Tu2.6 15:00~15:15

Title: Experimental Design of a Low Phase Noise Coupled Optoelectronic Oscillator at 10 GHz.....81

- **Oriane Lelièvre, Vincent Crozatier, Pascale Nouchi, Daniel Dolfi, Loic Morvan, (Thales Research & Technology, France); Ghaya Baili, (Thales Research and Technology & TRT-FR, France); Olivier Llopis, (LAAS-CNRS, France); Fabienne Goldfarb, (Fabien Bretenaker, Laboratoire Aimé Cotton, France)**

Abstract: We present an experimental study on two key elements to design a low phase noise coupled optoelectronic oscillator (COEO). Fiber lengths and dispersions are investigated to highlight the differences between the optical and optoelectronic loops. After optimization, a 10 GHz COEO at 1.5 μm with a total of 590 m of fiber exhibits phase noise levels of -125 dBc/Hz at 1 kHz and -140 dBc/Hz at 10 kHz.

Tu2.7 15:15~15:30

Title: A compact optical-microwave phase detector based on a polarization modulator.....85

- **Juan Wei**, (Nanjing University of Aeronautics & Astronautics); **Shilong Pan**, (Nanjing University of Aeronautics & Astronautics, P.R. China); **Jungwon Kim**, **Shuangyou Zhang**, (KAIST, Korea)

Abstract: A compact optical-microwave phase detector is proposed and its performance is evaluated by synchronizing an 8-GHz voltage-controlled oscillator to a 250-MHz mode-locked laser. The residual out-of-loop phase noise is -115 dBc/Hz (-146 dBc/Hz) at 1 Hz (100 kHz) off-set frequency and the integrated RMS timing jitter from 1 Hz to 100 kHz is 839 as. The proposed phase detector has a compact structure and is easy to implement using all commercial devices to achieve subfemtosecond synchronization between optical pulses and microwave oscillators.

Coffee Break: 15:30~15:45

Session 5: Microwave signal processing (BSPA session 3)

Session chair: Nathan Gomes

Tu3.1 15:45~16:15(Invited)

- **Jerome Bourderionnet**, (Thales Research & Technology, France)

Title: Silicon photonic circuits for RF filtering and LIDAR applications.....N/A

Tu3.2 16:15~16:30

Title: Performance Evaluation of CoMP for Downlink 60-GHz Radio-over-Fiber Fronthaul.....88

- **Yu Tian, Ka Lun (Alan) Lee and Christina Lim, Ampalavanapillai Nirmalathas**, (The University of Melbourne, Australia)

Abstract: We propose and experimentally demonstrate a downlink 60-GHz millimeter-wave radio-over-fiber fronthaul incorporating coordinated multipoint (CoMP) transmission scheme. CoMP function is implemented in the centralized baseband unit to obtain the transmission diversity. Space-time diversity gain is exploited to improve the data rate of cell-edge users as well as the coverage of 60-GHz small cells. To serve a cell-edge user, Alamouti space-time block code (STBC) is used between two coordinated remote radio heads (RRHs). 2 Gbps 4-QAM signal was transmitted over 3 km fronthaul link. Experimental results show that receiver sensitivity of CoMP system can be improved by 1.8 dB compared with two RRHs transmission without STBC at BER=1e-4. The impact of time synchronization errors between two cooperative channels is also analyzed. The coordinated fronthaul scheme employing STBC can be tolerable to much higher delays than would be possible for two channels transmission without STBC.

Tu3.3 16:30~16:45

Title: Dual-band linear frequency-modulated continuous wave radar receiver with high image rejection based on microwave photonic I/Q mixer.....92

- **Ziyi Meng, Jianqiang Li, Chunjing Yin, Yuting Fan, Feifei Yin, Yue Zhou, Yitang Dai, Kun Xu,** (Beijing University of Posts and Telecommunications, P.R. China)

Abstract: We propose a dual-band linear frequency-modulated continuous wave (LFMCW) radar receiver based on a microwave photonic in-phase and quadrature (I/Q) mixer, able to simultaneously operate on two different bands over a very broad frequency range. The sharing of hardware resources and joint processing of dual bands are implemented by applying a special dual-band sensing waveform. An unambiguous and independent distance measurement of S- and C-bands is demonstrated experimentally. The results exhibit a high and uniform image rejection more than 28 and 30 dB for S- and C-bands, allowing a further improvement of around 15 dB and 10 dB using digital signal processing (DSP).

Tu3.4 16:45~17:00

Title: Proposal and Demonstration of SIM-OFDM Based Radio-over-Fiber System.....96

- **Tang Tang, Xihua Zou, Peixuan Li, Wei Pan,** (Southwest Jiaotong University, P.R. China)

Abstract: We propose and experimentally demonstrate a radio-over-fiber (RoF) system employing subcarrier-index modulation (SIM) orthogonal-frequency-division multiplexing (OFDM) signal. Thanks to the introduction of a new freedom in terms of SIM, a robust and energy-effective transmission solution is achieved for the RoF system. In the experiments, the 8-GHz QPSK-SIM-OFDM and conventional QPSK-OFDM signals are transmitted in an RoF system with a 10-km single-mode fiber (SMF) link. Compared with conventional QPSK-OFDM, the proposed QPSK-SIM-OFDM for RoF system is verified with higher energy efficiency and a lower bit error ratio (BER) for a medium or high signal-to-noise ratio (SNR). Concerning the energy efficiency of the proposed RoF system, defined as the total amount of reliably decoded bits normalized by the energy, it is about 1.5 times higher than that of conventional QPSK-OFDM.

Tu3.5 17:00~17:15

Title: High-resolution characterization of parametric sampling based photonic phase locking.....100

- **Guang Yang, Weiwen Zou, Jianping Chen,** (Shanghai Jiao Tong University, P.R. China)

Abstract: We demonstrate a novel photonic phase locking between the pulse train from a passively mode locked laser and the photonic signal generated from an actively mode locked laser. A high-resolution characterization of the photonic phase locking is also presented. In the phase locking loop, the phase detection is employed by the parametric sampling in a photonic crystal fiber and its residual error is characterized by both the phase noise measurement and the digitization of the sampling results. The residual phase noise measurement derives an integral timing jitter of 1.7 fs and the digitization reaches an 8-bit resolution at 220 GHz carrier, which verify the good performance of the phase locking loop.

Tu3.6 17:15~17:30

Title: Resolution improvement of the large bandwidth and high-speed electrical spectrum analyzer based on dual optical frequency combs.....104

- **Yuhua Duan, Lei Zhang, Liao Chen, Xi Zhou, Chi Zhang, Xinliang Zhang,** (Huazhong University of Science and Technology, P.R. China)

Abstract: An all-optical electrical spectrum analyzer is demonstrated based on dual optical frequency combs and microwave photonics, and it improves the resolution to be 250 MHz over 10-GHz bandwidth, with the 1-kHz frame rate. The spectrum is directly obtained in the time domain, using as low as 10-MHz acquisition bandwidth, without any post-processing.

Reception: 18:30~20:30

China National Convention Center (CNCC)



Wednesday 25 October 2017

Room: Auditorium(三楼报告厅)

Opening: 8:30~8:40

Session: Plenary II

8:40~9:20 Prof. John Bowers

Title: Heterogeneous Photonic Integration in Microwave Photonics.....N/A

Abstract: Heterogeneous integration of III-V and SOI wafers has enabled hundreds of optical devices to be integrated onto a chip for a variety of applications including 100 and 400 Gbps transceivers, integrated LIDARs, compact short pulsed modelocked lasers, widely tunable narrow linewidth lasers and fully-integrated photonic microwave tracking generators. Other applications include integrated sources with efficient second harmonic generators. Lasers at wavelengths from 4.8 to 1 micron have been integrated on silicon using heterogeneous integration. Digital optical synthesis has been demonstrated where a widely tunable III-V laser on silicon can be stabilized to 1 Hz. Finally, we discuss prospects and advantages of quantum dot lasers epitaxially grown on silicon wafers.

9:20~10:00 Prof. Ton Koonen

Title: Indoor Ultra-High Capacity Optical Wireless Communication using Steerable Infrared Beams.....107

Abstract: Free-space infrared beams can offer unprecedented data capacity to devices individually, by means of unshared connections which have a large link power budget. Two solutions based on passive diffractive modules are presented which perform wavelength-controlled 2D beam steering while minimizing power consumption. Downstream capacities up to 112Gbit/s per beam were experimentally demonstrated. In a hybrid system demonstrator, 60GHz techniques provided upstream capacity up to 5Gbit/s. Also an all-optical optical wireless communication system concept has been demonstrated, and a novel concept for an aperture-and-bandwidth-optimized integrated optical receiver is presented.

Coffee Break: 10:00~10:15

Session 6: Radio over fiber (BSPA session 4)

Session chair: Jose Capmany, Zizeng Cao

We1.1 10:15~10:45 (Invited)

- **Xihua Zou**, (Southwest Jiaotong University, China)

Title: Microwave Photonics for High-speed Railway Applications: communication, detection and sensing.....N/A

We1.2 10:45~11:00

Title: VCSEL-SSMF-based Radio-over-Fiber link for low cost and low consumption Wireless Dense Networks.....111

- **Jacopo Nanni and Francesco Pizzuti** (University of Bologna, Italy); **Jean-Luc Polleux** (ESY-COM-ESIEE-UPEM, France); **Catherine Algani** (Cnam, France); **Giovanni Tartarini** (DEI, University of Bologna, Italy)

Abstract: This paper presents a possible Radio-over-Fiber (RoF) system which can be implemented in current and next generations of cellular networks such as LTE or future 5G. The system proposed is based on low cost and low consumption optical components such as 850 nm Single Mode Vertical Cavity Surface Emitting Lasers (VCSELs) and Standard Single Mode Fiber (SSMF) of G.652 type. The performances are evaluated through the computation of the Error Vector Magnitude (EVM) for an entire LTE frame of 10 ms for 20 MHz band signal in band 20 of the standard. Appropriate countermeasures were adopted against the bandwidth reduction due to the behavior of the G.652 fiber, which in the first optical window stops to exhibit monomodality. This allowed to achieve high modulation format transmission is done for various input RF powers and for distances stretching up to 1.5 km.

We1.3 11:00~11:15

Title: Photonic Sub-sampling of Signal at 43.1-GHz Using Optical Comb Based on an Optoelectronic Oscillator.....115

- **Rui Guo, Huayang Du, Huanfa Peng, Xiaofeng Peng, Cheng Zhang, Lixin Zhu, Juhao Li and Zhangyuan Chen** (Peking University, P.R. China)

Abstract: A 10 GS/s photonic sub-sampling ADC using optical comb based on an optoelectronic oscillator is proposed and experimentally demonstrated. The SSB phase noise of the optoelectronic oscillator is measured to be -128 dBc/Hz at 10 kHz offset and the aperture jitter of the photonic ADC is 40.3 fs with an integral interval from 1 kHz to 10 MHz. 23 GHz and 43.1 GHz signals are sampled by the system with the ENOB of 5.0 bits and 4.2 bits.

We1.4 11:15~11:30

Title:Phase-Balanced Differential Vector Modulation by Laser and Electroabsorption Modulator.....118

- **Praimezt Mekbungwan**, **Ukrit Mankong** (*Chiang Mai University, Thailand*); **Keizo Inagaki** (*National Institute of Information and Communications Technology, Japan*); **Tetsuya Kawani-shi** (*Waseda University & National Institute of Information and Communications Technology, Japan*)

Abstract: Directly modulated laser can be used as phase modulator due to chirp effect. However, accompanying amplitude modulation also results. By using EA Modulator in combination, light amplitude may be compensated enabling both amplitude and phase modulation of lightwave, which is an alternative method to conventional IQ modulator. Since light phase is proportional to intensity, we propose cumulative phase- balance coding to solve the limitation in the laser operating range for differential M-PSK and M-QAM modulation. The technique applies parallel DC-balance coding with phase-balance symbol mapping. The cumulative phase in high-order differential modulation is always bounded, it is for the first time, to our knowledge.

We1.5 11:30~11:45

Title: GHz-wide Arbitrary-shaped Microwave Photonic Filter Based on Stimulated Brillouin Scattering Using Directly-modulated Laser.....122

- **Wei Wei and Lilin Yi** (*Shanghai Jiao Tong University, P.R. China*); **Yves Jaouën** (*Telecom ParisTech, France*); **Weisheng Hu** (*Shanghai Jiao Tong University, P.R. China*)

Abstract: We present a cost-efficient GHz-wide arbitrary-shaped microwave photonic filter based on stimulated Brillouin scattering in fiber. By employing a directly-modulated laser with well-designed current waveform and feedback adjustment, the filter shape has been arbitrarily controlled with high precision.

