THE 2023 IEEE INTERNATIONAL TOPICAL MEETING ON MICROWAVE PHOTONICS

Program

Nanjing, China

15-18 October, 2023

Contents

Hosts

天元实验室
Tianyuan Laboratory

National Key Laboratory of Microwave Photonics

Nanjing University of Aeronautics and Astronautics

Institute of Semiconductors, Chinese Academy of Sciences

Beijing University of Posts and Telecommunications

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Welcome

On behalf of the Organizing Committee, we are pleased to welcome you to the 2023 IEEE International Topical Meeting on Microwave Photonics (MWP 2023), to be held in Nanjing, China, on October 15-18, 2023. MWP 2023 serves as an international forum for researchers from around world working in all aspects of microwave photonics. MWP 2023 is organized by National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics & Astronautics (NUAA), with Institute of Semiconductors, Chinese Academy of Sciences, Beijing University of Posts & Telecommunications and Southwest Jiaotong University. It is sponsored by the Institute of Electrical and Electronics Engineers, IEEE Photonics Society, IEEE Microwave Theory and Technology Society, Optica, Chinese Society for Optical Engineering, Chinese Laser Press, and the Institute of Electronics, Information and Communication Engineers.

On October 15th, 2023, a workshop will be organized. We sincerely welcome all the participants to join in and enjoy this celebration. The technical sessions begin on October 16th, starting from a plenary session with 3 plenary talks given by Prof. Andrew Weiner, Prof. Siyuan Yu and Prof. David J. Moss. For the regular sessions, there are 2 Tutorial Talks and 7 Invited Talks, 42 Orals and 41 Posters. All these papers were reviewed and selected by the Technical Program Committee.

We would like to acknowledge the sponsors for their partnership in sponsoring this conference. We express our sincere gratitude to all the members of the Organizing Committee and the Technical Program Committee for the hard work and contributions.

Finally, we wish all the participants have a fruitful and productive conference, and also an unforgettable stay in Nanjing.

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General Information

■ **Hotel Information**

	Name	Address
Conference Hotel	International Youth Convention Hotel	No.9, Jinshajiang West Street, Nanjing, Jiangsu
Banquet Venue	The Yihe Garden Nanjing	No. 8 Taojia Lane, Nanjing, Jiangsu

■ **Lunch Break**

Lunch is served at Yuhua leisure bar on the 7th floor of the convention center, Main Building of International Youth Convention Hotel

■ **Banquet**

Date and Time: 2023.10.17, 19:00--22:00

Venue: Mantingfang Banquet Hall, The Yihe Garden Nanjing

Free shuttle bus will depart from the conference hotel to the banquet venue at 17:40, and from the banquet venue to the conference hotel at 21:00.

■ **Onsite Speaker Preparation**

All presenters should check in at the corresponding session room at least 30 minutes prior to their scheduled talk to upload and check their presentation. No shows of the oral presentation will be reported to conference management and these papers will not be published.

- The duration of a paper presentation slot is 15 minutes (Invited speech is 25 minutes).
- Your punctual arrival and active involvement in each session will be highly appreciated.
- Get your presentation PPT or PDF files prepared and backed up.
- Laptop (with MS-Office & Adobe Reader), projector & screen, laser sticks will be provided by the conference organizer.

■ **Duplication/ Recording**

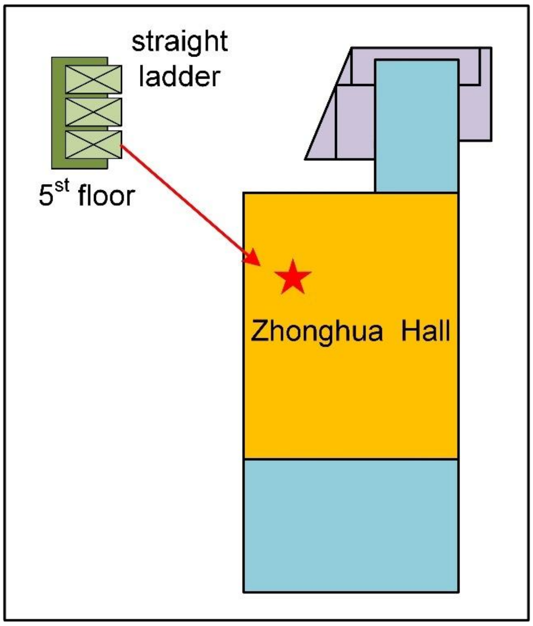
Unauthorized photography, audio taping, video recording, digital taping or any other form of duplication is prohibited in the conference.

■ **Security**

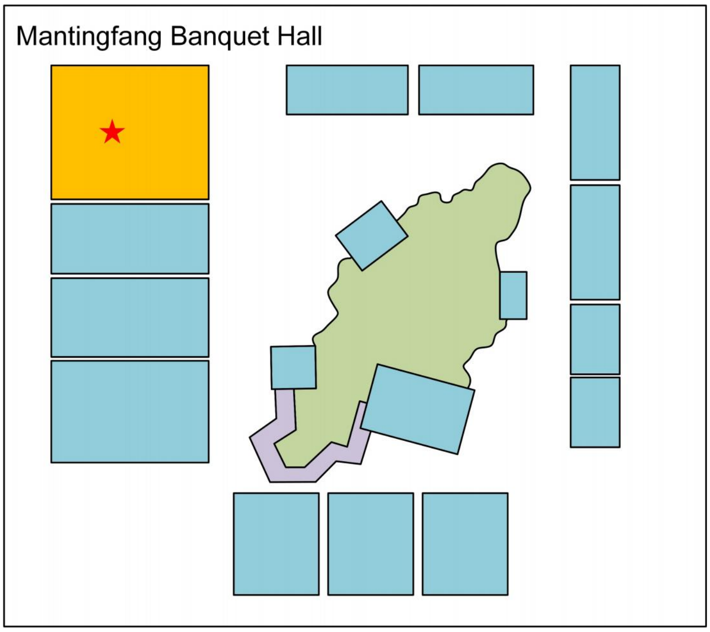
Please ensure that you take all items of value with you at all times when leaving a room. Do not leave bags or laptops unattended.

Floor Plan

- **Plan of International Youth Convention Hotel**



- **Plan of the Yihe Garden Nanjing**



Program at a Glance

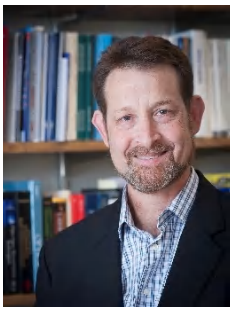
October 15	From 10:00	Registration	
	12:00--13:30	Lunch	
	13:30--15:35	Workshop: Frontiers of Microwave Photonics (I)	
	15:35--15:50	Tea Break	
	15:50--17:30	Workshop: Frontiers of Microwave Photonics (II)	
October 16	08:30--09:20	Opening Ceremony	
	09:20--10:10	Plenary Talk (I): Ultrabroadband Radio-Frequency Photonics: From Waveform Generation & Filtering to Classical & Quantum Frequency Combs	
	10:10--10:20	Tea Break	
	10:20--11:10	Plenary Talk (II): Optoelectronic Devices and Photonic Integration Circuits Aimed at Microwave Photonics	
	11:10-12:00	Plenary Talk (III): Ultra-high Bandwidth Applications of Optical Microcombs	
	12:00--13:30	Lunch	
	13:30--15:45	Young Scientist Award Competition	[**Tutorial Talk**] Progress on Advanced Signal Processing with High Speed Photomixers
			Microwave Photonic Interferometric System for Monitoring Delay and Temperature of Optical Cables Deployed in Radio Telescope Arrays
			Deep Learning Assisted Wide-range Microwave Photonic Sensing
			Demonstration of a Wideband 28 GHz Analog Radio-over-Fiber Optical Fronthaul Transmission Enabling Nonlinearity Tolerance
			Low-loss Wavelength-selected Tunable Optical Delay Lines for Microwave Photonic Signal Processing
			Hybrid Integrated Full-Chip Photonic Payloads Based on InP and Si3N4 Platform
	15:45--16:00	Tea Break	
	16:00--17:55	**Oral Session 1:** Waveform Generation and Signal Sources	[**Invited Talk**] Comb based Microwave Photonic Signal Generation and Processing
			Millimeter-level Resolution Waveform Generation by Period One Laser Dynamics with Optical Frequency Down-conversion
			Efficient Optical-to-sub-THz Carrier Frequency Down-Conversion by UTC-PD-Integrated HEMT
			High-Accuracy Target Recognition Scheme Based on Photonic Radar and Optical Reservoir Computing
			Towards Low-noise Tuneable THz Generation
			Compact and Robust Silicon Waveguide to Hollow Metallic Waveguide Coupling using a Quarter-Wave Dielectric Slot Waveguide for mmW and THz Waves
			93 GHz Wireless Transmission based on a Fully Packaged mm-Wave Band Optical Clock Generator

October 17	08:00--10:10	Best Student Paper Award Competition (I)	[**Tutorial Talk**] Programmable Schemes on Temporal Processing of Wide-bandwidth Optical Signals
			[**Invited Talk**] Low Loss Photonic Integrated Circuits: from Prototype to Volume
			Self-characterization Method for Integrated Optical Delay Lines
			Microwave Photonics for Networked Staring Radar
			Programmable RAMZI Filter for Integrated Microwave Photonic Processors
	10:10--10:20	Tea Break	
	10:20--12:05	Best Student Paper Award Competition (II)	High-speed Arbitrary Waveform Generation Based on The Temporal Vernier Effect
			Sparse Radio Frequency Signal Sampling based on 1-bit Quantized Photonic Compressive Sensing System
			Reconfigurable Silicon Integrated RF Photonic Filter Toward Wireless Communication
			FMCW Laser Ranging Breaks the Coherence Length Limitation via Phase Noise Cancellation
			Integrated Photonics for Multi-channel RF Scanning Receivers
			Optical Convolution Operations Based on Multimode Interference
			Narrowband Optical Signal Denoising Through All-fiber Temporal Talbot Effects
	12:05--13:30	Lunch	
	13:30--15:20	**Oral Session 2:** Transmission and Measurement	[**Invited Talk**] High Speed OE Conversion Technology for Optical Wireless Communications in Beyond 5G
			[**Invited Talk**] Microwave Photonic Discrete-frequency Processing
			Multi-channel Sampling Time Delay Measurement and Control for Time-wavelength Interleaved Photonic Analog-to-digital Converters
			RF/FSO Mixed Communication System Incorporating Photonic Aggregation for Improved Spectral Efficiency and Suppressed Co-frequency Interference
			Tunable Narrowband Microwave Photonic Filter Using Stimulated Brillouin Scattering by Precisely Controlling the Gain and Loss Spectra
			Reduction of Influence of Phase Modulation for SBS Mitigation on Output Power Enhancement in Photonic-based 10-GHz Generation by Optical Pulse Compression
	15:20--15:35	Tea Break	
	15:35--18:00	Poster Session	

October 18	08:00--09:40	**Oral Session 3:** Devices and Subsystems	[**Invited Talk**] Millimetre Resolution Photonic Radar for UAV and Vital Sign Detection
			Wideband Microwave Photonic Beamformer Based on a Spiral Bragg Grating Waveguide
			Photonic RF Channelization Based on Electro-optic Ring Modulator
			A Frequency Modulated Continuous Wave LiDAR System Based on Reservoir Computing
			Dual-wavelength-modulation mm-wave System Based on Single-sideband Signals
			Optimal Coupling for the Reduction of Bimodality in 850nm-VCSEL-Based Radio-over-G.652-Fiber
	09:40--09:50	Tea Break	
	09:50--11:45	**Oral Session 4:** Integrated Microwave Photonics	[**Invited Talk**] Integrated Lithium Niobate Microwave and Millimeter-wave Photonic Circuits
			Microwave Photonic Filter with User-defined Reconfigurability and High Frequency Selectivity
			Time Phase Shifting Based Demodulation Method for Fast Optical Fiber Transfer Delay Measurement
			High-Speed Waveguide-coupled Photodiode Arrays on Thin-film Lithium Niobate Platform
			Integrated Reconfigurable Modulator for Microwave Photonic Filtering
			High-speed Evanescently-coupled Waveguide MUTC Photodiodes with Bandwidth Over 220 GHz
			Integrated Lithium Niobate Optical Vector Network Analyzers Based on Single-sideband Modulators
	11:45--13:30	Lunch	
	13:30--15:25	**Oral Session 5:** Microwave Photonic Systems	[**Invited Talk**] Photonic Integrated Circuits for RF Waveform Generation
			Wideband and Low-Phase-Noise Chirped Pulses Generation Based on an Injection-Locked Optoelectronic Oscillator
			Compact Optical 90° Hybrid Based on a Wedge-shaped 2 × 4 MMI Coupler and a 2 × 2 MMI Coupler on Thin-film Lithium Niobate Platform
			Tandem Neural Networks for the Inverse Programming of Linear Photonic Processors
			Photonics-assisted RF Signal Storage Scheme
			Enhancing Detection Performance of Multi-band Photonic Radars Through Band Fusion with Coherent Processing
			Experimental Investigation of an Optical Reservoir Computer with MZI-based Optical Mask
	15:25--15:40	Tea Break	
	15:40--18:00	Post Deadline Session	

Plenary Talk

Monday
16, October



Ultrabroadband Radio-Frequency Photonics: From Waveform Generation & Filtering to Classical & Quantum Frequency Combs

Andrew Weiner

Time: 09:20—10:10 | Zhonghua Hall, 5F

Purdue University, America

Abstract: In this plenary talk, I touch on examples of our work over the years connecting ultrabroadband photonics and radio-frequencies. Photodetection of femtosecond pulses manipulated using pulse shapers and dispersion can be used for RF arbitrary waveform generation, while RF modulation of optical frequency combs in conjunction with pulse shapers and dispersion enables RF photonic filtering. Frequency combs formed via nonlinear wave mixing in on-chip microresonators (Kerr combs), which offer potential as compact sources for a variety of applications, including RF signal generation, benefit from RF and RF photonic techniques for measurement and stabilization. Pumping on-chip microresonators below the threshold for classical comb generation yields quantum frequency combs, consisting of high-dimensionally entangled photon pairs, which are characterized and manipulated using RF phase modulation. An overall theme is the interplay of analog RF and photonics techniques for operating on broadband signals in both the RF and optical domains.

Biography: Andrew Weiner is the Scifres Family Distinguished Professor of Electrical and Computer Engineering. He is a member of the U.S. National Academy of Engineering and of the National Academy of Inventers and was selected as a Department of Defense National Security Science and Engineering Faculty Fellow. Weiner presently serves as Editor-in-chief of Optics Express, an all-electronic, open access journal publishing more than 3000 papers a year emphasizing innovations in all aspects of optics and photonics, and previously served a three year term as Chair of the National Academy's U.S. Frontiers of Engineering Meeting. After Prof. Weiner earned his Sc.D. in electrical engineering in 1984 from the Massachusetts Institute of Technology, he joined Bellcore, at that time a premier telecommunications industry research organization, first as Member of Technical Staff and later as Manager of Ultrafast Optics and Optical Signal Processing Research. He joined Purdue as Professor in 1992, and has since graduated close to 40 Ph.D. students. Prof. Weiner has also spent sabbaticals at the Max Born Institute for Nonlinear Optics and Ultrashort Pulse Spectroscopy, Berlin, Germany and at JILA, University of Colorado and National Institute of Standards and Technology, Boulder, Colorado.

Prof. Weiner's research focuses on ultrafast optics, with a focus on processing of extremely high speed lightwave signals and ultrabroadband radio-frequency signals. He is especially well known for his pioneering work on programmable generation of arbitrary ultrashort pulse waveforms, which has found application both in fiber optic networks and in ultrafast optical science laboratories around the world.

Plenary Talk

Monday
16, October

Optoelectronic devices and photonic integration circuits aimed at microwave photonics

Siyuan Yu

Time: 10:20—11:10 | Zhonghua Hall, 5F

Sun Yat-sen University, China

Abstract: The transmission, detection and processing of microwave photonic signals require optoelectronic and photonic devices that support high signal to noise ratio (SNR), high linearity, high optical power, large bandwidth, high quality (Q) factor and reconfigurability. Many optoelectronic devices and photonic integrated circuits (PICs) developed for digital optical communications are no longer suitable for microwave photonics.

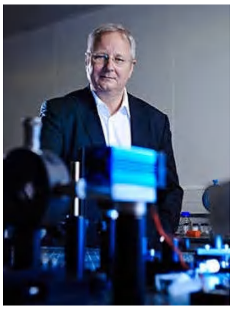
This talk will review some fundamental issues that may limited the performance of optoelectronic devices and PICs in microwave photonics. Approaches and developments in resolving these issues will be reviewed. Active optoelectronic devices such as semiconductor lasers and photodetectors will be covered. The development of PIC technology based on various platform materials and various integration technologies for microwave photonics will be discussed.

