

2012 Annual Report

Opto-Electronics Laboratory
(Prof. Hamamoto Group)

Applied Science for Electronics and Materials
Interdisciplinary Graduate School of Engineering Sciences,
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2. Research Summary

- **Head**

Kiichi Hamamoto, Professor, Dr. Sc. Techn.

- **Doctor Course Students**

3th Year

Jiao Chen, Ms. Sci.

Daisuke Nakashima, Mr. Eng.

Yasuhiro Hinokuma, Mr. Eng.

1th Year

Yutaka Cyaen, Mr. Sci.

Mohammad Nasir Uddin, Mr. Eng.

- **Master Course Students**

2th Year

Kazuki Ikeda, Mr. Bc. Eng.

Takaaki Kizu, Mr. Bc. Eng

Makoto Jizodo, Mr. Bc. Eng

Hokazono Hirohito, Mr. Bc. Eng.

Zhao Zhao, Mr. Bc. Eng.

1th Year

Miki Tsujino, Ms. Bc. Eng.

Asuka Fujino, Mr. Bc. Eng.

- **Bachelor Course (4th year)**

Atsushi Saeki, Mr.

Yuta Sato, Mr.

2. Research Summary

We are studying about the optical device such as the semiconductor laser and integrated optical element.

- **Ubiquitous bio-sensing by using optical waveguide gas-cell**

Photonic integrated circuits, which is consisted from optical waveguide, is researched to realize compact breath sensing system. On the year of FY2012, we have mainly attributed to reduce down the waveguide loss. In addition, we have started to research on cavity ring-down method integrated with optical amplifier to compensate the above mentioned waveguide loss. These results will be presented in the future at domestic and international conferences.

- **Multi-mode transmission light source**

Space division multiplexing/ mode division multiplexing are now intensively researched world widely to satisfy the huge demand of data-traffic, however, the devices especially mode-converter and mode-coupler are not still well-developed so far. We have researched the devices based on MMI, and have confirmed that they work among entire C-band.

- **Single wavelength active-MMI LD/MMI filter for FTTH**

We have researched on single-wavelength active-MMI LD for FTTH. Over 42dB SMSR has been confirmed on 2012. Simultaneously, we have researched on wide-band optical filter based on MMI.

- **Optical mode switch**

We have proposed optical mode switch to realize compact and low power consumption optical router.

3. Research Topics

● Proposal of Novel Strip High-Mesa Waveguide for Infrared Absorption Sensing

Daisuke Nakashima and Kiichi Hamamoto

In addition, an excess loss at waveguide bending was also estimated by using finite difference time domain method (FDTD method). Figure 3 shows the result^[4]. The estimated excess loss at the micro-bending was almost similar compared to the high-mesa waveguide. We could successfully confirm that the micro bending of the curvature radius below 10 μm can be exploitable in case of the strip high-mesa waveguide, as well as the high-mesa waveguide.

From these result, we could successfully confirm the potential of utilizing strip high-mesa waveguide especially for infrared absorption sensing.

For realizing compact infrared absorption sensing device, a gas-cell-utilizing optical waveguide is attractive due to the possibility of long optical path integration^[1]. The higher optical power portion out of the waveguide (we define this portion as " Γ_{out} ") is the key feature for the infrared absorption^[2]. We evaluated the optical field profile and Γ_{out} of the waveguide eigen-mode by using finite element (FEM) electromagnetic field analysis. The optical field profile depends on the waveguide geometry, in particular on the width w and the etching depth in the lower cladding layer d , and therefore Γ_{out} needs to be estimated depending on these parameters.

As is shown in Fig. 1(b), the core layer of the strip waveguide is formed on top of the lower cladding layer. The required etching depth is sufficient with only the core layer thickness. Therefore, this waveguide structure offers a benefit of relatively simple processing compared with the high-mesa waveguide shown in Fig. 1(c). For instance, in the case of using Si for the core and SiO₂ for the cladding, as is shown in Fig. 1, the typical etching depth of the high-mesa waveguide approximately reaches to 1.6 μm , while an etching depth of 300nm is sufficient for the strip waveguide. However, one critical issue remains in the strip waveguide for sensing applications. As shown in Fig. 1(b), the optical field profile is more strongly concentrated in the substrate due to its refractive index configuration^[3]. To overcome this problem, here, we newly propose a **strip high-mesa waveguide**^[4], as shown in Fig. 1(a). In the strip high-mesa waveguide, of which a part of the lower-cladding layer was etched down slightly, most of the optical field comes out of the waveguide, and the optical field becomes similar compared to the high-mesa waveguide shown in Fig. 1(c).

We examined the dependence on the waveguide width w . Figure 3 shows the results^[4]. Here, we use Si for the core layer with a thickness of 260nm and a refractive index of 3.48 at $\lambda = 1550\text{nm}$, SiO₂ for the cladding layer with a refractive index of 1.44 at $\lambda = 1550\text{nm}$, and the etching depth in the lower cladding layer $d = 500\text{nm}$ for the strip high-mesa waveguide. As shown in the figure, Γ_{out} exceeds approximately 71% at the waveguide width $w = 290\text{nm}$. This value was higher than that of the high-mesa waveguide of 56%.

