Misalignment Tolerance Analysis and Fabrication for High-Efficient Parallel Optical-Electrical Convertor Module

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Abstract **– A compact, high-efficient, and passively assembled parallel optical-electrical convertor module (POECM) for active optical cable application is proposed. This paper presents our structure of POECM, optical design simulation results, fabrication, and data transmission test results, in sequence. We confirmed data rate of total throughput 21.6 Gbps (5.4 Gbps x 4 channels).**

I. INTRODUCTION

Currently, huge data transmission performance between storage equipment and servers in data center has been required because of rapidly increasing of internet data traffic, such as, e-mail, cloud, and multi-media service [1]. The emergence of high definition television and higher speed PC interface also needs the new interconnection to substitute for existing electrical interface cables. As an alternative technology of it, active optical cables based on various optical modules have been recently developed [1]-[4].

II. DESIGN OF PARALLEL OPTICAL-ELECTRICAL CONVERTOR MODULE

We suggest a parallel optical-electrical convertor module (POECM) capable of high speed data transmission, passive assembly, and high-efficient optical coupling. The convertor is composed of a transmitter chip, a receiver chip, a vertical-cavity surface-emitting laser (VCSEL) array, a photodiode (PD), a submount, a right angled microlens array (RAMA) with precise guide holes, a MT ferrule including multi-mode fibers (MMFs) and guide pins, a printed circuit board (PCB), and so on, as shown in Fig. 1. The transmitter and receiver chips with high speed performance over 5 Gbps/channel were used to drive the 4 channels VCSEL array and to amplify the photo-current from the 4 channels PD array, respectively. These chips were die-bonded on the carefully designed PCB and were wire-bonded with the VCSEL and PD array as well as signal lines on the PCB in order to connect directly high speed electrical signals. Meanwhile, the convertor was passively assembled through installing the microlens and the MT ferrule after mounting two fine polished balls on the guide holes of the submount, in sequence.

This paper focuses on the optical design, instead of electrical design and packaging issues. To analyze the optical coupling structure of it in detail, a simplified optical coupling schematic and 3 dimensional ray-optic simulation result from *Lighttools* are shown in Fig. 2. The diverged beam from the VCSEL converts to a parallel beam by the bottom lens after passing through D1 distance on Z axis. The parallel beam is totally reflected on the 45^{o}-angled facet. The reflected beam is focused by the side lens and is coupled into the MMF after passing through D2 distance on Y axis. On the other hand, the coupling procedure at the receiver part is in reverse order of transmitter part, as shown in Fig. 2 (b).

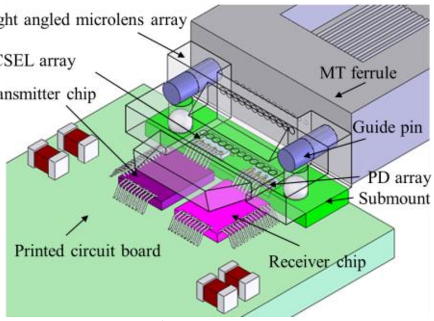
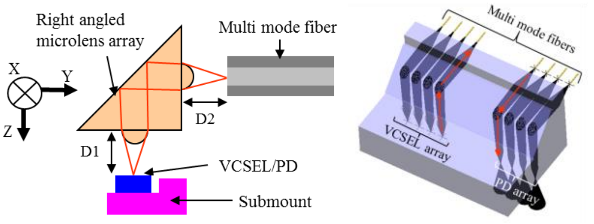


Fig. 1. Detailed schematic of our parallel optical-electrical convertor module.

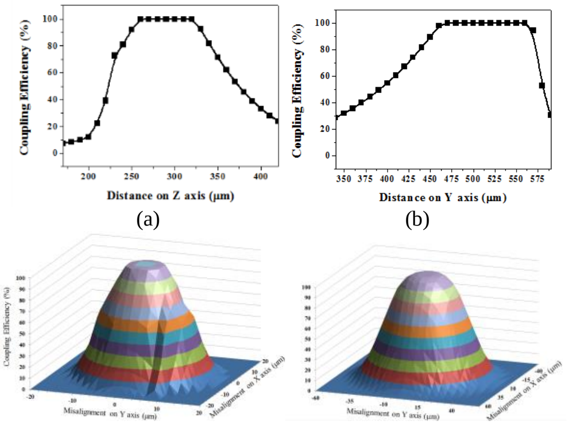


(a) (b)

Fig. 2. Drawings of (a) an optical coupling schematic and (b) ray-optic simulation result.

