2020
Annual Report

Opto-Electronics Laboratory
(Prof. Hamamoto Group)

Applied Science for Electronics and Materials Interdisciplinary
Graduate School of Engineering Sciences,

Kyushu University

High-light 2020

We made a certain progress about the research and development of photonic integrated circuit toward breath sensing even under the COVID circumstance. We made further investigation in optical amplifier assist CRDS waveguide sensing, and clarified the impact of the noise influence. We made it in oral presentation at OSA Sensor Congress 2020 (on-line). As to photonic integrated circuit configuration, especially polarization rotator, asymmetric power splitter, and spot-size converter are the keys for it and thus we have newly designed them based on nano-pixel technology. We report the results of them at OECC 2020 (Taiwan) via on-line. Presently we are on the way of the actual implementation toward system demonstration at final FY.

High speed direct modulation has been hard to try further experiment due to the restrictions of COVID. For this reason, we mainly research about the theoretical model of the phenomena, as a basis of future 1 Tbps direct modulation.

And, 3D waveguide fabrication has just being re-started, and fundamental work of it was employed. We plan to introduce AI technology in it presently.

Besides, one new doctor (Dr. Wenying Li) has come out from our laboratory on 2020.

On 2020, we run the following 3 topics. Please see the following pages in detail.

1. Optical sensing by using photonic integrated circuit
2. High speed mode selective light source by using active-MMI laser diode
3. Mode multiplexing device

Asymmetric-ration Optical Power Couplers Based on Nano-Pixel Structure

Yu Han, Wenying Li, Zanhui Chen, Leiyun Wang, Haisong Jiang, Kiichi Hamamoto

Photonic breath sensing chip requires compact and high performance asymmetric-ration optical power couplers [1]. Although couplers with an output power ratio 1:1 have been widely studied in the past, constructing asymmetric-ration optical power couplers is still an issue. Artificial intelligence (AI) assisted design is an effective technique for realizing complex optical structures. We have designed asymmetric-ration optical power couplers by using AI assisted design [2, 3]. Two couplers with the targeted splitting power ratio as 1:9 and 1:99 have been designed as shown in Fig. 1. The performance of the devices have been confirmed by using finite-difference time-domain method as shown in Fig. 2. The devices have excess optical loss lower than 0.5 dB. The achieved design also exhibited wide operation wavelength ranging from 1500-1600 nm in addition to sufficient fabrication tolerance of ±10 nm (± 11%).

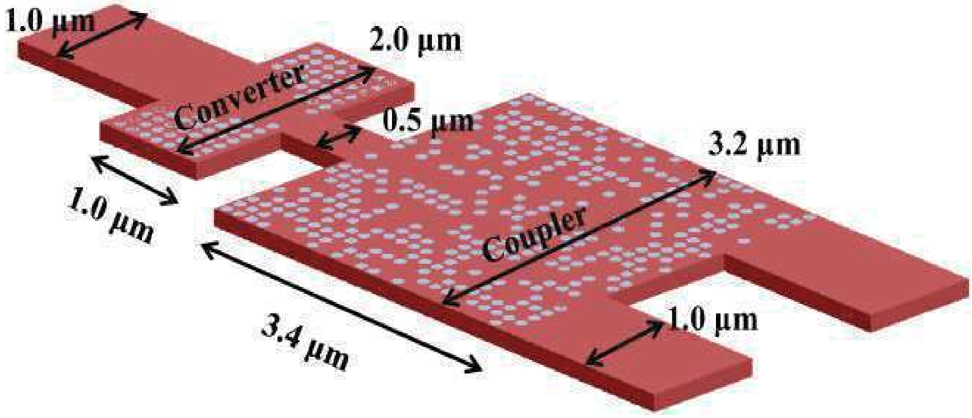
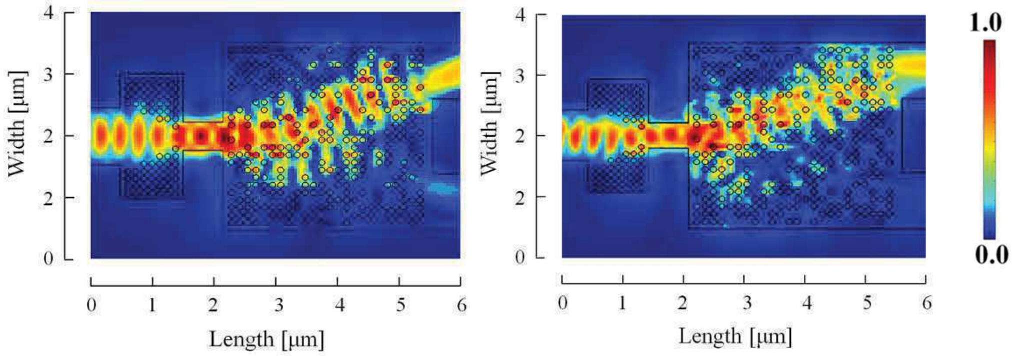