Biography: Prof. Siyuan Yu (Fellow of OPTICA) received his Bachelor degree from Tsinghua University in 1984, Master degree from Wuhan Institute of Post and Telecommunications in 1987, and PhD from the University of Glasgow, UK, in 1997. He had been Professor of Photonic Information Systems at the University of Bristol, UK, before joining the School of Electronics and Information Engineering, Sun Yat-sen University, China.

Prof. Yu has carried out research in the physics and technologies of optoelectrnic devices and photonic integrated circuits as well as their applications in optical systems and networks for over 35 years, focusing on innovative photonic component technologies aimed at addressing key issues at link and network levels. He contributed to areas such as integrated high-speed optical switches, novel semiconductor lasers, all-optical logic circuits and integrated quantum photonic circuits on various materials including III-V semiconductors, silicon nitride, and lithium niobate. He is also a pioneer on the application of the orbital angular momentum of photons for ultra-high-capacity information transmission. He has published more than 230 papers including two Science cover features, co-edited a book, and has been granted several international patents.

Plenary Talk

Monday
16, October



Ultra-high Bandwidth Applications of Optical Microcombs

David J. Moss

Time: 11:10—12:00 | Zhonghua Hall, 5F

Swinburne University of Technology, Australia

Abstract: I will review our work on the applications of integrated optical microcombs.

Biography: Distinguished Prof. Moss is Director of the Optical Sciences Centre at Swinburne University and Deputy Director of the newly established Australian Research Council Centre of Excellence COMBS (Centre for Optical Microcombs for Breakthrough Science). He is a Life Fellow of the Institute of the IEEE, Fellow of Optica, and Fellow of the SPIE. He has a 35 year history of R&D in photonics, nonlinear optics, nanophotonics, quantum optics, opto-electronics and optical communications. He was in industry for 7 years with Hitachi and JDS Uniphase in Canada. Dist. Prof. Moss has published over 900 research papers highlighted by 3 Nature papers, a Science, 8 Nature Photonics, Nature Reviews Chemistry and a Nature Physics.

Frontiers of Microwave Photonics (I)

Time: 13:30—15:35 | Golden Concert Hall, 1st floor
Chair: Ming Li

13:30-13:55

[Invited Talk] Optical Wireless Communications with Silicon Photonic Integrated Circuits

Ke Wang

Royal Melbourne Institute of Technology, Australia

Abstract: The optical wireless communication technology has been widely envisioned as a candidate for next-generation wireless communications, particularly short-range communications, taking advantage of the broad license-free bandwidth, the immunity to electromagnetic interference, and the physical layer security. However, conventional optical wireless communications rely on discrete components. To realise high-performance and compact optical wireless transceivers, the silicon photonic integration provides a promising solution. In this talk, we will review recent progress on silicon photonic integrated components and circuits for optical wireless communications, and discuss key challenges.

Biography: Ke Wang is currently an Associate Professor and Assistant Associate Dean at the School of Engineering, Royal Melbourne Institute of Technology (RMIT University), Australia. He was an Australian Research Council (ARC) DECRA Fellow. His research focuses on optical wireless communications, terahertz communications, machine learning hardware accelerator, and silicon photonic integrations. He has published >200 papers and received a number of national and international awards, such as Marconi Society Paul Baran Young Scholar Award, Victoria Fellowship Award, Young Tall Poppy Science Award, and the Geoff Opat ECR Prize.

13:55-14:20

[Invited Talk] Topological electro-optic modulator based on silicon nitride loaded lithium niobate

Yong Zhang

Shanghai Jiaotong University, China

Abstract: Electro-optic modulators, which convert signals from the electrical to the optical domain, are at the heart of optical communication, and quantum technology. Next-generation electro-optic modulators require high-density integration, compact footprints, large bandwidths, and low power consumption. They are challenging to achieve with established integrated Mach-Zehnder interferometer (MZI) or microring devices. In this work, we report the first topological modulator to realize the most compact electro-optic LN modulator with a bandwidth higher than 28 GHz. A topological interface state in a one-dimensional lattice is implemented on a thin-film LN substrate. We implement the topological modulator with a compact size of 1.6 × 140 μm2, which is one to four orders of magnitude smaller than the reported thin film LN modulators with bandwidths exceeding 28 GHz, to the best of our knowledge. Furthermore, we present a Mach-Zehnder LN modulator incorporating topological slow-light waveguides and capacitively loaded slow-wave electrodes. We demonstrate a record-breaking low half-wave voltage length product ($V_\pi L$) of 0.21 V·cm and an incomparable electro-optic modulation bandwidth of 110 GHz without roll-off.

Biography: Yong Zhang joined Shanghai Jiao Tong University, Shanghai, China, as an Assistant Professor in 2015 and became an Associate Professor in 2019. He received the Ph.D. degree from the Huazhong University of Science and Technology, Wuhan, China. He has more than 60 journal and conference papers, including Light Science Applications, Laser Photonics Reviews, Advanced Optical Materials, OFC/ECOC/CLEO, etc. His research areas cover hybrid integrated devices, high-speed electro-optic modulators, silicon polarization and mode multiplexing devices. He was an Editorial Board Member of the Journal of Semiconductors and a Guest Editor for Science China Information Sciences (2017). He was the Vice-Chair (2020-) of the IEEE Photonics Society Shanghai Chapter.

14:20-14:45

[Invited Talk] Integrated Microwave Photonics for Antenna Beamforming

Maurizio Burla

Technischen Universität Berlin, Germany

Abstract: Optical approaches for radio frequency antenna beamforming have been first proposed in the early 1990s, to provide solutions offering broad instantaneous bandwidth and large amount of tunable delays for phased array radars. With the enormous progress of radio frequency integrated circuits, optical beamforming techniques went out of the spotlight. But today we see a resurgence of interest toward this approach driven by the need of flexible antenna beam control for sub-THz waves in next generation wireless communications and by the capabilities offered by photonic integration. Starting from the history of the topic, this talk will provide an insight of the current trends.

Biography: Maurizio Burla (S’08-M’12-SM'22) received his received his B.Sc. and M.Sc. degrees from the University of Perugia, Perugia, Italy, in 2005 and 2007, respectively, and his PhD degree from the University of Twente, Enschede, The Netherlands in 2013.

From 2012 to 2015 he has been a FQRNT Research fellow at INRS-EMT, Montreal, Canada, working on integrated-waveguide technologies for ultrafast all-optical signal processing and microwave photonics. In 2015 he moved to the Institute of Electromagnetic Fields, ETH Zurich, Switzerland, to work on microwave plasmonics and THz wireless communications with an SNSF Ambizione fellowship. Since 2022 he is the Chair of High Frequency Technology and Photonics at TU Berlin, Germany.

Prof. Burla's works received best paper awards at the IEEE International Topical Meeting on Microwave Photonics for his research contributions on programmable integrated photonic and plasmonic devices for sub-THz signal processing.

14:45-15:10

[Invited Talk] Photonic Technologies for Terahertz Beam Steering and 6G Communications

Peng Lu

Universität Duisburg-Essen, Germany

Abstract: As THz technologies advance, spectra beyond 92 GHz have been allocated for 6G communications. The first wireless communications standards for the 300 GHz band have been published by ITU-R F.2416-0 and IEEE 802.15.3d-2017. One challenge of THz technologies is the high free-space path loss. To address this, and to realize THz systems for mobile applications, beam steering technologies are essential. This talk will provide an overview of THz frequency allocation for 6G communications. Furthermore, we will discuss our latest research on photonic integrated circuits for THz beam steering. In the end, results for 6G fixed wireless access and mobile communications using photonic technologies will be presented.

Biography: Peng Lu received his B.Sc. and M.Sc. degrees in NanoEngineering / Nano-Optoelectronics from the University of Duisburg-Essen in 2014 and 2016, respectively. Since 2017, he has been affiliated with the Department of Optoelectronics at the Center for Semiconductor Technology and Optoelectronics (ZHO) at the University of Duisburg-Essen. Currently, he leads the research on THz access points for mobile 6G applications. His current research interests include Si-based photonic integrated chips, terahertz beam-forming technologies utilizing phased arrays and leaky-wave antennas, as well as hybrid and heterogeneous photonic integration platforms.

15:10-15:35

[Invited Talk] Reconfigurable Silicon Photonics Platform for the implementation of Spectr-temporal Neuromorphic Schemes

Charis Mesaritakis
University of the Aegean, Greece

Abstract: In this work we present numerical results concerning a lightweight photonic neuromorphic scheme, able to process high-speed signals such as telecom data and image streams, directly in the spectral domain. The proposed scheme consists of spectral slicing nodes realised assuming a photonic reconfigurable platform that are able to spectrally decompose and process microwave signals. Results using a physically accurate emulation platform, confirm that the proposed neural nodes can outperform typical digital neural networks. Performance is highlighted in tasks that include the MNIST dataset classification experimental event based imaging cytometry datasets and high baud-rate optical signal equalization.

Biography: Assoc. Prof. Charis Mesaritakis acquired his diplom, M.Sc and Ph.D from National and Kapodistrian Univeristy of Athens (Greece). His Ph.D thesis focused on the experimental characterisation and numerical modelling of novel regimes of quantum dot mode locked lasers for telecomm and biomedical applications. He has participated as a researcher in multiple FP6-FP7 and Horizon EU projects. He has been awarded a postdoctoral EU Marie-Curie Fellowship, involving high precision laser telemetry in Thales III-V Labs (France); Followed by two competitive national research grants, PROMITHEAS from the J. Latsis foundation and HFRI NEBULA, both focusing on the investigation of photonic neuromorphic technologies. Currently he serves as technical manager for the EU NEoteRIC and for the EU PROMETHEUS Horizon research projects, focusing on photonic neuromorphic and quantum computing paradigms tailored to biomedical applications. Since 2019, he is an associate professor at the department of Information and Communication Systems Engineering at the University of the Aegean. He is author and co-author of more than 100 publications in highly cited journals and international conferences focusing on quantum-dot/well laser neuron dynamics, hardware for implementing neuromorphic schemes and physical layer security.

Frontiers of Microwave Photonics (II)

Time: 15:50—17:30 | Golden Concert Hall, 1st floor
Chair: Ming Li

15:50-16:15
[Invited Talk] Heterogeneous silicon photonic: from material platforms to applications

Lin Chang
Peking University, China

Abstract: Heterogeneous photonic technologies have led to remarkable breakthroughs in integrated photonics over last few years. In this talk, we will introduce the key progress on several heterogeneous photonics platforms, which support integrated narrow linewidth laser and microcombs using multi-material integration. We will also discuss the potential heterogeneous photonics holds for diverse applications.

Biography: Dr. Chang is an assistant professor at Peking University. His research focus is on integrated photonics, particularly heterogeneous technology for silicon photonics. Dr. Chang developed several heterogeneous platforms that supports semiconductor lasers, microcombs and microwave photonic devices. He has published more than 30 papers in top journals. Dr. Chang is the recipient of “2023 IEEE Photonic Society Young Investigator Award”.

16:15-16:40

[Invited Talk] Novel optoelectronic oscillators

Tengfei Hao

Institute of Semiconductors, Chinese Academy of Sciences

Abstract: An optoelectronic oscillator (OEO) is a closed microwave photonic feedback loop that is capable of producing high-quality microwave signals with ultra-low phase noise. In this talk, we review our recent works on novel OEOs, including a novel Fourier domain mode-locked OEO for chirped microwave signal generation, PT symmetric OEO for stable single-frequency oscillation, optoelectronic parametric oscillator for phase-controlled operation, soliton OEO for frequency-hopping microwave signal generation, and integrated OEOs with very compact size.

Biography: Tengfei Hao received the Ph.D. degree in physical electronics from the University of Chinese Academy of Sciences, Beijing, China, in 2021. He is currently an Assistant Professor with the Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China. He has authored or coauthored more than 40 papers in peer-reviewed journals. His research interests include microwave photonic signal generation and processing, as well as integrated microwave photonics.

16:40-17:05

[Invited Talk] Nonvolatile Reconfigurable Tunable Basic Units for Microwave Photonic Processor

Hongtao Lin

Zhejiang University, China

Abstract: Microwave photonics processors are the enabling technology for future microwave systems. However, they face challenges such as high power consumption, low operational stability, and significant thermal and optical crosstalk. This is due to the tunable basic units (TBU) are still based on thermo-optic modulation techniques, and there is an urgent demand for ultra-compact, near-zero-power, multifunctional, nonvolatile TBU for the future programmable microwave photonic processors. Chalcogenide phase change materials (PCMs) are a promising candidate for ultra-compact and zero-static-power-consumption TBU due to their high refractive index contrast reversible amorphous-crystalline phase transition. In this talk, we will introduce the " Zero change" platform we developed for monolithic back-end-of-line integration of phase change materials in silicon photonics. Two distinct chalcogenide phase change materials (PCM) with remarkable nonvolatile modulation capabilities were integrated to build a series of nonvolatile TBUs. The near-zero-power consumption capability made them emerging candidates for future microwave photonic processors.

Biography: Hongtao Lin is ZJU100 Plan Professor at the College of Information Science & Electronic Engineering, Zhejiang University, Hangzhou, China. He was a Postdoc fellow at the Massachusetts Institute of Technology. His research focuses on chalcogenide-integrated nanophotonics and silicon hybrid integrated photonics. He has published more than 80 journal publications, including publications in Nature Photonics, Nature Communication, Optica, etc. His works had been selected to be included in “Optics in 2014” and “Optics in 2018” by OSA’s Optic & Photonics News.

17:05-17:30

[Invited Talk] Microwave photonic signal processing using a quantum dash mode-locked laser

Lawrence R. Chen
McGill University, Canada

Abstract: Optical frequency combs (OFCs) enable a diverse range of applications, including optical communications, signal processing, and RF / microwave photonics (MWP). In this presentation, we review recent work on quantum dash mode-locked lasers as OFC sources for MWP signal processing applications. Specifically, we demonstrate that the QD OFC can be used to implement the following: (1) optical true time delay for photonic beamforming, (2) reconfigurable MWP filtering and in particular, linear filter responses for instantaneous frequency measurement, and (3) arbitrary waveform generation.

Biography: Lawrence R. Chen is a Professor in the Department of Electrical and Computer Engineering and the Academic Lead and Faculty Scholar of the Enhancing Learning and Teaching in Engineering initative in the Faculty of Engineering at McGill University. His research interests include fiber and integrated photonics, optical communications, and microwave photonics, as well as engineering education, particularly learning systems and mechanisms and the intersections between the teaching and learning environments, identity, equity, diversity, inclusivity, and accessibility.

Young Scientist Award Competition

Session chair: Chester Shu

13:30-14:30

[Tutorial Talk] Progress on Advanced Signal Processing with High Speed Photomixers

Ghaya Baili

Thales Research and Technology, France

Abstract: High fidelity signal processing, having multigigahertz bandwidths, constitutes one of the major challenging technology needed for further advance in radar, surveillance and communications systems. An innovative signal processing architecture, based on a wideband photonic sampler or mixer and triggered by a low jitter laser, is developed in TRT. Different sampler's technologies are presented and compared in terms of optical efficiency, conversion losses and non-linearities. High repetition rate, low jitter and ps pulses lasers, with innovative architectures, are presented. Optically assisted and all-optical signal processing use cases are investigated. As an example, a high-fidelity photonic- ADC with an input bandwidth larger than 40 GHz, an instantaneous bandwidth of 2 GHz and an ENOB larger than 6, is presented.

Biography: Ghaya Baili was born in Tunisia in 1980. She graduated from the Ecole Supérieure d'Optique (France) in 2004 with a Master of Optics and Photonics from the University of Paris XI. She was awarded in 2008 a PhD degree in laser Physics from the University of Paris XI. She joined Thales Research & Technology, France in 2005. Her main research interests include laser physics, optoelectronic generation and processing of microwave signals, non-linear optics in fibers, opto-electronic devices and sub-systems, atomic clocks for time and frequency references as well as photonic integrated circuits. Dr BAILI has about 80 publications in refereed journals, about multiple communications in international conferences. She is member of the Société Française d'Optique.

14:30-14:45

Microwave Photonic Interferometric System for Monitoring Delay and Temperature of Optical Cables Deployed in Radio Telescope Arrays

Nanni Jacopo[1*], Lenzi Enrico[2], Perini Federico[3], Monari Jader[3], Mattana Andrea[3], Kenney David[4], Wu Alex[5], McPhail Andrew[4], and Tartarini Giovanni[6]

*[1]DEI-University of Bologna, [2]Optorad s.r.l.s, [3]IRA-INAF, [4]ICRAR-Curtin University, [5]ICRAR-Curtin University, (*now with the Defence Science and Technology Group- DSTG), [6]DEI -University of Bologna*

Abstract: The on-field validation of a fiber delay monitoring system (FDMS) based on a microwave Michelson's interferometer operating over optical fiber is presented. The FDMS has been designed for monitoring the impact of optical cables installed in radioastronomy applications. The system was tested in the second version of the Aperture Array Verification System (AAVS), which represents the prototype for the upcoming low frequency radioastronomy plant Square Kilometre Array (SKA-Low),

installed on site at the Murchison Radio Observatory, in Western Australia. The FDMS has been used to monitor two different typologies of cable installation: Surface Laid and Underground Buried. This work shows that the behavior of the delay measurement agrees with the measured average temperature of the cable, which depends on several aspects other than the air temperature. The FDMS can be used also to estimate the average temperature effects of the fiber optic cables.

