A High Spectral Efficiency Radio Over Fiber Link Based on Coherent Detection and Digital Phase Noise Cancellation

Peng Li ©, Ruoshi Xu ©, Zheng Dai ©, Zhenguo Lu ©, Member, IEEE, Member, OSA, Lianshan Yan, Senior Member, IEEE, Fellow, OSA, and Jianping Yao ©, Fellow, IEEE, Fellow, OSA

Abstract—An approach to transmitting two independent microwave vector signals on a single optical carrier with one polarization state based on coherent detection and digital phase noise cancellation is proposed and experimentally demonstrated. At the transmitter, two independent microwave vector signals are modulated on an optical carrier via a dual-drive Mach-Zehnder modulator (DD-MZM). The modulated optical signals are transmitted over a single-mode fiber (SMF) and sent to a coherent receiver. At the receiver, the optical signals are detected where a local oscillator (LO) optical wave generated by a second free-running laser source is also applied. To recover the two microwave vector signals, a novel digital signal processing (DSP) algorithm is developed and applied to eliminate the joint phase noise terms from the transmitter and the LO laser sources as well as the unstable offset frequency between the two laser sources. An experiment is performed. The transmission of two independent 16 quadrature amplitude modulation (16-QAM) microwave vector signals at 4 GHz with a symbol rate of 1 GSymbol/s over a 9-km SMF is demonstrated. The transmission performance in terms of error vector magnitudes (EVMs) and bit error rates (BERs) is also evaluated.

Index Terms—Coherent detection, digital signal processing (DSP), laser frequency offset, laser phase noise, phase noise cancellation, Radio over fiber (RoF).

I. INTRODUCTION

Radio over fiber (RoF), a technique to transmit microwave signals over an optical fiber link, has been well studied for the past few decades and can find applications such as antenna remoting, cable television (CATV), and broadband wireless access, due to its intrinsic advantages including low insertion loss, large bandwidth, and immunity to electromagnetic interference (EMI) [1]–[4]. A conventional RoF link based on intensity modulation and direct detection (IM-DD), in which a microwave signal is modulated on an optical carrier by changing the carrier intensity and then detected after fiber transmission at a photodetector (PD), has a simple structure and low cost. But such a link has a low spectral efficiency, since only the intensity-modulated optical signal can be detected. In addition, the receiver sensitivity is limited due to the use of direct detection. To ensure a good signal-to-noise ratio (SNR), a high optical power is needed, which is not wanted especially considering the nonlinearity of the fiber link. A coherent RoF link, on the other hand, can detect both intensity- and phase-modulated optical signals and has about 20 dB higher receiver sensitivity due to the use of coherent detection [5]. In a coherent RoF link, a local oscillator (LO) light source which is usually not phase-locked to the transmitter laser source is used to perform coherent detection. The joint phase noise and the offset frequency from the two laser sources will be directly translated to the detected microwave signal, making the transmission performance greatly degraded. To solve this problem, numerous schemes have been proposed. For example, an optical phase-locked loop (OPLL) can be used to lock the phase terms of the transmitter and LO laser sources [6]–[8], thus the joint phase noise at the receiver is fully canceled. Since the two light sources, however, are located at different locations, the loop length is very long, making effective phase locking hard to achieve. The use of a two-tone LO light source at a coherent receiver can also eliminate the joint phase noise and offset frequency from the two laser sources [9], [10]. But to generate a two-tone light source, a high-quality microwave source and a Mach-Zehnder modulator (MZM) are needed, making the systems complicated and costly. Recently, digital phase noise cancellation solutions have been proposed to eliminate the phase noise and the offset frequency at a digital signal processing (DSP) unit [11]–[16]. For example, an intensity-modulated optical signal, when detected coherently at a receiver, can have two equal-amplitude quadrature signals with the joint phase noise in both signals. By summing the squared versions of the in-phase and quadrature components,
the joint phase noise is fully eliminated [11], [12]. However, this approach allows only a single microwave vector signal to be transmitted, making poor use of the optical spectrum resources. To increase the spectral efficiency, two microwave vector signals modulated on a single optical carrier based on both intensity modulation and phase modulation were proposed [13], [16]. To ensure effective detection, a pilot tone or a modulated optical signal must be orthogonally polarized with the optical signals. Since two orthogonal polarization directions are being used, the data rate cannot be further increased based on polarization multiplexing, making the spectral efficiency limited. To improve the spectral efficiency, we proposed an approach to transmitting four microwave vector signals on a single optical carrier based on optical independent sideband modulation (OISB) and optical orthogonal modulation [15]. Again, two additional electrical pilot tones at different frequencies are employed, which again reduces the spectral efficiency and the system flexibility and energy efficiency are also poor.

