Application of high-speed photonic devices for fiber wireless and optical wireless communications

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***Abstract*—High data rates and low latencies will be indispensable in next generation communication devices. To achieve these targets, the use of wireless communication technology combined with photonics and optics is expected to have significant potential. In this paper, we present the two key high speed photonic devices and their application in advanced fiber and optical wireless communications. Both an integrated device with a 100 GHz uni-travelling carrier photodetector and a 100 GHz pHEMT amplifier, and a two-dimensional photodetector array (2D-PDA) device, are introduced in addition to fiber wireless and optical wireless communication demonstrations.**

Keywords—fiber wireless, optical wireless communications, high speed photodetectors

I. INTRODUCTION

In advanced wireless communications in 5G technology, frequency band allocation can be expanded from the microwave region to the millimeter-wave region (28–40 GHz) and higher frequency using the E-band as a new radio band (5G-NR) is discussed to increase the data rate, connectivity, and decreasing the latency. Moreover, the 100 GHz frequency range including the D-band is a highly attractive frequency band for beyond-5G (B5G) that involves not only a low atmospheric attenuation but also a wider bandwidth compared to those in the microwave region. To mitigate heavy data traffic, a number of small cells have to be implemented for outdoor radio fields or indoor fields. On the other hand, optical-based wireless communication is another good candidate in the advance wireless system in addition to the electric-based radio wireless communication. Both a fiber wireless system based on the analog radio over fiber and an optical wireless system using laser-light beam (Fig. 1) are suitable for satisfying the requirements in B5G.

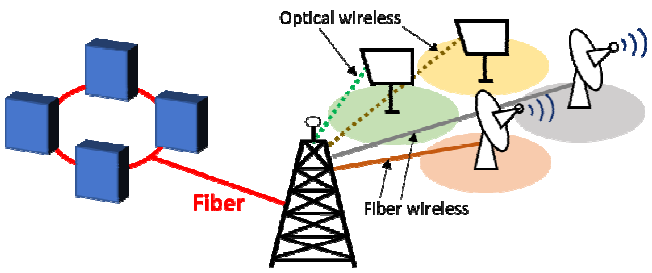

Fig. 1 Optical network connected to radio and optical wireless system

In fiber wireless links (Fig. 2(a)), the low optical power in the fibers will be delivered to the base-station or base-band unit through the optical fibers, owing to the presence of many fiber branches in the small cell system. Therefore, high gain optical to electrical (O/E) converters with a high output are required in the 100 GHz region to preserve high signal-to-noise ratios in wireless communication. Here, a high sensitivity and high output 100 GHz photodetector is an indispensable component in advanced fiber wireless links. An advantage in the system is that the microwave to millimeter-wave signal can be easily transmitted through fiber and it is easy to deliver radio signals to small cells using fiber. Compared to the optical wireless communication, the data rate might not be as high, which is a disadvantage.

Another scenario for the advanced high-speed wireless communication in small cell systems is the use of optical wireless point-to-point communications in free space without fiber cables (Fig. 2(b)). An advantage of the optical wireless systems is that they can achieve high data rates above 50 Gbps/λ, which are comparable to those in fixed fiber communications. A drawback in the wireless link is the optical coupling between a pencil beam laser-light on a transmitter and an optical receiver in a far distance free space.

In this paper, we present high-speed photonic devices fabricated in-house and their application in wireless communications toward B5G.

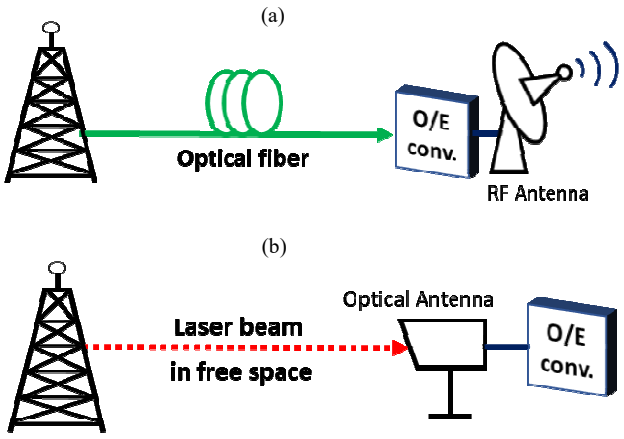

Fig. 2 (a) Configuration of fiber wireless system, and (b) optical wireless system

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II. Overview

A. Fiber wireless using 100 GHz photodetector

We designed and fabricated a 100 GHz-range integrated photoreceiver using both a 100 GHz uni-travelling carrier type photodetector (UTC-PD) and a 100 GHz pHEMT amplifier, which enables a high output power of approximately +10 dBm with a high O/E conversion efficiency. In the UTC-PD design, the carrier concentration, layer thickness, and boundary condition between the layers are well optimized for zero-bias operation. A 20 dB high gain pHEMT amplifier consisted of four gain blocks in the 3 mm x 4 mm chip. In the demonstration, the 12 Gbps (OFDM, 16 QAM) high data rate fiber wireless communication with 90 GHz carrier frequency is presented using the integrated 100 GHz photoreceiver [1].

B. Optical wireless using photodetector array

A two-dimensional multi-pixel type photodetector array device was designed for free space optics (FSO) beam direct detection with a high optical alignment robustness. A 6 × 6 square shaped alignment layout was adopted, and a total pixel number of 32 including the elimination of four corner pixels enabled photodetection for a large area of 250 μm × 250 μm. (3 dB bandwidth of 11.2 GHz, responsivity of 0.35 A/W). The high data rate optical wireless demonstration at 100 Gbps was presented using the wavelength division multiplexing technique [2], and a 40 Gbps high data rate could be achieved by a maximum ratio combing technique in space diversity [3] using multi-output signals in the PD array.

Acknowledgment

This research was conducted in part under the contract "R&D of high-speed THz communication based on radio and optical direct conversion" (JPJ000254) in conjunction with the Ministry of Internal Affairs and Communications of Japan. We thank all technical staff in the photonic device laboratory at NICT.

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