We1.6 11:45~12:00

Title: High-resolution and Real-time Inverse Synthetic Aperture Imaging based on a Broadband Microwave Photonic Radar.....125

- **Qingshui Guo** (*NUAA, P.R. China*); **Fangzheng Zhang** (*Nanjing University of Aeronautics & Astronautics, P.R. China*); **Ziqian Wang** (*China Electronics Technology Group Corporation, P.R. China*); **Pei Zhou** (*NUAA, P.R. China*); **Shilong Pan** (*Nanjing University of Aeronautics & Astronautics, P.R. China*)

Abstract: A microwave photonic radar system with optical generation and de-chirping processing of broadband linear frequency modulated continuous-wave signal is proposed for high-resolution and real-time inverse synthetic aperture radar (ISAR) imaging. A K-band microwave photonic radar prototype is established and the ISAR imaging feasibility is experimentally investigated. The imaging results verify that the proposed radar works well and is hopefully to find wide applications where high-resolution and real-time radar imaging is required.

Lunch 12:00~13:30

Session 7: New techniques for RoF

Session chair: Ton Koonen, Ming Li

We2.1 13:30~14:00 (Invited)

- **Xinying Li**, (Georgia Institute of Technology)

Title: Photonics-aided W-band wireless millimeter-wave signal transmission.....N/A

We2.2 14:00~14:30 (Invited)

- **Leslie Ann Rusch** (University Laval, Canada)

Title: Virtualizing Cloud RAN by piggybacking on WDM-PON channels.....N/A

We2.3 14:30~14:45

Title: High-Capacity Dynamic Indoor Network Utilizing Optical Wireless and 60-GHz Radio Techniques.....128

- **Ketamaw Mekonnen** (Eindhoven University of Technology, The Netherlands); **Nicola Calabretta** (COBRA Research Institute, The Netherlands); **Eduward Tangdiongga** (Eindhoven University of Technology & Institute for Photonic Integration, The Netherlands); **Ton Koonen** (IPI, Eindhoven University of Technology, The Netherlands)

Abstract: We propose a full-duplex dynamic indoor optical-wireless system using photonic integrated circuits with multicasting capability of 10 Gb/s on-off-keying data, backed up by a 60 GHz radio system with data capacity of >40 Gb/s to realize reconfigurable and reliable high-capacity links to wireless users equipped with localization and tracking functionalities.

We2.4 14:45~15:00

Title: Real-time Wireless OFDM Communication in THz-band Using Optical DFT Processing.....132

- **Koichi Takiguchi** (Ritsumeikan University, Japan)

Abstract: Real-time THz-wave wireless OFDM communication, which is assisted by optical technology, is reported. A 4 x 10 Gbit/s THz-wave OFDM signal is transferred into an optical OFDM signal, and the optical OFDM signal is successfully demultiplexed into four sub-carrier channels with an integrated-optic DFT circuit.

Session 8: Microwave signal processing

Session chair: Xiaoke Yi, Yitang Dai

We3.1 16:00~16:30 (Invited)

- **Wangzhe Li**, (Institute of Electronics Chinese Academy of Sciences, China)

Title: Microwave photonic synthetic aperture radar.....N/A

We3.2 16:30~16:45

Title: Optical phase lock loop as high-Q filter for optical frequency comb line selection.....135

- **Katarzyna Balakier and Haymen Shams** (University College London (UCL), United Kingdom); **Martyn Fice, Lalitha Ponnampalam, Chris Graham, Cyril Renaud and Alwyn Seeds** (University College London, United Kingdom)

Abstract: This paper describes the first optical phase lock loop (OPLL) based on a photonic integrated circuit (PIC) fabricated using a generic foundry process and off-the-shelf electronic components. The PIC contains a DBR laser that is for the first time frequency and phase stabilized in reference to an Optical Frequency Comb Generator (OFCG) line. The OFCG used in this demonstration offers 19 highly coherent lines spaced by 15 GHz. The OPLL can attenuate all adjacent comb lines and noise by more than 50 dB below the power of the selected comb line. Hence, the OPLL can be considered as an ultra-selective optical filter. The OPLL output is a single mode DBR laser line, with frequency offset from the reference comb line exactly selectable over the frequency range 4 GHz to 12 GHz. The laser can be current tuned over a 1 THz (8 nm) range enabling the different comb lines to be selected. The coherence between DBR laser and comb lines is demonstrated by measurements of the heterodyne signal residual phase noise level, which is below -100 dBc/Hz at 5 kHz offsets from the carrier. This is a record low value for an OPLL based on a monolithically photonic integrated circuit. Such an OPLL could be used for high purity, tuneable millimetre and THz wave generation.

We3.3 16:45~17:00

Title: 16 Gbps RoF Link at 20 GHz Carrier Frequency using a Silicon Photonics Transmitter and Receiver.....139

- **Kasper Van Gasse and Joris Van Kerrebrouck** (Ghent University, Belgium); **Amin Abbasi** (Ghent University - imec, Belgium); **Guy Torfs** (Ghent University & imec, Belgium); **Johan Bauwelinck and Gunther Roelkens** (Ghent University - imec, Belgium)

Abstract: In future radio access networks, radio-over-fiber links will be a key enabling technology. A link which is cost-effective in both deployment and operation will be of paramount importance to the development of such networks. Using silicon photonics for the transmitter and receiver is a cost-effective and high-performance solution. In this work we present a link which can transport up to 16-Gbps 16-QAM data on a 20-GHz carrier over 5-km of SMF. The transmitter is a III-V-on-Si directly modulated laser and the receiver is a Ge-on-Si photodetector on a silicon photonic integrated circuit, co-integrated with a SiGe BiCMOS TIA. This is to the best of our knowledge the first Si PIC based RoF link with a directly modulated laser.

We3.4 17:00~17:15

Title: Experimental Investigation of Phase Noise Tolerance of SSB THz Signals.....143

- **Luis Gonzalez Guerrero, Haymen Shams** (University College London (UCL), United Kingdom); **Irshaad Fatadin** (National Physical Laboratory, United Kingdom); **Martyn Fice** (University College London, United Kingdom); **Mira Naftaly** (National Physical Laboratory, United Kingdom); **Alwyn Seeds** (University College London, United Kingdom); **Frédéric Van Dijk** (Alcatel Thales III-V Lab, France); **Cyril Renaud** (University College London, United Kingdom)

Abstract: Wireless bridges operating at THz frequencies have drawn a lot of attention in recent years. This application requires multiple optical local oscillators (LOs) throughout the link and, hence, the accumulated phase noise may impose a major challenge for its practical implementation. Of all the techniques to mitigate phase noise, single sideband (SSB) modulation is a very promising candidate due to its simple implementation. In this paper, we show, for the first time, the transmission of a 6 GBd SSB QPSK signal at 250 GHz and investigate the impact of laser phase noise on the quality of the THz signal. The performance of the system is investigated by digitally tuning the linewidth of the optical local oscillator up to 10 MHz. The results show no observable penalty associated with increasing linewidth, confirming the validity of SSB for applications where multiple domain conversions are required.

We3.5 17:15~17:30

Title: Photonic high speed ultra-wideband microwave spectral scanning.....147

- **Yihan Li** (IMRA America, Boulder Research Lab, USA); **Naoya Kuse** (IMRA America Inc., Boulder Research Labs, USA); **Martin Fermann** (IMRA America, Inc., USA)

Abstract: In this work we propose and experimentally demonstrate a photonics-assisted microwave spectral scanning system that realizes high-speed sweeping over ultra-broad bandwidth. Enabled by coherent dual electro-optical frequency combs and a recirculating optical frequency shifter, the proof-of-concept experimental setup handles the frequency range from ~ 1 to 8 GHz with 1.2 MHz spectral resolution within 14 μ s. The proposed schematic can be easily upgraded to larger bandwidth coverage, fast scan speed or finer spectral resolution, making it extremely interesting for microwave sensing applications.

We3.6 17:30~17:45

Title: Reconfigurable photonic generation of arbitrary RF chirped waveforms based on a single CW laser.....151

- **Hugues Guillet de Chatellus**, (LIPhy & CNRS/UGA, France); **Come Schnebelin**, (LIPhy, France); **Maurizio Burla, Luis Romero Cortés, Jose Azana**, (INRS-EMT, Canada)

Abstract: We demonstrate a novel technique for the generation of fully-reconfigurable radio frequency chirped waveforms with extremely simple hardware based on a single CW laser and a frequency-shifting loop. All the waveform parameters, namely sign and value of the chirp rate, bandwidth, repetition rate and chirp duration are fully reconfigurable by simply tuning the frequency of a MHz-range single RF tone. In addition, the envelope of the generated RFCW can be shaped arbitrarily. We experimentally report the generation of arbitrary RF chirps with time duration ranging from 1 ns to over 100 ns, bandwidth above 28 GHz, and time-bandwidth product exceeding 1000, limited only by the detection bandwidth available.

Banquet: 19:00~21:00

Laoshe Teahouse, (Shuttle bus is available)

Thursday 26 October 2017

Room: Auditorium (三楼报告厅)

Session 9: Photonic microwave beam-forming and radar

Session Chair: Ken-ichi Kitayama

Th1.1 8:30~9:00 (Invited)

- **François Deborgies**, The European Space Agency (ESA), the Netherlands

Title: Space application of photonics.....N/A

Th1.2 9:00~9:15

Title: A Photonics-Assisted Beamformer for K-band RF Antenna Arrays.....154

- **Netsanet Tessema, Ailee Trinidad and Ketamaw Mekonnen, J. H. C. (Johan) van Zantvoort, Frans Huijskens and Zizheng Cao, Eduward Tangdiongga, A. B. (Bart) Smolders and Ton Koonen** (IPi, Eindhoven University of Technology, The Netherlands)

Abstract: We present an experimental demonstration of radio beamforming using an optical chip for application in K-band satellite communication. Via coherent combination of four RF channels, close to 12 dB beamforming gain is obtained. As a result, the transmission capacity is enhanced from 8-QAM, 5.81 Gbps to 32-QAM, 9.68 Gbps of multi-carrier data. For 4 channel beamforming, error-free performance ($BER < 1E-12$) is obtained with 8-QAM data. The tuning of the optical beamforming chip is done electronically via a software interface by a computer.

Th1.3 9:15~9:30

Title: Electro-Optic Modulator for Pre-Equalization of Fiber Chromatic Dispersion Utilizing Travelling-Wave Electrodes and Polarization-Reversed Structures.....158

- **Tomohiro Ohno, Hiroshi Murata and Atsushi Sanada** (Osaka University, Japan)

Abstract: We have proposed a pre-equalizing electro-optic modulator by utilizing travelling-wave electrodes and polarization-reversed structures for the compensation of signal distortion caused by fiber chromatic dispersion effect. In this paper, the first experimental demonstration of pre-equalization is reported. The proposed device is promising for long-haul fiber communication systems and microwave photonic applications.

Th1.4 9:30~9:45

Title: Distributed optical fiber sensing based on coherence-length gated microwave photonics interferometry.....161

- **Liwei Hua, Yang Song, Baokai Cheng, Wenge Zhu, Qi Zhang and Hai Xiao** (Clemson University, USA)

Abstract: This paper reports a highly sensitive distributed optical fiber sensing technique based on resolving the optical interference information in the microwave frequency domain. This technique uses a microwave intensity modulated coherent light through cascaded weak reflectors along a single mode fiber (SMF). The microwave is used to resolve the location of each reflector along the SMF. The coherence length of the optical carrier performs as the time domain gate and segments the optical interference between reflectors in the time domain. Within the coherence length, a small optical path difference change between two reflectors produces a change in the amplitude of the corresponding time domain pulses. The sensitivity of sub- μm for distributed strain sensing has been demonstrated.

Th1.5 9:45~10:00

Title: 1 Gbaud QPSK Wireless Receiver using an Opto-Electronic Mixer.....165

- **Ahmad Mohammad, Haymen Shams, Chin-Pang Liu, Katarzyna Balakier, Chris Graham, Michele Natrella, A. j. Seeds and Cyril Renaud** (University College London, United Kingdom)

Abstract: This paper presents the first demonstration of an uni-travelling carrier photodiode (UTC-PD) used as a receiver of a wirelessly transmitted quadrature phase shift keying (QPSK) signal. In this demonstration, a 1 Gbaud QPSK signal centered at 33.5 GHz was transmitted over a wireless distance of 1.4 m. At the receiver, an UTC-PD is used to down-convert the RF signal to an intermediate frequency (IF) of 9.5 GHz by mixing the RF signal with a heterodyne signal at 24 GHz. The down-converted signal is captured by the real time scope for further digital signal processing. The error vector magnitude (EVM) of the demodulated signal was measured to be 18%, which corresponds to a bit error rate (BER) of 10^{-8} .

