

2014
Annual Report

Opto-Electronics Laboratory
(Prof. Hamamoto Group)

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

High-light 2014

A New staff member, Assistant Professor Haisong Jiang, has joined into our laboratory since April 2014. Optical mode switch was invited at two international conference (ECIO-MOC 2014 (Nice, France), and PS / APC 2014 (San Diego, USA). A new precise mask-aligner has been installed which is expected to contribute to high resolution mask aligning. On this year, we have started new idea, that is called advanced-OAM. This idea is to realize unlimited ch number on MCF theoretically, and thus the fundamental principle has been proposed in domestic as well as international conferences. On the year of 2014, a new doctor was born, and the total amount counts up 8 doctors through this laboratory.

We have research the following 5 topics on the year. For more detail, please see the each topic page.

1. Optical sensing by using photonic integrated circuit
2. Active-MMI laser diode
3. Optical mode switch
4. Higher order mode light source
5. Advanced OAM mode device

Gas sensing using silica high-mesa waveguide

W-Y Li, H. Hokazono, Haisong Jiang and K. Hamamoto

Population aging arises the requirement of health management. This may lead to the desire of compact health-check system that is used for daily health. Breath sensing system is attractive because human-breath contains various disease-markers. Sensing using waveguide^[1-2] is one of the way to realize compact breath sensing system, and high-mesa waveguide can be used for breath sensing (gas sensing in human breath) owing to its unique structure of that core can contact to the outside gas. Fig. 1 shows the structure of high-mesa waveguide. When light propagates inside of the waveguide, a certain portion of the light profiles out from the waveguide which is utilized for gas absorption^[3].

Experiment system is shown in Fig.2. In the cycle loop, silica high-mesa waveguide (4.5cm length) is set in a hermetic chamber with CO₂ inside. The waveguide is pigtailed with standard fibers at the both facets. When a pulse light of 4ns pulse-width is injected into the cycle loop, 99:1 coupler depicts 1% of light power, and thus this power is evaluated at the oscilloscope. This system works like cavity ring down^[5] as the optical power decreases as the propagation light experiences higher cycle, and the gas concentration is evaluated by the decreasing time of the pulse light.

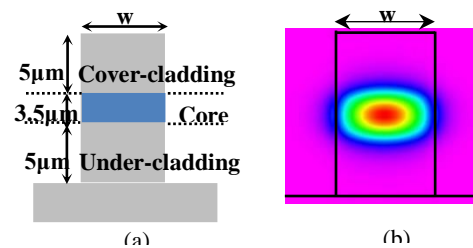


Fig.1 High-mesa waveguide. (a) Schematic cross section, (b) simulated

Fig. 3 shows waveforms we got at different concentration of CO₂. As shown in the figure, light intensity decreases much faster as CO₂ concentration decreases. This result proves clearly that gas absorption happened by using silica high-mesa waveguide. The absolute CO₂ concentration was estimated by using 1/e decay time (i. e., cavity ring down time) with comparison to “without CO₂” condition. The cavity ring-down times were estimated to be $\tau_g = 13.6\mu s$ for the case of 50% concentration of CO₂ and $\tau = 14.8\mu s$ for the case without CO₂, respectively. By using these cavity ring-down times, we estimated that the concentration was to be 46% that was similar to 50%.