14:45-15:00	**Deep Learning Assisted Wide-range Microwave Photonic Sensing**

Xiaoyi Tian, Yeming Chen, Yiming Yan, Liwei Li, Luping Zhou, Linh Nguyen, and Xiaoke Yi*

The University of Sydney

Abstract: We present deep learning (DL) assisted widerange microwave photonic (MWP) sensing using optical microresonators. The measurement range is extended by using a tunable laser to switch the optical carrier wavelength among a group of points, dividing the wide optical transmission spectrum of interest into segments with bandwidths suitable for the radio frequency operational bandwidth of the sensor. By adopting DL techniques to process the combined interrogation output of each segment, the laser wavelength instability effect can be mitigated, enabling accurate wide-range MWP sensing. As a proof-of-concept, a MWP sensor operating at two carrier wavelengths and adopting principal component analysis-assisted deep neural networks is demonstrated experimentally for glucose concentration measurement. The system operation range is doubled to 67.4 GHz. The estimation root-mean-square error in the presence of both thermal interference and laser wavelength instability is achieved to be 3.4-fold better than that using linear fitting.

15:00-15:15	**Demonstration of a Wideband 28 GHz Analog Radio-over-fiber Optical Fronthaul Transmission Enabling Nonlinearity Tolerance**

Tingting Song*, Christina Lim, and Ampalavanapillai Nirmalathas

The University of Melbourne

Abstract: A 1 GHz wideband analog radio-over-fiber link at the RF carrier frequency of 28 GHz is demonstrated over a 10 kilometer fiber transmission using 64-Quadrature amplitude modulation (64-QAM), with the nonlinearity analysis indicating that the link performance is limited by the frontend analog RF components at the transmitter. Such nonlinearity can be improved by a low-complexity modified cut-and-paste probabilistic shaping (M-CAP-PS) approach. M-CAP-PS-based 64-QAM is also demonstrated to improve the system bit-error-rate performance with a data rate of 5.54 Gb/s.

15:15-15:30	**Low-loss Wavelength-selected Tunable Optical Delay Lines for Microwave Photonic Signal Processing**

Yiwei Xie[1], Shihan Hong[1], Jiachen Wu[1], Ruitao Ma[1], Caibin Yu[2], and Daoxin Dai[1*]

[1]Zhejiang University, [2]Chongqing Optoelectronics Research Institute

Abstract: We propose and demonstrate a programmable low-loss 16-channel silicon-based microwave photonic signal processor using elliptical microrings and delaylines. The ellipital microrings offers flat-top filtering response to select/combine the carrier wavelength of the input optical signal. The following sixteen-channel delaylines are realized by ultra-low-loss broadened waveguides and low-phase-error Mach-Zehnder interferometer for 3.2 ps time-delay step. The overall insertion loss of the processor including the fiber-to-chip coupling loss is 10 dB. This programmable silicon photonic processor is demonstrated successfully to verify several microwave photonic signal processing functionalities: tunable delay line, beam beamforming and tunable radio-frequency filtering.

15:30-15:45	**Hybrid Integrated Full-Chip Photonic Payloads Based on InP and Si3N4 Platform**

Dong Liang[1*], Ahmad W. Mohammad[2], Chris Roeloffzen[3], Qinggui Tan[1], Yangjing Wang[1], and Sami Musa[4]

[1]CAST Xi'an, [2]LioniX International BV, [3]LioniX BV, [4]VA-Photonics

Abstract: Here, we demonstrate a hybrid integrated photonic satellite repeater with large-scale multiplexing potential and high flexibility. Hybrid integration of InP/Si3N4 external cavity laser, arrayed InP modulators and semiconductor optical amplifier (SOAs), as well as multifunctional Si3N4 signal processors, to fulfill a 1x4 Ka-band repeater module with on-chip arrayed frequency down-conversion and outstanding narrowband photonic channelization. Combined with the full-chip photonic repeater, broadband, highly integrated, and cost-effective communications satellite payloads would become realizable more quickly in the near future.

Oral Session 1: Waveform Generation and Signal Sources

Session chair: Ziqian Zhang

16:00-16:25

[Invited Talk] Comb Based Microwave Photonic Signal Generation and Processing

Xiaoxiao Xue

Tsinghua University, China

Abstract: Integrated optical frequency comb generation is an emerging technique that may revolutionize various applications ranging from communications to spectroscopy. The most notable function of a frequency comb is perhaps acting as a frequency gear that coherently links microwave with light. This places optical frequency comb in a unique position in the vast field of microwave photonics. The microwave photonic applications of optical frequency combs include low-phase-noise microwave generation, arbitrary waveform generation, true-time-delay beamforming, channelized receiver, etc. In this presentation, I will introduce recent advances of integrated frequency combs from the perspective of microwave photonics. Current challenges will also be briefly discussed.

Biography: Xiaoxiao Xue received both his B.Eng. (2007) and Ph.D. degrees (2012) from Tsinghua University. He joined the Department of Electronic Engineering at Tsinghua University as an assistant professor in 2016, and was promoted to an associate professor in 2019. His research interests include temporal cavity soliton physics, integrated optical frequency combs, microwave photonic signal generation and processing. Some of his leading research findings have been published in high-impact journals including Nature Photonics, Light: Science & Applications, and Laser & Photonics Reviews.

16:25-16:40 **Millimeter-level Resolution Waveform Generation by Period One Laser Dynamics with Optical Frequency Down-conversion**

Guanqun Sun[1], Xiaoyue Yu[1], Fangzheng Zhang[1*], Zhidong Lv[2], Yuewen Zhou[1], Boyang Wu[1], Changming Zhang[3], Xianbin Yu[2], and Shilong Pan[1]

[1]National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics and Astronautics, [2]Zhejiang University, [3]Zhejiang Lab

Abstract: A millimeter-level resolution waveform generation method is proposed. In this method, period one dynamics in an optically injected semiconductor laser is used to generate a broadband frequency-swept red-shifted sideband. By heterodyning this optical sideband with a frequency tunable reference laser, broadband frequency modulated signals with arbitrary central frequency can be generated. In the experiment, the generation of signals with bandwidths of 26 GHz (23-49 GHz) and 24 GHz (110-134GHz) is demonstrated, which enables a radar range resolution as high as 6 mm. The proposed method is a promising solution to generating broadband frequency modulated signals with the bandwidth over 20 GHz in arbitrary frequency bands, which can find applications in further high-resolution radars.

16:40-16:55	**Efficient Optical-to-sub-THz Carrier Frequency Down-conversion by UTC-PD-Integrated HEMT**

Tsung-Tse Lin[1*], Mitsuki Watanabe[2], Dai Nagajima[2], Keisuke Kasai[1], Masato Yoshida[1], Tetsuya Suemitsu[3], Taiichi Otsuji[1], and Akira Satou[1]

[1]Research Institute of Electrical Communication, Tohoku University, [2]Research Institute of Electrical Communication, School of Engineering, Tohoku University, [3]New Industry Creation Hatchery Center, Tohoku University

Abstract: We experimentally investigate the carrier frequency down-conversion of optical signals to sub-THz signals by the unitraveling-carrier-photodiode-integrated high-electron-mobility transistor (UTC-PD-integrated HEMT) photonic double-mixer. First, we investigate the effect of high-intensity subcarrier signal input on enhancement of its double-mixing conversion gain. The fabricated UTC-PD-integrated HEMT demonstrates the linear increase in the conversion gain by up to +6.8 dB with increasing the subcarrier signal intensity from +0.63 dBm to +6.63 dBm without saturation, and the conversion gain enhancement of +6.8 dB from -51.0 dB to -44.2 dB is achieved at 110-GHz photomixing frequency. Second, we investigate the effect of the shape and size of the UTC-PD mesa on the conversion gain. We show that further enhancement of the maximum conversion gain, +5 dB, can be achieved by employing the circular-shaped mesa with an optimal diameter close to the diameter of the input Gaussian beam. These results demonstrate that the UTC-PD-integrated HEMT is feasible for efficient carrier frequency down-conversion in the future beyond 5G wireless networks.

16:55-17:10	**High-accuracy Target Recognition Scheme Based on Photonic Radar and Optical Reservoir Computing**

Jian Zhu, Pei Zhou*, Yigong Yang, Zhigang Tang, and Nianqiang Li

Soochow University

Abstract: A high-accuracy target recognition scheme based on photonic radar and optical reservoir computing is proposed and demonstrated. The adoption of broadband photonic radar enables the acquisition of high-resolution range profiles (HRRPs) of the targets. A semiconductor laser-based optical reservoir computing (RC) system is used to achieve high recognition accuracy based on such HRRPs. With four small objects as targets, the performance of the proposed target recognition scheme is experimentally investigated. The results show that a high recognition accuracy of 95% is achieved based on photonic radar (8-GHz bandwidth) and optical RC. Therefore, the proposed scheme provides a promising solution for small target recognition in security check, traffic control, air defense and other related applications.

17:10-17:25	**Towards Low-noise Tuneable THz Generation**

Win Indra[1*], Zitong Feng[2], Josef Vojtěch[3], Meng Ding[4], Bo Shi[4], and Radan Slavik[4]

[1]Optoelectronics Research Centre, University of Southampton, [2]National Physical Laboratory, [3]CESNET a.l.e, [4]Optoelectronics Research Centre University of Southampton

Abstract: We phase locked a commercial telecom ITLA (integrable-tunable-laser-assembly) laser to an optical frequency comb with carrier frequency within the telecom C-band (1527 nm - 1565 nm). We achieved short-term integrated phase noise of 1.1 rad^2 and long-term frequency stability below ± 0.4 Hz. Fractional frequency instability for Terahertz source generated via photomixing of two such lasers is calculated and compared with the state-of-the-art.

17:25-17:40	**Compact and Robust Silicon Waveguide to Hollow Metallic Waveguide Coupling Using a Quarter-wave Dielectric Slot Waveguide for mmW and THz Waves**

Ashish Kumar[1*], Mushin Ali[2], Daniel Headland[1], and Guillermo Carpintero[1]

[1]University Carlos III of Madrid, [2]Leapwave Technologies

Abstract: This paper presents a novel technique for efficient waveguide coupling between a hollow metallic waveguide and a silicon dielectric rod waveguide in the 75–110 GHz range. The technique uses a short section of dielectric slot waveguide as a quarter-wave matching section to enhance robustness, reliability, compactness and yield for all-silicon terahertz integrated devices and systems, compared to those that employ conventional tapered-spike couplers. The transmission and reflection responses of the quarter-wave matched and tapered dielectric rod waveguides are presented, showing less than 2 dB loss. Reflection below -10 dB is achieved over the 75-110 GHz, reaching the lowest reflection magnitude of -25 dB at 97 GHz. The strong localization of the E-field with quarter-wave matching enables contactless coupling of mm waves, even in cases where there is a small separation.

17:40-17:55	**93 GHz Wireless Transmission Based on a Fully Packaged mm-wave Band Optical Clock Generator**

Alberto Montanaro[1], Claudio Porzi[2], Fawad Ahmad[2], Marco Chiesa[3], Antonio D'Errico[4], Alessandra Bigongiari[4], Aina Serrano Rodrigo[3], Federico Camponeschi[5], Marco Romagnoli[1], Antonella Bogoni[2], and Antonio Malacarne[1]

[1]CNIT, [2]Scuola Superiore Sant'Anna, [3]Camgraphic srl, [4]Ericsson, [5]SCUOLA SUPERIORE SANT'ANNA

Abstract: The mm-wave frequency spectrum offers the possibility to afford the increasing demand of high data-rate communication links. Microwave-photonics techniques can be advantageously used for reconfigurable generation of very high frequency clocks with superior phase noise performance with respect to purely electrical techniques, with the additional functionality of remote distribution of the signal through fiber-optics or free-space optic links. Here we present a fully packaged optoelectronic assembly of a CMOS-compatible silicon-based photonic integrated circuit for optical frequency comb generation with reconfigurable free spectral range given by an RF driving local oscillator. Through optical filtering and photodetection, a 98 GHz electrical clock has been derived and employed for successful 93 GHz wireless transmission of complex modulation formats carrying up to 4 Gb/s data rate, demonstrating the suitability of the solution for 5G and next generation 6G mobile networks.

Best Student Paper Award Competition

Session chair: Ghaya Baili & Michael Geiselmann

08:00-09:00

[Tutorial Talk] Programmable Schemes on Temporal Processing of Wide-bandwidth Optical Signals

Chester Shu

Chinese University of Hong Kong, China

Abstract: The direct manipulation of optical pulse trains and signals in the time domain provides an efficient method for regulating their characteristics such as phase, amplitude, repetition rate, and signal-to-noise ratio. The approach allows for flexible control over their temporal and spectral properties. This presentation reviews the advancements in the application of temporal and spectral Talbot effects, using spectral phase filtering and temporal phase modulation, for light wave processing. Additionally, the integration of linear Talbot processing with ultrafast nonlinear processing presents a versatile method for managing optical signals. We will discuss our recent studies on the combined application of Talbot effects and nonlinear phenomena, including cross-phase modulation and four-wave mixing in both fiber and silicon photonic platform, focusing on the generation and processing of optical frequency combs for telecommunications. We will also share findings on programmable processing concerning comb properties such as tooth spacing, amplification factor, signal-to-noise ratio, and waveband conversion.

Biography: Chester Shu received the BSc degree in Physics from the University of Hong Kong in 1985 and the PhD degree in Applied Physics from Columbia University in the City of New York in 1991. His research interest is on developing enabling technologies for advanced optical communications, microwave photonics, and optical sensing. In particular, he focuses on the generation, processing, and characterization of optical signals for applications in diverse fields. He has made original contributions in multi-dimensional processing of optical signals using both linear and nonlinear techniques. He also worked on the generation of programmable optical frequency combs with ultrawide spacings using both fiber-optic and silicon photonic platforms, supporting advanced coherent and direct-detection communication systems with unmatched performances in signal quality and power consumption. Currently, he is a Professor and the Chairman of the Department of Electronic Engineering at the Chinese University of Hong Kong. Prof. Shu has published widely and delivered many research talks in the field of optical signal processing. He is the Subject Editor-in-Chief (Optical Communication) of Electronics Letters. He was a senior editor of IEEE Photonic Journal and a topical editor of Optics Letters. Prof. Shu is fellow of Optica and HKIE, and a senior member of IEEE.

09:00-09:25

[Invited Talk] Low Loss Photonic Integrated Circuits: from Prototype to Volume

Michael Geiselmann

LIGENTEC, Switzerland

Abstract: In this talk, we present progress on scaling the fabrication of thick film silicon nitride photonics integrated circuits to volume and discuss the advantages of low loss photonic integrated circuits. We will present the LIGENTEC offering for low loss silicon nitride PICs for applications including microwave photonics. Options of active integration, such as LNOI are discussed. The offering includes fast R&D cycles in low volume PIC fabrication though multi-project wafer runs to high volume PIC fabrication in an automotive qualified CMOS line.

Biography: Michael Geiselmann (President & CCO) studied physics and engineering at University Stuttgart and Ecole Centrale Paris. After his PhD at ICFO in Barcelona in 2014 he joined the laboratory of Prof. Kippenberg at EPFL in Lausanne, where he advanced frequency comb generation on integrated silicon nitride chips towards applications and was involved in several international research projects. In 2016, he co-founded LIGENTEC and brought the company to the international stage of photonic integration.

09:25-09:40	**Self-characterization Method for Integrated Optical Delay Lines**

Pablo Martínez-Carrasco Romero[1*], Tan Huy-Ho[2], and José Capmany Francoy[1]

[1]Universitat Politècnica de València, [2]Ottawa Wireless Advanced System Competency Centre Huawei Technologies Canada Co., Ltd

Abstract: We present a calibration technique for Optical True Time Delay Lines, which effectively optimizes the number of active elements and footprint by dispensing with attenuators or test ports. Additionally, we demonstrate its accuracy for applications beyond beamforming by synthesizing variable optical interleavers on a silicon photonic chip.