In this paper, we propose an approach to transmitting two independent microwave vector signals modulated on a single optical carrier with one polarization state based on coherent detection and digital phase noise cancellation. At the transmitter, the intensity of an optical carrier is modulated by two independent microwave vector signals at a dual-drive Mach-Zehnder modulator (DD-MZM) biased at the quadrature transmission point. A modulated optical signal is generated, then is transmitted to the receiver over a single-mode fiber (SMF) and detected at a coherent receiver where an LO light generated by another free-running laser source is applied. To effectively recover the two microwave vector signals, a DSP algorithm is developed to eliminate the phase fluctuation including joint phase noise and unstable offset frequency introduced by the transmitter laser source and the LO laser source. The proposed scheme is evaluated experimentally. In the experiment, two independent 16 quadrature amplitude modulation (16-QAM) microwave vector signals at 4 GHz with a symbol rate of 1 GSymb/s are transmitted over a 9-km SMF and recovered at a coherent receiver. The transmission performance of the RoF link is evaluated by measuring the error vector magnitudes (EVMs) and bit error rates (BERs). The results show that the EVMs for the two recovered 16-QAM signals are 9.27% and 9.75%, which are good enough to achieve error-free transmission with forward error correction (FEC).

Two microwave vector signals. To perform coherent detection, a second optical wave generated by a free-running laser source, as a LO light, is also sent to the coherent receiver. At the output of the coherent receiver, two electrical signals are generated which are sampled by an oscilloscope (OSC) and processed by a DSP unit.

Assume that the two microwave vector signals are given by

\[ s_1(t) = m_1(t) \cos \left( \omega_c t + \theta_1(t) \right) \]
\[ s_2(t) = m_2(t) \cos \left( \omega_c t + \theta_2(t) \right) \]

where \( m_1(t) \) and \( m_2(t) \) are the amplitudes of the two microwave signals, \( \theta_1(t) \) and \( \theta_2(t) \) are the phases of the two microwave signals, and \( \omega_c \) is the center angular frequency of the two microwave vector signals. When the DD-MZM is biased at the quadrature transmission point, under small-signal modulation, the optical field at the output of the DD-MZM can be approximately expressed as [17]

\[
E_s(t) = \frac{\sqrt{2P_s L}}{2} \exp \left[ j \left( \omega_c t + \varphi_c(t) \right) \right] \\
\times \left[ \exp \left( \frac{\pi}{\sqrt{\pi}} s_1(t) \right) + \exp \left( \frac{\pi}{\sqrt{\pi}} s_2(t) + \frac{\pi}{2} \right) \right]
\]

\approx \frac{\sqrt{2P_s L}}{2} \exp \left[ j \left( \omega_c t + \varphi_c(t) \right) \right] \\
\left\{ \frac{\pi}{\sqrt{\pi}} |s_1(t) + js_2(t)| + 1 + j \right\}

(3)

where \( P_s \) is the optical power of the optical wave at the output of the LD, \( \omega_c \) is the angular frequency of the optical wave, \( L \) is the link loss between the LD and DD-MZM, \( \varphi_c(t) \) is the phase noise induced by the LD, and \( V_c \) is the half-wave voltage of the DD-MZM. From (3), it can be seen that the two microwave