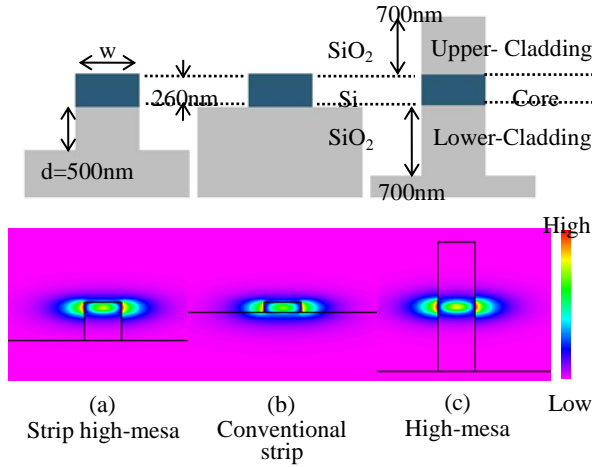


Fig. 1. Schematics of waveguide cross section and the

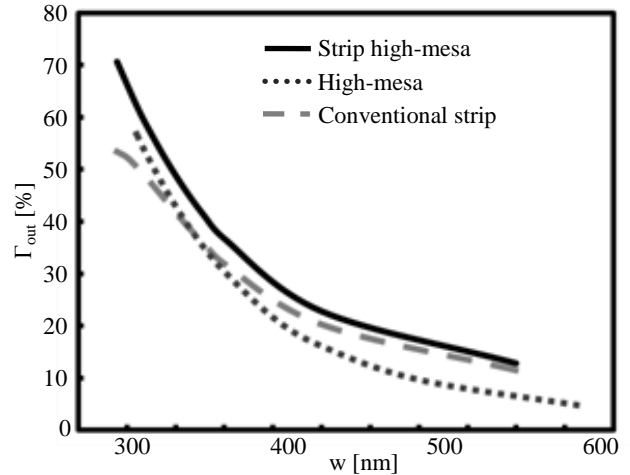


Fig. 2. Γ_{out} , defined as optical power portion out of the waveguide, as a function of waveguide width w .

参考文献：

- [1] S. Yano et al., IPNRA, IWA7, 2007
- [2] S. Yano et al., 信学技報, 106 (284), 27, 2006
- [3] A. Intekhab et al., JJAP, 49 (12), 122503, 2010
- [4] D. Nakashima et al., APEX, 5 (6), 062202, 2012

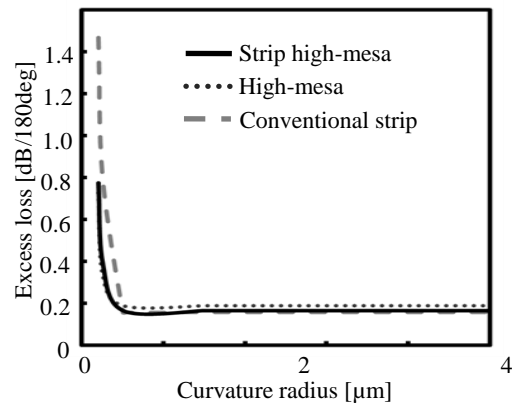


Fig. 3. Excess loss at waveguide bends.

3. Research Topics

● Loss Analysis on Sensing Waveguide

Jiao Chen, and Kiichi Hamamoto

Compact health-check system has been desired for an increasing demand on daily health-care, recently. Among many diagnostics methods, breath-content analysis is one of the candidates for daily health-care, as it contains various disease-markers and is noninvasive to human-beings. One of the attractive tools for breath-content analysis is infrared spectroscopy due to its superior capability in ppm-order sensitivity of various kinds of breath contents [1]. We have researched on a compact breath-sensing system by utilizing photonic integrated circuits with telecom-band infrared spectroscopy. From this viewpoint, high-mesa waveguide is attractive for its potential of being utilized for infrared absorption [2]. However, one of the critical issues for high-mesa waveguide lies in its high propagation loss, since high propagation loss consumes light power, which restricts sensing limitation [3]. We have reported that the scattering loss is the main loss contributor for SOI based high-mesa waveguide and the scattering loss can be decreased by utilizing mid-infrared light and thicker core thickness. As result, we prove that the scattering loss can be decreased to 0.072dB/cm, theoretically.

This time we proposed Silica high-mesa waveguide for its low propagation loss possibility, as shown in Fig.1. The evaluated propagation loss as a function of waveguide width is shown in Fig.2. The propagation loss shows 0.65dB/cm when $w=2.3\mu\text{m}$, which is higher than expected value of lower than 0.1dB/cm. Because the refractive index difference between core and cladding is only 2.5%, we suspected that maybe the radiation loss takes a large part of propagation loss. We evaluated the relation between the propagation loss and under-cladding layer thickness which is shown in Fig.3. From Fig. 3 we know when under-cladding layer thickness is $5\mu\text{m}$ the radiation loss should be lower than 0.03dB/cm. So we proposed to make under-cladding layer thickness be 5, lower than 0.1dB/cm propagation loss is expected.

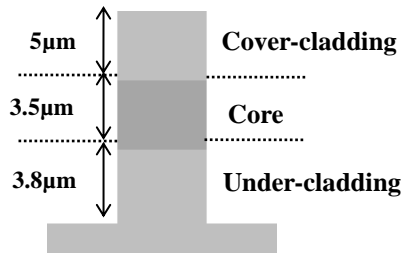


Fig. 1. Schematic of Silica high-mesa waveguide cross section.

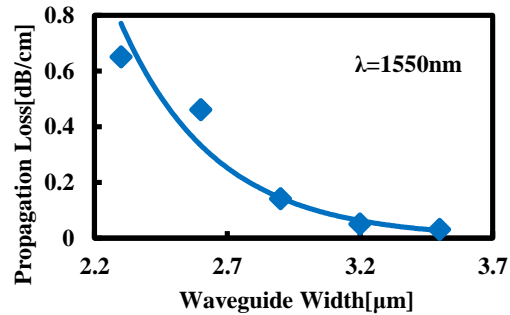


Fig. 2. Propagation loss as a function of waveguide width.