09:40-09:55	**Microwave Photonics for Networked Staring Radar**

Darren Griffiths[*], Mohammed Jahangir, Gwynfor Donlan, Jithin Kannanthara, Michail Antoniou, Christopher Baker, and Yeshpal Singh

University of Birmingham

Abstract: Modern radar systems are capable of detecting small moving objects such as drones on the kilometer scale. The complex and evolving environment poses challenges such as interference, clutter induced phase noise and obstruction of targets. Networked radar systems are a potential solution but also bring their own challenges such as synchronization. In this paper, the effect of the oscillator on the networked radar is discussed and how microwave photonics are able to be integrated into the network for superior phase noise and synchronization performance.

09:55-10:10	**Programmable RAMZI Filter for Integrated Microwave Photonic Processors**

Cristina Catalá-Lahoz[1*], Daniel Pérez-López[2], Tan Huy-Ho[3], and José Capmany[1]

[1]Photonics Research Labs, iTEAM, Universitat Politècnica de València, [2]iPronics Programmable Photonics S.L., [3]Ottawa Wireless Competency Centre, Huawei Technologies Canada Co., Ltd.

Abstract: This paper introduces an optimization technique for a fully tunable RAMZI (Ring-Assisted Mach-Zehnder Interferometer) filter, specifically focusing on its application in integrated microwave photonic processors. The proposed filter design eliminates the need for monitoring components and employs a novel optimization technique that operates independently in each ring by switching between the two arms of the filter. Additionally, the filter can be configured to implement different filter architectures, allowing for flexible filtering requirements in communication systems. Experimental demonstrations were conducted using the device as an interleaver, implementing various types of IIR (Infinite Impulse Response) filters and SCISSOR (Side-Coupled Integrated Spaced Sequence of Resonators) filters. These results demonstrate the exceptional reconfigurability of the filter design proposed herein in terms of bandwidth and central frequency.

10:20-10:35	**High-speed Arbitrary Waveform Generation Based on The Temporal Vernier Effect**

Yiran Guan[1], Guangying Wang[1], Jiejun Zhang[1*], and Jianping Yao[2]

[1]Jinan University, [2]University of Ottawa

Abstract: High-speed arbitrary waveforms with a sampling rate over 100 GSa/s are of fundamental interest for various applications, such as spectroscopy, radar, optical communications, and biological imaging. In this paper, we propose and experimentally demonstrate a novel approach to the photonic generation of high-speed arbitrary waveforms based on the temporal Vernier effect with a simple and low-cost architecture involving a mode-locked laser (MLL) and a fiber loop. We show that the high sampling rate can be realized by matching two different temporal scales, i.e., the period of the optical pulse train from the MLL and the round-trip time of the fiber loop. The approach is evaluated experimentally. Two arbitrary waveforms with a widely tunable sampling rate from 5 to 250 GSa/s are generated. The fidelity of the generated waveforms is also evaluated by calculating the average root mean square error, which is as low as 0.0479.

10:35-10:50	**Sparse Radio Frequency Signal Sampling based on 1-bit quantized Photonic Compressive Sensing System**

Yuxiang Cai, Xiaohu Tang, Yamei Zhang*, and Shilong Pan*

National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics and Astronautics

Abstract: A 1-bit quantized photonic compressive sensing (PCS) system is proposed and experimentally demonstrated. The 1-bit quantization is realized with a comparator. Compared with the commonly used high-precision quantizer, the 1-bit quantizer can effectively solve the problems associated with low quantization rate, high power consumption, and storage pressure when quantizing a high-frequency signal. A proof-of-concept experiment is constructed. A two-tone signal in the range of 0~1 GHz is successfully captured and reconstructed with the proposed system under a sampling rate of 250 MSa/s.

10:50-11:05	**Reconfigurable Silicon Integrated RF Photonic Filter toward Wireless Communication**

Zihan Tao, Yuansheng Tao, Ming Jin, Ruixuan Chen, Haowen Shu*, and Xingjun Wang*

Peking university

Abstract: Integrated microwave photonic filters (IMPFs) are capable of offering unparalleled reconfigurability. However, to achieve high reconfigurability, complicated system structures and modulation formats are always required, which put great pressure on power consumption and controlment. Here, we propose a streamlined architecture for a wideband and highly reconfigurable IMPF on the silicon photonics platform. For various practical filter responses and avoiding complex auxiliary devices and bias drift problems, a phase-modulated flexible sideband cancellation method is employed based on the intensity-consistent single-stage-adjustable cascaded-microring (ICSSA-CM). The IMPF exhibits an operation band extends to mm-wave (≥ 30 GHz) and other extraordinary performances including high spectral resolution of 220 MHz and large rejection ratio of 60 dB are obtained. Moreover, Gbps-level RF wireless communications are demonstrated for the first time towards real-world scenarios.

11:05-11:20	**FMCW Laser Ranging Breaks the Coherence Length Limitation via Phase Noise Cancellation**

Xiuyuan Sun[1,2], Gang Hu[1,2], Hangtian Lu[1,2], Zhongyang Xu[1,2*], and Shilong Pan[1,2]

[1]National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics and Astronautics, [2]National Key Laboratory of Microwave Photonics

Abstract: Phase noise (PN) of a laser source is a limitation on the measurement range for a frequency-modulated continuous-wave (FMCW) laser ranging system. A narrow-linewidth laser is required to achieve long-range ranging. We proposed a FMCW laser ranging system which is able to break the limitation of coherence length via pilot-assisted PN cancellation. The system adds an acousto-optic modulator (AOM) to generate a frequency known pilot signal, from which the PN can be extracted. PN-cancellated signal can be obtained by removing the extracted PN term. The experimental results show the proposed system can recover the coherent peak beyond the 8-times of coherence length and achieve 0.88-cm precision at 861.39 m. This method can be used to achieve long-range of FMCW laser ranging using a wide linewidth laser.

11:20-11:35	**Integrated Photonics for Multi-channel RF Scanning Receivers**

Federico Camponeschi[1*], Luca Rinaldi[2], Claudio Porzi[1], Filippo Scotti[2], Paolo Ghelfi[2], Pietro Bia[3], Marco Bartocci[3], Antonio Zaccaron[3], and Antonio Manna[3]

[1]Scuola Superiore Sant'Anna, [2]CNIT, [3]Elettronica Spa

Abstract: Electronic warfare (EW) receivers face strict requirements, balancing high performance with small size. To this extent, photonics offers a solution by providing wide bandwidth, flexible tuning, and immunity to electromagnetic interference. Recent advances in integrated photonics also offer potential reductions in weight and size, while demonstrating microwave photonics application capabilities. In this paper, we present the design and simulation results of a 6-channel EW receiver. It covers a wide frequency range from 0.5 to 40 GHz, with an instantaneous bandwidth of 1.333 GHz, suitable for modern radars. Our approach is based on hybrid integration, combining silicon nitride (SiN) and indium phosphide (InP) photonics platforms.

11:35-11:50	**Optical Convolution Operations Based on Multimode Interference**

Xiangyan Meng, Guojie Zhang, Nuannuan Shi[*], and Ming Li[*]

Institute of Semiconductors, CAS

Abstract: The convolutional neural network is a significant category of deep learning that faces limitations in terms of electrical frequency and memory access time when processing massive amounts of data. Optical computing has shown promise in improving processing speeds and energy

efficiency. However, most existing optical computing schemes are not easily scalable due to the quadratic increase in the number of optical elements with the computational matrix size. To address this issue, we have developed a compact on-chip optical convolutional processing unit on a low-loss silicon nitride platform. This unit demonstrates its capability for large-scale integration. Three 2×2 correlated real-valued kernels are made of two multimode interference cells and four phase shifters to perform parallel convolution operations. Ten-class classification of handwritten digits from the MNIST database has been successfully experimentally demonstrated with the accuracy of 92.17%.

11:50-12:05	**Narrowband Optical Signal Denoising Through All-Fiber Temporal Talbot Effects**

Majid Goodarzi*, Manuel P. Fernandez, and Jose Azana

Institut National de la Recherche Scientifique

Abstract: We propose and experimentally demonstrate an all-fiber Talbot-based method to denoise MHz-bandwidth optical signals buried under noise. The method achieves up to 9 dB of optical signal-to-noise ratio improvement for the multiple target signals. Additionally, our approach preserves an undistorted version of the input waveform with significantly improved quality. The method involves phase-only transformations in both the time and frequency domains, accomplished through appropriate temporal phase modulation and chromatic dispersion. These transformations effectively prepare the signal for noise removal, which is achieved through time-domain filtering. Subsequently, the inverse dispersion is applied to retrieve the processed and noise-filtered signal. The demonstrated technique is a promising solution for noise filtering in narrowband optical signals, with applications in microwave photonics and optical signal processing.

Oral Session 2 Transmission and Measurement

Session chair: Xiaoxiao Xue

13:30-13:55

[Invited Talk] High Speed OE Conversion Technology for Optical Wireless Communications in beyond 5G

Toshimasa Umezawa

National Institute of Information and Communications Technology, Japan

Abstract: We present newly developed large aperture high speed photodetector technologies implemented to an optical wireless transceiver for fixed optical wireless and mobile optical wireless communications. In the fixed optical wireless communication demonstration, multi parallel output s in a PD array device, which consisted of small PD pixels in N x N aligned arrangement design, was used for spatial diversity signal processing to improve the SNR and for WDM beam direct detection using several different resonant wavelengths in a resonant cavity N x N PD array. For the mobile optical wireless communication in short range low moving speed communication applications, a newly developed single output type multi stacked PIN PD, which had an expanding aperture design not in sacrifice of 3dB bandwidth, was implemented to a mobile free space optical transceiver. Thanks to the large aperture PD with high 3dB bandwidth, the beam fluctuation affection on the PD surface was mitigated while moving the transceiver. Those high speed photodetector technologies and the optical transceiver design for optical wireless communications will be discussed and its high speed communication demonstration will be introduced as well.

Biography: Toshimasa Umezawa (Member, IEEE) received B.E. and M.E. degrees in electronics from Nagaoka University of Technology, Niigata, Japan, in 1984 and 1986, respectively. From 1987 to 2011, he worked for the Yokogawa Electric Corporation; he was with the Centra l Research Laboratory and with the Photonics Business Department. In 1992, he was a visiting scholar in the Department of Applied Physics, Stanford University, and he received a Ph.D. degree in electronics from Tokyo University, Tokyo, Japan, in 1995, where he was engaged in research on superconductor devices, photonics devices, and their applications. In 2011, he joined the National Institute of Information and Communications Technology (NICT), Tokyo, Japan. He is a member of the Institute of Electrical and Electronics Engineers (IEEE), the Institute of Electronics, Information, and Communication Engineers (IEICE), the Japan Society of Applied Physics (JSAP). His current research interests are E O devices and photonic integrated circuits and millimeter wave photonics.

13:55-14:20

[Invited Talk] Microwave Photonic Discrete-frequency Processing

Yitang Dai

Beijing University of Posts and Telecommunications, China

Abstract: With the rapid development of RF technology to high-speed and intelligent direction, there is an urgent need to break through the traditional digital and analog technology facing the "bandwidth bottleneck", to enhance the signal processing capabilities of electronic systems. Here, we propose that the “microwave photonic discrete-frequency processing” is a novel way for broadband analog signals. We summarize the arbitrary amplitude and phase control of RF spectrum with up to MHz resolution, which is called “RF waveshaper”. The unique phase, delay, and dispersion control is demonstrated, as well as applications in rapidly-tunable delay line, real-time Fourier transform, time stretching and reversal. Optical devices used for microwave signal tend to have poor spectral resolution, thus becoming a performance constraint for spectrum processing. We show the “bandwidth scaling” technique would be a feasible way to achieve both broad band and high resolution, as well as the integration.

Biography: Yitang Dai received the B.S. and Ph.D. degrees in electronic engineering from Tsinghua University, Beijing, China, in 2002 and 2006, respectively. From 2007 to 2008, he was engaged in postdoctoral research with the University of Ottawa, Ottawa, ON, Canada. From 2008 to 2010, he was engaged in postdoctoral research with Cornell University, Ithaca, NY, USA. He is currently a Professor with the State Key Laboratory of Information Photonics and Optical Communications, Beijing University of Posts and Telecommunications, Beijing, China. His research interests include microwave photonics signal generation and processing, analog optical computing, and integrated photonics.

14:20-14:35

Multi-channel Sampling Time Delay Measurement and Control for Time-wavelength Interleaved Photonic Analog-to-digital Converters

Xiaohu Tang[1], Yamei Zhang[2*], Lihan Wang[1], Kunlin Shao[1], Ping Li[1], and Shilong Pan[1]

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Abstract: Multi-channel sampling time delay (STD) measurement and control is theoretically and experimentally demonstrated for time-wavelength interleaved photonic analog-to-digital converters. The intermediate frequency (IF) fixed frequency sweeping method is adopted to extract the phase shift of the down-converted IF signal for STD estimation. The experimental results demonstrate that the proposed method exhibits a measurement jitter of below 10 fs and a control accuracy of better than 25 fs within a short period.

14:35-14:50

RF/FSO Mixed Communication System Incorporating Photonic Aggregation for Improved Spectral Efficiency and Suppressed Co-frequency Interference

Haikun Huang[1], Shengkang Zeng[2], Lingzhi Li[2], Yu Huang[2], Jiejun Zhang[2*], and Jianping Yao[3]

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Abstract: A radio frequency (RF)/free-space optical (FSO) mixed communication system incorporating photonic aggregation is proposed and experimentally demonstrated. Four co-frequency binary phase shift keying (BPSK) microwave signals received by four antennas are aggregated to a single polarization 16 quadrature amplitude modulation (16QAM) optical signal, and the optical signal with octuple spectral efficiency is transmitted over a free-space link. On the receiver side, the 16QAM signal from four microwave channels is decoded simultaneously by a single optical coherence receiver. A proof-of-concept experiment is conducted to verify the effectiveness of the proposed technique. An RF/FSO mixed communication system incorporating photonic aggregation supporting wireless communications at a baud rate of 1 G-baud is demonstrated. The error vector amplitude (EVM) is measured to be 5.68%.

14:50-15:05	**Tunable Narrowband Microwave Photonic Filter Using Stimulated Brillouin Scattering by Precisely Controlling the Gain and Loss Spectra**

Renheng Zhang[1], Wenting Wang[2*], Ninghua Zhu[1,3]

[1]Institute of Semiconductors, Chinese Academy of Sciences, [2]Xiongan Institute of Innovation, Chinese Academy of Sciences, [3]Xiongan Institute of Innovation, Chinese Academy of Sciences

Abstract: A novel scheme of narrowband microwave photonic filter based on stimulated Brillouin scattering (SBS) is proposed and experimentally demonstrated. The frequency response of a conventional SBS-based microwave photonic filter depends on the shape of Brillouin gain spectrum. It has a 3 dB bandwidth of about 10 MHz to 30 MHz. In this work, the bandwidth is reduced through a composite SBS process in which two Brillouin loss lines are superimposed upon a central Brillouin gain. By carefully tuning the frequency detuning between the gain and loss pumps and their power ratios, the 3 dB and 20 dB bandwidths are reduced to 5.4 MHz and 14.2 MHz, respectively. The tunability of center frequency is also verified. In addition, the filter has a high out-of-band rejection of 55 dB over a large frequency range due to the vector attributes of SBS amplification.

15:05-15:20	**Reduction of Influence of Phase Modulation for SBS Mitigation on Output Power Enhancement in Photonic-based 10-GHz Generation by Optical Pulse Compression**

Yuma Sakai[*], Keita Ogawa, Masayuki Suzuki, and Hiroyuki Toda

Doshisha University

Abstract: We numerically demonstrate reduction of influence of optical phase modulation for SBS mitigation on output power enhancement in photonic-based 10-GHz generation by optical pulse compression in a standard single-mode fiber (SSMF). Dispersion compensation by a dispersion compensating fiber is effective to cancel the phase modulation of the 10 GHz output caused by dispersion of the SSMF whereas the power enhancement is more than 5 dB.

Poster Session

PS-01	**Phase-tunable Microwave Photonic Mixer Based on Lithium-niobate-on-insulator Chip**

Wenhu Shi[1], Xiaoxiao Yao[1], Jiaqi Shen[1], Shuang Wang[1], Zhilin Ye[2], Jiakang Shi[2], Guoxin Cui[2], Simin Li[1], and Shilong Pan[1*]

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Abstract: We propose and experimentally demonstrate a phase-tunable microwave photonic mixer. The mixer consists of an optically generated local oscillator (LO) and a wavelength-division modulation chip. The chip, which is fabricated on a lithium niobate on insulator (LNOI) substrate, consists of two micro-ring filters, two phase modulators, and two optical couplers. In the experiment, a frequency-doubled optically generated LO at 33.7 GHz is generated by double-sideband suppressed-carrier modulation. The two sidebands are coupled into the chip, and two micro-ring filters select and separate them into two phase modulators (PMs) to achieve wavelength-division modulation. A radio frequency (RF) signal and a direct current bias voltage signal are applied to the two PMs respectively. As a result, a 12 GHz RF signal is successfully converted to a signal with a frequency of 21.7 GHz, and the phase of the converted signal can be tuned from 0° to 360°.