II. PRINCIPLE

Fig. 1 shows the schematic diagram of the proposed RoF transmission link based on coherent detection and digital phase noise cancellation. At the transmitter, a laser diode (LD) is used as the transmitter laser source to generate an optical wave, which is sent, via a polarization controller (PC), to a DD-MZM. The DD-MZM has a Mach-Zehnder interferometer (MZI) structure with a phase modulator (PM) in each of the two arms. The DD-MZM is biased at the quadrature transmission point. Two independent microwave vector signals are applied to the DD-MZM via the two radio-frequency (RF) ports. A modulated optical signal is generated and is transmitted over an SMF to a receiver, where coherent detection and DSP are performed to recover the

![Fig. 1. Schematic diagram of the proposed RoF transmission link based on coherent detection and digital phase noise cancellation. LD: laser diode; PC: polarization controller; PM: phase modulator; DC: direct current; DD-MZM: dual-drive Mach-Zehnder modulator; SMF: single-mode fiber; LO: local oscillator; BPD: balanced photodetector; ADC: analog-to-digital converter; DSP: digital signal processing.](image-url)
vector signals are linearly mapped to the optical domain with a phase shift of 90° introduced due to the bias of the DD-MZM at the quadrature transmission point.

After transmission over the SMF, the modulated optical signal is coherently detected at the coherent receiver. The coherent receiver consists of a 90° optical hybrid and two balanced photodetectors (BPDs). A free-running optical wave generated by the LO light source, is given by

\[ E_{LO}(t) = \sqrt{P_{LO}} \exp j [\omega_{LO} t + \varphi_{LO}(t)] \]  \hspace{1cm} (4)

where \( P_{LO} \) is the optical power of the optical wave at the output of the LO laser source, \( \omega_{LO} \) is the angular frequency of the optical wave, and \( \varphi_{LO}(t) \) is the phase noise induced by the laser source. After the 90° optical hybrid, four optical signals are obtained, which are given by

\[ E_1(t) = E_s(t) + E_{LO}(t) \]  \hspace{1cm} (5)

\[ E_2(t) = E_s(t) - E_{LO}(t) \]  \hspace{1cm} (6)

\[ E_3(t) = E_s(t) - jE_{LO}(t) \]  \hspace{1cm} (7)

\[ E_4(t) = E_s(t) + jE_{LO}(t) \]  \hspace{1cm} (8)

Then, the four optical signals are detected at the two BPDs and the photocurrents are given by

\[ i_1(t) = \frac{1}{2} R [E_1(t) E_1^*(t) - E_2(t) E_2^*(t)] \]

\[ = \frac{R \sqrt{2P_s P_{LO}}}{2} \left\{ \cos [\Delta \omega t + \varphi(t)] \right\} \]

\[ + \frac{R \sqrt{2P_s P_{LO}}}{2} \pi \frac{1}{V_e} \left\{ s_1(t) \cos [\Delta \omega t + \varphi(t)] \right\} \]

\[ i_2(t) = \frac{R}{2} [E_3(t) E_3^*(t) - E_4(t) E_4^*(t)] \]

\[ = \frac{R \sqrt{2P_s P_{LO}}}{2} \left\{ \sin [\Delta \omega t + \varphi(t)] \right\} \]

\[ + \frac{R \sqrt{2P_s P_{LO}}}{2} \pi \frac{1}{V_e} \left\{ s_1(t) \sin [\Delta \omega t + \varphi(t)] + s_2(t) \cos [\Delta \omega t + \varphi(t)] \right\} \]  \hspace{1cm} (9)

\[ i_3(t) = \frac{R \sqrt{2P_s P_{LO}}}{2} \pi \frac{1}{V_e} \left\{ s_1(t) \cos [\Delta \omega t + \varphi(t)] \right\} \]

\[ + s_2(t) \sin [\Delta \omega t + \varphi(t)] \]  \hspace{1cm} (10)

where \( R \) is the responsivity of the BPDs, \( \Delta \omega = \omega_c - \omega_{LO} \) is the angular frequency difference between the optical waves from the transmitter laser source and the LO laser source, and \( \varphi(t) \) is the joint phase noise introduced by the two laser sources. As can be seen from (9) and (10), the first term in each of the two currents is the phase fluctuations, including the joint phase noise and the unstable offset frequency between the transmitter laser source and LO laser source while the second term is a microwave vector signal, which is affected by the phase fluctuations. If the frequency difference between the two laser sources is lower than the center frequency of the microwave vector signal, the two terms can be easily separated by a digital filter.

