30-Gbit/s Wireless Transmission over 10 meters at 300 GHz

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***Abstract*—This paper presents a real-time error-free 30-Gbit/s transmission at over 10-m distance using a 300-GHz-band coherent system. Frequency and phase stabilized carrier signals are photonically generated with use of an optical frequency comb and an integrated optical filter/combiner light-wave circuit.**

I. INTRODUCTION

RECENTLY, there has been a growing interest in the application of terahertz (THz) waves, whose frequencies range from 100 GHz to 1 THz, to ultra-broadband wireless communications [1, 2]. Photonic techniques have been efficiently employed to generate and modulate THz carrier signals. Real-time and error-free transmission experiments have so far been demonstrated at bit rates of 40 Gbit/s and 48 Gbit/s for a single polarization system and a polarization-multiplexed one, respectively, using a photonics-based transmitter and a direct detection receiver at 300 GHz at a typical link distance of 0.5 meters [3].

In order to increase not only the bit rate but also the transmission distance, introduction of coherent techniques for generation and detection of THz carrier signals is effective and practical [4, 5]. In this paper, we will present coherent 300-GHz-band wireless link based on photonics technologies, and demonstrate a real-time and error-free transmission at a bit rate of 30 Gbit/s with a transmission distance of 10 meters.

II. EXPERIMENTAL SETUP

Figure 1 shows a block diagram of 300-GHz-band wireless link. The photonics-based transmitter consists of an optical frequency comb generator (OFCG), an integrated optical filter/combiner and a photodiode module, while the receiver is a sub-harmonic mixer pumped by a local oscillator (LO) signal at 150 GHz.

As for the OFCG, we have used two electro-optic (EO) phase modulators driven by 25-GHz sinusoidal signals to generate sidebands of over 400-GHz width. In our experiment, we have optimized the amplitude and phase of 25-GHz signals applied to each modulator to maximize the intensity of two optical carriers separated at 300 GHz.

As we previously reported the importance of optical carrier-phase stabilization between the optical filter and the combiner in the coherent systems [4], we have integrated an arrayed waveguide grating (AWG) filter and a coupler on the planar silica substrate instead of using optical fiber cables to connect these components. The optical signal is modulated with the optical intensity modulator driven by the pulse pattern generator.

Figure 2 shows the optical spectra measured after the integrated optical filter and combiner without and with the on-off keying (OOK) data modulation, where the frequency separation of the two optical carriers is 300 GHz, corresponding to the wavelength difference of 2.4 nm. Carrier-to-noise ratio exceeds 45 dB, which is enough for an error-free transmission.

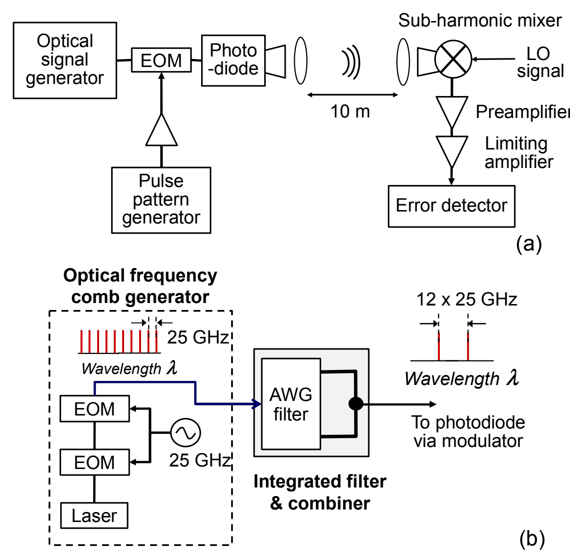

Fig. 1. Experimental set up of 300-GHz-band coherent wireless transmission system. EOM: electro-optic modulator, AWG: arrayed waveguide grating.

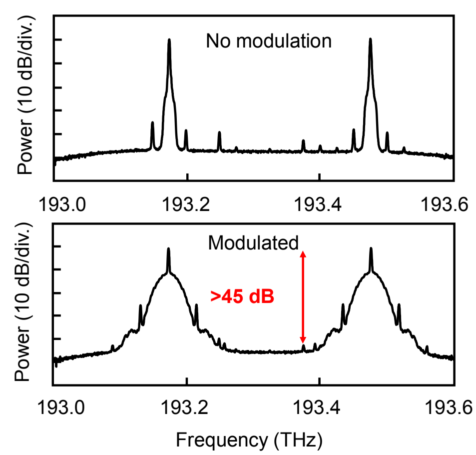

Fig. 2. Optical spectra before the photodiode without modulation (upper), and with OOK modulation (lower).