Fig. 1 Schematic of the couplers



(a) (b)

Fig. 2 Simulated light propagation in (a) 1:9 and (b) 1:99 coupler at the wavelength of 1550 nm

【References】

[1] W. Li, Y. Han, et. al., Jpn. J. Appl. Phys. 58, SJJD01, 2019.
[2] Yu Han, et. al., .OECC 2020, T6-2, October 2020.
[3] Yu Han, et. al., OSA continuum 4(2), 556, 2021

Proposal of photon-photon resonance control scheme on active-MMI laser diode

He Xiao, Keiichiro Shoda, Keiichiro Koudu, Haisong Jiang, and Kiichi Hamamoto

Optical inter-connection is highly developd due to computer technology. And the direct modulation laser diode (DML) might the one of the transmitter candidites especially for futere mobile IT devices because of its merits of low energy comsumption and small size. However, the modulation speed of DML has been limited by the CPR phenomenon. In order to overcome this problem, we design the the 3×1 active-MMI laser diode [1, 2] , as shown in fig.1 to utilize the Photon-Photon resonance phenomenon to extend the modulation bandwidth.

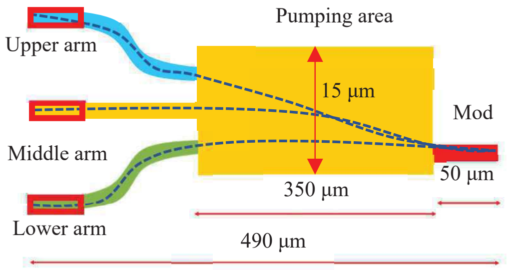


Fig.1 Schematic example of active-MMI laser diode

Because of the stucture of active-MMI laser diode which consists of muliti arms, it is not only used to exploit the PPR phenomenon but also can be used to control the position of the PPR. As shown in fig.2, we keep the current charge in middle arm, lower arm and the pumping area as 55mA, 57mA, and 172mA and change the current injection in upper arm from 34mA-49mA in the step of 3 mA. And we can see that the PPR is shifted with the current change.

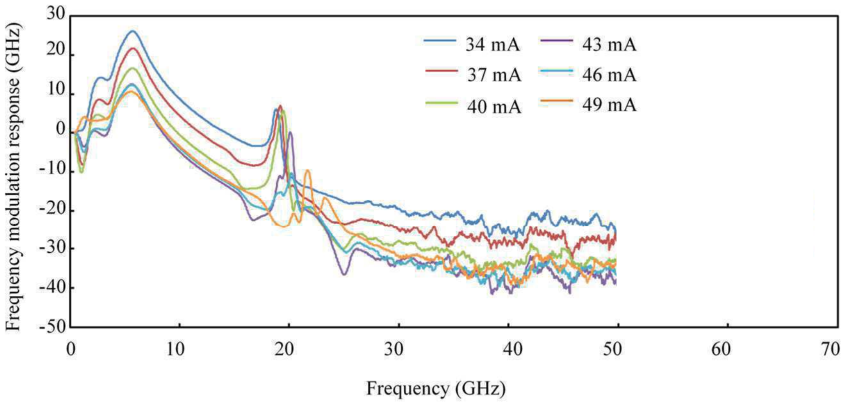


Fig. 2 Small signal response of the fabricated active-MMI LD

By changing the current injection into arms, the peak position of the PPR can be can be controled, which provide a methode for us to extend the modulation bandwidth by shifting it away from the CPR or close to the CPR to filling the damping between the CPR and it.