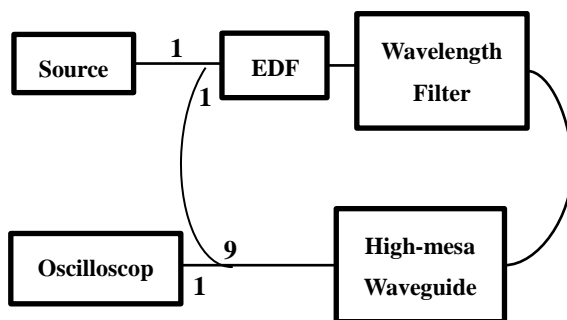


Fig.2 Experiment system based on CRDS system

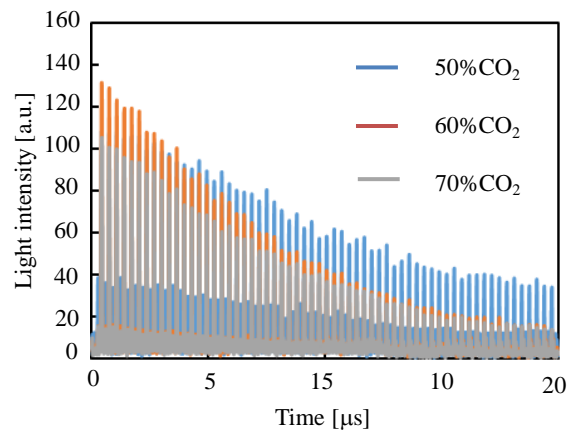


Fig. 3 CO₂ (50-70%) gas sensing

Reference

- [1] A. Wilk et al., Anal. Bioanal. Chem., Vol. 402, Issue 1, pp. 397-404 (2012).
- [2] S. Yano et al., Con. Proc. IPNRA, IWA7, 2007.
- [3] P. Zalicki et al., J. Chem. Phys., Vol. 102, Issue 7, pp. 2708-2717 (1995).

High Bandwidth Active MMI-LD for High Speed Communication Application Using Split Pump Scheme

Mohammad Nasir Uddin, Hong Bingzhou, Takuya Kitano, Haisong Jiang and Kiichi Hamamoto

Laser diode capable of high speed direct modulation is one of the key solution for short distance applications due to their low power consumption, low cost and small size features. Realization of high modulation bandwidth for direct modulated laser maintaining the above mentioned feature is needed to enhance the short distance, low cost data transmission. One of the promising approach is to push the carrier photon resonance (CPR) frequency by boosting up the photon density in modulation section and enhance it further by inducing resonance between two spectrally neighbored longitudinal modes of the laser cavity, generally known as photon photon-photon resonance (PPR). Strong secondary resonance peak in the modulation response, introduced by PPR results a significantly higher 3dB bandwidth. Moreover further enhancement is achieved by introducing a second resonance peak in modulation response, occasioned by the interaction of spectrally neighbored longitudinal mode inside the multimode section of MMI-LD cavity. Because of these enhanced dynamics owing to enhanced photon density and advantage of having multimode section to explore PPR in active MMI-LD, we have been able to successfully confirm a significantly wide direct modulation bandwidth of 15.2 GHz and shown in fig. 4. Aforementioned enhancement is almost double then the last reported direct modulation bandwidth of 8 GHz. Moreover, the advantage of having large multimode active pumping section behind the splitted modulation section is the key contributor for having higher photon density in modulation section without increasing the device length. Required photon density to achieve more than 40 GHz 3 dB bandwidth for direct modulation is also clarified for the future high speed design [2] in fig. 2 The relation between the mode separation and PPR frequency is presented as mode separation function of the lateral mode locked longitudinal mode in figure 7.

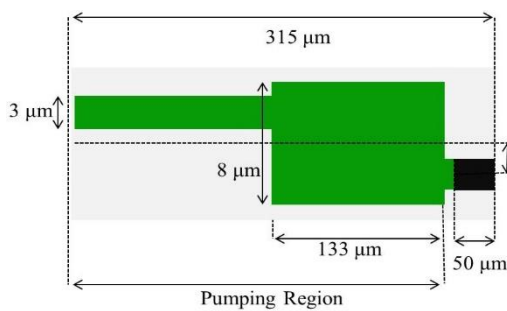


Fig. 1. Schematic view of active MMI-LD.

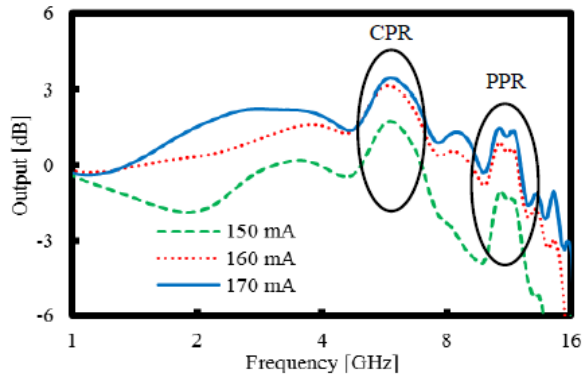


Fig. 2. Bias dependent small signal modulation response of split pump active MMI-LD.