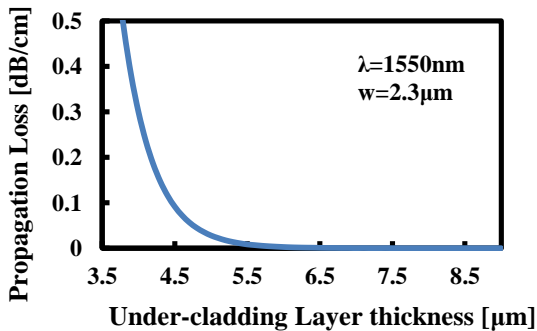


Fig. 3. Propagation loss as a function of under-cladding layer thickness.

References:

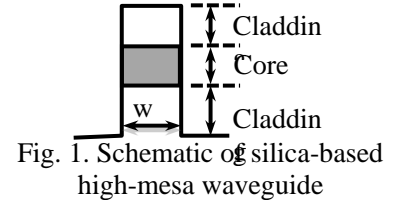
- [1] M. Mürtz, Opt. & Photo. News, vol. 16, no. 1, pp. 30, 2005.
- [2] Y. Matsunaga, etc, Engg. Sci. Rep., Kyushu Univ., vol. 30, pp. 1, 2008.
- [3] S. Yano, etc, IEICE Techn. Rep. OPE 2006-96, pp. 27, 2006.

3. Research Topics

● Silica-Based High-Mesa Waveguide for Compact Breath-Sensing System

Hirohito Hokazono, and Kiichi Hamamoto

When the concentration of some volatile compounds in breath is higher than regular level, it usually indicates that some abnormality has occurred in the body. We consider the use of infrared absorption spectroscopy to measure the components of a low concentration in the breath for health-check system. But this method is necessary the effective optical path length of a few meters to measure high sensitive breath sensing. Since part of the core layer is exposed to the gas phase as shown in Fig. 1, we propose



high-mesa waveguide as the gas detection unit due to the fact that a certain portion of the propagation light profiles in the gas phase as shown in Fig. 2. The higher portion of propagation light in the gas phase, we define this portion as “ Γ_{out} ”, is desired for higher sensitivity in the infrared absorption. It’s difficult to breath sensing since the common optical waveguide silicon material have significant propagation loss. We considered the silica-based high-mesa waveguide, which low propagation loss is expected. As a result, Γ_{out} is shown in Fig. 3 and up to 2.7 %. In curve 180 degree, such as Fig. 4, radiation loss is 0.06 dB/180deg when waveguide width equals 2.3 μm and curvature radius equals 10 μm . Therefore the Γ_{out} exists and high density integrating is possible for silica-based high-mesa waveguide. We expect that it has low propagation loss, which is two digits lower than that of silicon material. So it’s expected that silica-based high-mesa waveguide will contribute to breathe sensing application in the future.

We are researching about optical waveguide for compact breath-sensing system.

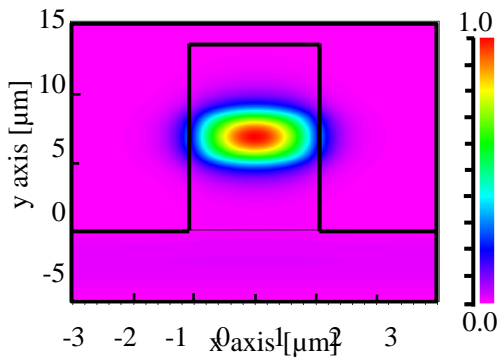


Fig. 2. Optical field of silica-based high-mesa waveguide

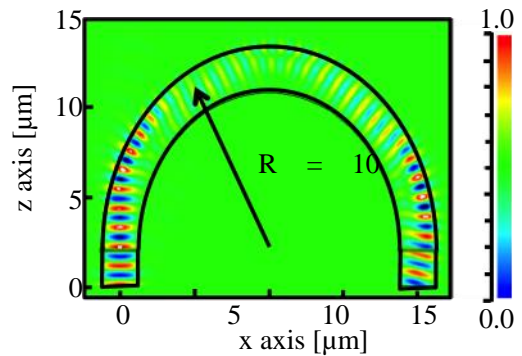


Fig. 4. Optical field of curve waveguide

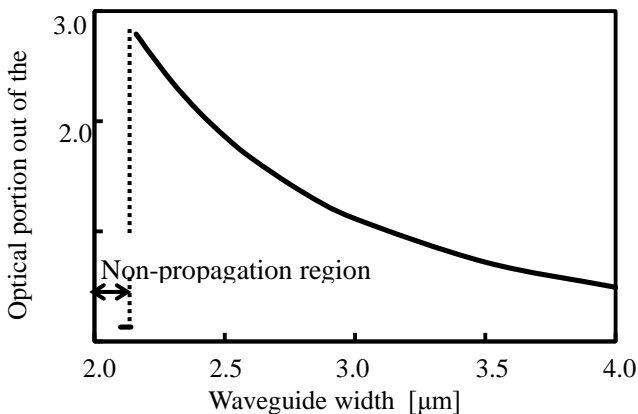


Fig. 3. Optical portion out of the waveguide, Γ_{out} as a function of waveguide width