Coffee Break: 10:00~10:15

Session 10: Microwave photonic characterization and instruments

Session Chair: Cyril Renaud

Th1.6 10:15~10:45 (Invited)

- **Toshimasa Umezawa**, (National Institute of Information and Communications (NICT), Japan)

Title: Ultrafast photo-diode.....N/A

Th1.7 10:45~11:15 (Invited)

- **Jonathan Klamkin**, (University of California, Santa Barbara (UCSB), USA)

Title: 3D hybrid photonic integration.....N/A

Th1.8 11:15~11:30

Title: Optoelectronic Recirculating Delay Line Implementation of a High-Q Optoelectronic Oscillator.....168

- **Stavros Iezekiel, Georgios Charalambous, Andreas Perentos and G. k. m. Hasanuzzaman** (University of Cyprus, Cyprus)

Abstract: A dual-loop optoelectronic oscillator incorporating an optoelectronic recirculating delay line in order to circumvent the limitations of optical coherence associated with all-optical loops is demonstrated. The optoelectronic oscillator produces a very stable signal at 5.4 GHz (suitable for WLAN 802.11n and 4G-WiMAX systems) with a sub-Hz 3-dB bandwidth and a Q-factor in excess of $10E+10$. A phase noise of -115 dBc/Hz is recorded at 10 kHz offset, owing to the reduction in phase induced intensity noise, whilst side modes are significantly suppressed for offset values in the range 100 kHz - 1 MHz.

Th1.9 11:30~11:45

Title: Noise measurement and modeling of a dual-frequency VECSEL at cesium clock wavelength.....172

- **Hui Liu, Fabienne Goldfarb, Nessrine Guerchi and Chang-Hoong Chow** (Laboratoire Aimé Cotton, CNRS, France); **Ghaya Baili** (Thales Research and Technology & TRT-FR, France); **Isabelle Sagnes** (Laboratoire de Photonique et de Nanostructures (CNRS-UPR20), France); **Fabien Bretenaker** (Laboratoire Aimé Cotton, France); **Grégoire Beaudoin** (CNRS, France)

Abstract: We study the noise of a class-A dual-frequency vertical external cavity surface emitting laser at Cesium clock wavelength. Both the intensity noise and phase noise of the beatnote between the two orthogonal polarized modes are measured and modeled. The intensity noise of the two orthogonal laser modes and its correlation are well predicted by a theory based on modified rate equations. The phase noise of the beatnote is predicted by the theory based on thermal effect and phase/amplitude coupling effect.

Th1.10 11:45~12:00

Title: In-Fibre Diffraction Grating Based Beam Steering for Full Duplex Optical Wireless Communication.....176

- **Guoqing Wang and Usman Habib** (University of Kent, United Kingdom); **Zhijun Yan** (Huazhong University of Science and Technology, P.R. China); **Nathan J Gomes** (University of Kent, United Kingdom); **Lin Zhang** (Aston University, P.R. China); **Chao Wang** (University of Kent, United Kingdom)

Abstract: A novel approach to achieve wavelength controlled optical beam steering using a 45° tilted fiber grating (TFG) for full-duplex indoor optical wireless transmission is proposed and experimentally demonstrated for the first time. The 45° TFG functions as an in-fiber passive diffraction device for wavelength steered light emission and reception, which enables full-duplex optical wireless transmission. The unique advantages of using an in-fiber TFG device for beam steering include high diffraction efficiency, low cost, compactness and inherent compatibility with existing fiber links. In a proof-of-concept experiment, free-space full-duplex transmission over 1.4 m with data rate of 9.6 Gb/s per beam has been demonstrated using 2.4 GHz bandwidth signals.

Lunch: 12:00~13:30

Session 11: Microwave photonic sensing and other applications

Session Chair: Chao Wang

Th2.1 13:30~14:00 (Invited)

- **Kebin Shi**, (Peking University)

Title: Sensing and imaging applications by using mode-locking laser based microwave photonics.....N/A

Th2.2 14:00~14:30 (Invited)

- **Longfei Shen, JePPIX**, (the Netherlands)

Title: High-speed membrane-type photodetectors on silicon substrates for wireless communications.....N/A

Th2.3 14:30~14:45

Title: Radio-over-Fiber-supported 60GHz Multiuser Transmission using Leaky Wave Antenna.....N/A

- **Usman Habib** (University of Kent, United Kingdom); **Matthias Steeg and Andreas Stöhr** (University of Duisburg-Essen, Germany); **Nathan J Gomes** (University of Kent, United Kingdom)

Abstract: Simultaneous transmission to multiple users using a single-feed leaky-wave antenna (LWA) has been demonstrated. A composite signal transported through a Radio-over-Fibre (RoF) setup is upconverted to V-band frequencies and a LWA is used to direct different user data to their respective locations. An EVM analysis has been performed for two-user and three-user transmission for a range of angular locations. A performance analysis for user interference has been carried out by varying the signal spacing for 152 MHz and 305 MHz bandwidth OFDM signals, centered at 61.75 GHz after 4m of wireless transmission. The experimental results show degradation not only due to insufficient frequency spacing between the channels but also when the sidelobe interference of the neighboring data channels is higher.

Th2.4 14:45~15:00

Title: 28 GHz 5G Radio over Fibre using UF-OFDM with Optical Heterodyning.....180

- **Eamonn Martin** (Dublin City University, Ireland); **Colm Browning** (DCU, Ireland); **Arman Farhang** (CONNECT, Trinity College Dublin, Ireland); **Manh Ha Hoang** (Dublin Institute of Technology, Ireland); **Matthias John** (Trinity College Dublin & Dublin Institute of Technology, Ireland); **Max James Ammann** (Dublin Institute of Technology, Ireland); **Linda Doyle** (Trinity Collage Dublin, Ireland); **Liam Barry** (Dublin City University, Ireland)

Abstract: A 5G millimeter-wave radio over fibre optical fronthaul system based on optical heterodyning, utilising an externally injected gain switched distributed feedback laser, is successfully demonstrated. Five bands of UF-OFDM are transmitted over 25 km of fibre and a 28 GHz Vivaldi Antenna wireless link. Transmission performance below the 7% FEC limit is achieved with an aggregate total data rate of 4.56 Gb/s.

Th2.5 15:00~15:15

Title: MIMO Capable RoF System with Improved SFDR using Quadruple Sidebands.....184

- **Yumeng Yang, Michael J Crisp and Tongyun Li, Richard Penty, Ian White** (University of Cambridge, United Kingdom)

Abstract: An RoF system using a quadrature-multiplexing technique is shown experimentally to improve the 3rd order SFDR by 2.7dB over an intrinsic optical link. As a result of orthogonality between quadrature sidebands, the system can support MIMO.

Th2.6 15:15~15:30

Title: A Photonics-based RF Scanning Receiver Exploiting Digital Feed-forward Lasers Noise Cancellation.....187

- **Daniel Onori** (Scuola Superiore Sant'Anna, Italy); **Antonella Bogoni and Paolo Ghelfi** (CNIT, Italy)

Abstract: This paper presents an innovative architecture of photonics-based RF scanning receiver that exploits a digital feed-forward noise cancellation method for removing the beat noise between the lasers used in the scheme, instead of a complex laser locking mechanism as in a previous implementation. Moreover, compared with conventional channelized implementations, it reaches wide operating frequency range and reduced encumbrance, avoiding the need for bulky RF components such as RF filter banks and synthesizers. An experimental validation shows an RF input range of 0÷27.5 GHz and instantaneous bandwidth of 2 GHz. Further developments will increase the range over 40 GHz. Implementing the scheme through integrated photonics technologies will reach high environmental stability and reduced size weight and power consumption, meeting the increasing requirements of wideband real-time RF signal analysis.

16:30~17:30

Postdeadline Session (TBD)

Wednesday, 25 October 2017

BSPA poster session

13:00-14:00

- Every BSPA candidate also need to prepare a poster presentation, TPC members will discuss concerned technical details with authors in this session.
- The specified size of poster is 80cm (weight) * 120cm (height).
- BSPA award ceremony will be held in the banquet.

Poster Session

15:00-17:30

WEP.1

High-precision and Long-range distance measurement independent of temperature based on two optoelectronic oscillators.....191

- **Zhiqiang Fan, Jun Su, Tianhang Zhang, Ning Yang and Qi Qiu** (*University of Electronic Science and Technology of China, P.R. China*)

Abstract: A high-precision and temperature insensitive long-range distance measurement (DM) based on frequency detection is proposed and experimentally demonstrated. Two optoelectronic oscillators (OEOs) are grouped into a cross-referencing structure by Dense Wavelength Division Multiplexing (DWDM), which can greatly increase the measurement accuracy by reducing the influence of the environment such as temperature on the long fiber in the two OEOs. Because the long fiber is shared by the two OEOs, the frequency drifts caused by the long fiber are equal, then the surrounding disturbance for the measurement is overcome by mixing the oscillation frequency of the two OEOs .etc.

WEP.2

THz Beam Forming and Beam Switching using Lens-Assisted Quasi-Optical THz Transmitter.....195

- **Peng Lu and Vitaly Rymanov** (*University of Duisburg-Essen, Germany*); **Sebastian Dülme** (*Universität Duisburg-Essen, Germany*); **Benedikt Sievert, Andre Rennings and Andreas Stöhr** (*University of Duisburg-Essen, Germany*)

Abstract: In this work, we present a lens-assisted quasi-optical THz transmitter using log-periodic toothed antenna (LPTA) integrated photomixer for beam forming and beam switching. The directivity of the proposed quasi-optical THz transmitter featuring one LPTA and highly-resistive silicon quasi-optics exceeds 26 dBi within the frequency range of 300-400 GHz. A steerable beam direction in the range of $\pm 56^\circ$ is achieved by a linear shift of the LPTA position on the extended hemispherical lens assembly. Further, a beam switching approach is realized with a 1x2 LPTA array and shows tilted main beam angles of $\pm 33^\circ$. Finally, we study the influence of mutual coupling on the input antenna impedance of the linear antenna array.

WEP.3

Theoretical and Experimental Development of On-chip Colliding Pulse Mode-Locked Lasers.....199

- **Carlos Gordon and Myriam Cumbajin** (*Universidad Técnica de Ambato, Ecuador*); **Guillermo Carpiñero** (*Universidad Carlos III de Madrid, Spain*); **Julien Javaloyes** (*Universitat de les Illes Balears, Spain*)

Abstract: We report the successful theoretical and experimental optimization of the absorber length of on-chip colliding pulse mode-locked semiconductor laser working at 50 GHz repetition rate. The fundamental approach is that the active-passive integration provides freedom to choose the desired gain section to saturable absorber length ratio in order to obtain stable mode-locked regimes. We have developed four on-chip colliding pulse mode-locked laser structures with saturable absorber lengths ranging from 20 μm to 50 μm in steps of 10 μm with fundamental repetition rate at 25 GHz and twice this frequency at 50 GHz due to the colliding pulse mode-locked regime. The agreement in the theoretical and experimental demonstration is that the smallest SA considered (20 μm) exhibits the shortest pulse width, close to the transform limited time bandwidth product. The theoretical study was carried out by using the simulation tool called FreeTWM which is a free travelling wave model software designed for the study of the dynamics of multi-section semiconductor lasers, while the experimental analysis was executed on the samples fabricated on a generic InP photonic integrated technology through a multi-project wafer run.

WEP.4

Experimental Research on the Integrated Optical Injection-Locked DFB Laser Fabricated by the Reconstruction Equivalent Chirp Technique.....203

- **Yunshan Zhang** (*Nanjing University of posts and Telecommunications, P.R. China*); **Guowang Zhao** (*Nanjing University, P.R. China*); **Lianyan Li** (*Nanjing University of posts and Telecommunications, P.R. China*); **Yuechun Shi** (*Nanjing University, P.R. China*); **Jilin Zheng** (*PLA University of Science and Technology, P.R. China*); **Zhike Zhang and Yu Liu** (*Institute of Semiconductors, Chinese Academy of Sciences, P.R. China*); **Jun Lu and Yinchao Du** (*Nanjing University, P.R. China*); **Wenxuan Wang** (*Nanjing University & Nanjing College of Information Technology, P.R. China*); **Hui Zou** (*Nanjing University of posts and Telecommunications, P.R. China*); **Xiangfei Chen** (*Nanjing University, P.R. China*)

Abstract: The design, fabrication and characterization of the integrated optical injection-locked (OIL) DFB lasers are presented. The master laser (ML) and the slave laser (SL) are fabricated in a single chip. The gratings of the ML and SL are designed utilizing the reconstruction equivalent chirp (REC) technique. Thus the fabrication difficulty of the integrated OIL DFB lasers is relaxed using the equivalent sampled Bragg gratings. Comparing with the unlocked DFB laser, the relaxation oscillation frequency of the OIL DFB laser increases from 7.5 GHz to 27 GHz and the response bandwidth is enhanced dramatically.

WEP.5

Reconfiguring the 16×16 silicon optical switch for optical beam steering application.....206

- **Weihan Xu** (*Shanghai Jiaotong University (SJTU), P.R. China*); **Liangjun Lu and Linjie Zhou**

(Shanghai Jiao Tong University, P.R. China); **Jianping Chen** (SJTU, P.R. China)

Abstract: We experimentally demonstrate a 1×8 optical phased array (OPA) for one dimensional beam steering based on a 16×16 Benes-type silicon optical switch. The device shows a far-field pattern with 0.32° beam width, revealing the new application potential for the optical switch as a multi-functional platform.

