20-Gbaud QPSK Coherent Radio Transmission at 325 GHz with High-Gain Antennas

Atsushi Kanno[1], Toshiaki Kuri[1], Isao Morohashi[1], Iwao Hosako[1], Tetsuya Kawanishi[1], Yuki Yoshida[2], Ken'ichi Kitayama[2]

[1]National Institute of Information and Communications Technology, Koganei, Tokyo 187–0032, Japan.

[2]Osaka University, Suita, Osaka 565–0871, Japan.

***Abstract*—High-speed coherent transmission at 325 GHz is successfully demonstrated with a 20-Gbaud QPSK signal. A frequency-locked terahertz signal can be provided by an optical-modulation-based optical frequency comb signal. A high-gain antenna with a gain of 46 dBi is suitable to extend the transmission distance up to 15 m without requiring a terahertz amplifier.**

I. Introduction

To enhance network functionality, including wired-wireless seamless connectivity, the capacity of wireless services needs to be increased. For frequency allocation in radio space, millimeter-wave and submillimeter-wave radio are candidates for high-speed wireless services because of their broad available bandwidths. In particular, the submillimeter-wave band at frequencies greater than 275 GHz (the so-called "terahertz wave" band) has possible broad bandwidths useable for high-capacity radio communication [1,2]. However, electronics-based devices do not currently provide such high-capacity signals. Therefore, photonics-based techniques based on advanced optical communication with digital signal processing (DSP) can be used for high-capacity radio signal transmission [3,4]. However, photonics-based technology cannot realize a high-power output, and the possible transmission distance is limited to several meters.

In this study, we demonstrate a 40-Gb/s-class coherent radio signal transmission in the 300-GHz band using advanced photonics technology. An optical subharmonic IQ mixer (SHIQM), employing optical modulation based on optical frequency comb generation, realizes high-symbol-rate multilevel signal generation [5,6,7]. A high-gain antenna set as both a transmitter and receiver can extend the transmission distance without requiring a terahertz amplifier.

II. Experimental Setup

The experimental setup for high-capacity transmission with high-gain antennas is shown in Fig. 1. The optical SHIQM operates at 25 GHz as a local oscillator (LO), generating a radio-friendly optical signal at a carrier frequency of 325 GHz with a quadrature phase-shift keying (QPSK) signal whose symbol rate is 16–32 Gbaud. The seed signals for QPSK generation are provided by a two-channel pulse pattern generator (PPG) with a pseudorandom bit stream. The generated optical signal is boosted by an erbium-doped fiber amplifier (EDFA), followed by an optical bandpass filter (OBPF), for suppression of amplified spontaneous emission noise. The amplifier optimizes the optical power level for input to a photomixer (PM). The PM converts the optical signal (with a frequency separation of 325 GHz) to a 325-GHz terahertz-wave signal. An antenna with a gain of 46 dBi irradiates the signal to the air, and the antenna at the receiver collects the transmitted signal. A subharmonic mixer (SHM), operated at a 12.5-GHz LO signal, performs frequency down-conversion from 325 GHz to 25 GHz. An intermediate frequency (IF) amplifier optimizes the signal level for input to an analog-to-digital converter (ADC). A digital storage oscilloscope is used as the ADC, and offline DSP compensates for transmission impairments and demodulation. All the experiments were performed in a large-scale anechoic chamber at NICT, which is shown in Fig. 2.

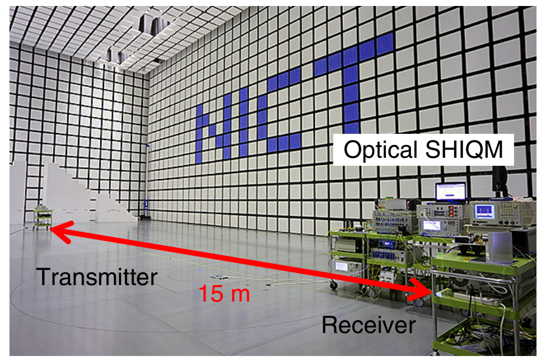

Fig. 2 Photo of experiment under 15-m air transmission.

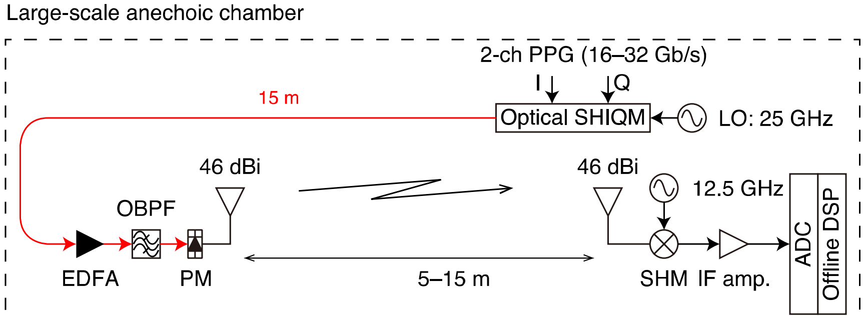

Fig. 1 Experimental setup for high-symbol-rate coherent transmission using optical SHIQM.