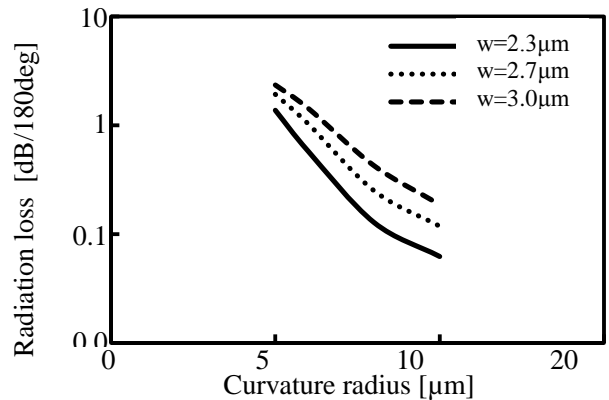


Fig. 6: Curve radiation loss as a function of curvature radius

3. Research Topics

- Research of Multi-Mode Transmission Device

Yutaka Chaen, and Kiichi Hamamoto

Present data traffic is significantly increasing, and spatial multi-mode multiplexing is expected to become one of the next generation transmission technologies to catch up such that huge demand for data traffic [1]. As present transmission system is in principle based on wavelength division multiplexing (WDM), it is important to realize wavelength independent multi-mode devices. We have proposed MMI structured multi-mode devices for future spatial multi-mode multiplexing transmission, and we have successfully confirm that the designed MMI (Multi-Mode Interference) based multi-mode combiner showed superior multiplexing (0^{th} and 1^{st} order modes) characteristics of below 0.5 dB excess loss for full C-Band theoretically [2].

Figure 1 shows the schematic of the MMI multi-mode combiner and its layer structure. When 0^{th} mode is incident upon the upper access waveguide and 1^{st} mode incident upon the lower, two modes will be combined together in output waveguide. Odd modes like 1^{st} mode also get 85 % output, but input port has to be lower port at the same circumstances. Figure 2 shows the wavelength and polarization dependency of MMI multi-mode combiner. 0.5 dB down bandwidth is the bandwidth where both TE and TM modes transmission had dropped for 0.5dB.

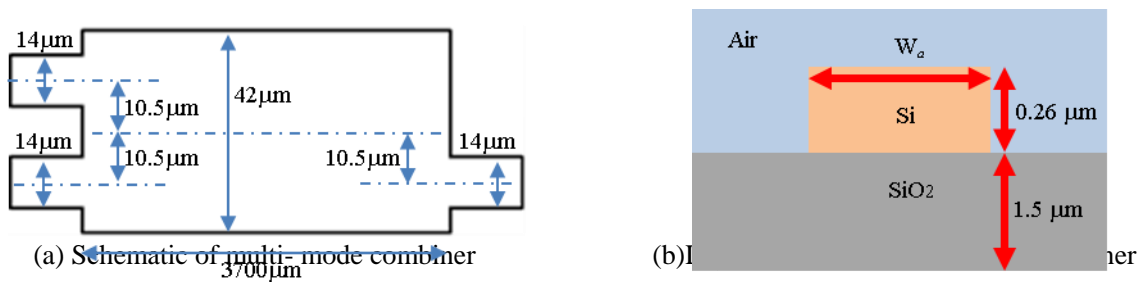


Fig.1. MMI structure and layer structure of MMI multi-mode combiner

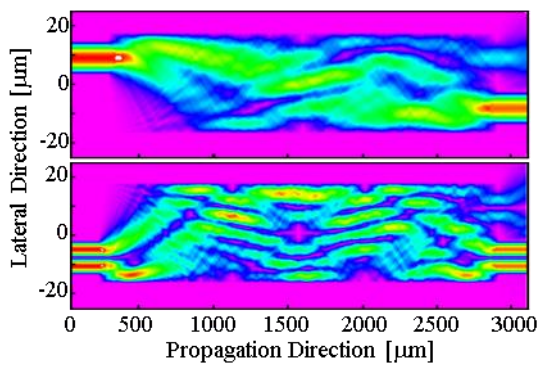


Fig.2. Simulation result of light propagation inside multi-mode combiner. Upper shows 0^{th} mode and lower shows 1^{st} mode

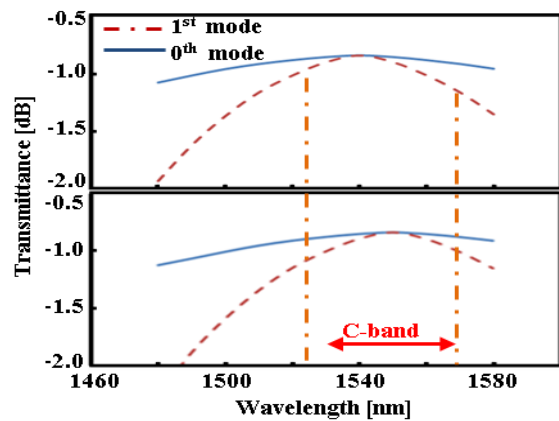


Fig.3. Wavelength dependency of multi-mode combiner for TE and TM polarization for TE and TM polarization

References

[1] M. Nakazawa, ECOC, 2nd Plenary Talk, pp. 31, 2010

[2] Y. Chaen, et.al., MOC, 2011

3. Research Topics

● Mode Converter by Using MMI for Multi-Mode Transmission

Zhao Zhao, and Kiichi Hamamoto

Under the background of the information traffic increment recently, as a means of increasing the transmission capacity in the future, the multi-mode transmission technology has been attracting attention. Our research is about the basis of the mode converter structure which is one of the key devices for the multi-mode transmission system. In this research, we have investigated the design factors of the mode converter structure based on the multimode interference waveguide, and realized a low conversion loss which is also independent to wavelength and polarization in the wavelength bandwidth area which is below 0.5 dB excess loss for full C-Band theoretically when convert the fundamental mode to the first-order mode

Figure 1 shows the schematic of the MMI multi-mode converter and its layer structure. When 0th mode is inserted from the left access waveguide, 1st mode will be got at the right output waveguide. Figure 2 shows the wavelength and polarization dependency of MMI multi-mode converter. 0.5 dB down bandwidth is the bandwidth where both TE and TM modes transmission had dropped for 0.5dB.