WEP.6

Experimental Examination of SSBI Suppression Using SiP Microring Resonators.....210

- **Mingyang Lyu and Xun Guan** (Laval University, Canada); **Zhihui Cao** (Center of Optics Photonics and Laser, Université Laval, Canada); **Wei Shi** (Laval University); **Leslie Rusch** (Université Laval, Canada)

Abstract: We propose a novel scheme using a microring resonator (MRR) structure in silicon photonics (SiP) for the elimination of signal-to-signal beat interference (SSBI) in a direct detection, optical orthogonal frequency division multiplexing (DDO-OFDM) system. Unlike other SSBI cancellation techniques, SiP-based MRR shows unique advantages such as compactness and low cost. We examine performance as a function of MRR characteristics, with particular attention to signal wavelength drift vis-a-vis the MRR operating point. In the experimental demonstrations, an EVM reduction of 6% is realized.

WEP.7

Conditions for Parametric and Free-Carrier Oscillation in SOI Ring Cavities with Active Carrier Removal.....214

- **Ryan Hamerly** (Massachusetts Institute of Technology, USA); **Meysam Namdari and Levon Mirzoyan** (Technische Universität Dresden, Germany); **Dodd Gray and Christopher Rogers** (Stanford University, USA); **Kambiz Jamshidi** (Technische Universität Dresden, Germany)

Abstract: We model optical parametric oscillation in ring cavities, focusing on silicon at $1.55 \mu\text{m}$, as a potential frequency-comb source for microwave and terahertz generation. Oscillation is possible if free-carrier absorption can be mitigated; this can be achieved using carrier sweep-out in a reverse-biased p-i-n junction to reduce the carrier lifetime. By varying the pump power, detuning, and reverse-bias voltage, it is possible to realize amplification in cavities with both normal and anomalous dispersion. Furthermore, a free-carrier self-pulsing instability leads to rich dynamics when the carrier lifetime is sufficiently long.

WEP.8

Ultra-compact Linear Chirped Microwave Signal Generator.....218

- **Siqi Yan, Feng Zhou, Jianji Dong and Xinliang Zhang** (Huazhong University of Science and Technology, P.R. China); **Yunhong Ding** (Technical University of Denmark, Denmark); **Shengqian Gao and Xinlun Cai** (Sun Yatsen University, P.R. China)

Abstract: A novel concept to generate linear chirped microwave signal is proposed and experimentally verified. The frequency to time mapping method is used while the Mach-Zehnder interferometer based on the photonic crystal waveguide is employed as the key device with its significant advantages of the ultra-compact footprint and simple design.

WEP.9

Narrow-linewidth Microwave Generation by Optoelectronic Oscillators with AlGaInAs/InP Microcavity Lasers.....221

- **Yue-De Yang** (*Institute of Semiconductors, Chinese Academy of Sciences, P.R. China*)

Abstract: We have proposed and demonstrated the 1.55 μ m AlGaInAs/InP microcavity laser based optoelectronic oscillators (OEOs) for narrow-linewidth microwave signal generation. The 3-dB linewidth of the generated microwave signal is less than 1 kHz, although the linewidth of the microcavity laser is around tens of MHz. The frequency of the microwave is determined by the detuning frequency for OEO with microcavity laser under optical injection, and by the center frequency of the electrical filter for the dual-loop OEO with a single microcavity laser. We believe that the microwave generation based on WGM microcavity lasers can provide potential compact integration solutions.

WEP.10

Design and Optimization of Photodetector Array Electrodes.....224

- **Kang Zhao, Yongqing Huang, Jiarui Fei, Xiaofeng Duan, Kai Liu and Xiaomin Ren** (*Beijing University of Posts and Telecommunications, P.R. China*)

Abstract: We designed and optimized a high-speed, low-loss electrodes applied to photodetector array (PDA) using simulating software HFSS. The designed electrodes structure was fabricated and tested. Compared with the electrodes before optimization, the insert loss decreased by 1.1dB at 40GHz and the bandwidth increased by 8GHz.

WEP.11

Dynamical range and stability enhancement in electrically fused microknot optical resonators.....227

- **Alexandra Logvinova and Gal Gottlieb** (*Tel Aviv University, Israel*); **Shir Shahal** (*Bar Ilan University, Israel*); **Moti Fridman** (*Bar Ilan University, Israel*); **Yoav Linzon** (*Tel Aviv University, Israel*)

Abstract: Microknot resonators, locally fused using a two-probe technique, have exhibited significantly improved optical performance and mechanical stability. They have been operated with low losses both in-situ and as transferred devices. We found consistently more than threefold dynamical range enhancement, which remained stable in time, in electrically fused MKRs. These devices can be harbored in next generation optical sensors, actuators, and opto-mechanical applications incorporating MKR-assisted micro-structures, taking advantage of this simple and robust fusing technique.

WEP.12

Polarization-insensitive electro-absorption optical modulator using ITO-enhanced D-fiber.....231

- **Manoj Shah, Rong Lu, Tianliang Liu, Yong Liu** (*University of Electronic Science and Technol-*

ogy, Chengdu, P.R. China)

Abstract: We report on the fiber-optic polarization-intensive optical modulator architecture by transferring Al/HfO₂/ITO/ HfO₂ stack around the core region of the D-fiber. The proposed modulator is capable of offering extinction ratio as high as 23.71 dB and insertion loss as low as 1.01 dB for the transverse electric (TE) mode. Concurrently, for transverse magnetic (TM) mode are 23.93 dB and 1.07 dB. The polarization sensitive loss (PSL) at ON-State of ~ 0.056 dB ensures similar modulating ability for both TE and TM modes. The 3 dB modulating bandwidth of 45.85 GHz is realized with active length of 10 μm at the expense of 0.39 pJ/bit. The operating wavelength ranges between ~ 1475 nm and ~ 1625 nm with optical bandwidth excess of 150 nm.

WEP.13

50Gb/s InP-base Mach-Zehnder Modulator.....235

• **Hua Yang** (Tyndall National Institute, UCC, Ireland)

Abstract: This paper demonstrates a push-pull traveling-wave Mach-Zehnder modulator on InP which operates up to 50Gb/s in C band optical transmission system. This MZM could potentially be integrated to form the IQ modulators, Dual IQ modulators and PM-IQ modulators to achieve higher operating speed.

WEP.14

Performance Analysis of Reverse Biased Silicon Mach-Zehnder Modulators Using Slow Light Corrugated Waveguides: Bandwidth and Loss Study.....237

• **Seyedreza Hosseini and Kambiz Jamshidi** (Technische Universität Dresden, Germany)

Abstract: Performance of a slow light modulator using corrugated waveguide operating at band edge is studied in terms of bandwidth and loss. It is shown that the electrical bandwidth of the slow-light modulator can be enhanced compared to non-slow light modulators using the same drive voltage, by decreasing the length of the modulator. Limitations imposed by the slow light structure in terms of loss and optical bandwidth are also investigated for medium slow-down factor values using numerical simulations. The loss and optical bandwidth due to the slow light effect would respectively increase and decrease by increasing the slow-down factor. The loss remains in an acceptable range of 3 dB and the optical bandwidth would be slightly more than 400GHz using a slow-down factor of 3. This analysis could open up a new horizon for the realization of high-speed modulators which are useful for microwave photonics applications in the existing photonic IC Foundries.

WEP.15

Theoretical and Experimental Investigations about wavelength switching of a current tuned multi-section DFB laser based on REC technique.....240

• **Hao Wang, Yinchao Du, Kanglong Lin and Jun Lu** (Nanjing University, P.R. China); **Yating Zhou** (Changzhou Institute of Technology, P.R. China)

Abstract: The wavelength-switching time of a multi-section tunable semiconductor distributed feedback (DFB) laser based on reconstruction equivalent chirp (REC) is studied and measured. The measurement system is based on the Mach-Zehnder interferometer (MZI) with two arms hav-

ing almost the same length. The measurements are studied both in theory and experiments. All the results are presented and discussed, to help the optimization of testing and packaging such tunable lasers in future.

WEP.16

Utilizing a Novel Configuration for Side-Lobes Suppression of a Dielectric Optical Nanoantenna.....244

- **Yue Xu** (*China Academy of Space Technology, P.R. China*); **Tao Dong** (*Space Star Technology CO., LTD, P.R. China*); **Hang Zhao** (*Huazhong University of Science & Technology, P.R. China*)

Abstract: A novel configuration operating at 1550 nm based on silicon-on-insulator substrate is proposed for side-lobes suppression of a dielectric optical nanoantenna. The proposed configuration consists of reflection gratings which can reflect the downward light back. By using this configuration, the side-lobe level can be improved by 12.78 dB.

WEP.17

Optimized bias Voltage for suppressing the second harmonics of the silicon microring modulator in the application of microwave photonic links.....247

- **Lin Gui** (*Shanghai Second Polytechnic University*)

Abstract: In the application of microwave photonic links, a solution is proposed to suppress the harmonic of the silicon microring modulator by optimizing the bias voltage applied on this modulator, and the influence of input rf power on this bias voltage is also analyzed. Simulation results show that this optimized bias voltage varies by the input rf power due to the nonlinearity in the silicon microring modulator, while the optimized phase shift of the resonance wavelength of the microring in the process of modulation is steady compared with the optimized bias voltage. These results can be utilized to calculate the optimized bias voltage, which is helpful to suppress the second harmonics in application of the microwave photonic links.

WEP.18

Electric field sensor based on evanescent field of micro-nano fiber and electro-optic polymer.....251

- **Chonghui Zhang, Shuguo Xie and Xuchun Hao** (*Beihang University, P.R. China*)

Abstract: This paper presents an OEFS (optical electric field sensor) based on evanescent field characteristics of MNF (micro-nano fiber) and electro-optic effect of electro-optical polymer to solve the problem of large size, large influence on measuring field and low sensitivity in the traditional electric field sensors. The sensor body is fabricated using a MNF coating Special electro-optic polymer. In the case of MNF with a diameter of several microns, most of the energy in the optical fiber exists in the electro-optic polymer in the form of evanescent field. The refractive index of electro-optic polymers changes with small change of external electric field, which results in the change of energy intensity and evanescent depth of evanescent field, and then affects the intensity of output light of sensor. By detecting the output light intensity of the sensor, the information of the spatial electric field can be obtained. At the end of the paper, the feasibility of the sensor scheme is verified by simulation and experiment.

WEP.19**Electro-absorption modulator-based optoelectronic oscillator.....255**

- **Peppino Primiani** (III-V Lab, France); **Frédéric Van Dijk** (Alcatel Thales III-V Lab, France); **Mehdi Alouini** (Institut de Physique de Rennes - Université Rennes 1 - CNRS, France)

Abstract: In the perspective of a monolithic integration of an optoelectronic oscillator on photonic integrated circuits, we evaluate the performances of integrated DFB laser and electro-absorption modulator devices. For this purpose two identical chips have been used, the first for laser emission and amplitude modulation and the second for photo-detection. The impact of the bias voltage on the modulation performances has been measured, the link performances have been evaluated for different bias conditions and the system has been evaluated in a 10 GHz oscillator.

WEP.20**Tunable multi-loop optoelectronic microwave resonators.....258**

- **Vitaliy Vitko, Andrei Nikitin, Alexey Ustinov and Boris Kalinikos** (St. Petersburg Electrotechnical University, Russia)

Abstract: A theoretical model describing the resonant frequencies of a tunable optoelectronic oscillator on the optical and spin-wave delay lines is presented. In the theoretical model, the optical delay line has two configurations. The first configuration was formed by parallel connection of optical waveguides having various lengths. The second one is the serial connection of optical waveguides closed in rings. The transmission characteristics for the generators of both configurations are obtained. The paper presents the results of numerical simulations of transmission characteristics for circuits containing one, two and three optical delay lines. The results are compared for cases of parallel and serial connection.

WEP.21**Optical phased array with elephant couplers.....262**

- **Lisheng Wang, Hongwei Chen, Bo Yang, Minghua Chen, Shizhong Xie** (Tsinghua University, P.R. China)

Abstract: This paper gives a novel optical phased array design with elephant couplers. Imaging results of 1-dimensional and 2-dimensional optical phased array are verified by simulation. With small surface area, the elephant couplers can achieve large scale integrations.

WEP.22**Design For Mode Field Coupling Of Active And Passive Waveguide.....265**

- **Shuangxing Dai, Lijuan Yu, Jianguo Liu; Ning-Hua Zhu** (Institute of Semiconductors, Chinese Academic of Sciences, P.R. China)

Abstract: The process where a laser and a Si waveguide were coupled was simulated by MATLAB. In order to obtain the coupling efficiency accurately and quickly, an improved finite-difference beam-propagation method(FD-BPM) and the simple transparent boundary condition(STBC) were selected. Several spot-size convertors (SSCs) of different structure with tapered Si waveguide, square SiON waveguide and SiO₂ layer were designed, simulated and analyzed. On the

basis of the results, the effects of the structure of the tapered Si, the shape of the SiON waveguide and the overall SSC length on the coupling efficiency were analyzed. On the other hand, the influence of the refractive index of the SiON waveguide on the coupling efficiency was discussed. The optimum refractive index range with the best coupling efficiency was obtained. They had an instructive significance for the design of the SSC.