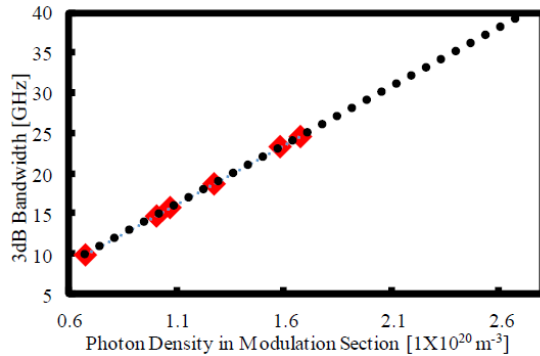


Fig. 3. Eye diagram 2.5 Gbps (Back to Back).

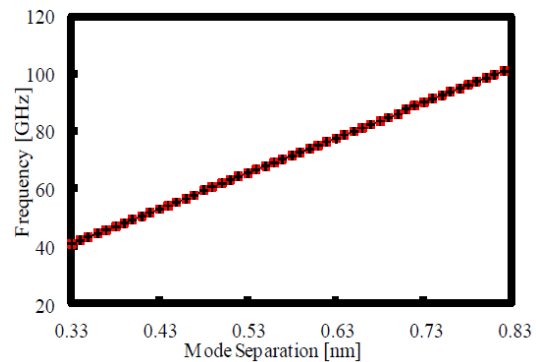


Fig. 4. PPR frequency as a function of mode separation.

References

- [1] M. N. Uddin, et.al., ECIO-MOC – 2014. [2] M. N. Uddin, et.al., JJAP - 2014

Optical Mode Switch

Ryan Imansyah, Luke Himbele, Tatsushi Tanaka, Haisong Jiang and Kiichi Hamamoto

We compared the optical space switch and proposed the optical mode switch which can reduce the chip size^[1-3]. In order to verify the basic operation principle of the optical mode switch, cross state device is represented with a different arm length corresponding to the refractive index shift and bar state is represented by symmetrical arm length, as it is shown in Fig. 1 (b) and Fig. 1(c) respectively^[3]. Fig. 1 (a) shows the schematic diagram of an optical mode switch. By injecting the current into the phase shift region we can control the refractive index of that arm and make a π phase difference of the optical signals from the two arms. The different arm length replaced this condition, just simply to get the same result when we inject the current to optical mode switch device.

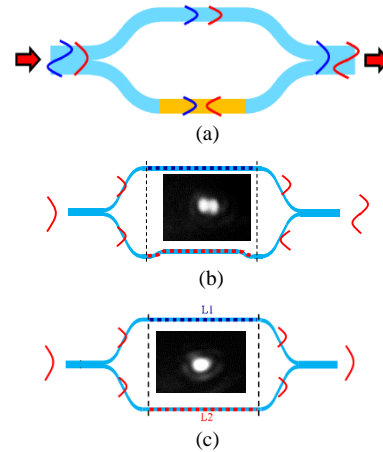


Fig. 1. Schematic concept of (a) optical mode switch, (b) different arm length device and (c) symmetrical arm length device.

In order to verify the potential mode crosstalk of the optical mode switch, we also fabricated and integrated mode filter with the optical mode switch. To filtering the fundamental mode and 1st order mode, we use the simple 1×3 symmetrical rectangular shape of MMI device that is shown in the Fig. 2.