PS-02	**Simultaneous and Diverse Dual-band Microwave Signals Generator based on RF Domain Dual-loop Fourier Domain Mode Locking Optoelectronic Oscillator**

Ziyi Dong[1], Peng Hao[1*], and X. Steve Yao[2]

[1]Hebei University, [2]syao@ieee.org

Abstract: We propose and demonstrate experimentally a simultaneous and diverse dual-band microwave signals generation technique based on RF domain dual-loop Fourier domain mode locking optoelectronic oscillator (FDML-OEO). Two rapidly-tunable bandpass microwave filters (TBF) are parallel in the RF feedback link, and used for mode selection. Adjusting the drive signal of two TBFs, the TBFs are reconfigured and dual-band and dual-format linearly chirped microwave waveforms (LCMWs) can be generated based on the FDML OEO. In addition, the central frequencies of two frequency bands are independently tunable, and the modulation formats of waveforms at two frequency bands can also be diverse, this approach has potential in generating agile broadband multi-format radar waveforms with low phase noise and excellent pulse-to-pulse coherence directly from an OEO. This RF domain dual-loop diode-tuned FDML-OEO can be applied to advanced multi-band radar and wireless communication systems.

PS-03	**A Photonic Frequency Divider using a DO-MZM-based Optoelectronic Oscillator**

Li Yang, Shifeng Liu, Mingzhen Liu, Changlong Du, Xiangqian Xu, and Shilong Pan[*]

National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics and Astronautics

Abstract: A novel photonic frequency divider with a ratio of 1/2 is proposed and successfully demonstrated, utilizing a DO-MZM-based optoelectronic oscillator. The unique feature of this system

lies in the utilization of complemental intensity modulation realized by the dual-output Mach-Zehnder modulator (DO-MZM), which enables effective suppression of common mode noise at the output of a balanced photodetector (BPD) in the optical loop. the differential detection of the BPD, the signal-to-noise ratio of the loop is improved while the frequency-divided signal's noise floor is decrease. In a proof-of-concept experiment, we have achieved successful frequency division ratio of 1/2 on an injection signal ranging from 8 to 26 GHz down to 4 to 13 GHz. Moreover, the proposed frequency divider exhibits superior phase noise characteristics compared to a commercial electrical frequency divider.

PS-04	**Active Mode-locking Optoelectronic Oscillator based on a High-Q Microring Resonator**

Tian Cui[1], Dapeng Liu[2], Zhenzhou Tang[1*], Naidi Cui[2], and Shilong Pan[1*]
[1]National Key Laboratory of Microwave Photonics, [2]Chongqing United Microelectronics Center

Abstract: An active mode-locking optoelectronic oscillator (AML-OEO) utilizing a microring resonator (MRR)-based microwave photonic filter (MPF) is proposed. The active mode locking is achieved by inserting a Mach-Zehnder modulator (MZM) into a conventional OEO loop and varying the frequency of the signal apply to the MZM. Experimental results show that harmonic mode-locking at fundamental, second-order, fifth-order, and tenth-order produces microwave frequency combs (MFCs) with repetition frequencies of 4.4856 MHz, 8.9712 MHz, 22.428 MHz, and 44.856 MHz, respectively. Compared with the free-running OEO, the phase noise of MFCs is the same for different orders, all around -85 dBc/Hz@10 kHz, but the supermode noise rejection ratio is improved.

PS-05	**Coherent Signal Combination Based on a Highly Stable Fiber Transmission System**

Xi Wang, Wei Wei[*], Weilin Xie, and Yi Dong
Beijing Institute of Technology

Abstract: We present an ultra-stable wideband receiving system for distributed coherent signal combination. A 500 Mbps binary phase shift keying signal with a carrier frequency of 10 GHz is transmitted from two remote ends to the local end via two 20 km fiber links for combination. The transmission delay variation of the optical links has been detected and precisely compensated for by adopting a 27.4 GHz probe signal. Thanks to the highly stable transmission link with a stability better than 20 fs, the two signals have a relative delay variation of merely 1.95 ps. The signal-to-noise ratio of the combined signal is increased by 2.9 dB which is close to the theoretical value of 3 dB. The proposed wideband signal receiving and combination system can be widely used in distributed coherent radars and multi-antenna interferometric detection.

PS-06	**Photonic Generation of Arbitrary Waveforms with Tunable Repetition Rate Based on Fractional Temporal Talbot Effect**

Wenjie Lai[1, 2, 3, 4], Bin Wang[1, 2, 3, 4], and Weifeng Zhang[1, 2, 3, 4*]
[1]Beijing Institute of Technology, [2]Key Laboratory of Electronic and Information Technology in Satellite Navigation, [1]Beijing Institute of Technology Chongqing Innovation Center, [4]Chongqing Key Laboratory of Novel Civilian Radar

Abstract: We propose and experimentally demonstrate a photonic approach to generate arbitrary waveforms with a tunable repetition rate based on fractional temporal Talbot effect. With the use of optical real-time Fourier transformation, arbitrary waveform generation is enabled by shaping the

spectral of the optical signal. By specifically designing the dispersion parameter, fractional temporal Talbot effect is caused, which can be leveraged to tune the repetition rate of the waveforms. An experiment is performed, two rectangular waveforms with a repetition rate of 10.28 GHz and 15.42 GHz, and a triangular waveform with a repetition rate of 10.28 GHz are experimentally generated. The proposed approach holds great advantages including simple structure, tunable repetition rate, and low requirement on the input signal.

PS-07	**Optical All-Pass Filter Realized by Optical Interference**

Kaixiang Cao[1], Yu Chen[1], Weijun Jiang[1], Xu Lu[2], Yuan Yu[1, 3*], and Zhang Xinliang[1, 3]
[1]*Wuhan National Laboratory for Optoelectronics,* [2]*China Information and Communication Technologies Group Corporation,* [1]*School of Optical and Electronic Information*

Abstract: Optical all-pass filters (APFs) are key devices to manipulate phase without introducing amplitude degradation. Here, we proposed to achieve an APF by interfering the two output lights from a dual-injection microring resonator (MRR) and a straight waveguide. The APF can be implemented under arbitrary coupling coefficients of the MRR, which relax the design and adjustment of the device. In experiment, the APF achieve a phase change of 1.8π from 5 to 40 GHz with an amplitude variation of only 1.6 dB. A microwave photonic phase shifter based on the APF is also demonstrated.

PS-08	**Silicon-Integrated 8-Channel 6-bit Tunable Optical True-Time Delay Lines with High Switching Speed and Low Loss**

Ziheng Ni[1], Liangjun Lu[1, 2*], Yuanbin Liu[1], Yixuan Wang[1], Jianping Chen[1, 2], and Linjie Zhou[1, 2]
[1]*Shanghai Jiao Tong University,* [2]*SJTU-Pinghu Institute of Intelligent Optoelectronics*

Abstract: Fast reconfiguration time of several nanoseconds is highly required for microwave photonic beamformers such as in 5/6G wireless communication systems. However, most previously reported integrated optical true-time delay lines (OTTDLs) have a response time of tens of microseconds. In this study, we propose and demonstrate silicon-integrated 8- channel 6-bit tunable OTTDLs with fast tuning speed for the first time. All the delay lines are identical with a delay step of 4.93 ps, and a maximum delay of 310.84 ps. With the overall optimized low-loss delay waveguides, 3-dB couplers, and electro-optic optical switches, we realize an OTTDL with an average fiber-to-fiber insertion loss of 11 (7) dB working in the electro-optic (thermo-optic) mode within a wavelength range of 1520-1580 nm. The electro-optic switching speed is 8 ns and 15 ns for the rising and falling time, respectively. By turning on PIN-diode-based variable optical attenuators (VOAs) to suppress leakages, the delay ripple can be suppressed to < 0.45 ps over a broad bandwidth of 20-43.5 GHz.

PS-09	**On-Chip Photonic MMW Joint Communication and Radar System**

Miaomiao Fang[1], Mingzheng Lei[2*], Liang Tian[2], Jiao Zhang[1, 2], Bingchang Hua[2], Yuancheng Cai[2], Xiaodong Wei[1], Jianjun Yu[2], and Min Zhu[1, 2*]
[1]*Southeast University,* [2]*Purple Mountain Laboratories*

Abstract: Silicon photonics chips have enormous development potential in the integration and miniaturization of microwave photonic systems. A photonics-assisted joint communication and radar (JCR) system in the millimeter-wave (mmW) band based on a novel silicon photonics front-end module (FEM) is proposed and demonstrated. The FEM mainly integrates an intensity modulator, a photodetector, a variable optical attenuator, and a 2×2 optical coupler. In the proof-of concept experiment, JCR signals in a time-division multiplexing pattern with different bandwidths centered on the 28 GHz were generated. A 36-Gbit/s communication rate over a 2-m wireless distance was

successfully achieved. Furthermore, a range detection accuracy of less than 12.3 mm for single user and a range resolution of 49.4 mm for two users were observed.

PS-10	**Full W-band Photonic Frequency Hopping Generator Based on High-order Optical Frequency Multiplication**

Yuchao Liu, Fan Yang*, Zhencan Yang, Hao Jiang, Feiliang Chen, Mo Li, and Jian Zhang*
University of Electronic Science and Technology of China

Abstract: Millimeter-wave and terahertz wireless communications is advancing rapidly due to the vast unexplored spectrum resources and the potential to realise terabit links, with major research efforts ramping up around the world. However, the increase in data rates also poses significant challenges to link security such as leakage if eavesdroppers attempt to intercept it, especially in some sensitive areas such as the military and commercial industry. Frequency hopping technology can effectively ensure the confidentiality and jamming resistance of communications, and its performance can be improved as the hopping bandwidth increases. In this paper, we propose a novel millimeter-wave photonics frequency hopping generator based on high-order optical frequency multiplication, with ultrawide hopping bandwidth and versatile operating frequency. A frequency hopping bandwidth of 35 GHz is achieved, covering the entire W-band from 75 GHz to 110 GHz. The proposal will be a viable solution for secure millimeter-wave and terahertz wireless links.

PS-11	**Tunable Broadband Mm-Wave Signal Generation based on Injection Lock of Selected OFC Lines**

Jichen Qiu[1], Bing Wei[1], Xiaobing Xiao[2], Ling Yang[3], and Xiaofeng Jin[1*]
[1]Zhejiang University, [2]Southwest China Institute of Electronic Technology, [3]Zhejiang University

Abstract: A novel photonic-based tunable broadband signal generator for millimeter wave (mm-wave) signals is demonstrated. An optical frequency comb (OFC) is employed for optical injection locking (OIL) of two slave lasers with different wavelengths. Due to the high gain filtering function provided by the OIL, two salve lasers within the locking range can be tuned and locked by the selected comb lines of the OFC. In the experiment, a 25-line flattened OFC is generated by cascading Mach-Zehnder modulators (MZMs) with a mode spacing of 2 GHz. The locking range of two slave lasers is measured to be 1.1 GHz as injection ratio of -40 dB, consistent with the simulation. The spur suppression ratios (SSRs) are measured to be 60 dB in a span of 10 MHz. The RF power flatness of generated broadband tunable mm-wave signal is tested to be within 3.84 dB for frequency 2 GHz to 48 GHz.

PS-12	**Fiber-based Multiple-access Frequency Transfer with Optical Frequency Combs**

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Abstract: We demonstrate fiber-based multiple-access frequency transmission using two optical frequency combs. The optical frequency comb connects the optical and microwave domains. The highly stable microwave frequency was transmitted in a 3km optical-fiber link. The experimental results show that with the phase compensation technique, the frequency instabilities at the remote site are 8.7×10^{-15} and 1.0×10^{-17} for averaging times of 1 s and 10^3 s. At the accessing node along the fiber link, frequency instabilities are 6.9×10^{-15} and 1.1×10^{-17} for averaging times of 1 s and 10^3 s. Compared to the uncompensated transmission, frequency instabilities are reduced by two orders

of magnitude for both the remote site and the accessing node. Thus, the proposed frequency transmission technique has potential application for disseminating ultra-stable frequency references to multiple precision devices.

PS-13	**Broadband Terahertz Equivalent-time Sampling System Based on A Photoconductive Antenna**

Hongqi Zhang[1, 2], Zuomin Yang[1, 2], Zhidong Lyu[1, 2], Hang Yang[1, 2], Lu Zhang[1, 2], Xiaodan Pang[3], Oskars Ozolins[3], Xianmin Zhang[1], and Xianbin Yu[2*]

[1]Zhejiang University, [2]Zhejiang lab, [3]KTH Royal Institute of Technology

Abstract: In recent years, remarkable achievements have been witnessed in developing terahertz (THz) communication systems with high data rates. However, the analyzers/receivers of most THz communication systems still heavily rely on electronic circuits with limited bandwidth, obstructing the further exploration of THz resource. In this work, an equivalent-time sampling (ETS) system based on a conventional photoconductive antenna (PCA) is proposed for capturing high-speed THz signals. The PCA is excited by ultrashort optical pulses from a low repetition-rate mode-locked laser (MLL) and hence alternates the sampling of highspeed THz signals into low-frequency domain. The proposed ETS system for THz signals is theoretically analyzed and experimentally demonstrated. In the proof-of-concept experiment, an on-off keying (OOK) signal with a baud rate of 15 Gbaud are successfully sampled and evaluated. The proposed THz ETS system can be easily accessible by low-speed electronics, which is expected to bring new opportunities for high-speed THz time-domain analyzer.

PS-14	**Flexible Graphene-based Antenna for Generating Electromagnetic Waves Carrying Orbital Angular Momentum**

Zuxian He[1, 2], Shoudong Gu[3, 4], Tuz Vladimir[3, 4], Xiaolong Wang[5, 6], and Fesenko Volodymyr[7]

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Abstract: Recently, flexible antennas have attracted great interest due to the variety of areas of their practical use. Here we propose a design of a flexible antenna for generating electromagnetic waves carrying orbital angular momentum (OAM). The ANSYS HFSS electromagnetic solver is used for fullwave numerical simulations targeted to obtain suitable antenna parameters. A prototype of the graphene-based antenna for operating in the microwave range is manufactured and tested. The obtained experimental results confirm the possibility of the proposed antenna with a curved surface to stably generate waves carrying OAM.

PS-15	**Dual-output Microwave Photonic Frequency Up-converter Based on A Dual-polarization Dual-parallel Mach-Zehnder Modulator**

Jianxin Ma*

Beijing University of Posts and Telecommunications

Abstract: A dual-output microwave photonic frequency upconverter with optically frequency-doubled local oscillator based on a dual-polarization dual-parallel Mach-Zehnder modulator is proposed.

Simulation and experimental results show that the proposed structure can simultaneously up-convert the IF signal to X-band and Ku-band, with a fixed 6 GHz LO signal, and the undesired signal suppression ratio is about 19 dB in X-band and in Ku-band.

PS-16	**A Compact Photonic Radar Based on Single Polarization Multiplexing Modulator**

Qingshui Guo[1, 2*], Kun Yin[2], and Chen Ji[1, 2]

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Abstract: A compact double frequency photonic radar with coherent receiving based a polarization multiplexing Mach-Zehnder modulator (PM-MZM) is proposed. In which, one PM-MZM can perform seed signal loading and broadband echoes receiving, simultaneously. By balanced in-phase/quadrature detection of the polarization de-multiplexing signal from PM-MZM with single sideband filtered out, the complex de-chirped signal can be obtained. The K-band photonic radar with targets detection and inverse synthetic aperture radar imaging is experimentally demonstrated with a resolution better than 2.0 cm in range.

PS-17	**Silicon-Based Integrated True-Time Delay Line with Adjustable Large Delays**

Shuyue Zhang[1], Qiang Zhang[2*], and Hui Yu[2*]

[1]Zhejiang University, [2]Zhejiang Lab

Abstract: In this work, we design, manufacture and package a large delay adjustable silicon-based true-time delay line chip. Specifically, we focused on evaluating the performance of a single switch within the chip. Meanwhile, in order to ensure efficient and accurate measurement of the switching state voltage while mitigating the impact of state voltage drift, we devise a semi-automatic scanning program, which facilitates the precise acquisition of the switching state voltage over an extended period. The chip showcases impressive features, including a substantial delay step of 20 ps and a maximum delay time of 2.54 ns. Moreover, it exhibits commendable signal transmission capabilities, with a clear and observable eye diagram shape at 30Gbps under a 2^{51}-1 pseudo-random bit sequence (PRBS) signal. Furthermore, we find that the power penalty difference between the longest and shortest signal paths is minimal, measuring only 0.1686 dB.