WEP.23

An Optically Tunable Frequency-Multiplying Optoelectronic Oscillator Through Equivalent Phase Modulation.....269

- **Yang Chen** (*East China Normal University, P.R. China*); **Shifeng Liu and Shilong Pan** (*Nanjing University of Aeronautics & Astronautics, P.R. China*)

Abstract: A novel optically tunable frequency-multiplying optoelectronic oscillator (OEO) to generating a high frequency microwave signal without using an optical filter is proposed and experimentally demonstrated. The upper dual parallel Mach-Zehnder modulators (DP-MZM) integrated in a dual-polarization quadrature phase shift-keying (DP-QPSK) modulator is properly biased as an equivalent phase modulator (e-PM), which functions in conjunction with a phase-shifted fiber Bragg grating (PS-FBG) in the OEO loop to form a high-Q microwave photonic band-pass filter, while the lower DP-MZM in the DP-QPSK modulator functions as a frequency multiplier for high frequency microwave signal generation by multiplying the oscillation signal in the OEO loop. An experiment is performed. A fundamental microwave signal from about 7.5 GHz to 12.5 GHz is generated in the OEO loop, which is then frequency quadrupled using the frequency multiplier. The phase noise performance of the generated signal is also investigated.

WEP.24

Phase Noise Study Based on Transfer function in Coupled Optoelectronic Oscillators.....273

- **Ramin Khayatzaheh, Vincent Aurox, Gilles Bailly and Arnaud Fernandez, Olivier Llopis** (*LAAS-CNRS, France*)

Abstract: In this paper, the transfer function theory is used to model the phase noise power spectral density in coupled optoelectronic oscillators. A resonator is placed into the model in order to take into account the quality factor (Q) enhancement due to the optical loop. The results of this model are then compared with experimental measurement results. The model is able to describe the phase noise spectrum shape and to give indications on the noise contributors, which helps in improving oscillator's performance.

WEP.25

1-GHz, Compact Mode Locked Femtosecond All-Polarization Maintaining Erbium-doped Fiber Oscillator.....277

- **Linhao Huang, Yue Zhou, Yitang Dai, Feifei Yin, Jian Dai and Kun Xu** (*Beijing University of Posts and Telecommunications, P.R. China*)

Abstract: Semiconductor saturable absorber mirror (SESAM) mode-locked all-polarization

maintaining (PM) fiber oscillator with a fundamental repetition rate up to 1 GHz centered around 1558 nm was demonstrated. With a 450 mW incident pump power, the oscillator is operating at the soliton mode-locked regime due to intracavity anomalous dispersion. The spectral width and compressed pulse duration is 9.4 nm and 379 fs, respectively. The obtained pulse maintains a good pulse quality with an average power of 7.46 mW, corresponding to a pulse energy of 7.3 pJ. The mode-locked fiber oscillator is compact, SESAM burnt-free and robust with an all-polarization maintaining fiber configuration.

WEP.26

Sensitivity Improvement of Phase Noise Measurement System Using Photonic-delay Based Frequency Discriminator.....280

- **Xiaofeng Peng** (Peking University, P.R. China); **Qing Yin** (China Academy of Space Technology, P.R. China); **Huanfa Peng, Yongchi Xu, Cheng Zhang, Lixin Zhu, Juhao Li and Zhangyuan Chen** (Peking University, P.R. China)

Abstract: By suppressing the additive phase noise induced by light scattering in the optical fiber and optical interference due to the optical reflection in a microwave phase noise measurement system using photonic-delay based frequency discriminator, the sensitivity improvement of 10 dB is experimentally achieved. Using the proposed measurement scheme, a single sideband phase noise is measured to be -145 dBc/Hz at 10 kHz offset for a 10-GHz OEO.

WEP.27

Frequency quadrupling microwave signal generation based on an optoelectronic oscillator with low phase noise.....284

- **Zenghui Chen, Jian Dai, Yue Zhou, Feifei Yin, Jianqiang Li, Yitang Dai and Kun Xu** (Beijing University of Posts and Telecommunications, P.R. China)

Abstract: A frequency-multiplying radio frequency (RF) source based on the optoelectronic oscillator (OEO) with low phase noise has been proposed and experimentally demonstrated. With the optical carrier suppression process, the frequency quadrupling can be achieved by biasing the intensity modulators at the minimum transmission point simultaneously inside and outside the OEO loop. In the proof-of-concept experiment, the high quality RF signal at 21.44 GHz is obtained with the phase noise of -111.19 dBc/Hz at 10 kHz offset frequency. The proposed scheme provides a novel strategy for high frequency and low phase noise signal generation based on low frequency devices.

WEP.28

Output power enhancement in photonic-based 60-GHz generation by optical pulse compression with a dispersion shifted fiber.....288

- **Takashi Yamaguchi** (Doshisha University, Japan); **Shigenobu Sakakibara, Yui Otagaki and Hiroshi Murata** (Osaka University, Japan); **Hiroyuki Toda** (Doshisha University, Japan)

Abstract: In this manuscript, we propose to use optical pulse compression in a dispersion-shifted fiber (DSF) to enhance the output power in photonic-based RF generation. In a 60-GHz RF generation experiment using a DSF, an RF gain due to the optical pulse compression of 5.2 dB was

obtained at a fiber length of 15 km and an average power to the DSF of 20.0 dBm.

WEP.29

Triangular Waveform Generation Based on Polarization Modulated Optoelectronic Oscillator.....291

- **Tingwei Wu, Chongfu Zhang and Huan Huang** (*University of Electronic Science and Technology of China, P.R. China*); **Jianqiang Li** (*Beijing University of Posts and Telecommunications, P.R. China*); **Songnian Fu** (*Huazhong University of Science & Technology, P.R. China*); **Kun Qiu** (*University of Electronic Science and Technology of China, P.R. China*)

Abstract: We propose a novel scheme for the generation of triangular waveform. In this scheme, under the tradition condition of optoelectronic oscillator (OEO), the polarization angle of the light beam is controlled and entered into the Mach-Zehnder modulator (MZM) with an angle for the best modulation axis. According to the characteristics of MZM, a part of the light field executes carrier suppression, and the orthogonal part is not modulated. Through experimental demonstration, we can find that the oscillation is established and the modulation index of the MZM is set to be 1.51, a triangular waveform can be generated by controlling the state of polarization properly, and a high-quality microwave signal can be achieved simultaneously.

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Photonic generation of low phase noise millimeter-wave signal based on an ultrahigh Q optoelectronic hybrid bandpass filter.....295

- **Anni Liu, Jingliang Liu, Jian Dai, Yitang Dai, Jianqiang Li, Yue Zhou, Tian Zhang and Kun Xu** (*Beijing University of Posts and Telecommunications, P.R. China*)

Abstract: A millimeter-wave (mmW) optoelectronic oscillator employing ultra-high Q optoelectronic hybrid bandpass filter is proposed. The novel filter with Q value of 30000, bandwidth of 1 MHz and centre frequency of 29.99 GHz has been demonstrated. Based on this ultra-narrow bandpass filter, a 29.99 GHz millimetre-wave signal is successfully generated with the single-sideband phase noise about -113 dBc/Hz at 10 kHz frequency offset. Besides, the measurement results show that the spurs in the mmW oscillator has been suppressed effectively, and the spurious suppression ratio reaches more than 83 dBc.

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Agile photonic arbitrary waveform generation based on a single CW laser.....299

- **Hugues Guillet de Chatellus** (*LIPhy & CNRS/UGA, France*); **Come Schnebelin** (*LIPhy, France*)

Abstract: We propose and demonstrate a new and extremely simple concept of reconfigurable photonic generation of arbitrary RF waveforms, based on a single CW laser and a frequency shifting loop. Our system does not require broadband light source or fast electronic generator. It is capable of generating arbitrary RF waveforms with duration ranging from 1 ns to more than 100 ns, and with dynamic performances beyond state of the art photonic AWG techniques (spectral bandwidth > 25 GHz, TBWP > 500, limited by detection). Our concept, which can be seen as spectral shaping with a resolution in the MHz range, is expected to open a wide range of applications in microwave photonics.

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- **Xin Xu, Lan Yu, Wenshan Cong, Xiong Luo and Anle Wang** (Air Force Early Warning Academy, P.R. China)

Abstract: A method of generating large bandwidth linear chirped microwave waveform (LCMW) with a double frequency-tuning scheme, which is based on a frequency tunable optoelectronic oscillator (TOEO) and a recirculating polarization modulation loop (RPML), is proposed. The frequency can be tuned finely by the TOEO, and also can be tuned coarsely while the multiplication factor can be changed by adjusting the polarization controller and the polarizer. The simulation indicates that the method effectively increases the frequency tunable range and the bandwidth and achieves the multiplication factor tunable. Besides, the method avoids the use of external microwave source to improve the quality of the signal.

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- **Haitao Tang, Yuan Yu, Lu Xu and Xinliang Zhang** (Huazhong University of Science and Technology, P.R. China)

Abstract: A new widely tunable optoelectronic oscillator based on cascade microwave photonic filters is proposed and demonstrated. The oscillating frequency can be tuned from 0 to 40 GHz and the side-mode suppression ratio exceeds 40 dB during the tuning process. The measured phase noise is -98 dBc/Hz at 10 kHz offset frequency when the oscillation frequency is set as 21 GHz.

WEP.34**Ultra-broadband optical single sideband modulation with large sideband suppression ratio.....308**

- **Jinglan Zhang and Yuan Cao** (Jinan University, P.R. China); **Erwin Chan** (School of Engineering and Information Technology, Charles Darwin University, Australia); **Xudong Wang, Xinhuan Feng, Bai-ou Guan** (Jinan University, P.R. China)

Abstract: A simple and effective technique to obtain a single sideband RF modulated optical signal over a very wide frequency range is presented. It uses low-cost off-the-shelf components to realize optical single sideband modulation with a large sideband suppression ratio. Experimental results demonstrate single sideband modulation with more than 30 dB suppression in the unwanted sideband over a wide 2-40 GHz frequency range.

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- **Xiuyou Han, Yuchen Shao and Yufeng Bing** (Dalian University of Technology, P.R. China); **Ming Li** (Institute of Semiconductors, Chinese Academy of Sciences, P.R. China); **Yiying Gu**

and Mingshan Zhao (Dalian University of Technology, P.R. China)

Abstract: A polarization multiplexed dual-loop OEO based on a phase-shift fiber Bragg grating (PS-FBG) is proposed and experimentally demonstrated. The tunable frequency from 1 GHz to 4 GHz of microwave signal is successfully generated by changing the wavelength of the tunable laser source (TLS). The side mode suppression ratio (SMSR) of 61 dB is obtained with the polarization multiplexed structure. The phase noise with different fiber length in the loop and at different generated microwave frequencies are measured and analyzed. The phase noise of -116 dBc/Hz@10 kHz is achieved.

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- **Tianchi Sun** (Drexel University & Drexel University, USA); **Afshin Daryoush** (Drexel University, USA)

Abstract: Low phase noise signal generated in a small structure is required for communication and high resolution imaging. A DBR based multi-mode laser is combined with mode-locking method to build frequency stabilized and tunable RF signal generator. The number of the output mode from each laser is adjustable using reflecting band of distributed Bragg reflector and amplitude modulator while the phase section in integrated laser system provides frequency tuning. An increased mode number output results in a more frequency stable beat-notes; a simulated phase noise of -150 dBc/Hz at offset frequency 10 kHz for 10 GHz RF output is achieved using 60 locked mode.

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- **Christian Daniel Muñoz, Karim Elayoubi** (Institut Supérieur de l'Aéronautique et de l'Espace ISAE-SUPAERO & Institute of Technology Antoine de Saint Exupéry, France); **Angélique Rissons** (ISAE Institut Supérieur de l'Aéronautique et de l'ESPACE, France); **Sergio Villamizar and Gloria Margarita Varón Durán** (Universidad Nacional de Colombia, Colombia)

Abstract: In this article, we propose the generation of a microwave signal through a VCSEL Based Optoelectronic Oscillator (VBO) for free space communication applications. This system is implemented using VCSELs in the O-band and C-band. The signals generated at 1.25 GHz and 2.49 GHz are used to produce experimentally Return-to-Zero On Off Keying (RZ-OOK) and Return-to-Zero Differential Phase Shift Keying (RZ-DPSK) modulations for free space optical communication.

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- **Guang Chen and JianXin Ma, Chong Xiu Yu** (Beijing university of posts and telecommunications, P.R. China)

Abstract: We present channel multiplexing with a single optical intensity modulator by incorporating tandem optical single-sideband modulation and orthogonal multiplexing technique with DSP-assisted coherent detection. Quality factor above 6 is demonstrated experimentally for all BPSK channels.

