1Tb/s Intradyne Coherent Receiver for Optical Fiber Transmission over 100km

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***Abstract*—Intradyne coherent receivers that incorporate hybrid integration of InP-based high-speed waveguide photodiode array chips and polarization multiplexed optical hybrids for coherent detection have been implemented, achieving 1 Tb/s optical fiber transmission over a distance of 100 km.**

***Index Terms*—Coherent receiver, photodiode, silicon photonics, and optical fiber transmission.**

I. Introduction

In recent years, coherent optical detection-based optical transceiver technology has emerged as a next-generation solution to address the rapidly increasing demands of data traffic. This advancement is driven by the proliferation of AI services and diverse streaming platforms, which has significantly increased the need for scalable data center infrastructures. Thus, extensive research and development efforts are being dedicated to optimizing coherent optical transmission technology for high-efficiency data handling and future-proof network architectures. Data center interconnect links that once operated at 100 and 200 Gb/s are now being upgraded to a coherent optical transceiver of 400 and 800 Gb/s to handle the torrent of data and accommodate the continuous addition of new data centers and the expansion of existing ones [1]. Coherent optical transmission technology is expected to contribute significantly to the future development of Passive Optical Networks (PONs) by enhancing their performance and capabilities [2]. Coherent optical communication technology offers significant advantages when applied to low-earth orbit satellite communication and free-space optical communication, primarily by overcoming the limitations of traditional intensity modulation and direct detection. The key benefits are enhanced sensitivity, improved spectral efficiency, and robustness against atmospheric and channel disturbances [3]. In particular, the increasing demand for huge capacity data transfer in data centers is projected to require transmission rates of up to terabits per second (Tb/s) to support emerging AI workloads and hyperscale computing applications.

In previous work, we fabricated InP-based waveguide photodiode array chips and planar lightwave circuits (PLCs) including 90° optical hybrids (OHs) and polarization beam splitters (PBSs) and implemented intradyne coherent receivers (ICRs) at 800 Gb/s with hybrid integration to minimize polarization-dependent loss and improve chip-to-chip coupling efficiency into the photodiodes from the PLC. In this study, we demonstrated 1 Tbps optical fiber transmission over a distance of 100 km using the ICRs at rates of more than 80 GBaud of 64-QAM with polarization multiplexed division (PMD).

II. Optical Components

A. Balanced photodiodes

High-speed balanced photodiodes are crucial in coherent optical transceivers because they enable a process called coherent detection. Unlike a standard photodiode that measures the intensity of an incoming signal, a balanced photodiode measures the interference between two light signals, which is the cornerstone of coherent reception. Based on our previous works [4], [5], we fabricated InP-based WG-PD array chips up to a 3dB bandwidth of 70 GHz [6] with the absorber thickness reduced to 150 nm and the InGaAsP graded layer was inserted between the absorber and the p-InP cladding layer, the 3dB bandwidth of more than 60 GHz was achieved due to reduced resistivity, as shown in Fig. 1.

B. Hybrid integration

Planar lightwave circuits (PLCs) are highly useful for coherent optical transceivers because they allow for the miniaturization and integration of multiple optical components onto a single chip. This approach addresses the size, cost, and complexity challenges of building high-performance coherent systems [6], [7]. We used Silica PLCs designed to be 6-μm-thick and 6-μm-wide cross-section which is suitable for coupling into standard optical fibers and chip-to-chip integration, as shown in Fig. 2. Here, a variable optical attenuator, OHs, and PBSs have been monolithically integrated in the silica PLC.

C. Coherent optical transmission

We demonstrated hybrid-intrated ICRs and evaluated optical fiber transmission over 100 km up to 1 Tb/s as shown in Fig. 3. Arbitrary Waveform Generator (AWG) was used to create the complex electrical signals that modulate the laser and was programmed to generate a high-speed, multi-level signal corresponding to the chosen modulation format of 64-QAM at more than 80 GBuad for 1 Tb/s. We used a 100 km fiber spool to simulate different transmission distances and evaluate how the signal degrades due to chromatic dispersion and other fiber impairments. A high-speed real-time oscilloscope was used to