Reference

[1] B Hong, et al, Tech. Dig. OFC., TH3B.4. (2018).
[2] S Murakami, et al, Tech. Dig. MOC., G-4. (2019).

Single-Dimensional Multiplexer Using Nano-pixel Structure for High-density and Flexible Mode-Multiplexing System

Yunjie Wang, Haisong Jiang

Along with the Network Communications developing, the amount of network data-traffic keeps growing sharply. The data-traffic in the data center has been rapidly increasing especially. A lot of researchers are focused on the problem of the power consumption due to data-traffic increasing. Linearly polarized (LP) mode based multiplexing has been widely used in SDM long distance transmission experiments. But because of the mode degeneration and mode crosstalk, it's hard to realize more than 100 modes multiplexing, and required MIMO (multi-in multi-out) processing, which causes the Time-delay trouble in data-center. Several types of de-multiplexer have been made but, the maxim modes multiplicity of them is around 10 modes, which not enable making problem resolved substantially. As one way to overcome these issues, one possible solution is realizing Spatial multiplexing transmission in data center. To realize high modes multiplexing and high integration in the non-MIMO multimode transmission, we have studied a phase control type single-dimensional spatial mode de-multiplexer based on slab waveguide. The performance of the slab waveguide for single dimensional spatial mode is investigated in this work. With the support of the Python, and the algorithms in MOST module of RSOFT software, now it realizes continuously analyzing and relearning the internal structure of the slab waveguide, so as to continuously improve the structure in terms of data. Adjust the equipment experimentally to realize the ideal fabrication of coupling waveguides and limit size of the air hole exploration.

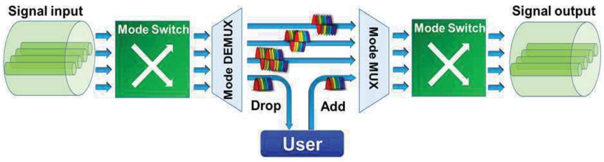


Fig. 1. the schematic of Mode-division Multiplexing

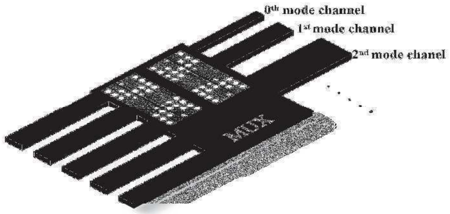


Fig. 2. Mode-division Multiplexer

Figure 2 shows the schematic of the light selective mode of de-multiplexer, which also is regarded as the slab waveguide region. Figure 3 shows the deep learning process and optimized Nano-pixel structure. To achieve this, the results of each simulation will import the data in Excel form into Python, combined the program to change the structure of the internal air hole, and then calculate the processed data group with MOST(Multi-Variable Optimization and Scanning Tool) module of RSOFT, finally get a good structural condition after repeated simulations.