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- **Feng Fan, Jingjing Hu, Wenwu Zhu, Jiabin Wang, Yiyang Gu, Zhenlin Wu, Xiuyou Han and Mingshan Zhao** (Dalian University of Technology, P.R. China)

Abstract: We propose and demonstrate a tunable optoelectronic oscillator (TOEO) based on coupled double loops (CDLs) and stimulated Brillouin scattering (SBS). By the incorporation of CDLs and SBS, we not only increase the side-mode suppression ratio (SMSR) of the SBS-based OEO, but also enhance the stability of the generated signals. Microwave signals with a widely tunable range from 2 GHz to 18 GHz are generated. When the oscillation frequency is chosen as 5, 10, or 15 GHz, the phase noise is lower than -90 dBc/Hz at 10 kHz frequency offset and the SMSR is superior to 60 dB. Furthermore, the frequency drift is less than 0.3 ppm and the power drift is below 0.2 dB at 10 GHz in lab condition within 30 minutes, which proved the stability of the generated signals.

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Broadband optical chaos generation by constructing a simple hybrid feedback loop.....329

- **Chenkun Luo, Mengfan Cheng, Xingxing Jiang, Lei Deng, Minming Zhang, Changjian Ke and Songnian Fu, Ming Tang, Deming Liu** (Huazhong University of Science and Technology, P.R. China); **Ping Perry Shum** (Nanyang Technological University & Network Technology Research Centre, Singapore)

Abstract: An electro-optic chaos generator is proposed based on phase modulation to intensity modulation conversion and an analog-digital hybrid feedback loop. The analog part takes the digital sequences from shift registers as input and converts them into analog noise like signal, from which new bits are determined. The effective bandwidth and complexity of the output analog signal can reach a high level with properly selected system parameters. the proposed scheme has the potential for applications in optical secure communication, chaotic radar and random number generation.

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- **Sergi Garcia Cortijo** (Universitat Politècnica de Valencia, Spain); **Javier Hervás** (Universidad Politécnica de Valencia & ITEAM, Spain); **Ivana Gasulla** (Universidad Politécnica de Valencia, Spain)

Abstract: We report the first experimental demonstration of multi-cavity optoelectronic os-

cillators where the different cavities are hosted in a single multicore fiber. Different configurations are implemented on the same 20-m 7-core fiber link, exploiting both unbalanced dual-cavity operation (loop lengths are a multiple of a reference value) and multi-cavity Vernier operation (loop lengths are slightly different).

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- ***Yongfeng Wei; Kai Sun (Inner Mongolia University, P.R. China); Xinlu Gao; Shanguo Huang(Beijing University of Posts and Telecommunications, P.R. China)***

Abstract: A novel photonic approach to the implementation of a RF photonic phase shifter is proposed. It is based on a polarization dependent optical phase modulator and a dual-parallel Mach-Zehnder modulator. The phase shift of RF signal has a predefined linear relationship with the dc bias voltage of the optical phase modulator. This enables users to easily determine the control voltage needed to realize the desired phase shift of RF signal. It can realize multiple photonic RF phase shifters simultaneously applied in optical controlled Phased Array Antennas. Results show the RF phase shifter can achieve a continuous -180-180 degrees phase shift with little phase and amplitude variations over a wide frequency range.

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- ***Wenshan Cong, Lan Yu, Xin Xu, Jin Zhang(Air Force Early Warning Academy, P.R. China)***

Abstract: A photonic approach to generate phase-coded signal with large frequency continuous tunability based on dual parallel unbalanced temporal pulse shaping (DP-UTPS) system is proposed. In DP-UTPS system, in order to realize the different intensity modulation of the input optical Gaussian pulse in the upper and lower branches, sine signal and cosine signal are respectively applied. When the corresponding Gaussian pulse signals are fed into the upper and lower branches, the phase coded signal will be generated. The frequency of the phase code signal can be continuously tuned by adjusting the dispersion value of the linearly chirped fiber Bragg grating (LCFBG). The generated phase-coded signal with large frequency continuous tunability and high pulse compression ratio are verified by three simulation experiments.



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- **Hakimeh Mohammadhosseini and Martijn J. R. Heck** (Aarhus University, Denmark)

Abstract: Bandwidth limitation of current wireless frequency bands and the energy consumption are challenges that have to be addressed by future 5G wireless networks. The millimeter wave (mm-wave) spectrum, spanning 30 GHz to 300 GHz, is a prime candidate to resolve the bandwidth limitation issue in future networks. High-speed electronics, though, are quite energy-inefficient for such mm-wave signal generation. Photonic-based sources are an alternative to provide the required frequencies and bandwidth, i.e., the field of microwave photonics. .etc.

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- **Gufeng Li, Tao Shang, Yan Gao, Yinling Zhang and Dan Chen** (Xidian University, P.R. China)

Abstract: We propose and verify a scheme to both improve the gain and linearity of the down-converted analog photonic link. We utilize the different electro-optic coefficients of the phase modulator to realize the suppression of the third-order intermodulation distortion. And the link gain is improved by full spectrum utilization. The simulation results show that the SFDR is improved by ~14dB. And the link gain is increased by ~13.43dB compared to the linearized downconversion link without full spectrum utilization.

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- **Marc Sans, Cyril Renaud and John Mitchell** (University College London, United Kingdom)

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- **Sun-Young Jung, Chang-Hun Kim and Sang-Kook Han** (Yonsei University, Korea)

Abstract: We proposed a pulse shaping enhanced optical pulse division multiplexing (e-OPDM)

to effectively reduce optical beating interference (OBI) in a multi carrier based optical access network. A potential to accommodate a large number of uplink multiple access was verified by using the proposed technique. Performance improvement was experimentally demonstrated by EVM of uplink signal according to optical pulse delay.

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- **Tien Dat Pham, Atsushi Kanno and Naokatsu Yamamoto** (National Institute of Information and Communications Technology, Japan); **Tetsuya Kawanishi** (Waseda University & National Institute of Information and Communications Technology, Japan)

Abstract: In this paper, we investigate the performance of OFDM and FBMC signals after transmission over a seamless fiber-wireless fronthaul system. We also examine the performance of OFDM signals using different multiple radio access techniques after being transmitted over the seamless system. We confirm that the fronthaul system has a big influence on the performance of new 5G waveforms and multiple access techniques, and a cooperation between radio access and transport networks should be considered to increase the signal performance and operation efficiency.

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- **Muhsin Ali, Luis Enrique Garcia Muñoz and Guillermo Carpintero** (Universidad Carlos III de Madrid, Spain)

Abstract: A new concept for integrated photonic transmitter (PT) is presented for radio-over-fiber (RoF) wireless communication in E-band frequencies. The device features a high power and high frequency photodiode (PD) integrated with a wideband and high gain tapered slot antenna with a built-in biasing network on an RF laminate. Presented approach allows for simpler and low loss optoelectronic integration. The full-wave simulations show that for the optimised PT the PD-to-antenna insertion loss is as low as 0.4dB and a gain of 14.5dBi. This allows the realisation of an efficient RoF front-end with low footprint that can be extended to mmWave phased-array systems.

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- **Jia Ye, Lianshan Yan, Houjun Wang, Wei Pan, Bin Luo, Xihua Zou and Yan Pan** (Southwest Jiaotong University, P.R. China)

Abstract: A phase-shift Assisted OFDM-RoF system employing optical heterodyning is proposed and experimentally demonstrated. By using the phase shift of optical signal to represent the sign data of the OFDM signal, a significant improvement of the power efficiency can be obtained compared to the conventional DCO-OFDM. 10GHz/1.8Gbps 4QAM PSA-OFDM RoF transmission over 10km SMF and 2m wireless is experimentally achieved.

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- **Usman Habib and Anthony Aighobahi** (*University of Kent, United Kingdom*); **Terry Quinlan and Stuart D Walker** (*University of Essex, United Kingdom*); **Nathan J Gomes** (*University of Kent, United Kingdom*)

Abstract: Coverage at millimeter-wave (mmW) frequencies is a constraining bottleneck. Spatial diversity and spatial multiplexing multiple-input multiple-output (MIMO) improve performance over a spread of user locations and these can benefit from wider antenna spacing. Radio-over-Fiber (RoF) transport provides flexibility in deploying a number of widely-spaced Remote Antenna Units (RAUs) connected to the same Central Unit (CU). Hence, mmW systems with an integrated analog RoF fronthaul are strong candidates for use in future 5G networks. An approach to measure channel coefficients individually for MIMO processing has been demonstrated in a RoF transported 2x2 MIMO system at 60 GHz. Experimental results verify this approach through real 2x2 experiments.

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- **Yongsheng Gao** (*Northwestern Polytechnical University, P.R. China*); **Wei Jiang** (*China Academy of Space Technology, P.R. China*)

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- **Xiuyou Han, Bofan Huo, Yuchen Shao, Shuo Wang and Mingshan Zhao** (*Dalian University of Technology, P.R. China*)

Abstract: RF self-interference cancellation for Full-Duplex communication with a microwave photonic technique is proposed and demonstrated experimentally. It is based on an integrated dual-parallel Mach-Zehnder modulator (DP-MZM), where the sub-MZMs (MZM1 and MZM2) are biased at the quadrature point and the minimum point, respectively. It avoids the optical interference at the combining Y branch waveguide. The self-interference cancellation performance for 2.4 GHz, the standard of wireless service of WiFi (IEEE 802.11), is investigated. The cancellation depth as high as 83 dB is obtained for single frequency signal. And for the signal with a bandwidth from 10 MHz to 100 MHz, the cancellation depth larger than 44 dB is completed.

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- **Zhihua Zhou, Jing He, Rui Deng, Qinghui Chen, Lin Chen** (*Hunan University, P.R. China*)

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- **Weicheng Yuan, Chongfu Zhang and Kun Qiu** (*University of Electronic Science and Technology of China, P.R. China*)

Abstract: We have studied a non-orthogonal multiple access (NOMA) scheme combined with filter-bank multicarrier (FBMC) in radio over fiber (RoF) (NOMA/FBMC-RoF) downlink system for 5G communications. In this scheme, intensity modulation and direct detected (IM/DD) is employed, and we find that this NOMA/FBMC-based RoF-5G communication system can offer a high throughput, a flexible bandwidth allocation and a higher system capacity for a larger number of users through the theoretical and simulation analysis. The effects of power allocation and modulation order on bit error rate (BER) performance are then investigated. These results have shown that this scheme has an optimal power allocation value between users, and the modulation order used by different users can also much affect system performance.

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- **Renata Leibel, Jean Pierre von der Weid** (*Pontifical Catholic University of Rio de Janeiro, Brazil*); **Patryk Urban** (*Ericsson AB, Sweden*)

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- **Wenwu Zhu, Yiyang Gu, Feng Fan, Xiuyou Han, Jia Li, Jingjing Hu, Zhenlin Wu and Mingshan Zhao** (*Dalian University of Technology, P.R. China*)

Abstract: In this paper, we would like to review and present our latest progress on microwave photonic signal transmission and processing, including linearization of analog photonic link, generation of ultrapure radiofrequency signal and elimination of self-interference.

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Analysis and Performance Improvement of Wireless Transmission of Digitalized RoF Signal.....397

- **Tomohiro Nakamura, Daiki Fujimoto, Kazuo Kumamoto and Katsutoshi Tsukamoto** (*Osaka Institute of Technology, Japan*)

Abstract: Radio-on-Fiber has been widely used for solve blind area problem in cellular system. However, it requires optical fiber installation beforehand. Thus cost becomes high, and if optical fiber received damage because of disaster and so on, it requires long time to recover them. We have been proposed cascaded Radio over Fiber and wireless digitalized Radio on Radio entrance link for small cell mobile access. However, digital Radio-on-Radio transmission requires very large bitrate to transmit various RF signals, and wireless transmission error occurs deterioration of transmission signal quality. So this paper analyzes performance of wireless transmitted digital Radio-on-Radio signal and proposes the scheme improved not only transmission quality but also channel capacity. In this paper, some basic transmission experiment results will be shown and discussed.

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- **Ramon Maia Borges and Dionisio Noque, Andre Marques Muniz, Hugo Filgueiras** (*National Institute of Telecommunications, Brazil*); **Matheus Sêda** (*Inatel, Brazil*); **Antonella Bogoni** (*CNIT, Italy*); **Arismar Cerqueira S. Jr.** (*INATEL, Brazil*)

Abstract: We experimentally investigate the performance of an all-optical and ultra-wideband RF amplification method for 5G networks, as a function of temperature. The proposed approach employs the optical nonlinear effect four-wave mixing for performing photonics-based RF amplification in analog and digital radio-over-fiber systems. The thermal characterization from -10 to +70°C demonstrates a flat photonics-based RF gain from 300 kHz to 50 GHz, as well as no significant phase noise fluctuation due to temperature variation. It illustrates the methodology applicability in real operational conditions of a base station and shows a promising direction to use optical backhauls as active medium for amplifying RF signals besides performing data transmission.