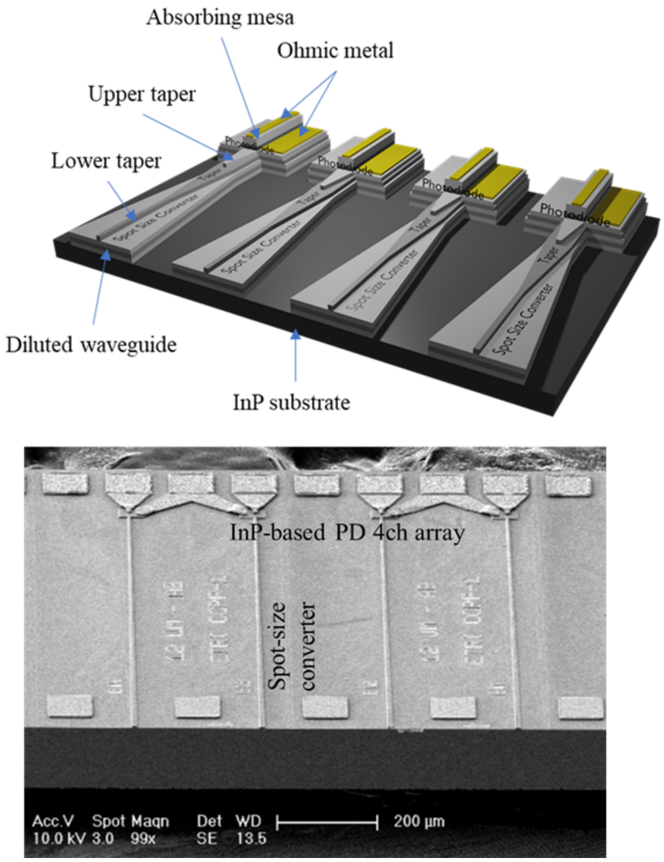

Fig. 1. Fabricated WG-PD array chip.

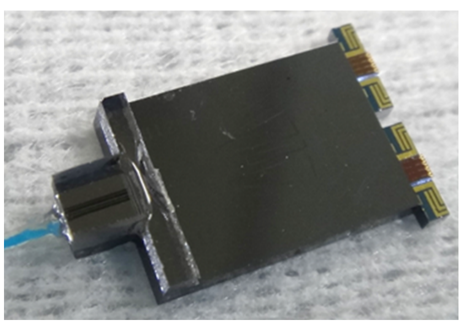

Fig. 2. Hybrid-integration of the WG-PD array chip and the PLC chip.

capture the electrical output from the balanced photodiode. The raw electrical data captured by the oscilloscope is processed by the off-line DSP that performs complex algorithms for clock and carrier recovery, dispersion compensation, and polarization demultiplexing to reconstruct the original data.

III. Conclusions

We have fabricated ICRs with hybrid integration of InP-based photodiode array chips and silica-based PCL including OHs and PBSs for receiving PDM-QAM signals. As a result, the ICR demonstrated coherent optical transmission over 100km at a rate per wavelength of 1 Tb/s.

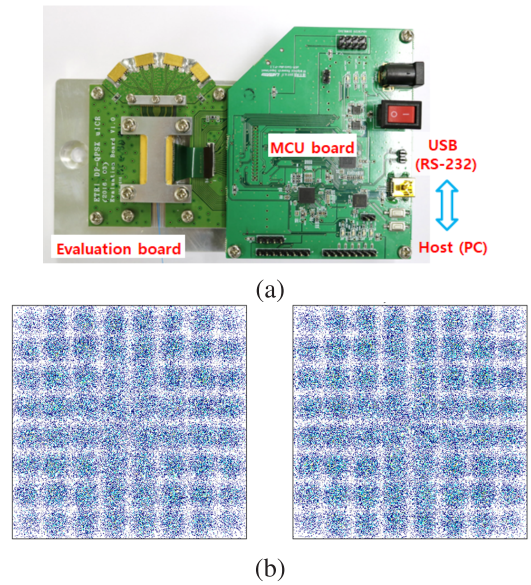

Fig. 3. Fabricated ICR with the control board (a) and measured constellations of X and Y polarizations at 1 Tb/s (b).

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