III. COUPLING EFFICIENCY AND MISALIGNMENT TOLERANCE SIMULATION

We simulated the coupling efficiency (CE) and analyzed the misalignment tolerance in order to find the optimal alignment position of the VCSEL and PD array. Figure 3 shows these simulation results. First, the maximum CE in vertical direction of the optical elements are obtained at about 300 μm as the best VCSEL's distance (D1) on Z axis and at about 500 μm as the best MMF's distance (D2) on Y axis, as shown in Fig. 3 (a) and (b), respectively. We already know that the optimal position of the horizontal direction is where the optical axis of the lens is matched. But, misalignment tolerance analysis on the horizontal plane was conducted because it offers important guide lines about bonding accuracy during die-bonding the VCSEL and PD on the submount.



(a) (b)

(c) (d)

Fig. 3. Simulated results of (a) CE along VCSEL's distance on Z axis, (b) CE along MMF's distance on Y axis, (c) CE versus VCSEL's misalignment on X and Y axis, and (d) CE versus PD's misalignment on X and Y axis.

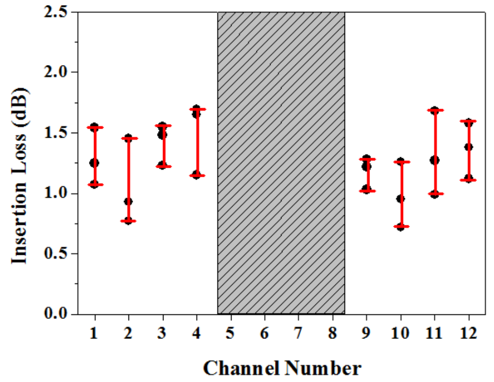


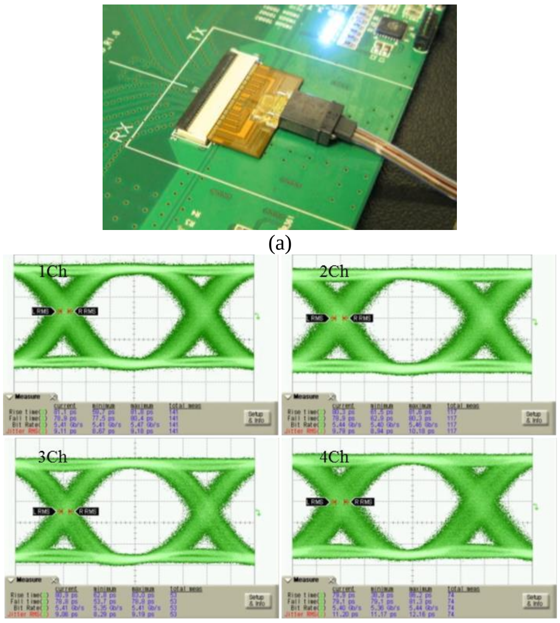
Fig. 4. Measured result of insertion loss per channel (channel 1 ~ 4 : transmitter region, channel 9 ~ 12 : receiver region, and channel 5 ~ 8 : empty region).

According to Fig. 3 (c) and (d), 1 dB misalignment tolerances of the VCSEL and PD array were simulated as ±8 μm and ±16 μm, respectively. Thus, we concluded that the VCSEL and PD array should be accurately bonded below about ±10 μm.

Like above simulated results, finding the optimal position and tolerance does not need to consider the material loss, the surface roughness, and reflectance of the RAMA. But, insertion loss (IL) measurement should be required to obtain real coupling efficiency. Thus, we measured the ILs, as shown in Fig. 4. Average IL and standard deviation in the transmitter region were measured as low 1.31 dB and 0.293 dB, respectively. And, average IL and standard deviation in the receiver region were measured as low 1.2 dB and 0.268 dB, respectively. Therefore, we can confirm the high coupling efficiency more than 75% of the POECM.

IV. FABRICATION OF PARALLEL OPTICAL-ELECTRICAL CONVERTOR MODULE

As the structure illustrated in Section II, we passively assembled each component of the POECM after accurately bonding the VCSEL and PD array on the submount under the guide line described in Section III.



(a)

(b)

Fig. 5. Photograph of (a) the fabricated parallel optical-electrical convertor module and (b) measured eye diagrams of each channel at 5.4 Gbps data rate.

Figure 5 (a) shows the completed POECM installed on the evaluation board.

To verify the high speed data transmission performance of our POECM, we measured eye diagrams of each channel, as shown in Fig. 5 (b) and confirmed the error free condition at 5.4 Gbps data rate.

V. CONCLUSION

In summary, the proposed compact structure of our POECM, the optimal optical design, and the data transmission performance are presented in this paper.

We expect that it will be a key component in active optical cable application. The POECM can be applicable at various interface optical modules, such as Infiniband, High Definition Multimedia Interface (HDMI), and DisplayPort (DP), etc.

ACKNOWLEDGMENT

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