Then, the two photocurrents, \( i_1(t) \) and \( i_2(t) \), are sent to the DSP unit where an algorithm is performed to eliminate the joint phase and unstable offset frequency introduced by the two laser sources and recover the two microwave vector signals. Two flow charts to show the algorithm are shown in Figs. (2) and (3).

The first terms (\( i_4(t) \) and \( i_6(t) \)) of the two photocurrents (\( i_1(t) \) and \( i_2(t) \)) are obtained via a digital low-pass filter (LPF), while the second terms (\( i_3(t) \) and \( i_5(t) \)) are obtained by using a digital bandpass filter (BPF). The detailed signal processing can be expressed by the following expressions.

\[ i_3(t) = BPF(i_1(t)) \]

\[ = \frac{R \sqrt{2P_s P_{LO}}}{2} \pi \frac{1}{V_e} \left\{ s_1(t) \cos [\Delta \omega t + \varphi(t)] - s_2(t) \sin [\Delta \omega t + \varphi(t)] \right\} \]  \hspace{1cm} (11)

\[ i_4(t) = LPF(i_1(t)) \]

\[ = \frac{R \sqrt{2P_s P_{LO}}}{2} \left\{ \cos [\Delta \omega t + \varphi(t)] \right\} \]

\[ - \sin [\Delta \omega t + \varphi(t)] \]  \hspace{1cm} (12)
\[ i_5(t) = BPF(i_2(t)) \]
\[ = \frac{R\sqrt{2P_sLP_{LO}}}{2} \pi \left\{ \begin{array}{c}
   s_1(t) \sin(\Delta \omega t + \varphi(t)) \\
   + s_2(t) \cos(\Delta \omega t + \varphi(t))
\end{array} \right\} \]
\[ i_6(t) = LPF(i_4(t)) \]
\[ = \frac{R\sqrt{2P_sLP_{LO}}}{2} \left\{ \begin{array}{c}
   \sin(\Delta \omega t + \varphi(t)) \\
   + \cos(\Delta \omega t + \varphi(t))
\end{array} \right\} \]
\[ i_7(t) = (i_4(t) + i_6(t)) \ast i_3(t) + (i_6(t) - i_4(t)) \ast i_5(t) \]
\[ = P_sLP_{LO}R^2 \frac{\pi}{\pi} s_1(t) \]
\[ i_8(t) = (i_4(t) + i_6(t)) \ast i_5(t) - (i_6(t) - i_4(t)) \ast i_3(t) \]
\[ = P_sLP_{LO}R^2 \frac{\pi}{\pi} s_2(t) \]

It can be seen from (15) and (16), the two microwave vector signals \((s_1(t) \text{ and } s_2(t))\) are recovered and free from the joint phase noise and unstable offset frequency.