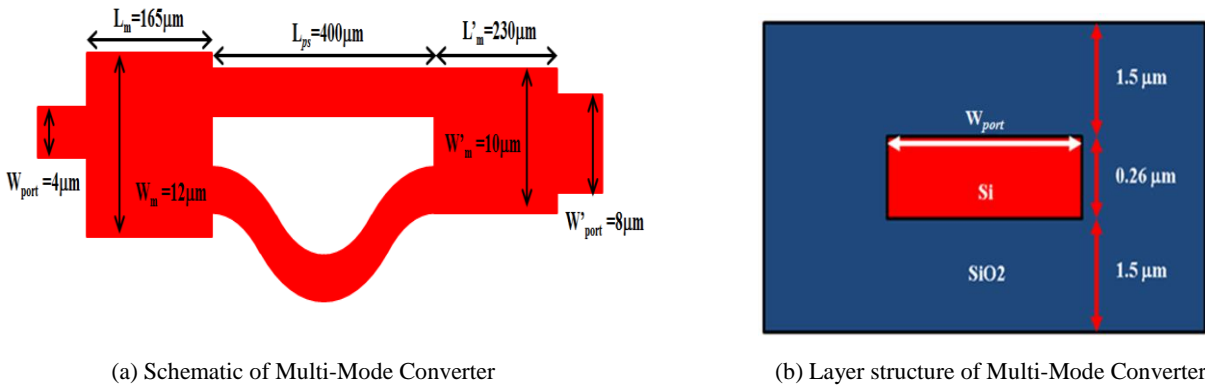


Fig.1. MMI structure and layer structure of MMI multi-mode Converter

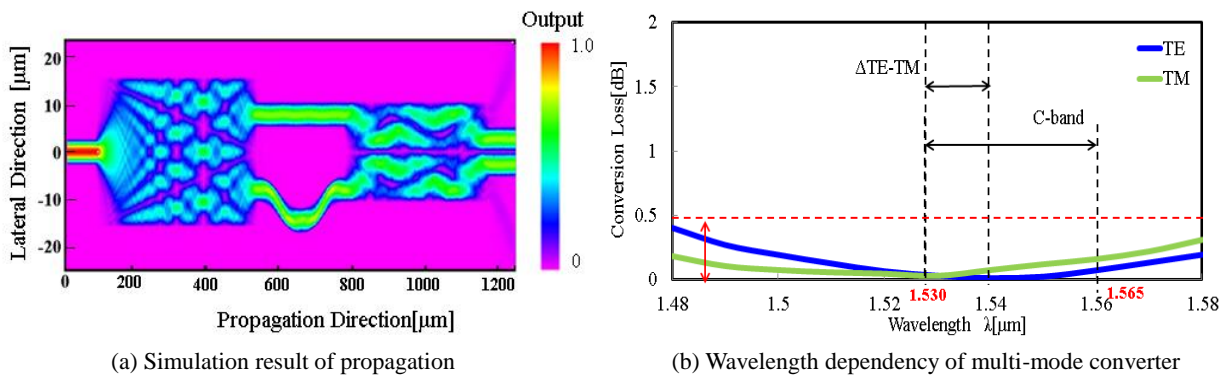


Fig.2. Evaluation results of MMI multi-mode Converter

References

- 1] J. Leuthold, J. Eckner, et. al., JLT, 16(1998)1288-1239 [2] Z. Zhao, et. al., IEICE, C-3-2, (2012)

3. Research Topics

● Spectral linewidth measurement for single wavelength active MMI LD

Takaaki Kizu, and Kiichi Hamamoto

Recent rapidly growing data traffic requires light source of having higher power with low cost. Single wavelength active multi mode interferometer laser (MMI LD) is attractive for the high output power without grating that leads to low cost¹⁻³. So far, we have reported maximum power of 8 mW, and single wavelength emission with side-mode suppression ratio (SMSR) of 31 dB using asymmetric active MMI LD at room temperature^[1]. However, to meet the required performance to realize the next generation of communication networks (100Gbit Ethernet^[2-3]), it is necessary to achieve less than 20 MHz of spectral line width. We measured spectral line width by delay self homodyne measurement^[4]. Figure 1 shows Setup for line width measurement, and figure 2 shows experimental result. Figure 3(a) shows experimental landscape, and figure 3(b) shows picture of active MMI LD.