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Qiang Lv (*The 54th Research Institute of China Electronics Technology Group Corporation, P.R. China*)

Abstract: We proposed and demonstrated a novel photonic and digital hybrid flexible satellite payload with resources sharing for multi-channel communication payloads at L, S, Ku and Ka

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- **Chongfu Zhang and Huan Huang** (University of Electronic Science and Technology of China, P.R. China); **Jianqiang Li** (Beijing University of Posts and Telecommunications, P.R. China); **Songnian Fu** (Huazhong University of Science & Technology, P.R. China); **Yun Ling and Kun Qiu** (University of Electronic Science and Technology of China, P.R. China)

Abstract: In this paper, we propose a method that can realize the phase stabilized of time and frequency between central office and remote antenna array simultaneously. The wavelength division multiplexing (WDM) technology is employed to transmit multiple radio frequencies and broadband time base signals with stable phase based on phase conjugate method and fiber dispersion through the same single optical fiber link. Optical frequency comb (OFC) is used to generate optical carriers to carry multiple local oscillator (LO) signals. Our method can improve performance because the phase offsets of different antennas are compensated individually, as well as this scheme can reduce the system cost and simplify the structure of array antenna-based stationary phase transmission system. Finally, the theoretical analysis and the simulation results verify the feasibility of the stabilized-phase multiplexed method.

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- **Gustavo Amaral, Luis Ernesto Ynoquio Herrera, Pedro Tovar and Elisa Carneiro** (Pontifical Catholic University of Rio de Janeiro, Brazil); **Patryk Urban** (Ericsson AB, Sweden); **Jean Pierre von der Weid** (Pontifical Catholic University of Rio de Janeiro, Brazil)

Abstract: We propose a frequency-reusable architecture for fiber-extend copper lines with spectrally efficient multiple copper line monitoring. In-service simultaneous multi-copper and fiber monitoring is possible with the right choice of frequency bands, a result backed by the Error Vector Magnitude measurement of data channels in simultaneous coexistence with monitoring channels. The proposed monitoring method enables centralized single-ended line testing of hybrid fiber-copper architectures.

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- **Qianmei Yang and Calvin C K Chan** (The Chinese University of Hong Kong, Hong Kong)

Abstract: Cloud radio access network (C-RAN) is a persuasive solution to the burst capacity in

future 5G mobile system and it can tackle the tidal effect in mobile networks for better resource utilization. We propose a remote radio head (RRH) protection scheme to assure the availability of the RRHs. A protection layer is proposed to support re-configurable protection of the RRHs, with good scalability.

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Proposal and Analysis of Novel Fiber-optic Relaying Schemes for MIMO Mobile Communication.....420

- **Ikuya Kitamura, Yuki Mizusawa, Kazuo Kumamoto and Hong Zhou** (*Osaka Institute of Technology, Japan*); **FengPing Yan** (*Beijing Jiaotong University, P.R. China*)

Abstract: In this paper, we propose two novel fiber-optic relaying schemes, one using SM technology and another using STBC and MRC diversity reception technologies, for MIMO mobile transmission. Using single RoF link to relay MIMO signals, the proposed schemes have much lower system complexity and cost than the conventional RoF relaying system. Computer simulation confirmed that the proposed SM-RoF scheme has almost the same transmission performance, while the proposed STBC-MRC-RoF scheme can achieve much better performance compared with the conventional one.

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- **Hui Gao, Ye Deng and Zhipeng Zhou** (*Nanjing Research Institute of Electronics Technology, P.R. China*); **Hui Yang and Yongchuan Xiao** (*Chongqing Acoustic-Optic-Electronic Co., LTD, P.R. China*)

Abstract: The relativity between the additive phase noise of a direct modulation analog optical link and the RF power level as well as the relativity between the additive phase noise of this link and the average optical power at the photodiode (PD) input are experimentally investigated. The results show the phase noise far from the carrier can be suppressed by setting the RF power level to the maximum achievable while keeping the PD operate under the proper saturation status. Through link optimization, the phase noise difference between the signal source and the one after link transmission at the frequency offset ≥ 100 kHz has been reduced to ≤ 5 dB. Furthermore, the phase noise close to the modulation frequency is proved to be mainly caused by up-converted low frequency intensity noise and can be suppressed when reducing the laser Relative Intensity Noise (RIN).

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Coherent RF Channelizer Based on Dual Optical Frequency Combs and Image-Reject Mixers.....427

- **Zhenzhou Tang, Dan Zhu and Shilong Pan** (*Nanjing University of Aeronautics & Astronautics, P.R. China*)

Abstract: A broadband photonic RF channelizer with large in-band interference suppression is proposed and experimentally demonstrated based on dual optical frequency combs (OFCs) and photonic image-reject mixers (IRMs). A Ku-band RF signal with a bandwidth of 5 GHz is channelized into five sub-channels with 1-GHz instantaneous bandwidth. The in-band interference, which is a serious problem of conventional photonics-based RF channelizer, is suppressed by more than 25 dB.

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- **Peixuan Li, Wei Pan, Xihua Zou, Lianshan Yan and Bin Luo** (*Southwest Jiaotong University, P.R. China*)

Abstract: A simple multi-service radio over fiber (RoF) system to simultaneously transmit frequency-doubling vector signal (FDVS) and low-radiofrequency signal (LRS) in a single wavelength is proposed. At the center office (CO), an integrated dual-parallel Mach-Zehnder modulator is utilized to implement double-sideband modulation with carrier (DSB+C) for the LRS and the carrier-suppressed double-sideband modulation (CS-DSB) for the FDVS, respectively. More importantly, a 90-degree phase shift is introduced to the DSB signal to eliminate the inter-band beating interferences (IBBIs) arising from the beating terms of optical subcarriers induced by these two signals. In the experiments, a 0.5-Gbaud QPSK FDVS at 16 GHz and a 4-GHz LRS carrying 1.25 Gbit/s OOK data have been simultaneously transmitted successfully, showing the effective elimination of IBBIs. In the 10-km fiber link, the power penalties for the OOK data and QPSK signal are estimated as 0.44 dB and 1 dB, respectively.

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- **Xiang Zhu, Dan Zhu and Shilong Pan** (*Nanjing University of Aeronautics & Astronautics, P.R. China*)

Abstract: A photonic analog-to-digital converter with multiplied sampling rate based on a fiber ring is proposed and demonstrated. Using optical pulses with 100-MHz repetition rate, equivalent sampling rates with multiplication factors of 5 and 7 are experimentally achieved. The proposed approach features simple configuration with no parallel structure, which can find application in photonics-based coherent digital radar systems.

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Cascaded and Parallel IIR Microwave Photonic Filters Based on Homogeneous Multicore Fibers.....438

- **Liang Huo, Lin Gan, Li Shen and Songnian Fu, Ming Tang** (*Huazhong University of Science and Technology, P.R. China*); **Chen Yang and Weijun Tong** (*YOFC, P.R. China*)

Abstract: We propose and demonstrate two types of infinite impulse response (IIR) microwave photonic filters (MPFs) with different structures, named cascaded structure and parallel structure. Both structures are based on the homogeneous multicore fiber (MCF) in which the inter-core power coupling has been established by tapering technique. The quality factors (Q factors) of cascaded and parallel structures are 143 and 136 respectively, which is much higher than that of one single IIR filter. These two structures show good reconfigurability and tunability by adjusting optical power and time delay. We anticipate that microwave photonics systems will benefit from these two types of IIR-MPFs in terms of compactness, reconfigurability, tunability and performance stability.

THP.27**Bandpass microwave photonic filter based on cascaded injected semiconductor lasers.....442**

- **Zhu Huatao** (PLA University of Science and Technology, P.R. China)

Abstract: In this paper, a bandpass microwave photonic filter (MPF) based on cascaded optically injected semiconductor laser is proposed and demonstrated by a proof-of-concept experiment. Combining the two gain spectra of the slave laser, the performance of the MPF is enhanced. The frequency response under different injection parameters are investigated. The central frequency of the passband can be tuned from 11.1 to 38.6 GHz.

THP.28**Optical Vector Network Analyzer Based on Distributed Feedback Semiconductor Optical Amplifier.....445**

- **Ye Deng, Bin Li, Hui Gao, Jinping Zhang and Zhipeng Zhou** (Nanjing Research Institute of Electronics Technology, P.R. China)

Abstract: A high resolution optical vector network analyzer (OVNA) based on a distributed feedback semiconductor optical amplifier (DFB-SOA) is proposed and experimentally demonstrated. The proposed OVNA is realized by mapping the transmission response of the optical device under test (ODUT) from optical domain to electrical domain. The key principle of the OVNA is the optical carrier recovery resulted from the wavelength-selective amplification of the DFB-SOA. A proof-of-concept experiment to measure the transmission response of an optical bandpass filter is successfully performed. The results show that our proposed OVNA can achieve bandpass response measurement with a resolution of 25 MHz.

THP.29**Electro-optical switching based demultiplexing in high-speed photonic analog-to-digital converter based on actively mode-locked laser.....448**

- **Lei Yu, Weiwen Zou, Guang Yang and Xinwan Li, Jianping Chen** (Shanghai Jiao Tong University, P.R. China)

Abstract: We demonstrate an electro-optical switching based demultiplexing scheme for high-speed photonic analog-to-digital converter system. In a 20 GHz actively mode locked laser based photonic analog-to-digital converter system, a Mach-Zehnder modulator is used as the electro-optical switching to demultiplex the 20 GS/s sampled series into two channels at the speed of 10 GS/s, which are then digitized at 10 GS/s in each channel. After data reconstruction and mismatch compensation, the spectral analysis of the digitized results shows an effective number of bits of 7 bits with 11 GHz input and 6 bits with 31 GHz input.

THP.30**Nondestructive Testing of Rubber Materials Based on The Reflective Terahertz Time-domain Spectroscopy.....451**

- **Zipeng Xu, Lijuan Li, Jiaojiao Ren and Guohua Cao** (Changchun University of Science and Technology, P.R. China)

Abstract: With the wide use of rubber as high performance sealing material in aerospace field, an effective nondestructive testing method is urgently needed to detect the product quality and thickness distribution of rubber materials. In this paper, the sample made by rubber material and metal plate bonding was detected by the reflective THz time-domain spectroscopy system. In order to avoid the problem of missed detection due to the pulse width of time domain signal itself, the time domain signal of the system was processed by deconvolution technique, which has effectively reduced the pulse width and improved the resolution of the system. The abnormal area was found by analyzing the test result. Combined with the manufacturing process of the sample, these abnormal area were judged to delamination defects. Through the processing of the flight time information of the time-domain waveform of each point in the test data, the two-dimensional thickness distribution of the rubber part of the sample was plotted under the precondition that the refractive index is known, which realize visualization of thickness distribution information. The study indicate that reflective THz time-domain spectroscopy technology can effectively detect delamination defect and thickness distribution of rubber material.

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Wideband Microwave Photonic Downconverter with Low Phase Noise and Improved Spurious-free Dynamic Range.....455

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Abstract: In this paper, based on optoelectronic oscillator (OEO) and post digital linearization techniques, a wideband microwave photonic downconverter with low phase noise and improved linearization is proposed and demonstrated. The local oscillator signal from OEO with 26GHz and radio frequency (RF) signal are fed to an intensity modulator (IM) at quadrature point, leading to downconversion at photodiode (PD). The achieved intermediate frequency signal (IF) is then digital linearized with post digital linearization operation to suppress the intermodulation distortion products. The experiment shows low phase noise and well suppressed third-order modulation distortion (IMD3). With the wideband microwave photonic downconverter, the spurious-free dynamic range (SFDR) is improved to 107.6 dB.Hz^{2/3}.

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High-isolation microwave photonic sub-harmonic mixer.....459

- **Jinglan Zhang and Yuan Cao** (Jinan University, P.R. China); **Erwin Chan** (School of Engineering and Information Technology, Charles Darwin University, Australia); **Xudong Wang** (Jinan University, P.R. China); **Xinhuan Feng** (Institute of Photonics Technology, Jinan University, P.R. China); **Bai-ou Guan** (Jinan University, P.R. China)

Abstract: A microwave photonic sub-harmonic mixer with a wide bandwidth, high RF-LO isolation and high RF/LO-IF isolation is presented. High isolation between the RF and LO ports is obtained by separately applying the RF signal and the LO into two Mach Zehnder modulators, which are far apart, inside an integrated two dual-parallel Mach Zehnder modulator to avoid crosstalk between signal electrodes. High isolation between the RF/LO and IF ports is obtained by designing the modulator bias voltages to largely suppress the optical carrier. Experimental results demonstrate sub-harmonic frequency mixing operation with > 40 dB RF-LO isolation, > 38 dB LO-IF

isolation and > 5 dB conversion efficiency for an input RF signal frequency range of 0.5-40 GHz.