PS-18	**Integrated Terahertz Beamforming System Based on Micromachined Silicon Interposer**

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Abstract: Terahertz communication is approaching the center of the stage in such a date-rate-demanding era. However, there are still several issues to be solved including integration and beam steering before bridging the gap between the generated THz wave and its practical usage. In this paper, three silicon-micromachined THz modules associated with THz wave radiation and transmission and their simulation results are presented. The 4×1 phased array achieves a realized gain of 10.2 dBi and a beam steering range of ± 22°. The CPW-to-hollow waveguide transition structure exhibits a bandwidth of about 50 GHz at -10 dB level and a return loss lower than -45 dB at working frequency. The proposed micromachined silicon platform reveals great scalability and

potentials in integrated THz systems.

PS-19 Narrowband Microwave Photonic Filter with Adjustable Bandwidth and High Peak Rejection

Li Liu*

School of Automation, China University of Geosciences

Abstract: A narrowband notch microwave photonic filter (MPF) with adjustable bandwidth and ultra-high rejection ratio is proposed and experimentally demonstrated leveraging a Mach–Zehnder interferometer (MZI) coupled Si3N4 ring resonator. The ring is designed with two interferometric coupling waveguides so as to tune the effective coupling coefficients between the bending waveguides and the resonator. Consequently, the bandwidth and the extinction ratio of the resonator could be adjusted. Leveraging the MZI-coupled Si3N4 ring, the experimental results illustrate that the 3dB-bandwidth of the notch microwave filters can be adjusted from 87 MHz to 1.12 GHz. Furthermore, during the bandwidth tuning process, the rejection ratios of the notch MPFs could obtain high values by utilizing the interference cancellation. To our knowledge, with maintaining ultra-high rejections beyond 60 dB, the 3dBbandwidth of the Si3N4-based notch MPFs is firstly verified with an adjustable range from tens of MHz to GHz level. The proposed narrowband MPF schemes with superior bandwidth tunability and ultra-high rejection ratios have various important applications in integrated radio frequency systems.

PS-20 Multi-antenna Photonic Frequency-Spatial Compressed Sensing Array for Joint Frequency and DOA Estimation

Tieliang Zhang[1], Yang Li[1*], Bo Yang[2], Wei Pan[1], Lianshan Yan[1], Hao Chi[2], and Xihua Zou[1]

[1]Southwest Jiaotong University, [2]Hangzhou Dianzi University

Abstract: A photonics-assisted compressive sensing (CS) array system based on uniform linear array (ULA) for wideband sparse radio frequency (RF) signals acquisition and direction of arrival (DOA) estimation is proposed. Each branch of the system consists of two cascaded Mach-Zehnder modulators (MZMs), an integrator, and a low-rate analog-todigital converter (ADC). The modulated pseudo-random binary sequence (PRBS) is the same across each coherent branch, so that the simultaneous orthogonal matching pursuit (SOMP) algorithm and the orthogonal matching pursuit (OMP) algorithms are sued to estimate the frequency and DOA. The introduction of multiple coherent branches not only enable the estimation of DOA but also improve the accuracy of the frequency recovery. The frequency estimation accuracy of multi-tone signals reaches 0.01 GHz, and the angle estimation accuracy reaches 1° at the signal noise ratio (SNR) of 10 Db in the simulations and experiments, which demonstrate the feasibility of the proposed method in joint frequency and DOA estimation.

PS-21 FPGA-based DBSCAN Clustering Nonlinear Equalizer Accelerator for MMW Radio-over-Fiber System

Wu Xu*, Peixuan Li*, Xihua Zou, Ningyuan Zhong, Wei Pan, and Lianshan Yan

School of Information Science & Technology, Southwest Jiaotong University, Chengdu, China

Abstract: Clustering algorithms have been widely applied in wireless/optical communication systems for nonlinear equalizations. However, for high-speed communication systems with enormous data volumes, the excessive computational time for clustering large numbers of data points greatly impede their practical applications. This work focuses on the acceleration of the state-of-art density-based spatial clustering of applications with noise (DBSCAN) algorithm using the field-programmable gate array (FPGA) platform. To this end, a novel parallel DBSCAN algorithm as well as its FPGA hardware architecture are proposed here. Also, its applications in a 60-GHz millimeter-wave radio over fiber (MMW-RoF) communication system for nonlinear equalizations are experimentally investigated. Validated by experiments, our DBSCAN accelerator can effectively improve the nonlinearity tolerance of the 60-GHz MMW-RoF system transmitting the single-carrier 64-QAM signal. More importantly, harnessing the Xilinx Ultrascale+ ZCU111 board, our proposal can achieve up to 7.2x speedup over the software implementation of the traditional sequential-DBSCAN (S-DBSCAN) on the AMD Ryzen7 5800H CPU, and 19.2x speedup than the FPGA implementation of the S-DBSCAN algorithm.

PS-22 On-chip Nanoseconds Tunable Microwave Photonic Narrow Bandpass Filter over a Wide Frequency Range

Yushu Jiang[1, 2, 3, 4], Yaming Liu[1, 2, 3, 4], Bin Wang[1, 2, 3, 4*], and Weifeng Zhang[1, 2, 3, 4]

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Abstract: We propose and demonstrate an on-chip nanoseconds tunable microwave photonic narrow bandpass filter over a wide frequency range using a high-Q racetrack micro-ring resonator (MRR). In the proposed filter based on phase modulation to intensity modulation (PM-IM) conversion, the racetrack MRR is the key component, in which multimode waveguides are employed to have a low-loss optical propagation for a high Q-factor. To enable ultrafast and wide tunability of the MRR, a lateral PN junction and a top-placed metallic micro-heater are incorporated. The PN junction is leveraged to realize the ultra-fast tuning speed, and the metallic micro-heater ensures a wide frequency tuning range. A silicon-based high-Q racetrack MRR chip is designed, fabricated, and evaluated. By incorporating the chip in a microwave photonic filter system, a filter with a narrow passband of 1.2 GHz, an ultrahigh tuning speed of less than 50 ns, and an ultrawide tuning range from 3 to 51 GHz is experimentally demonstrated, which is promising to be widely used in high-resolution radar systems and high-speed wireless communication systems.

PS-23 On-line Electro-optic Cross-correlation for Ultra-wideband Wireless Channel Sounding based on Dual Optical Frequency Comb

Jiarong Zhang[1], Chunlong Yu[1], Yihan Li[1, 2], Xin Zhao[1], and Zheng Zheng[1]

[1]School of Electronic and Information Engineering, Beihang University, [2]Shenzhen Institute of Beihang University

Abstract: In this work, an electro-optic cross-correlation scheme based on dual optical frequency comb is proposed to perform on-line pulse compression for photonic-assisted ultra-wideband (UWB) channel sounding. The proof-of-concept demonstration presents the compression of a 2-ns linear frequency modulated signal spanning 3 octaves (2 -12 GHz) to its bandwidth-limited form without off-line correlation computation. Such system significantly reduces the complexity of the digital signal processing in photonic UWB channel characterization, showcasing potentials in the application of the next generation of wireless communication where latency requirement is stringent.

PS-24 Single-soliton Microcombs Generation via Inter-mode Thermal Compensation in Si3N4 Microresonator

Mingyang Guo, Hui Liu, Junyi Yuan, Tian Zhang, Jian Dai[*], and Kun Xu

Beijing University of Posts and Telecommunications

Abstract: Soliton mode-locking in microresonator enables the generation of chip-scale coherent optical frequency combs, which has facilitated the applications of precision metrology and spectroscopy. In this work, with the assistance of inter-mode thermal compensation, we experimentally demonstrate the robust generation of the refined single solitons with solitons steps spanning more than 12GHz in a dual-mode coupled Si3N4 microresonator. This technique will pave the way for straightforward and robust generation of dissipative Kerr solitons microcombs for integrated photonics systems.

PS-25	**Tunable Single-Passband Microwave Photonic Filter with Enhanced Fineness**

Zhigang Tang, Pei Zhou*, and Nianqiang Li

Soochow University

Abstract: A tunable single-passband microwave photonic filter (MPF) with enhanced fineness is presented and demonstrated. The high-Q single-passband MPF is realized by cascading an optically injected semiconductor laser structure and an optoelectronic feedback resonator. In the proof-of-concept experiment, the center frequency of the MPF is tuned from 10 to 18 GHz by adjusting the optical injection parameters, and the 3-dB bandwidth is kept below 4.97 MHz. The proposed MPF offers tunability and high selectivity, and has potential applications in microwave communication systems and radar systems.

PS-26	**Simultaneous Image-reject Downconversion and Self-interference Cancellation for Full-duplex Communication**

Weiheng Wang[1], Shuanglin Fu[1], Jiayao Wang[1], Chao Wang[2], Mingshan Zhao[1], and Xiuyou Han[1*]

[1]*Dalian University of Technology,* [2]*University of Kent*

Abstract: A photonics-assisted simultaneous image-reject downconversion and self-interference cancellation for full-duplex communication is proposed. The image rejection is realized by optical sideband filtering and phase control. The intermediate frequency (IF) signal to be transmitted is used as the reference signal and combined with the received signal after image rejection in IF domain to cancel the self-interference caused by the strong transmitted signal. A proof-of-concept experiment is carried out. The experiment results show that an image rejection ratio of 30.5 dB and self-interference cancellation depth of 31.5 dB with 50 MHz bandwidth are realized. The weak signal of interest with 16-QAM modulation is well recovered after the cancellation of the strong interference.

PS-27	**Highly Sensitive Fiber Optic Sensing System Based on Two Fiber Bragg Gratings and Microwave Photonic Filter for Temperature Measurement**

Tongtong Xie[1], Yi Zhuang[2], Shichen Zheng[3], Yudong Wang[1], Mengyuan Wu[1], and Hongyan Fu[1*]

[1]*Department of Electronic Engineering, School of Electronic Science and Engineering (National Model Microelectronics College), Xiamen University,* [2]*Department of Electronic Engineering, School of Electronic Science and Engineering (National Model Microelectronics College) Xiamen University,* [3]*Department of Electronic Engineering, School of Electronic Science and Engineering (National Model Microelectronics College), Xiamen University Xiamen, China*

Abstract: We propose and experimentally demonstrate a highly sensitive fiber optic sensing system based on two fiber Bragg gratings (FBGs) and microwave photonic filter (MPF) for temperature measurement. The reflection intensity of the two FBGs is determined by their wavelength location at

the optical spectrum of the fiber optic interferometer sensor. The reflected light of the two FBGs are used as the two taps of the MPF, and the change of the FBGs' intensity caused by the temperature variations on the fiber optic interferometer sensor can be mapped to the change of the MPF's intensity. In our experiment, we have used the Sagnac interferometer (SI) as the temperature sensing element for a demonstration. The temperature applied to the SI can be demodulated by detecting the intensity of the MPF. The experimental results show that by detecting the intensity one of the peaks of the MPF, the sensitivity of 23.22 dB/°C, 13.71 dB/°C, 8.95 dB/°C can be achieved when the two FBG's wavelength interval is 0.5 nm, 1nm, and 1.5nm, respectively.

PS-28 Stable Frequency Unrepeatered Transmission Using Distributed Raman Amplifier Over 200 km Fiber Link

Baodong Zhao, Hao Gao, Jiahui Cheng, Jie Zhang, Song Yu, and Bin Luo*

Beijing University of Posts and Telecommunications

Abstract: We demonstrate stable frequency transmission over a 200 km repeaterless fiber link. Raman amplifiers are placed at the transmitter and the receiver to offset optical fiber attenuation. The frequency stability of the transmission system is 3.1×10^{-14}@1s, 1.8×10^{-17}@10000s.

PS-29 On-Chip Double-Fano-Enabled Reconfigurable Optical Notch Filter for Microwave Signal Processing

Xu Hong[1, 2, 3, 4], Bin Wang[1, 2, 3, 4], and Weifeng Zhang[1, 2, 3, 4*]

[1]Beijing Institute of Technology, [2]Key Laboratory of Electronic and Information Technology in Satellite Navigation, [3]Beijing Institute of Technology Chongqing Innovation Center, [4]Chongqing Key Laboratory of Novel Civilian Radar

Abstract: We propose and demonstrate a fully reconfigurable optical notch filter enabled by on-chip double-Fano resonance. The double-Fano resonance is realized by interfering two independent Fano resonances, of which each one is produced using an add-drop micro-disk resonator and a Mach-Zehnder interferometer. Metal micro-heaters are placed on top of the waveguide to tune each Fano resonance including the resonance wavelength and line shape. When the resonance wavelengths of the two Fano resonances are close to each other and their line shapes have a mirror image, a symmetrical optical notch filter is resulted from the interference of the two asymmetrical Fano resonances. By controlling micro-heaters, the bandwidth, extinction ratio (ER), and center wavelength of the resulted notch filter can be fully tuned. A chip is designed, fabricated, and characterized. The results show that the notch filter has a tunable bandwidth from 46 to 76 pm, a tunable ER from 0 to 30 dB, and a tunable center wavelength from 1544 to 1547 nm, which holds great potential for microwave signal photonic processing.

PS-30 Ultra-Narrow Pulse Shaping Based on Integrated Chirped Grating-Assisted Contradirectional Couplers

Hualin Pu, Jia Ye*, Zongxin Gan, Xiaojun Xie, Xihua Zou, and Lianshan Yan

Southwest Jiaotong University

Abstract: The on-chip pulse shaper is a key device that enables ultra-high-speed, ultra-wideband linear signal processing in a compact size with low power consumption. We propose a pulsed time-domain waveform shaping method based on chirped period Bragg gratings and contradirectional couplers, allowing flexible control of the grating's period to achieve frequency-specific reflections and reflection strengths. We demonstrate two types of time-domain sawtooth waveform generation and

analyze the relationship between the time-domain waveforms and the linear chirp period. Compared to other waveform generation schemes based on Fourier synthesis or time-domain synthesis, our method achieves direct time-domain pulse shaping through grating period design. The proposed method achieves sawtooth pulse generation with a pulse width of 6.1 ps.

PS-31 Multi-Band Linearly Frequency-Modulated Waveform Generation Based on Optical Heterodyne Detection

Zhiqiang Fan*, Xiang Li, Jun Su, Yunxiang Wang, Shuangjin Shi, and Qi Qiu*

University of Electronic Science and Technology of China

Abstract: A photonic-assisted tunable multi-band linearity frequency-modulated (LFM) waveform generator based on optical heterodyne detection is proposed and experimentally demonstrated. The multi-band LFM waveform is generated from a photodetector (PD), where a broadband LFM optical pulse and a multi-wavelength optical signal having the same magnitude at different wavelengths are heterodyne-detected. Experimental results show that a tunable multi-band LFM waveform generator is achieved. The bandwidth and temporal duration of each band and the center frequencies difference between different frequency bands have tuning ranges from 1 to 6.7 GHz, 1 to 10 μs, and 2 to 6.7 GHz, respectively. The demonstration shows new avenues to implement high-performance multi-band LFM waveform generators for multi-functional modern radar systems applications.

PS-32 A Simple Method for Generating Wideband Dual-chirp Microwave Waveforms Based on Monolithic Integrated Laser

Shilin Chen[1*], Tao Pu[1*], Li Wang[2], Jilin Zheng[1], Gengze Wu[1], Jin Li[1], Xin Zhang[3], and Jiaqi Zhao[1]

[1]*Army Engineering University of PLA,* [2]*Nanjing University of Science and Technology ZiJin College,* [3]*National University of Defense Technology*

Abstract: A method of generating broadband dual-linear frequency modulation signal microwave waveforms (DCMWs) based on monolithic integrated laser is proposed and verified by simulation. In this scheme, under the appropriate bias current, the integrated mutual injection semiconductor laser enters the P1 state, and then the linear frequency modulation signal is directly modulated to the front-end laser. In the simulation experiment demonstration, three kinds of DCMWs in the frequency range of 5~9 GHz are obtained, and the time bandwidth product (TBWP) reaches 800. The full width at half maximum (FWHM) of the three kinds of DCMWs are all less than 0.34 ns, and the peak sidelobe ratio (PSR) is higher than 15.1 dB. The scheme has the advantages of high integration, simple structure and easy regulation.

PS-33 Photonics-Assisted Adaptive Analog Wideband Self-Interference Cancellation Based on Digital Pre-modeling Search and Two-Tap Delay Adjustment

Taixia Shi, and Yang Chen*

East China Normal University

Abstract: A photonics-assisted adaptive analog wideband self-interference cancellation (SIC) approach for in-band full-duplex (IBFD) systems is proposed based on a digital-assisted delay and amplitude pre-modeling search method, as well as a two-tap delay adjustment method. By jointly using the premodeling search method, our previously reported segmented search method, and the two-tap delay adjustment method, the delay search and adjustment accuracy can be greatly improved without upsampling, while the search results can be obtained in one iteration only using an 8-μs search signal. An experiment is performed. By using the proposed approach, an analog cancellation depth of 23 dB can be achieved when the center frequency and baud rate of the self-interference are 1 GHz and 1 GBaud.