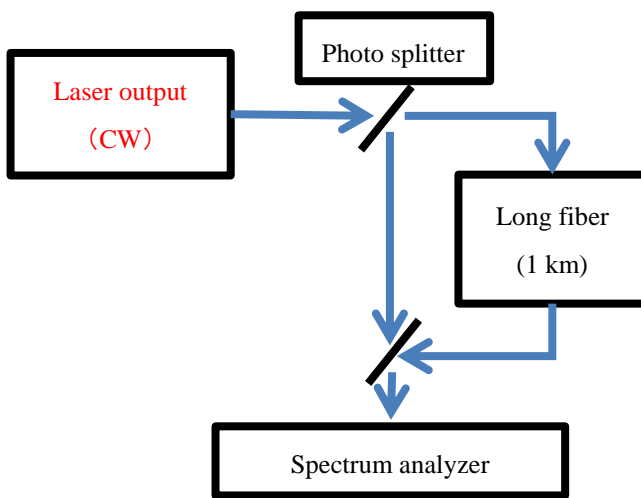


Fig. 1 Setup for delay self-homodyne measurement

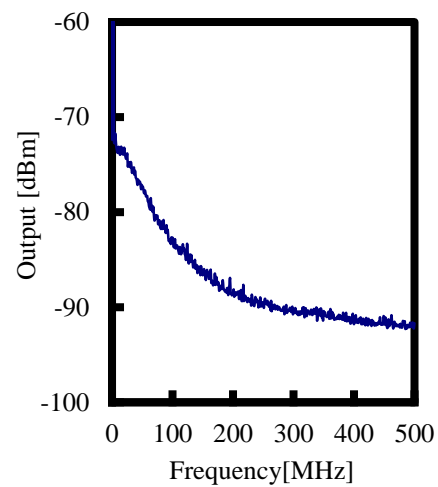


Fig. 2 Experimental result of measurement

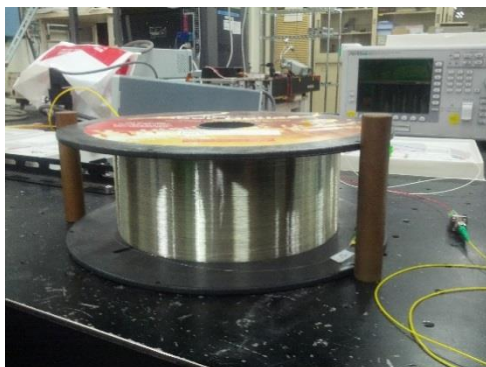


Fig. 3 Experimental landscape

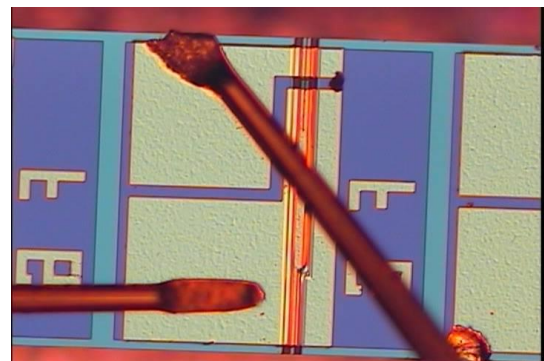


Fig. 4 Asymmetric active MMI LD

References

- [1] T. Kizu et al., IEICE2011-03, C-4-15, (2012)
- [2] OIF-ITLA-MSA-01.2,
<http://www.oiforum.com/public/documents/OIF-ITLA-MSA-01.2.pdf>
- [3] T. Nomura, et. al., IEICE technical report, EMD 96(1996)43-48
- [4] T. Suhara, "Semiconductor Laser Fundamentals", CRC Press, (2004)184-193

3. Research Topics

- **Wide-band optical filter using MMI (Multi-Mode-Interference)**

Kazuki Ikeda, and Kiichi Hamamoto

Recent rapid increase of data traffic especially due to the growing number of FTTH (fiber to the home) subscribers, WDM (wavelength division multiplex) technology will be used even for the FTTH based on the recently standardized 10G-PON (Gigabit-Passive Optical Network). We have a purpose to realize wide-band optical filter for 10G-PON. The optical filter using 1xN MMI (Multi-Mode Interference) waveguide have some merits like miniaturization, cost reduction, wide-band filter characteristic. Figure 1 shows the structure of MMI waveguide filter and the image of optical filter/. Introducing an ICP dry-etching machine from this year, we can work from simulation to device fabrication. Figure 2 shows the ICP dry-etching machine. Fig. 3(a) shows the end surface figure of the fabricating device by the SEM before the etching, and Fig. 3(b) shows the end surface after etching.

Reference

- [1] L. B. Soldano, et al., Journal of Lightwave Technology, Vol. 13, No. 4, pp. 615-627 (1995)
- [2] Bachmann, et al., Applied Optics, Vol. 34, No. 30, pp. 6898-6910 (1995)
- [3] K. Ikeda, et at, IEICE2011, C-3-50 (2011)

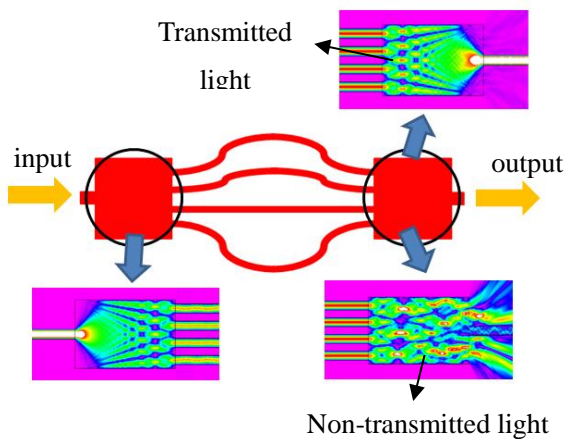
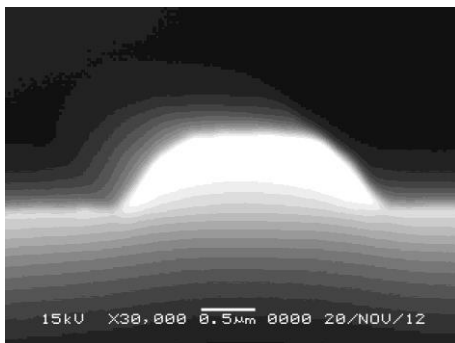