### III. EXPERIMENTAL SETUP AND RESULTS

To verify the proposed scheme, an experiment based on the setup shown in Fig. 1 is performed. A continuous-wave (CW) optical wave at 1550 nm generated by the transmitter laser source (Yokogawa, AQ2201) with a linewidth of 100 kHz and an output optical power of 8 dBm is sent to the DD-MZM (Fujitsu, FTM7821ER) via PC1. Note that PC1 is used to minimize the polarization-dependent loss (PDL). The DD-MZM has a half-wave voltage of 4 V, a 3-dB bandwidth of 10 GHz, and an insertion loss of 6 dB. Two independent 16 quadrature amplitude modulation (16-QAM) microwave vector signals generated by an arbitrary waveform generator (AWG, Keysight M8195A) with a sampling rate of 65 GSa/s and a bandwidth of 25 GHz are sent to the DD-MZM via the two RF input ports. The center frequency, baud rate, and output voltage of the two signals are set to be 4 GHz, 1 GSym/s, and 1 V, respectively. The DD-MZM is biased at the quadrature transmission point. A modulated optical signal is generated at the output of the DD-MZM, transmitted over a 9 km SMF, and sent to the coherent receiver (Discovery Semiconductors DP-QPSK 40/100 Gb/s Coherent Receiver Lab Buddy) through the signal port via PC2. Another CW optical wave at 1550.01 nm generated by the LO laser source (Agilent N7714A) with a linewidth of 100 kHz and an output optical power of 10 dBm is sent to the coherent receiver through the LO port via PC3. The two PCs (PC2 and PC3) are used to co-polarize the modulated optical signal and the LO optical signal. The wavelength difference between the transmitter laser source and LO laser source is 0.01 nm, corresponding to an offset frequency of 1.25 GHz. After coherent detection, the detected electrical signals are sampled by the digital storage oscilloscope (Agilent DSO-X 93204A) with a sampling rate of 80 GSa/s and a bandwidth of 32 GHz. The sampled signal is sent to the DSP unit where the two microwave vector signals are processed to eliminate the joint phase noise and the unstable offset frequency and to recover the two signals.

Fig. 4 shows the measured spectrum of the optical signal at the output of the coherent receiver \((i_1(t))\).

Fig. 5 shows the measured spectrum of the electrical signal at one of the two outputs of the coherent receiver \((i_1(t))\).
products generated between the 1.2 GHz microwave signal and the 4 GHz microwave vector signals at 2.8 and 5.2 GHz are observed, which agrees well with the theoretical analysis given by (9). The 1.2 GHz signal can be separated from the 2.8 and 5.2 GHz signals by an LPF, as shown in Fig. 6. The microwave vector signals can be separated from the 1.2 GHz microwave signal by using a BPF, as shown in Fig. 7. Through DSP, a recovery of one 16-QAM microwave vector signal \(i_7(t)\) free from the joint phase noise and the unstable offset frequency is achieved, as shown in Fig. 8. Fig. 9 shows the measured constellations of the two recovered 16-QAM microwave vector signals at the output of the DSP unit, where the optical power at the input of the coherent receiver is -10 dBm. The EVMs for the two microwave vector signals are calculated, which are 9.27% and 9.75%.

To further evaluate the performance of the system, the EVMs at different received optical power levels are measured, which are given in Fig. 10 and the corresponding BERs are shown in Fig. 11. When calculating the BERs, we assume that the noise after the DSP unit is a stationary random process with Gaussian statistics [18]–[20]. As can be seen, when the received optical power is -20 dBm, the EVMs for the two recovered 16-QAM microwave vector signals are 17.51% and 18.38% and the corresponding BERs are \(4 \times 10^{-3}\) and \(5.6 \times 10^{-3}\), which are beyond the FEC limit. When the optical power is increased to -18 dBm, the BERs are measured to be \(9.3 \times 10^{-4}\) and \(2 \times 10^{-3}\), which are well within the FEC limit. By employing a state-of-the-art FEC technique, a raw BER of up to \(3 \times 10^{-3}\) can be improved to an effective BER of \(1 \times 10^{-15}\) at the expense of a 6.7% overhead [21]. Error-free transmission can be achieved.
Fig. 10. Measured EVMs at different received optical power levels for the two recovered 16-QAM microwave vector signals transmitted over a 9-km SMF.

Fig. 11. BERs at different received optical power levels for the two recovered 16-QAM microwave vector signals transmitted over a 9-km SMF.