In the transmission experiment, THz beams are collimated by aspheric Teflon lenses (100-mm diameter) over the link distance of 10 meters. Simulated gain of such a lens antenna structure is 50 dBi. To perform a proper bit-error-rate (BER) testing enabling the clock synchronization between the pulse pattern generator and the BER tester, we constructed a round-trip link configuration as shown in Fig. 3. This is because that an off-line signal processing with a real-time oscilloscope or an A/D converter generally lacks the number of acquisition data, and misses low-frequency fluctuation, leading to possible over-estimation in the bit error rate.

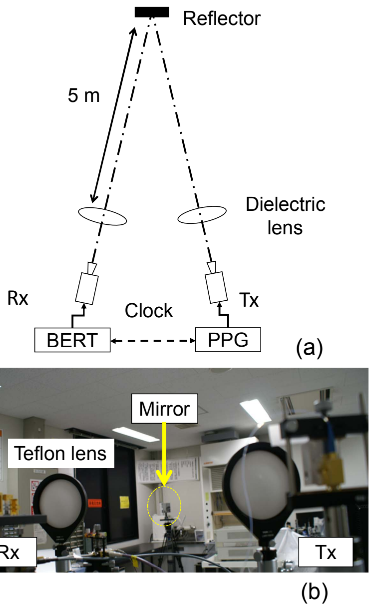

Fig. 3. Experimental set up to perform BER testing of wireless transmission at a distance of 10 m.

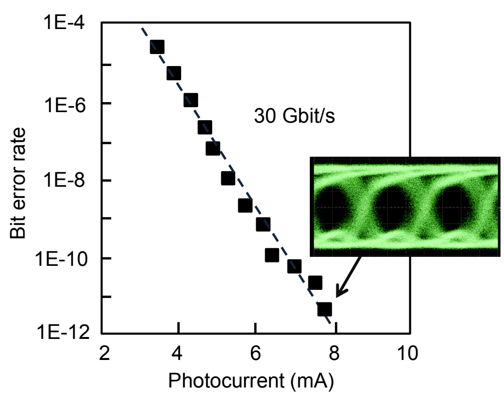

Fig. 4. BER characteristics and an eye diagram showing real-time error-free transmission at 30 Gbit/s.

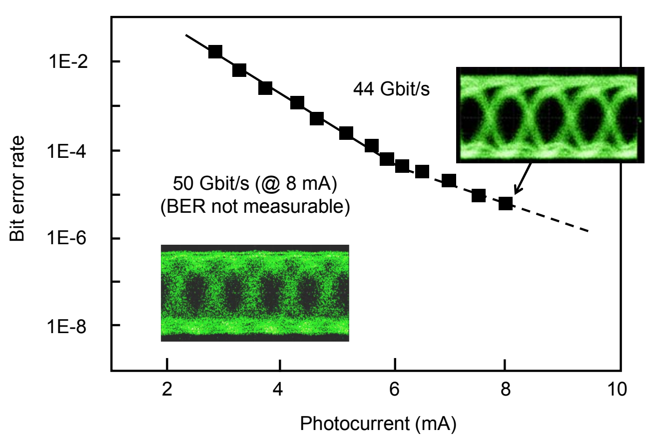

Fig. 5. BER characteristics and eye diagrams at 44 Gbit/s and 50 Gbit/s.

III. RESULTS

Figure 4 shows BER characteristics and an eye diagram at a bit rate of 30 Gbit/s and a link distance of 10 meters. Error-free ($BER<10^{-11}$) performance was confirmed for the photocurrent of ~8 mA, which corresponds to ~90-µW output power of the transmitter.

When we increased the data rate to 44 Gbit/s, the BER characteristics exhibited a gentle decrease against the photocurrent, and the BER was on the order of 10^{-6} at the photocurrent of 8 mA. There are several reasons for this limitation, but the most significant one is considered to be caused by the IF bandwidth of the sub-harmonic mixer. It must be mentioned that the transmitter has an enough bandwidth operating up to the OOK data rate of 50 Gbit/s.

IV. CONCLUSION

We have demonstrated the 300-GHz-band wireless link using a photonics-based coherent transmitter and a heterodyne receiver, and performed a 10-m distance wireless transmission experiment up to the data rate of 50 Gbit/s. Error-free transmission ($BER<10^{-11}$) has been confirmed at 30 Gbit/s. 50-Gbit/s performance will be feasible by improving the bandwidth of the receiver. In our future work, more complicated modulation scheme such as QPSK will be introduced in this coherent system to enhance the data rate.

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