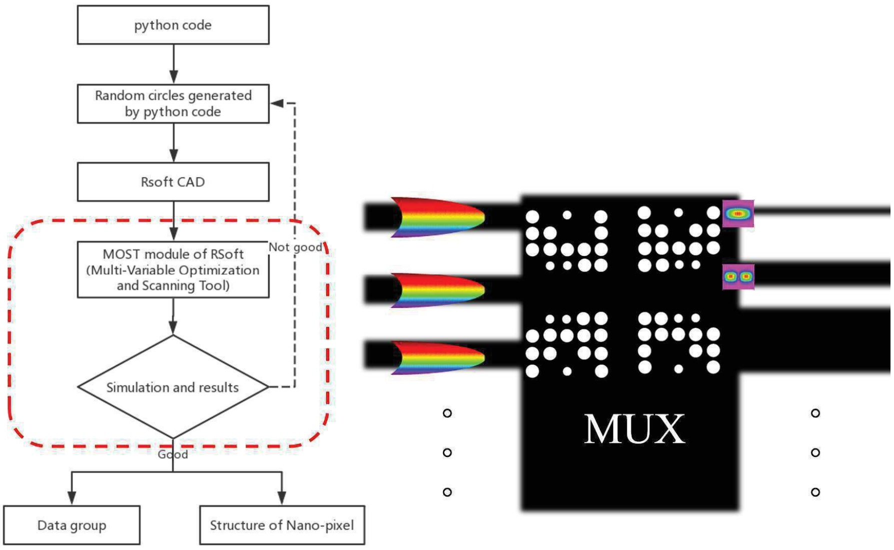


Fig. 3. the deep learning process and optimized Nano-pixel structure

Research on 3D waveguide fabrication technology for connection with multi-core-arranged fiber

Keisuke Iwasaki Shun Matsubara Jiang Haisong Kiichi Hamamoto

Multi-core-arranged fiber (MCF) is highly researched and developed to increase the transmission capacity per optical fiber. The purpose of this work is to connect the MCF and the optical mode switch [1], that our laboratory is developing, and we propose a connection method using a 3D waveguide (Fig. 1).

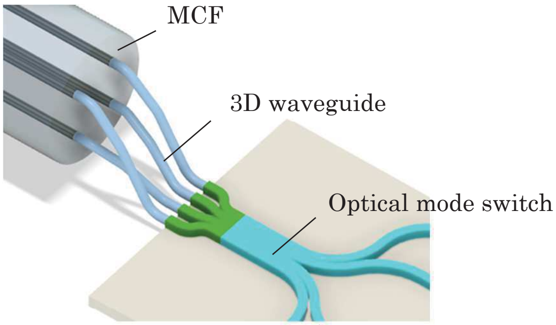


Fig.1 3D waveguide

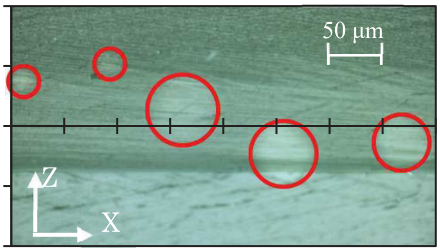


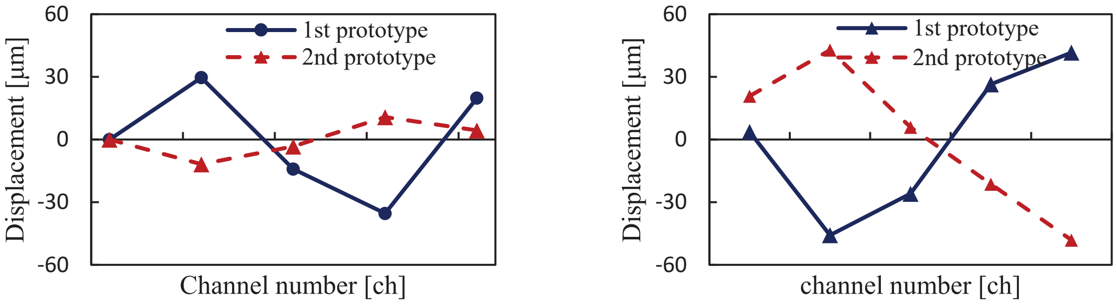
Fig.2 Cross section of the first waveguide

The 3D waveguide means the waveguide where cores are freely arranged in a lateral and perpendicular direction, and this is the technology for connecting the outputs of multiple optical mode switches arranged in a lateral direction and the core position of the MCF directly. However, optical axis alignment is a problem in optical connection technology, and its accuracy is required to be 1 μm or less [2].

We have focused on the mosquito method as a fabrication method for 3D waveguide and developed 3D waveguide fabrication machine. The fabrication machine consists of a stepping motor and a reed screw, and the expected mechanical resolution is 0.78 μm.

However, there was a misalignment of about 26 μm in the X direction and about 32 μm in the Z direction on the cross section of the first prototype waveguide, and the misalignment of the waveguide was a problem (Fig.2).