IV. CONCLUSION

We have proposed and experimentally demonstrated an approach to transmitting two independent microwave vector signals modulated on a single optical carrier with one polarization state based on coherent detection and digital phase noise cancellation. At the transmitter, a DD-MZM, which was biased at the quadrature transmission point, was employed to linearly map two 16-QAM signals to the optical domain, to generate two optical signals with a phase difference of 90°. After transmission over an SMF, the optical signals were detected at a coherent receiver, to which an LO light wave from a free-running laser source was applied. By using the developed algorithm, a recovery of the two microwave vector signals free from the joint phase noise and unstable offset frequency was achieved. An experiment was conducted. The transmission of two independent 16-QAM microwave vector signals at 4 GHz with a baud rate of 1 GSymbol/s over a 9-km SMF was demonstrated. The EVMs for the two recovered 16-QAM signals were measured to be 9.27% and 9.75%, which are good enough to achieve error-free transmission with FEC.

REFERENCES

Ruoshi Xu received the B.Eng. degree in optoelectronic information science and engineering from Tianjin University, Tianjin, China, in 2018. He is currently working toward the Ph.D. degree with the Microwave Photonics Research Laboratory, School of Electrical Engineering and Computer Science, University of Ottawa, Ottawa, ON, Canada. His current research interests include silicon photonics and analog radio-over-fiber systems.

Zheng Dai received the B.Eng. degree in electrical engineering and automation from Northwestern Polytechnical University, Xi’an, China, in 2015. He is currently working toward the Ph.D. degree with the Microwave Photonics Research Laboratory, School of Electrical Engineering and Computer Science, University of Ottawa, Ottawa, ON, Canada. His current research interests include parity-time symmetry and its applications in microwave photonics.

Zhenguo Lu (Member, IEEE) received the Ph.D. degree in 1992. He is currently a Principal Research Officer, a Team Lead of photonics, and a Project Leader of National Challenge Program High-Throughput and Secure Networks (HTSN) with the Advanced Electronics and Photonics (AEP) Research Centre, National Research Council (NRC) Canada, Ottawa, ON, Canada. Since 2006, he has also been an Adjunct Professor of electrical and computer engineering with the University of Ottawa, Ottawa, ON, Canada, and Concordia University, Montréal, QC, Canada. After obtaining the Ph.D. degree, he was an Alexander von Humboldt (AvH) Research Fellow to conduct research with the Institute of Semiconductor Electronics, RWTH Aachen, Germany, from 1993 to 1995. Then he was with the Terahertz Research Centre of Rensselaer Polytechnic Institute, NY, USA, for more than two years before he joined NRC as a Research Officer in October 1997. From 2000 to 2002, he was the R&D Director of BTI Systems Inc., Ottawa, ON, Canada. In April 2002, he re-joined NRC, as a Senior Research Officer. He is an Expert in the field of photonics devices and their applications in optical coherent communications, data center networks, 5G & beyond wireless networks, and satellite communications. He has authored or coauthored more than 250 refereed journal and conference proceeding papers, and eight U.S. patents. He has given more than 50 invited talks at the international conferences, universities, and industry companies.

Lianshan Yan (Senior Member, IEEE) received the Ph.D. degree from the University of Southern California, Los Angeles, CA, USA. He is currently a Full Professor and the Director of Center for Information Photonics and Communications, Southwest Jiaotong University, Chengdu, China. He is a Fellow of the Optical Society of America (OSA). He was the recipient of the IEEE Photonics Society Distinguished Lecturer Award during 2011–2013 and the IEEE LEOS Graduate Fellowship in 2002. He is currently the Chair of the Fiber Optics’ Technology Technical Group, OSA. He was the Co-Chair of the TPC member of more than 20 international conferences, including the Optical Fiber Communication Conference and Exhibition (OFC, since 2013), the European Conference on Optical Communication (ECOC, since 2013), and the Asia Communications and Photonics Conference (ACP, 2010–2012). He was an Associate Editor for the IEEE PHOTONICS JOURNAL.