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Narrowband widely tunable single passband microwave photonic filter using optical-injection of a Fabry-Perot laser diode.....463

- **Wenxuan Wang, Long Huang and Ji Tao** (Nanjing University, P.R. China); **Yunshan Zhang** (Nanjing University of posts and Telecommunications, P.R. China); **Xiangfei Chen** (Nanjing University, P.R. China)

Abstract: A novel approach to realize a microwave photonic filter (MPF) with a widely tunable passband using an optical-injected Fabry-Perot laser diode is proposed and experimentally demonstrated. The fundamental principle is based on the wavelength-selective amplification of the FP laser under optical injection. By applying the optical wave from a tunable laser source (TLS) to the PM, a phase-modulated optical signal is generated, which injects to the slave laser by the circulator. The overall operation corresponds to a single passband MPF with the central frequency of the single passband widely by changing the injection locking parameters of the TLS. The proposed MPF is experimentally evaluated. A single passband MPF with the bandwidth of 275 MHz and a frequency tunable range of 23 GHz is achieved. The insertion loss and out-of-band suppression ratios are 27.9 dB. These are useful in applications where high frequency and wideband tunability are required.

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Absolute time delay measurement of stimulated Brillouin scattering based all-optical pulse.....467

- **Xin Long, Weiwen Zou, Jianping Chen** (Shanghai Jiao Tong University, P.R. China)

Abstract: A novel scheme to determine the absolute time delay of an unknown signal in a stimulated Brillouin scattering based all-optical pulse compression system is demonstrated. Optical pulse train with high repetition rate is utilized as the probe lightwave to interact the counter-propagating pump lightwave modulated by the microwave signal to be processed. The finite optical fiber length brings in insufficient interactions between pump lightwave and probe pulses. The absolute time delay of the unknown microwave signal is determined by the pulse-compressed results that are carried by these probe pulse trains. The absolute time delay is experimentally demonstrated and is theoretically analyzed. The maximum experimental error is about 7 ns for a linearly frequency modulated pulse with 1 GHz sweep range.

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Optical Signal Processing Based On an Optoelectronic Oscillator Employing a Polarization-Dependent Phase Modulator.....471

- **Yu Tang, Muguang Wang, Jian Sun, Beilei Wu, Jing Zhang, Qi Ding, Hongqian Mu and Tangjun Li** (Beijing Jiaotong University, P.R. China)

Abstract: We propose and experimentally demonstrate a compact and flexible structure of optical signal processing using a polarization-dependent phase modulator (PM) based optoelectronic oscillator (OEO). The key concept of the proposed scheme is to use the polarization-dependent

feature of the LiNbO₃ crystal of the PM to perform special phase modulation to intensity modulation conversion. The phase modulation indexes along the principal direction and orthogonal direction of the PM are different. Thus an intensity signal can be obtained after the signals in the two orthogonal directions are combined at a polarization (Pol) after the PM. A polarization controller (PC) is inserted between the PM and Pol to introduce a static phase shift. One part of the special phase modulated data signal is introduced to the OEO loop to form a stable injected oscillation. While the other part is sent to a branch to do serial-to-parallel conversion or modulation format conversion. NRZ to return-to-zero (RZ) conversion with tunable duty cycle which can be adjusted by tuning the phase shift introduced by the PC continuously is achieved in the branch. The receiver sensitivity of the converted RZ signal at a bit error rate (BER) of 10⁻⁹ has an improvement of about 2 dB compared to the original NRZ signal.

THP.36

Optical pulse compression radar at double repetition rate with both positive and negative beat frequencies.....475

- *Ji Xiong, Lianlian Xie and Zinan Wang (University of Electronic Science and Technology of China, P.R. China)*

Abstract: A new method to improve the repetition rate of optical pulse compression radar is proposed. This technology can double the system repetition rate by using both the positive and negative beat frequencies of the received signal, without deteriorating spatial resolution. This method can also be implemented in microwave radars.

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Enhanced Stimulated Brillouin Scattering Effect by Using Multilayer Molybdenum Disulfide on Fibre End.....479

- *Wenqian Xu and Lilin Yi (Shanghai Jiao Tong University, P.R. China); Haiyan Nan (Southeast University, P.R. China); Wei Wei (Shanghai Jiao Tong University, P.R. China); Zhenhua Ni (Southeast University, P.R. China); Yves Jaouën (Telecom ParisTech, France); Weisheng Hu (Shanghai Jiao Tong University, P.R. China)*

Abstract: For the first time we observe that SBS gain can be enhanced by 1.5 dB with multilayer MoS₂ on fiber end. The SBS gain enhancement is observed within 200-MHz range, indicating the broadband Brillouin scattering characteristics of MoS₂.

THP.38

Design on Serial Optical Digital-to-Analog Converter and its Experiment.....482

- *Tianhang Zhang, Zhiqiang Fan, Jun Su, Ning Yang and Qi Qiu (University of Electronic Science and Technology of China, P.R. China)*

Abstract: Optical techniques have the potential to overcome limitations of electronic digital-to-analog conversion (DAC). A serial optical DAC (ODAC) utilizing the dispersion property of fiber-optic is proposed and demonstrated. The structure of the proposed DAC is designed based on the concerning of dispersive summing and electro-optic bit selection, which is easier to be realized compared with the conventional serial optical DAC. An implementation is experimentally demon-

strated at operating rate of 12.5 Gb/s. Tunable fiber-optic delay line (TFDL)-based phase matching is investigated. The technical issues to reach a higher performance of the proposed DAC are discussed, the designed schematic structure in this paper could be easily modified for realizing higher speed and higher resolution.

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Impact of Finite Extinction Ratio of Modulator on Photonic Time-Stretch System.....486

- **Changqiao Liu, Boyu Xu and Jin Xiaofeng** (Zhejiang University, P.R. China)

Abstract: In this paper, we analyze the impact of finite extinction ratio of modulator on the photonic time stretch (PTS) system and present concise expressions of all harmonics for modulation with a single-arm Mach-Zehnder modulator (MZM) and a push-pull MZM separately. The 3dB bandwidth of the system is investigated based on the theoretical analysis. Both numerical and experimental results are presented to verify the correctness of the theoretical model.

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Low-frequency Electrical Spectrum Analysis for High-frequency Characterization of Dual-Parallel Mach-Zehnder Modulators.....489

- **Heng Wang, Shangjian Zhang, Xinhai Zou and Yali Zhang, Yong Liu** (University of Electronic Science and Technology, Chengdu, P.R. China)

Abstract: A low-frequency electrical spectrum analysis method is proposed for microwave characterization of high-speed dual-parallel Mach-Zehnder modulators (DPMZMs) based on two-tone and bias-swing modulation. The method achieves the high-frequency modulation depth and half-wave voltage measurement of DPMZMs by using a low-frequency photodetector (PD). Moreover, it avoids any calibration for the roll-off responsivity in the photodetection through setting a specific frequency relationship between two-tone and bias-swing modulation.

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Bi-directional Comb-fiber Architecture for Resolution Improvement of Optical Quantization Employing Soliton Self-frequency Shift and Spectral Compression.....492

- **Xuyan Zhang and Zhiyao Zhang, Heping Li and Yong Liu** (University of Electronic Science and Technology, Chengdu, P.R. China)

Abstract: We demonstrate a high-resolution quantization scheme based on soliton self-frequency shift (SSFS) and spectral compression in a bi-directional comb-fiber architecture. Our scheme is composed of a Sagnac-loop-based mirror and a comb-like combination of two sections of interleaved single-mode fibers (SMFs) and high nonlinear fibers (HNLFs). The Sagnac-loop-based mirror is placed at the terminal of the bus line to reflect the optical pulses back to the bus line to achieve single-stage SSFS and three-stage spectral compression. Quantization with a resolution of 6.2-bit is obtained in the experiment, which is 1.2-bit higher than that of its uni-directional counterpart. Our bi-directional scheme can achieve higher quantization resolution with a small volume and a low cost compared with its uni-directional counterpart.

THP.42

Measurement of polarization mode coupling distribution in polarization maintaining fibers using microwave photonic filter technique.....495

- ***Ruolin Liao and Chaodong Wang, Ming Tang, Songnian Fu (Huazhong University of Science and Technology, P.R. China)***

Abstract: We propose a novel method to measure the polarization mode coupling (PMC) distribution in polarization maintaining fiber (PMF) through nondestructive way based on microwave photonic filter technique. A proof-of-concept experiment has been conducted and proves the feasibility of our proposed method. The location and strength of PMC along the PMF links can be identified precisely.

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Tunable Microwave Photonic Filter Based on Mode-Locked Fiber Laser.....499

- ***Enming Xu, Qiqi Hu, Weiran Ding, Jiachen Gu, Xiaozhen Feng, Zuxing Zhang and Peili Li (Nanjing University of Posts and Telecommunications, P.R. China)***

Abstract: A and tunable microwave photonic filter based on mode-locked fiber laser (MLFL) is proposed and experimentally demonstrated. The MLFL can be operated as a single-frequency source or a multiple-optical-carrier (MOC) source by adjusting the polarization state of MLFL, different transfer functions are realized. The filter based on the multiple-optical-carrier source shows a single-passband filter and an improved noise figure, and the tunability can also be achieved by adjusting the polarization state of MLFL. By cascading with a fiber ring structure, the filter shape can be varied by carefully matching the transfer functions of the two individual optical structures.

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A Linearized Photonic Sampling Structure by Using Polarization-Dependent Modulators in Sagnac Loop.....503

- ***Dong Liang (Xi'an Institute of Space Radio Technology, P.R. China); Yong Liu (University of Electronic Science and Technology, Chengdu, P.R. China); Xiaojun Li (National Key Laboratory of Science and Technology on space Microwave, P.R. China); Qinggui Tan and Wei Jiang (China Academy of Space Technology, P.R. China)***

Abstract: In this paper, a new photonic sampling structure with effective nonlinearity suppression and good signal-to-noise ratio (SNR) performance is proposed. The key feature of this scheme is the polarization-dependent modulators (P-DMZMs) and the sagnac loop structure. Attributing to the polarization sensitive characteristic of P-DMZMs, differences between transfer functions of the fundamental signals and distortions become visible. Meanwhile, the selection of specific biases in P-DMZMs provides the possibility of a preferable linearized performance for real-time photonic sampling. Simulation results indicate that the proposed scheme is capable for effective nonlinearity suppression and provides good SNR performance even in a large frequency range.

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A simplified stimulated Brillouin scattering pulse compression of broadband microwave signal based on differential detection.....507

- ***Yonglan Yang, Weiwen Zou, Xin Long, Jianping Chen (Shanghai Jiao Tong University, P.R.***

China)

Abstract: We experimentally demonstrate a simplified stimulated Brillouin scattering (SBS) pulse compression of broadband microwave signal based on differential detection. The simplified pulse compression without subtraction is implemented by use of a parallel delay line without SBS gain and a balanced photodetector. The experimental results shows a higher performance of pulse compression by eliminating the background noise and decreasing the quantizing noise.

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A reconfigurable microwave photonic filter based on a phase-shifted FBG of two phase shifts.....510

• **Ou Xu and Yishi Han** (Guangdong University of Technology, P.R. China); **Shaohua Lu** (Beijing Vocational College of Labour and Social Security, Beijing, P.R. China)

Abstract: A microwave photonic filter (MPF) with reconfigurable frequency responses using a phase-shifted fiber Bragg grating (PS-FBG) of two phase shifts is proposed and a two-passband filter is experimentally demonstrated with tunable frequency spacing. The PS-FBG with two phase shifts acts as an optical notch filter to suppress one sideband of the phase-modulated signals. Thus, the phase-modulated signals are converted to intensity-modulated single-sideband signals. When the wavelength of the optical carrier from a tunable laser source is tuned into different frequency ranges, the frequency responses of the MPF having two narrow passbands, one passband and one notch, or two notches can be achieved. For the dual-passband MPF, contrasting to a single-passband MPF, the advantages in sensor applications are discussed.

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Continuously Accessible Long-term Fiber Optic Memory of Microwave Signal.....513

Mikhail Belkin (Moscow State Technical University MIREA, Russia); **Olga Egorova** (Fiber Optics Research Center RAS, Russia); **Igor Gladyshev, Tatiana Bakhvalova** (Moscow State Technological University MIREA, Russia)

Abstract: The first continuously accessible long-term fiber optic radio-frequency memory based on distributed structure of low-power emitters with wavelength division multiplexing, multicore optical fiber as retarding medium, optoelectronic repeater unit, and optical recirculation time-delay circuit are developed and investigated.

THP.48

Feasibility Demonstration of Space-Division Multiplexed Transmission of IEEE 802.11n/ac Compliant MIMO Signals over OM3 Multimode Fiber.....516

Yilei, Jianqiang Li, Rui Wu, Zhiquan Wan, Yuting Fan, Feifei Yin, Yitang Dai, Kun Xu (Beijing University of Posts and

Telecommunications, P.R. China)

Abstract: Using commercial IEEE 802.11n/ac access points, the feasibility of 3x3 space-division-multiplexed MIMO transmission over a single OM3 multimode fiber is experimentally demonstrated. More than two-fold multiplexing gain is realized for up to 1km fiber length with a tight fiber bend radius of 2mm.