To verify the reason, we improved the method of fixing the syringe and needle used to discharge the core monomer. As a result, it was clarified that the misalignment in the X direction was reduced by 18 μm (Fig.3).



(a) (b)

Fig.3 Displacement of core position. (a) X-direction (b) Z-direction

【References】
[1] Kiichi Hamamoto et al, IEICE Elec., J100-C, 72 (2017).
[2] J. R. Stern and R. B. Dyott, Electron. Lett. , 7, 52 (1971).
[3] K. Yasuhara et al, Optics Express, 25, 8524 (2017).

Optical mode switch group

Zhang Jin

Recently, the data center IP traffic is getting higher and higher. In order to cope with the growing communication traffic to or from data center, we have proposed mode-division-multiplexing system using single dimensional mode-set to realize low power consumption and flexible reconfigurable network [1]-[3]. In this system, optical mode switch is one of the key-device. We have already proposed the 2×2 optical mode switch and demonstrated the fundamental element of it [4]-[7]. To realize much higher mode switch, we have proposed 1×N switch based on single dimensional mode-set as shown in figure1 [8].

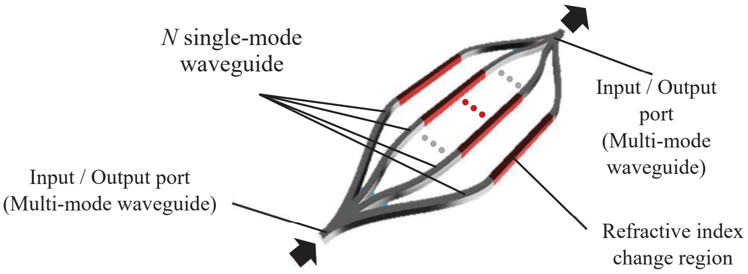


Fig.1 Proposed 1×N switch

But the feasibility of 1×4 mode optical switch was not yet reported. And it is necessary to confirm the performance of 1×4 mode optical switch in order to realize the higher mode evolution.

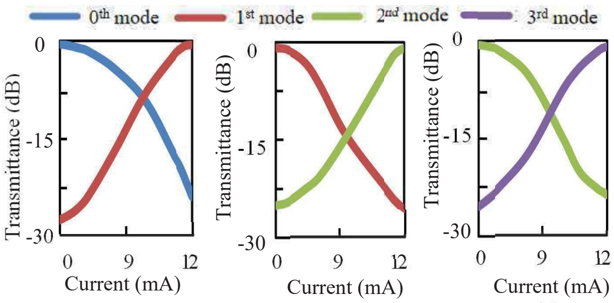
Calculation results of the internal loss[dB] of 1×4 optical mode switch is shown in table1. The vertical axis shows the input mode, and the horizontal axis shows the output mode. The internal loss is expressed by the formula:

$$L_m = 10 \log \frac{P_o}{P_i} \quad [\mathrm{dB}] \qquad (1)$$

Table 1 Calculation results of the internal loss[dB] of 1×4 optical mode switch. The vertical axis shows the input mode, and the horizontal axis shows the output mode.

	0th	1st	2nd	3rd
0th	-0.057	-0.062	-1.008	-0.947
1st	-0.062	-0.824	-0.057	-1.14
2nd	-1.008	-0.057	-1.0	-0.057
3rd	-0.947	-1.14	-0.057	-0.905

According to the results, it was confirmed that the internal loss was about -1 dB. And the transmittance for 1×4 optical mode switch is shown in figure 4.



(a) (b) (c)

Fig.4 Transmittance for 1×4 optical mode switch
(a) 0th mode is switched to 1st mode (b) 1st mode is switched to 2nd mode (c) 2nd mode is switched to 3rd mode

【References】

[1] K.I.Sato et. al., IEEE/OSA, A81-A93, (2009).
[2] Y. Xiong et. al, optica, 1098-1102, (2017).
[3] S. Ogawa et. al., (OECC)/PS2019, ThE105-106, (2019).