PS-34 Moving Target Trajectory Tracking Based on High-resolution Microwave Photonics Radar

Hongchen Chen, Tian Chai, Qingshui Guo*, and Kun Yin

Zhejiang Laboratory

Abstract: A moving target trajectory tracking system based on a real-time high-resolution coherent microwave photonics radar is experimentally demonstrated. In which, combining with the Doppler characteristics of moving target, the coherent radar system in K-band realizes a high-resolution moving target trajectory tracking functionality with stationary interferences suppressed, and the range resolution is better than 2.0 cm.

PS-35 Photonic Microwave Distribution with Femtosecond Lasers

Anan Dai[1*], Kemal Şafak[1], Andrej Berlin[2], and Kaertner Franz X.[3, 4]

[1]Cycle GmbH, [2]Cyce GmbH, [3]Center for Free-Electron Laser Science (CFEL), [4]Deutsches Elektronen-Synchrotron (DESY)

Abstract: Microwave distribution systems are critical for achieving the required resolution and performance in large-scale scientific facilities such as astronomical telescopes and X-ray free-electron lasers. In this paper, we present a photonic microwave distribution system based on femtosecond lasers and pulsed optical fiber transmission stabilization. Our experimental results show an additive timing jitter of only 10.62 fs RMS at a 5.712 GHz carrier integrated from 1 Hz to 1 MHz. The extracted 5.712 GHz microwave exhibits an ultra-low timing drift of only 13.3 fs RMS over 10 hours.

PS-36 Direct Modulation Bandwidth Enhancement in Two-section DFB Lasers with Phase-shifted Grating Reflector Based on the Detuned-Loading Effect

Hongming Gu, Yifan Xu, Yanting Guo, Guolong Ma, and Yunshan Zhang*

Nanjing University of Posts and Telecommunications

Abstract: A novel high-speed directly modulated two-section distributed feedback (TS-DFB) semiconductor laser based on the detuned-loading effect is proposed and investigated. The grating structure is designed by reconstruction-equivalent-chirp (REC) technique. A π phase-shift is introduced into the reflection grating, which can provide a narrow-band reflection region with a sharp falling slope on both sides of the reflection spectrum, thus enhancing the detuned-loading effect. In addition, the detuned-loading effect can be used twice when tuning the lasing wavelengths. The modulation bandwidth is increased from 17.5 GHz for a single DFB laser to around 24 GHz when the lasing wavelength is located on the left falling edge of the TS-DFB laser based on detuned-loading effect, and can be increased to 22 GHz for the right side.

PS-37 Density Operator Description for Superconducting Traveling-Wave Parametric Amplifiers

Christian Jirauschek, Özüm Asirim, Michael Haider, and Yongjie Yuan*

Technical University of Munich

Abstract: In this paper, we present a density operator de-scription for a dissipative-dispersive Josephson traveling-wave parametric amplifier. A quantum master equation has been derived for the description of dissipation and thermal fluctuations that arise from lossy dielectric substrates. The formalism is especially effective in the dispersive case. Based on the equation of motion of the system density operator, we investigate the amplification performance by predicting the signal gain and the total photon number, considering amplifier phase-mismatch present in real devices. In addition to the gain investigation, we perform a two-mode squeezing analysis for such structures.

PS-38 **Frequency-to-Space Mapping Based Instantaneous Frequency Measurement System with Improved Accuracy and Resolution**

Chongjia Huang[1], Erwin H. W. Chan[2*], and Peng Hao[1]
[1]*Photonics Information Innovation Center and Hebei Provincial Center for Optical Sensing Innovations, College of Physics Science & Technology, Hebei University,* [2]*Charles Darwin University*

Abstract: A frequency measurement system implemented using the frequency-to-space mapping technique is presented. It overcomes the drawbacks of limited measurement accuracy and resolution in the reported frequency-to-space mapping based frequency measurement systems. The system is capable to determine the frequencies of multiple different-frequency microwave signals over a wide frequency range with a fast response time and little errors. Experimental results are presented that demonstrate the concept of the proposed instantaneous frequency measurement system.

PS-39 **Interference-Resistant Photonically Generated Orthogonal Pair Multi-Chirp-LFM Waveform**

Hum Nath Parajuli[1*], Bikash Nakarmi[2], Ikechi Augustine Ukaegbu[1], and Aigerim Ashimbayeva[1]
[1]*Nazarbayev University,* [2]*Key Laboratory of Radar Imaging and Microwave Photonics Nanjing University of Aero. and Astro. Nanjing, China*

Abstract: We propose and demonstrate a photonically generated orthogonal up-down-chirp pair based multi-chirp linear frequency modulation (Ph-O-MLFM) radar waveform that offers inherent interference-resistant capability in detecting target objects in a multi-radar environment. As a proof-of-concept demonstration, in a simulation setup, we generate 4GHz, 1μs, Ph-O-MLFM and commonly used photonics-based LFM (Ph-LFM) signals using a dual-drive Mach-Zehnder modulator (DDMZM) incorporating photonics-based bandwidth synthesis. To evaluate the performance, we compare the effects of varying chirp rate and time period LFM interference signals on object detection with Ph-LFM and the proposed Ph-O-MLFM waveforms by analyzing the range profile obtained from the matched filtering method. The results demonstrate that the Ph-O-MLFM waveform mitigates LFM interferences with a peak-to-sidelobe power level of >11dB, and a range resolution of 4cm, whereas the Ph-LFM waveform is susceptible to coherent LFM interference. These results highlight the potential utilization of the proposed Ph-O-MLFM waveform in multi-radar environments.

PS-40 **High Efficiency and Compact Spot Size Converter for LNOI Integrated Device**

Yuxuan Cheng[1, 2], Jingjing Hu[1, 3], Lijie Zhang[1, 2], and Yiying Gu[1, 2*]
[1]*Key Laboratory of Advanced Optoelectronic Technology, Liaoning Province,* [2]*School of Optoelectronic Engineering and Instrumentation Science, Dalian University of Technology,* [3]*School of Physics, Dalian University of Technology*

Abstract: In this paper, we present a new design of spot size converter (SSC) for coupling between UHNA (Ultra-High Numerical Aperture) fiber and lithium niobate on insulator (LNOI) photonic wire waveguide. We demonstrate a novel structure in a cross-like arrangement composed by a central LN waveguide and four LN waveguides outside around. The crosslike structure collects the fiber spot

power with high power overlap efficiency and transmits with low loss, which converts the large-scale spot to a small size one. The SSC is designed using Bidirectional Eigenmode Expansion solver (EME solver) of MODE Solutions. It is very compact with a total length as short as 35 μm. The simulation result shows that the power overlap efficiency at the fiber-to-chip facet of proposed device can reach 93.8% (92.7%) and coupling loss is 1.85 dB (1.20 dB) for the TE (TM) mode at 1550 nm.

PS-41 Numerical Simulation of Thermorefractive Noise in Optical Microresonators

Yifan Wu, Jijun He*, Shilong Pan*

National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics and Astronautics

Abstract: We investigated the characteristics of a fundamental noise, i.e., thermorefractive noise (TRN), in optical microresonator using numerical simulations and performed a comparative analysis of the TRN in four prevalent integrated platforms. Our findings provide valuable insights for reducing the detrimental impact of thermorefractive fluctuations and can potentially improve the frequency stability of optical resonators.

Oral Session 3: Devices and Subsystems

Session chair: Yitang Dai

08:00-08:25

[Invited Talk] Millimetre Resolution Photonic Radar for UAV and Vital Sign Detection

Ziqian Zhang

University of Sydney, Australia

Abstract: Microwave photonics-enabled radar technology is gaining momentum due to its numerous advantages over conventional electronic approaches. Photonics technology's broad bandwidth and low-loss characteristics have led to a growing interest in generating, manipulating, and distributing microwave or RF signals to enhance radar sensing performance, offering improved sensing range resolution and precision to fulfil the needs of various application scenarios.

In this talk, we present a photonic stepped-frequency radar system enabled by a frequency-shifting loop. This addition to the photonic radar family exhibits promising features. The system architecture is uncomplicated, necessitating only MHz-level driving electronics, yet it boasts a bandwidth capacity exceeding 30 GHz, with signal quality on par with the state-of-the-art electronic signal generators. We employed this system to image a drone's propeller and to extract the vital signs from a living animal — a cane toad which serves as a proxy for a human, demonstrating the system's efficacy in real-world scenarios. We further showcase the system's capability to support radar and LiDAR sensing, underscoring its flexibility and potential for hybrid detection and sensor fusion, leading to more consistent and precise sensing outcomes. This photonic approach offers a new path toward high-resolution, rapid-response, and cost-effective hybrid radar-LiDAR modules with reduced system complexity for a wide range of practical applications.

Biography: Ziqian Zhang received the bachelor's degree in underwater acoustic engineering from Harbin Engineering University, Harbin, China, in 2015, the master's degree (MPhil) in telecommunication engineering in 2018 and the Ph.D. in degree in physics from the University of Sydney, Sydney, NSW, Australia in 2023. He is now a Postdoctoral Research Associate in the Eggleton Research Group at the University of Sydney. He received the Research Training Program (RTP) Scholarship from the Australian Government and the Postgraduate Research Scholarship in Microwave Photonic from the University of Sydney. He acquired one international patent and five invited talks, two of which were at the Conference on Lasers and Electro-Optics (CLEO). He was shortlisted as one of the top three for the Maiman Outstanding Student Paper Competition in the 2023 CLEO. His research focuses on microwave photonics, non-linear optics, photonic radar, LiDAR, and photonic integration.

08:25-08:40	Wideband Microwave Photonic Beamformer Based on a Spiral Bragg Grating Waveguide

Fengyuan Liu[1], Rongan Wu[1], Zhenmin Du[2], Hongwei Chen[2*], Zhenzhou Tang[1*], and Shilong Pan[1*]
[1]National Key Laboratory of Microwave Photonics, [2]Department of Electronic Engineering, Tsinghua University

Abstract: A microwave photonic wideband beamforming system based on an integrated spiral Bragg grating waveguide (SBGW) is presented for the first time. The SBGW used in this system has a total group delay of 1400 ps and a dispersion coefficient of -139.3 ps/nm within 10-nm operational bandwidth. By incorporating a multi-wavelength laser source, a 4-element wideband beamforming experiment is demonstrated. The far-field patterns have been measured and the results show that the beam-pointing angle remains consistent within a frequency range of 2 to 10 GHz. Our work validates the SBGW as a crucial component, enabling a low-cost and wideband beamforming system. Moreover, the proposed beamforming system has a continuous beam-steering capability and can be easily extended to multi-beam systems, which may find applications in photonics-based radar and communication systems.

08:40-08:55	Photonic RF Channelization Based on Electro-optic Ring Modulator

Zhengyi Wan[1], Qizhuang Cen[2], Yuedi Ding[3], Jinsong Xia[3], Kun Xu[1], Ming Li[2], and Yitang Dai[1*]
[1]Beijing University of Posts and Telecommunications, [2]Institute of Semiconductors, Chinese Academy of Sciences, [3]Huazhong University of Science and Technology

Abstract: A novel microwave photonic channelization scheme for a broadband radio frequency (RF) signal based on an electro-optic ring modulator is proposed and demonstrated. Due to the modulation and filtering functions of the ring resonator, the proposed microwave photonic channelizer can simplify the general traveling-wave modulator and optical filter into a single ring. In the proposed scheme, the input RF signal is multicast by an optical frequency comb (OFC), spectrally sliced by the ring resonator, and then channelized by an optical wavelength-division multiplexer (WDM). An 8-channel channelizer centered at 21~28 GHz with a 1 GHz step is achieved by numerical simulation and experiment.

08:55-09:10	A Frequency Modulated Continuous Wave LiDAR System Based on Reservoir Computing

Tianxiang Luan[1], Ruibo Zhang[2], Yue Yuanli[1], Shouju Liu[1], Ailing Zhang[2], and Chao Wang[1*]
[1]University of Kent, [2]Tianjin University of Technology

Abstract: A frequency modulated continuous wave (FMCW) light detection and ranging (LiDAR) system based on reservoir computing (RC) is proposed and its reliability is verified through simulations and experiments. Fundamentally different from previous approaches where Fourier analysis is always required to determine distance information, here temporal signal analysis using RC is adopted. The system is robust to nonlinearity in frequency modulation of optical carrier, hence improving the range detection resolution. An intensity-modulated light is injected into a semiconductor laser to deliberately generate a non-ideal nonlinear wavelength scanning light source. The change in distance corresponds to the change in the IF signal over time. The RC classifies the IF signal waveform in the time domain to eliminate the need for linearization, and determines the distance from the classification results. The distance measurement resolution of this method is 1 cm in the 6.1 GHz scanning range, which shows that the method effectively addresses the effect of source nonlinearity due to the scanning wavelength

while reducing computational complexity. The method has been demonstrated to reduce calculation cost.

09:10-09:25	**Dual-wavelength-modulation mm-wave System based on Single-Sideband Signals**

Luis Gonzalez-Guerrero[1*], Amol Delmade[2], Devika Dass[2], Colm Browning[2], Liam Barry[2], Frank Smyth[3], Horacio Lamela[1], and Guillermo Carpintero[1]

[1]Universidad Carlos III de Madrid, [2]Dublin City University, [3]Pilot Photonics

Abstract: Due to their simplicity, dual-wavelength-modulation (dual-λ-mod) photonic transmitters are an attractive alternative to conventional heterodyne systems for mm-wave/THz signal generation. In contrast to what has been reported in the literature, the authors of this manuscript believe that dual-λ-mod systems based on DSB-C modulation are subjected to power fading, rendering them useless for high-speed mm-wave/THz communications. To solve this, we propose a dual-λ-mod system based on SSB-C modulation. Using a GS laser, a 60-GHz SSBC dual-λ-mod system transmitting 2.5-GBd 16-QAM signals is demonstrated. A PD-input-power penalty of just 2.8 dB is measured with respect to the conventional heterodyne transmitter at a BER of 10−3 for optical B2B and 10 km fiber transmission.

09:25-09:40	**Optimal Coupling for the Reduction of bimodality in 850nm-VCSEL-Based Radio-over-G.652-Fiber**

Nanni Jacopo[1*], Saderi Giada[1], Bellanca Gaetano[2], Bosi Gianni[2], Raffo Antonio[2], Vadalà Valeria[3], Debernardi Pierluigi[4], Polleux Jean-Luc[5], Billabert Anne-Laure[6], Esfahani Maryam Nasr[1], and Tartarini Giovanni[1]

*[1]DEI - University of Bologna, [2]Department of Engineering-University of Ferrara, [3]Department of Physics-University Milano-Bicocca, [4]IEIIT-CNR, [5]ICON Photonics, [6]LeCNAM-ESYCOM-CN*RS

Abstract: A promising reduction of costs, consumption and environmental impact for infrastructures exploiting Radio-over-Fiber systems can be given by the use of Vertical Cavity Surface Emitting Lasers operating in the first optical transmission window (i.e., 850nm) and by the re-use of already installed G.652 fiber. However, the effectiveness of this combination of elements is strongly dependent on the presence of intermodal dispersion, produced mainly by the bi-modal propagation in the G.652 when operating in the first window. However, in principle, the excitation of each mode strictly depends on the coupling conditions, such as relative alignment and tilting between fiber and VCSEL, and the input field of the latter. The numerical and experimental analysis performed in this work shows the impact of different coupling conditions on the two-mode excitation focusing on its impact on multimode effects such as intermodal dispersion and modal noise.

Oral Session 4: Integrated Microwave Photonics

Session chair: Jerome Bourderionnet

09:50-10:15

[Invited Talk] Integrated Lithium Niobate Microwave and Millimeter-wave Photonic Circuits

Cheng Wang

City University of Hong Kong, China

Abstract: Integrated microwave photonics (MWP) is a powerful technology that leverages integrated photonic technologies for the generation, transmission, and manipulation of microwave signals in chip-scale optical systems. In this talk, I will discuss our recent efforts on developing a thin-film lithium niobate (LN) MWP platform that simultaneously features efficient, linear, and high-speed electro-optic modulators for high-fidelity microwave-optic conversion, low-loss functional photonic networks that can be configured for a variety of signal processing tasks, as well as large-scale, low-cost manufacturability. I will first discuss a variety of device-level building blocks with unprecedented performances, including low-loss photonic waveguides and resonators (0.03 dB/cm), broadband electro-optic modulators covering the entire millimeter-wave band (up to 300 GHz), high-linearity modulators with SFDR of 120 dB·Hz4/5, broadband power-efficient frequency comb sources, as well as ultra-compact inverse-designed photonic elements. Building upon this platform, we further demonstrate high-performance MWP system applications, including ultrahigh-speed analog signal processing, image edge detection, and in-situ optical vector analyzers.