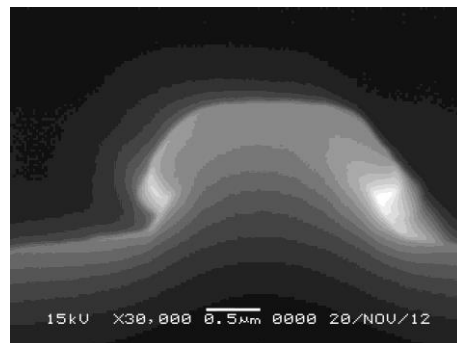
Fig.1: Schematic and beam profile of the optical filter.



Fig.2: ICP dry-etching machine. The designed devices are fabricated using this equipment.



(a) Before etching



(b) After etching

Fig.3: Device cross-section by using SEM.

3. Research Topics

● Optical Spatial Mode Switch

Makoto Jizodo, and Kiichi Hamamoto

We propose optical spatial mode switch which can switch among any optical spatial modes. The conventional optical spatial switch can be replaced to optical spatial mode switch by assigning the spatial mode information to the positional information. This optical spatial mode switch has a possibility to increase the integration density, through reducing the number of optical parts connected to optical switch or downsizing by reducing curved waveguides. In this paper, we report the simulation results of the principle of switching between 0th-order mode and 1st mode.

Figure 1 shows the schematic view of the spatial mode switch which can switch between 0th mode and 1st mode. This structure has an asymmetric Y-junction waveguide and symmetric Y-junction waveguide with variable refractive index (VRI) region. In the asymmetric Y-junction waveguide, injected 0th mode and 1st mode is split into different waveguides, and this phenomenon is called mode-sorting [1]. In the symmetric Y-junction waveguide, by using VRI region to control propagation constant of the waveguide, the inverse phenomenon of mode-sorting is occurred and it can generate 0th mode or 1st mode. In this structure, the VRI region is supposed to be injected current with PIN diode [2]. When the current is injected into upper waveguide in Fig.1, the device is in NOT switched state, and current injection into lower waveguide causes switched state. In NOT switched state, the crosstalk is about -29dB. And in switched state, the crosstalk is about -26dB. Figure 2 shows the simulation results, and table 3 shows the relationship between required refractive index variation and crosstalk.

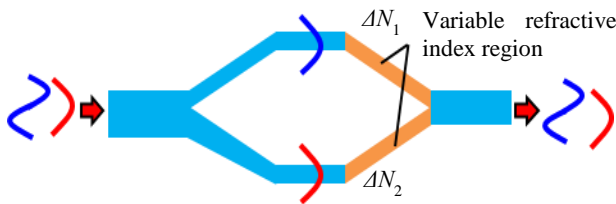


Fig.1 Schematic view of optical spatial mode switch.

Table1. Relationship between required refractive index variation and crosstalk.

Inject	Transmit	VRI	Crosstalk [dB]
0 th	0 th	-0.017	-29.2
1 st	1 st	-0.017	-29.4
0 th	1 st	-0.023	-26.2
1 st	0 th	-0.023	-26.3

Reference

- [1] N. Riesen and J. D. Love, Appl. Opt., 51(15), 2778-2783, 2012
- [2] J. V. Campenhout, et. al., Opt. Exp., 17(26), 24020-24029, 2009

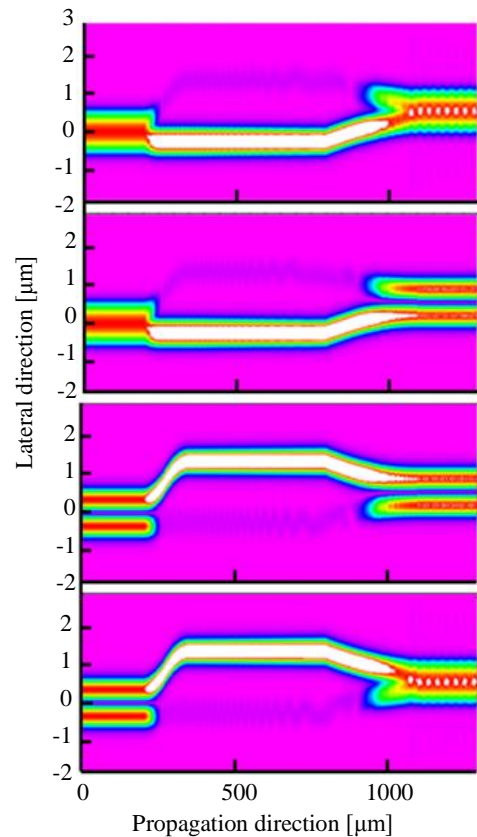


Fig.2 Simulation results of optical spatial mode switch.