Fig. 3 shows the simulation and experimental result that is shown as solid line and dash line respectively. For the bar-state where the ΔN is 0, the estimated crosstalk was approximately -12 dB for TE mode and -11 dB for TM mode, while the theoretical result that was shown as solid lines showed the same crosstalk between TE and TM. For the cross-state, it was realized at $\Delta N = 0.004$ as it was shown as a dashed lines in Fig. 3, this result matched well with the theoretical result. The estimated crosstalk of cross-state was approximately -10dB for both transverse electric (TE) and transverse magnetic (TM) modes at exactly same ΔN . This value is not sufficient for the practical use, however, there is a possibility that the best point may exit at slightly different ΔN of bellow 0.004.

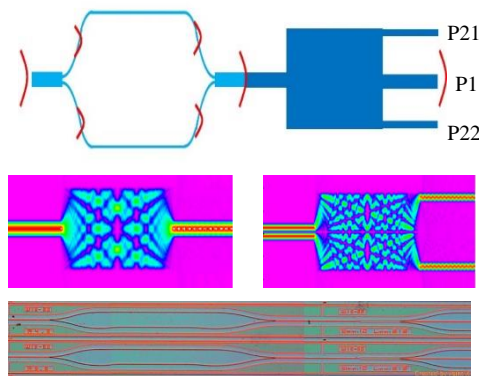


Fig. 2. Schematic of (a) MMI mode filter integrated optical mode switch, (b) BPM results of mode filter and (c) implemented device.

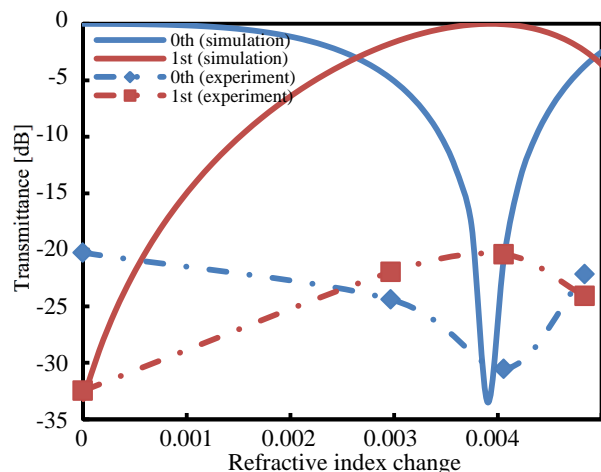


Fig. 3. The evaluated transmittance as a function of ΔN

Reference

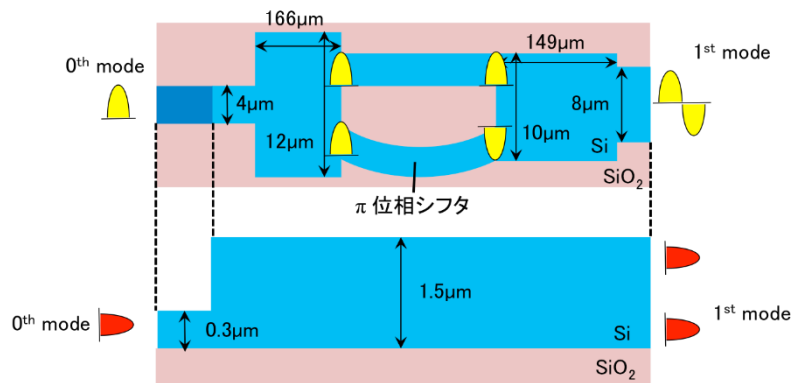
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- [2] M. Jizodo et al., OECC2013, TuPT-1 (2013).
- [3] T. Tanaka et al., OPE2014, 119 (2014).

Research of Optical Device for Multi-Mode Transmission

Yutaka Chaen, Kazuhiro Tanabe, Ryosuke Sakata, Haisong Jiang and Kiichi Hamamoto

Present data traffic is significantly increasing, and spatial multi-mode multiplexing (MDM) is expected to become one of the next generation transmission technologies to catch up such that huge demand for the data traffic [1]. To date, several approaches of mode converter have been proposed and demonstrated. The optical mode converter, optical mode multiplexer / demultiplexer, and multimode fiber are needed to achieve the practical use of MDM. So we have fabricated and evaluated the optical mode converter [2-3].