Jianping Yao (Fellow, IEEE) received the Ph.D. degree in electrical engineering from the Université de Toulon et du Var, France, in December 1997. He is currently a Distinguished University Professor and University Research Chair with the School of Electrical Engineering and Computer Science, University of Ottawa, Ottawa, ON, Canada. From 1998 to 2001, he was with the School of Electrical and Electronic Engineering, Nanyang Technological University (NTU), Singapore, as an Assistant Professor. In December 2001, he joined the School of Electrical Engineering and Computer Science, University of Ottawa, as an Assistant Professor, where he was promoted to an Associate Professor in May 2003, and a Full Professor in May 2006. He was appointed as a University Research Chair of microwave photonics in 2007. In June 2016, he was conferred the title of a Distinguished University Professor of the University of Ottawa. From July 2007 to June 2010 and from July 2013 to June 2016, he was the Director of the Ottawa-Carleton Institute for Electrical and Computer Engineering.

He has authored or coauthored more than 650 research papers, including more than 380 papers in peer-reviewed journals and more than 270 papers in conference proceedings. He is the Editor-in-Chief of the IEEE Photonics Technology Letters, a former Topical Editor of the Optics Letters, and a former Associate Editor for the Science Bulletin. He is an Advisory Editorial Board Member of the Optics Communications and served as a Steering Committee Member of the Journal of Lightwave Technology from 2017 to 2021. He was a Guest Editor of a Focus Issue on Microwave Photonics in Optics Express in 2013, a Lead-Editor of a Feature Issue on Microwave Photonics in Photonics Research in 2014, and a Guest Editor of a Special Issue on Microwave Photonics in IEEE/OSA Journal of Lightwave Technology in 2018. He was the Technical Committee Chair of IEEE MTT-S Microwave Photonics during 2017–2021 and an Elected Member of the Board of Governors of the IEEE Photonics Society during 2019–2021. He was a Member of the European Research Council Consolidator Grant Panel in 2016, 2018 and 2020, a Member of the Qualitative Evaluation Panel in 2017, and a panelist of the National Science Foundation Career Awards Panel in 2016. Prof. Yao was also served as the Chair of a number of international conferences, symposia, and workshops, including the Vice Technical Program Committee (TPC) Chair of the 2007 International Topical Meeting on Microwave Photonics, the TPC Co-Chair of the 2009 and 2010 Asia-Pacific Microwave Photonics Conference, the TPC Chair of the high-speed and broadband wireless technologies subcommittee of the IEEE Radio Wireless Symposium 2009-2012, the TPC Chair of the Microwave Photonics Subcommittee of the IEEE Photonics Society Annual Meeting 2009, the TPC Chair of the 2010 International Topical Meeting on Microwave Photonics, the General Co-Chair of the 2011 International Topical Meeting on Microwave Photonics, the TPC Co-Chair of the 2014 International Topical Meetings on Microwave Photonics, the General Co-Chair of the 2015 and 2017 International Topical Meeting on Microwave Photonics, and the General Chair of the 2019 International Topical Meeting on Microwave Photonics. He was also a Committee Member for a number of international conferences, such as IPC, OFC, CLEO, BGPP, and MWP. Prof. Yao was the recipient of the 2005 International Creative Research Award of the University of Ottawa. He was the recipient of the 2007 George S. Glinski Award for Excellence in Research. In 2008, he was awarded the Natural Sciences and Engineering Research Council of Canada Discovery Accelerator Supplements Award. Prof. Yao was selected to receive an inaugural OSA Outstanding Reviewer Award in 2012 and was one of the top ten reviewers of the Journal of Lightwave Technology 2015-2016. Prof. Yao was an IEEE MTT-S Distinguished Microwave Lecturer during 2013–2015. He was the recipient of the 2017-2018 Award for Excellence in Research of the University of Ottawa and was the recipient of the 2018 R.A. Fessenden Silver Medal from IEEE Canada.

Prof. Yao is a registered Professional Engineer of Ontario. He is a Fellow of the Optical Society of America, the Canadian Academy of Engineering, and the Royal Society of Canada.