4. Paper list

● Journal Publications

- (1) Zhigang Zang*, Keisuke Mukai*, Paolo Navaretti**, Marcus Duell**, Christian Velez**, and Kiichi Hamamoto*, “Thermal Resistance Reduction in High Power Superluminescent Diodes by Using Active Multi-Mode Interferometer”, Applied Physics Letters, Vol. 100, No. 31, pp. 10801-10804, Jan. 2012
*Kyushu University **EXALOS AG
- (2) Yasuo Hinokuma*, Yutaka Chaen*, Haisong Jiang*, Takuma Hagio*, Seiki Nakamura*, Akio Tajima**, and Kiichi Hamamoto*, “Single Wavelength Emission by Using Novel Asymmetric Configuration for Active Multi-mode interferometer Laser Diodes”, IEICE Electronics Express (ELEX), Vol. 9, No. 18, pp. 1448-1453, Sep. 2012
*Kyushu University **NEC Corporation
- (3) Daisuke Nakashima, and Kiichi Hamamoto, “Proposal of Novel Strip High-Mesa Waveguide for Infrared Absorption Sensing”, Applied Physics Express (APEX), Vol. 5, pp. 062202_1- 062202_3, Jun. 2012

● Conference Publications (International)

- (1) Yutaka Chaen, Zhao Zhao, Haisong Jiang, and Kiichi Hamamoto, “Full C-Band Spatial Multi-Mode Combiner Based on Multi-Mode Interference”, Technical Digest of 9th International Symposium on Novel Carbon Resource Sciences, P-53, pp. 116, 3rd Nov. 2012

● Conference Publications (Domestic)

- (1) Yasuhiro Hinokuma, Yutaka Chaen, Haisong Jiang, Takaaki Kizu, Takuma Hagio, Seiki Nakamura, Akio Tajima, and Kiichi Hamamoto, “First Single Wavelength Emission (CW@RT) on Active MMI LD”, Extended Abstracts of The 59th Spring Meeting of The Japan Society of Applied Physics and Related Societies, No. 1, 16-a-F3-9, pp. 53, 20th Mar. 2012 (Waseda University, Shinjuku)
- (2) Zhao Zhao, Yutaka Chaen, and Kiichi Hamamoto, “Mode Converter by Using MMI(Multi-Mode Interference) for Mode Multiplexing Transmission”, Proceedings of the IEICE General Conference 2012, No.1, C-3-2, pp. 151, 20th Mar. 2012 (Tsushima Campus, Okayama University, Okayama)
- (3) Haisong Jiang, Yutaka Chaen, Takuma Hagio, Kazuisao Turuda, Makoto Jizodo, Jing Xu, Christophe Peucheret, and Kiichi Hamamoto, “All-optical flip-flop operation based on asymmetric active-multimode interferometer bi-stable laser diodes”, Proceedings of the IEICE General Conference 2012, No.1, C-3-10, pp. 159, 20th Mar. 2012 (Tsushima Campus, Okayama University, Okayama)
- (4) Takaaki Kizu, Yasuhiro Hinokuma, Yutaka Chaen, Haisong Jiang, Takuma Hagio, Akio Tajima, and Kiichi Hamamoto, “First CW Single Wavelength Emission @RT on Active-MMI LD”, Proceedings of the IEICE General Conference 2012, No.1, C-4-15, pp. 266, 21st Mar. 2012 (Tsushima Campus, Okayama University, Okayama)
- (5) Makoto Jizodo, Daisuke Nakashima, Kanako Tagawa, and Kiichi Hamamoto, “Si-Wire Waveguide Optical Switch by Using Narrow Trench Electrode”, Proceedings of the IEICE General Conference 2012, No 1, C-2-46, pp.195, 22nd March 2012 (Tsushima Campus)

4. Paper list

- (6) Yutaka Chaen, Zhao Zhao, Makoto Jizoudou, and Kiichi Hamamoto, “Full C-band Spatial Multi-Mode Combiner Based on Multi-Mode Interference” , Proceedings of the IEICE General Conference 2012, No.1, C-3-89, pp. 238, 23rd March 2012 (Tsushima Campus, Okayama University, Okayama city)
- (7) Yasuhiro Hinokuma, Hitoshi Takeshita, Shigeru Nakamura, Tomoyuki Hino, Kiichi Hamamoto, and Akio Tajima, “Fundamental Evaluation on 1x8 Si-Photonics Optical Switch”, Proceedings of the IEICE General Conference 2012, No.1, C-3-42, pp. 60, 22nd March 2012 (Okayama University, Okayama city)
- (8) Yasuhiro Hinokuma, Yutaka Chaen, Haison Jiang, Takaaki Kizu, Takuma Hagio, Seiki Nakamura, Akio Tajima, and Kiichi Hamamoto, “Single CW wavelength emission by using novel asymmetric active multi-mode interferometer (MMI) LDs”, IEICE Technical Report, Vol. 112, No. 98, LQE2012-16, pp. 13-16, 22nd June 2012 (Minato-ku, Tokyo)
- (9) Yuuta Satou, Yutaka Chaen, Zhao Zhao, and Kiichi Hamamoto, “Fundamental Research on Quasi-LP₂₁ Mode Converter Device”, Proceedings of the IEICE Society Conference 2012, No. 1, C-3-15, pp. 132, 11th Sep. 2012 (Toyama University, Toyama)
- (10) Hirohito Hokazono*, Daisuke Nakashima*, Jiao Chen*, Miki Tsujino*, Yasuaki Hashizume**, Mikitaka Itoh**, and Kiichi Hamamoto*, “Silica-Based High-Mesa Waveguide for Compact Breath-Sensing System”, Proceedings of the IEICE Society Conference 2012, No. 1, C-3-16, pp. 133, 11th Sep. 2012 (Toyama University, Toyama)
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- (11) Makoto Jizodo, Asuka Fujino, and Kiichi Hamamoto, “Proposal of Optical Spatial Mode Switch”, Proceedings of the IEICE Society Conference 2012, No. 1, C-3-22, pp. 133, 12th Sep. 2012 (Toyama University, Toyama)

5. Alumni (affiliation)

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- **Doctor Course**

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