Figure 1 shows the schematic of optical mode converter from LP₀₁ mode to quasi-LP₂₁ mode which we fabricated, and near field pattern (NFP) with the converter. We added MMI (multi-mode interference) structure in vertical direction to the LP₁₁ mode converter which we already demonstrated, and confirmed quasi-LP₂₁ mode converting by BPM (beam propagation method) simulation [3]. We fabricated quasi-LP₂₁ mode converter and evaluated NFP, however the quasi-LP₂₁ mode converting was not demonstrated.



(a) Schematic diagram of LP₂₁ converter



(b) NFP of prototype device

Fig. 1. Prototype mode converter

Reference

- [1] J. Leuthold, J. Eckner, et. al., JLT, 16(1998)1288-1239
- [2] Y. Chaen, K. Tanabe, and Kiichi Hamamoto, MOC, 2013, H8
- [3] Y. Chaen, K. Tanabe, and Kiichi Hamamoto, OECC 2013, TuPL-14

Proposal of Channel Enhancement by using Novel Advanced OAM Mode for Transmission on N-core MCF

Hirohito Hokazono, Ryota Tanaka, Hatem El Serafy, Hodaka Sakamoto,
Haisong Jiang and Kiichi Hamamoto

Towards transmission capacity increase of the optical fiber, although the study of spatial multiplexing method by the multi-core fiber (MCF) has been actively, in order to increase transmission capacity, we set the smaller basic moment angle than OAM (Orbital Angular Momentum) Mode, and call advanced OAM mode. There is a possibility that you can set the number of channels more than the number of cores by MCF transmission using the advanced OAM mode. Figure 1 show the advanced OAM mode on the six-core MCF. Considered to be multiplexing and demultiplexing by phase device each mode of the advanced OAM at the input and output ends of the MCF, we have studied regarding phase device.

One of the important issue of mode demultiplexing is crosstalk. Figure 2 shows the relationship between the maximum number of charges and crosstalk in the six core MCF. Given the fact that the signal mode crosstalk -4dB by MIMO technology is guaranteed, the maximum charge number on the available theory is 5, it is possible to 11 channel transmission at this time. This is equivalent to approximately two times the number of cores, for further transmission channel number increases, improvement in crosstalk is essential. In general, regarding array waveguide number of the AWG used in the wavelength division multiplexing, although it is about 100 pieces, array waveguide number in the transmission system that we propose is limited to the number of cores N. When array waveguide is less and the like six, output lights should be originally output the waveguide would have been output, but the lights leaks to the other output waveguide. It is thought to be a lack of phase information due to the number of array waveguide is small. We are considering that this problem is to add the phase information by the phase control as a solution, artificially increasing the number of array waveguide.

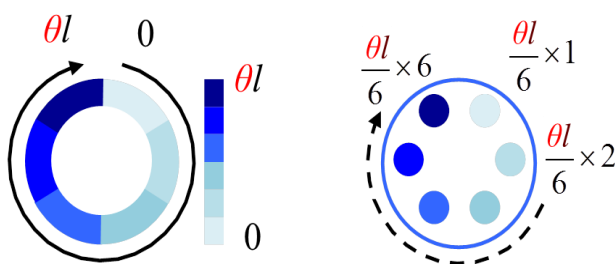


Figure 1 Advanced OAM mode on the six-core MCF

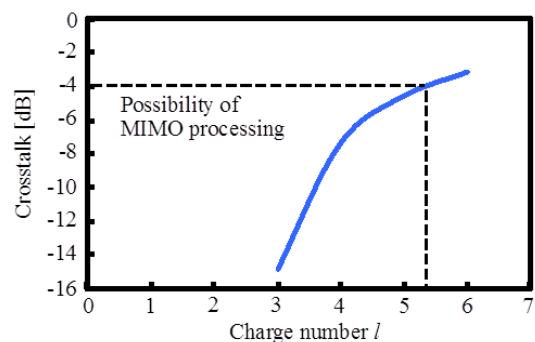


Figure 2 Relationship between the maximum number of charges and crosstalk in the six core MCF

Reference

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[2] R. Tanaka, et.al, OPE, 2014, 225, pp. 127-132