Biography: Dr. Cheng Wang is an Associate Professor of Electrical Engineering at City University of Hong Kong. He received his B.S. degree in Microelectronics from Tsinghua University in 2012, and his S.M. (2015) and Ph.D. (2017) degrees, both in Electrical Engineering from Harvard University, supervised by Prof. Marko Lončar. After conducting research as a postdoctoral fellow at Harvard, he joined City University of Hong Kong as an Assistant Professor in 2018. Prof. Wang's research focuses on the design and nanofabrication technology of integrated photonic devices and circuits. His current research effort focuses on realizing integrated lithium niobate photonic circuits for applications in optical communications, millimeter-wave/terahertz technologies, nonlinear optics, and quantum photonics. Since joining CityU, Prof. Wang has received a number of awards in research, including the NSFC Excellent Young Scientist Fund (HK & Macau) (2019), the Croucher Innovation Award (2020), The President's Award, CityU (2020), and 35 Innovators Under 35 (China), MIT Technology Review (2021).

10:15-10:30

Microwave Photonic Filter with User-defined Reconfigurability and High Frequency-selectivity

Xinyi Zhu*, Crockett Benjamin, Connor M. L. Rowe, Hao Sun, and José Azaña

Centre Énergie Matériaux Télécommunication Institut National de la Recherche Scientifique

Abstract: We propose and experimentally demonstrate a user-defined time-varying microwave photonic filtering system that enables versatile electronic reconfigurability of its spectral response at a

very high speed (~1.3 GHz) over a 40-GHz full frequency bandwidth and with a frequency resolution approaching its fundamental limit (filter's tuning speed). The system's performance is validated through the successful mitigation of time-varying frequency interferences in a nonstationary broadband microwave signal, showcasing its capability for fully reconfigurable and user-defined signal manipulation. The proposed method holds great potential for software-defined communication and advanced coding technology.

10:30-10:45	**Time Phase Shifting Based Demodulation Method for Fast Optical Fiber Transfer Delay Measurement**

Lihan Wang, Xiangchuan Wang*, and Shilong Pan*

National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics and Astronautics

Abstract: A fast optical fiber transfer delay (OFTD) measurement system based on time phase shifting is proposed to meet the requirement of dynamic measurement scenarios, such as distributed MIMO communication systems and free space laser positioning. The probe optical signal is modulated by a single-frequency electrical signal within a pulse envelope. The pulse envelope provides a time reference for unambiguous measurement, while the single-frequency modulation simplifies the signal processing requirements. With the demodulation in the time and phase domain, the OFTD demodulation computation complexity is reduced by N times, where N is determined by the collected data length. Therefore, the OFTD measurement speed is enhanced while ensuring measurement accuracy and range. Additionally, the proposed method avoids the need for broadband signal generation or frequency sweeping, thereby simplifying the system structure.

10:45-11:00	**High-Speed Waveguide-coupled Photodiode Arrays on Thin-film Lithium Niobate Platform**

Chao Wei[1], Yake Chen[1], Yang Sun[1], Zhongming Zeng[2], Jia Ye[1], Xihua Zou[1], Wei Pan[1], Xiaojun Xie[1*], and Lianshan Yan[1]

[1]Southwest Jiaotong University, [2]Suzhou Institute of Nano-Tech and Nano-Bionics

Abstract: The study presents a demonstration of InP/InGaAs modified uni-traveling carrier (MUTC) photodiode (PD) arrays heterogeneously integrated on the thin-film lithium niobate platform. To divide the input optical power evenly, a 1×N multimode interferometer (MMI) is employed to feed the PDs through N waveguides. The PD arrays, consisting of 2, 3, and 4 PDs, exhibit 3-dB bandwidths of 82 GHz, 67 GHz, and 62 GHz, respectively. The measured output power of the 1 × 4 PD array reaches -2.3 dBm at 30 GHz.

11:00-11:15	**Integrated Reconfigurable Modulator for Microwave Photonic Filtering**

Hong Deng*, and Wim Bogaerts

Gent University – imec

Abstract: In recent years, extensive research has been conducted on integrated microwave photonic filters. Most of these studies have focused on achieving a a unversally programmable spectral filter profile, or at least a widely tunable passband, by employing single sideband modulation. However, this approach often results in a complecated system with single sideband modulation and ring-loaded Mach-Zehnder interfometers. In this report, we propose a reconfigurable modulator scheme that generates radio frequency (RF) sidebands with a tunable phase relationship. This allows for the utilization of simple optical filters, such as cascaded microring resonators, to form universal microwave

photonic filters. Additionally, the modulator can be configured to function as a simple phase modulator or a Mach-Zehnder intensity modulator. Its specific performance can be optimized by considering trade-offs in other aspects to meet the application requirements. The effectiveness of the universal reconfigurable microwave photonic filter is verified through the use of two cascaded rings.

11:15-11:30	**High-speed Evanescently-coupled Waveguide MUTC Photodiodes with Bandwidth Over 220 GHz**

Li Linze, Wang Luyu, and Chen Baile[*]

Shanghai Tech University

Abstract: We demonstrate evanescently-coupled waveguide modified uni-traveling carrier (MUTC) photodiodes with an external responsivity of 0.18 A/W, and a 3-dB bandwidth over 220 GHz. RF output power reaches −4.36 dBm at 215 GHz.

11:30-11:45	**Integrated Lithium Niobate Optical Vector Network Analyzers based on Single-sideband Modulators**

Hanke Feng[1*], Tong Ge[2], yiwen Zhang[3], and Cheng Wang[2]

[1]city university of hong kong, [2]City University of Hong Kong, [3]City University of Hong Kong

Abstract: We report a chip-scale optical vector network analyzer based on LN single-sideband modulators, enabling in-situ and real-time probing of multi-dimensional information with kHz-level resolution for integrated optical devices.

Oral Session 5: Microwave Photonic Systems

Session chair: Cheng Wang

13:30-13:55

[Invited Talk] Photonic Integrated Circuits for RF Waveform Generation

Jerome Bourderionnet

Thales Research and Technology, France

Abstract: As part of the European Defense Agency-funded PICTURE project, we have investigated the potential of photonic integrated circuits technology towards radar applications, and in particular a photonics-based architecture for electronically scanned active array antenna systems, including multifunctional signal generation and detection. In this context, we discuss the developed devices, including integrated photonic transmit and receive modules with up- and down-conversion capability, powered by a mode-locked laser for frequency reference. Key elements such as narrowband optical bandpass filters are evaluated and benchmarked for different technology platforms (silicon-on-insulator and silicon nitride). Perspectives and lessons learned are presented, based on the evaluation of system performance with IF-to-RF and RF-to-IF conversion efficiencies.

Biography: Jérôme Bourderionnet (Dr.) holds a PhD in laser physics. Since 2001, he has been working in the Physics Dept. at Thales Research and Technology, in charge of the development of innovative concepts for radar and active optronic systems and also for fiber based sensors, including non-mechanical beam steering, slow light signal processing… In the past decade, he is particularly involved in the integrated photonics activity, for a various range of applications, including LiDAR, coherent beam combining for high power sources, free space communications, and microwave photonics for signal processing.

13:55-14:10 **Wideband and Low-Phase-Noise Chirped Pulses Generation Based on an Injection-Locked Optoelectronic Oscillator**

Yaming Liu[1,2,3,4], Bin Wang[1,2,3,4*], and Weifeng Zhang[1,2,3,4]

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Abstract: We propose and demonstrate a photonic approach to generate wideband and low-phase-noise chirped pulses using an injection-locked optoelectronic oscillator (OEO). In the proposed system, the injection-locked OEO is implemented to generate low-phase-noise microwave waveforms, and photonic-assisted microwave frequency multiplication is performed to increase the bandwidth of the generated waveforms. In the experiment, a dual-polarization dual-drive Mach-Zehnder modulator (DP-DDMZM) is a key component, in which one sub-DDMZM is incorporated into the OEO loop and the other sub-DDMZM is used to perform frequency multiplication. As a demonstration, linearly chirped microwave pulse with a bandwidth as wide as 6 GHz and phase noise as low as -116 dBc/Hz@10 kHz

is generated. The proposed system holds unique advantages of wide bandwidth and low phase noise, which is promising to be widely used in future highresolution and multi-function radar systems.

14:10-14:25	**Compact Optical 90° Hybrid based on a Wedge-shaped 2 × 4 MMI Coupler and a 2 × 2 MMI Coupler on Thin-film Lithium Niobate Platform**

Yake Chen[1], Yang Sun[1], Zhongming Zeng[2], Jia Ye[1], Xihua Zou[1], Wei Pan[1], Xiaojun Xie[1*], and Lianshan Yan[1]

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Abstract: We conducted an experimental demonstration of a wedge-shaped optical 90-degree hybrid coupler on the thin film lithium niobate (TFLN) platform, utilizing a pairedinterference-based 2 × 4 multimode interference (MMI) coupler and a general-interference-based 2 × 2 MMI coupler. The fabricated optical 90-degree hybrid coupler has a compact footprint with a length of 134 μm. In a coherent receiving system, the demonstrated hybrid coupler directly connects to the balanced photodiode array without waveguide crossing or cascaded phase shifters. The device exhibits an excess loss of less than 1.1 dB and a phase deviation of less than 5 degree over a spectral range of 1530nm-1560nm, which is promising to enable a compact heterogeneously integrated coherent receiving system on the thin film lithium niobate platform.

14:25-14:40	**Tandem Neural Networks for The Inverse Programming of Linear Photonic Processors**

José Roberto Rausell-Campo[1*], Daniel Pérez-López[2], Bhavin Shastri[3], and Daniele Melati[4]

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Abstract: Linear programmable photonic integrated processors have emerged as an alternative hardware platform for quantum, deep learning, and microwave photonic systems. Calibration and control of the photonic processor using deep learning techniques has proven to be challenging due to the one-to-many problem. This means that a given functionality of the processor can be achieved using different settings of the controllers. In this paper, we demonstrate how tandem neural networks can overcome this limitation in meshes of Mach-Zehnder interferometers by employing forward and inverse networks. This approach is independent of the mesh architecture and introduces a novel method for controlling photonic linear processors using deep neural networks. We provide an experimental demonstration using a 3x3 linear processor, achieving a control resolution higher than 7 bits.

14:40-14:55	**Photonics-assisted RF Signal Storage Scheme**

Pan Zhouyang, Ni Boyang, Sun Xiuyuan, Zhang Chao, Zhu Dan*, and Pan Shilong

National Key Laboratory of Microwave Photonics, Nanjing University of Aeronautics and Astronautics

Abstract: A novel photonics-assisted radio frequency (RF) signal storage scheme is proposed and demonstrated. By combining the low noise characteristics of the Raman fiber amplifier (RFA) and the high amplifier gain of the Erbium- doped fiber amplifier (EDFA), the storage depth, the storage time and the storage fidelity can be significantly improved. The experimental results show the system's capability to store a RF pulse with a 2-GHz bandwidth centered at 7 GHz and a pulse interval of 50 μs for more than 4.5 ms. The degradation of the signal-to-noise ratio (SNR) is observed to be less than

0.06 dB for each replication circulation. The demonstrated system offers a solution to achieve long-time storage of pulses with large bandwidth while maintaining a low noise figure (NF).

14:55-15:10	**Enhancing Detection Performance of Multi-band Photonic Radars Through Band Fusion with Coherent Processing**

Hum Nath Parajuli[1*], Ikechi Augustine Ukaegbu[1], Bikash Nakarmi[2], and Aigerim Ashimbayeva[1]
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Abstract: In this paper, we propose and demonstrate time-frequency analysis (TFA)-based spectral gap-filling and fast Fourier transform (FFT) and particle swarm optimization (PSO)-based coherent processing methods for achieving multi-band-radar fusion in the radar receiver. For the proof-of-the-concept demonstration, we generate photonics-based S-band (2GHz-4GHz) and C-band (6GHz-8GHz) linear frequency modulated (Ph-LFM) radar transmission signals using a dual-drive-Mach-Zehnder modulator (DDMZM) and simulate them in a multi-band-radar setup to detect two objects. Using the proposed TFA-based spectral gap-filling method, the missing band signal (4GHz- 6GHz) is estimated and fused with two echos of the S-band and C-band to achieve 6GHz bandwidth. Through the FFT and PSO-based coherent processing, the phase and amplitude imbalance among the bands is corrected, leading to a 12 dB improvement in peak-to-sidelobe level power in the range-profile compared to without coherent processing. This ensures the effectiveness of the proposed band fusion methods in enhancing resolution in multi-band radar systems.

15:10-15:25	**Experimental Investigation of An Optical Reservoir Computer with MZI-based Optical Mask**

Yuanli Yue[1], Shouju Liu[1], Ruibo Zhang[2], Tianxiang Luan[1], Ailing Zhang[2], and Chao Wang[1*]
[1]University of Kent, [2]Tianjin University of Technology

Abstract: In this paper, we have experimentally demonstrated a novel all-optical masking solution in photonic time stretch reservoir computing to eliminate the need of highspeed signal generator for digital masks. By leveraging the high chirp rate generated through an unbalanced Mach-Zehnder Interferometer (MZI) structure, we achieved a random optical mask in the spectral domain. Optical wavelengths, acting as virtual reservoir nodes, enable spectral mixing within the reservoir layer. Thanks to time-spectrum mapping in the photonic time stretch system, equivalent temporal masking is obtained. The develop system exhibits memory capacity through delayed optical feedback process. A full photonic reservoir computing system is implemented. Two experiments of waveform and digit-spoken signal classification have been carried out. Our experimental results show that MZI-based optical mask enables superior performance in photonic time stretch reservoir computing.

Travel in Nanjing

■ Dr. Sun Yat-Sen's Mausoleum

Covering an area of 80,000 square meters (about 20 acres), Dr. Sun Yat-sen's Mausoleum is located in the Purple Mountain Scenic Area in the east suburb of Nanjing City, Jiangsu Province. As the mausoleum of Dr. Sun Yat-sen, the father of the Republic of China, it is considered the Holy land of Chinese people both home and abroad. With deep historical significance, magnificent architecture and beautiful scenery, it is a must see when visiting Nanjing. Dr. Sun Yat-sen (1866-1925) was a great forerunner of the Chinese democratic revolution and led by Dr. Sun the Chinese people brought down the corrupt rule of the Qing Dynasty (1644-1911) and ended 2000 years of the feudal monarchy system, which led the people into a new age.

■ Presidential Palace

It is the landmark of the Presidential Palace. It was the former outer gate of Liang Jiang Viceroy in the Qing Dynasty. The gate of the palace was called "Genius Gate" during the period og Taiping Heavenly Kingdom. Designed by Yaobin, the present Western style reinforced concrete gate tower was built by the Nationalist Government in December, 1929. Three Chinese characters of "The Presidential Palace" engraved right in the middle of wall were personally inscribed by Zhou Zhongyue, the former Vice President of Examination Ministry of the Republic of China. A pair of stone lions in front of the gate are the remains of Liang Jiang Viceroy in the Qing Dynasty.

■ Nanjing Museum

Served as the Kuomintang's Preparatory Office of National Central Museum (founded by Mr. Cai Yuanpei in 1933). It is now a large comprehensive history and art museum, which covers a total area of over 70,000 square meters, 35,000 square meters construction area and includes two imposing ancient Liao-style palaces. It has a collection of 420,000 pieces of relics of many kinds, more than 2,000 pieces of which are of national treasures, especially the relics of archaeological excavations, ethnic minorities, foreign countries, royal court, Qing Dynasty literature and of surrender rites of Japanese troops in the Second World War as well.

■ Confucius Temple Area

As the "Mother River" of Nanjing, Qinhuai River is the cradle giving birth to ancient culture of Jinling (Nanjing). The Confucius Temple area, which is the most lively place at inner Qinhuai River, is the First AAAAA scenic area opened to the public for free. The Confucius Temple area has been historically known as the cream of Qinhuai River scenic area, which is commonly known as "Five-kilometer Qinhuai".

It is an area integrating natural sceneries, gardens, temples, schools, streets, civil residences with local customs and habits. With Confucius Temple ancient architectural ensemble as the center and the Five-kilometer Qinhuai Riveras the axis, it stretches from Dongshuiguan Park in the east to Xishuiguan Park in the west (Shuixi City-Gate).

■ Jiming Temple

Jiming Temple (Cock-crow Temple) is located on a hill in the northeast part of the city. It is an extraordinary location, and each edifice is built successively higher on the hill, as if the temple itself were climbing toward the sky. Most of the buildings are bright yellow, with dark red trim and beautiful tile roofs. The view east looks past the city wall and across Xuanwu Lake to the foothills of Purple Mountain.

Call for Papers

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MICROWAVE PHOTONICS

Scope

This special issue is launched for the top conference "2023 IEEE International Topical Meeting on Microwave Photonics" (MWP'2023, http://www.mwp2023.org/) in this field, held in 15-18 October, Nanjing, China. It is open to all kinds of presentations (extended versions of plenary, invited, oral talks and posters) in MWP'2023, as well as other submissions (not presented in MWP'2023) in the field of microwave photonics.

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