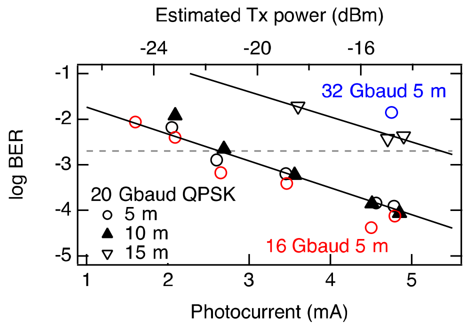

Fig. 3 Observed BERs at various symbol rates and transmission distances.

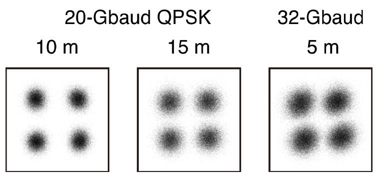

Fig. 4 Constellation maps of received QPSK signal for 20-Gbaud QPSK under 10-m and 20-m transmissions, and 32-Gbaud QPSK under 5-m distance.

III. Demonstration

The observed bit error rates (BERs) are shown in Fig. 3. The BERs for 5-m and 10-m transmissions are similar at 10–20 Gbaud. On the other hand, the under-15-m transmission with a 20-Gbaud QPSK has some differences compared to the 10-m transmission. This is because the border between the near- and far-fields is between 10 m and 15 m. The observed penalty between the two ranges is estimated at 8 dB. The penalty between the 5-m and 15-m transmissions, estimated using the Friis propagation equation, is approximately 4 dB. The difference between the estimated and observed values is possibly due to a misalignment of the antenna direction. Constellation maps of the received QPSK signal are also shown in Fig. 4. Clear symbol separation is exhibited during 20-Gbaud operation. It should be noted that the expected radio power at 300 GHz is approximately less than -13 dBm when the photocurrent is 5 mA. Using the high-gain antenna pair, 20-Gbaud QPSK radio transmission can be performed even if the output power is lower than 100 µW [8].

IV. Summary

40-Gb/s-class QPSK coherent radio signal transmission in the 300-GHz band is successfully demonstrated using an optical SHIQM. A high-gain antenna helps to extend the transmission distance, even if the transmitted radio power is very low. Optical technology will drive advanced radio communication and will help the development of the terahertz radio communication system as an advanced testbed.

References

[1] C. Jastrow, K. Munter, R. Piesiewicz, T. Kürner, M. Koch, and T. Kleine-Ostmann, "300 GHz transmission system," Electron. Lett., vol. 44, pp. 213–214 (2008).

[2] H.-J. Song, K. Ajito, A. Wakatsuki, Y. Muramoto, N. Kukutsu, Y. Kado, and T. Nagatsuma, "Terahertz wireless communication link at 300 GHz," IEEE Intl. Topic. Meeting Microw. Photon. (MWP2010), Montreal, Canada, WE3-2, Oct. 2010.

[3] A. Kanno, T. Kuri, I. Hosako, T. Kawanishi, Y. Yasumura, Y. Yoshida, and K. Kitayama, "Optical and millimeter-wave radio seamless MIMO transmission based on radio over fiber technology," Optics Express, vol. 20, no. 28, pp. 29395–29403 (2012).

[4] S. Koenig, D. Lopez-Diaz, J. Antes, F. Boes, R. Henneberger, A. Leuther, A. Tessmann, R. Schmogrow, D. Hillerkuss, R. Palmer, T. Zwick, C. Koos, W. Freude, O. Ambacher, J. Leuthold, and I. Kallfass, "Wireless sub-THz communication system with high data rate," Nature Photonics, vol. 7, pp. 977–981 (2013).

[5] A. Kanno, I. Morohashi, T. Kuri, I. Hosako, T. Kawanishi, Y. Yasumura, Y. Yoshida, and K. Kitayama, "16-Gbaud QPSK radio transmission using optical frequency comb with recirculating frequency shifter for 300-GHz RoF signal," IEEE Intl. Topic. Meet. Microw. Photon., Noordwijk, Netherland, S7.6, Sep. 2012.

[6] A. Kanno, T. Kuri, I. Morohashi, I. Hosako, T. Kawanishi, Y. Yoshida, Y. Yasumura, K. Kitayama, "Coherent terahertz communication based on DSP-aided radio-over-fiber technology," Infrared Millimeter-Wave and Terahertz Wave Conference, Mainz, Germany, Tu3-4, Sep. 2013.

[7] N. Sekine, A. Kanno, T. Kuri, I. Morohashi, A. Kasamatsu, I. Hosako, T. Kawanishi, Y. Yoshida, and K. Kitayama, "30-Gbps-class Terahertz transmission using optical sub-harmonic IQ mixer for backhaul/fronthaul directly connected to optical networks," IEEE 802 Plenary Session, Dallas, USA, doc.: IEEE 802.15-13-0653-00-0thz, Nov. 2013.

[8] A. Kanno, T. Kuri, I. Morohashi, I. Hosako, T. Kawanishi, Y. Yoshida, and K. Kitayama, "Coherent terahertz wireless signal transmission using advanced optical fiber communication technology," submitted to J. Infrared Millimeter-w. Terahertz-w.