

2018 Annual Report

Opto-Electronics Laboratory
(Prof. Hamamoto Group)

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

Kyushu University

High-light 2018

On 2018, our breath sensing research activity was selected for SECOM research foundation. By utilizing this opportunity, we have started new development toward system demonstration 4 years later. We also started new waveguide fabrication technology, and we have built-up and settled a new fabrication equipment for 3D waveguides. Right now we are considering to adopt AI technology for it.

Also, we had a certain impressive results on active-MMI laser diode which has been researched on Support Industry program, METI. One paper was accepted for OFC 2018. Later, invited talks were made at Photonics Europe, SPIE, and at a LQE/IEICE technical workshop.

On 2018, we run the following 4 topics. Please see the following pages in detail.

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

Gas Sensing Using Silica High-Mesa Waveguide

Wenyang Li, Yu Han, Zanhui Chen, Haisong Jiang and Kiichi Hamamoto

CRDS system utilizing waveguide for breath sensing realizes several meter optical path integration that has possibility for ppm-order gas sensing within a compact area^[1-2]. We have proposed optical amplifier assisted gas sensing system scheme^[3] to compensate waveguide propagation loss that may prevent ppm-order gas detection. Figure 1 shows the experiment set-up configuration of gas sensing system utilizing waveguide. The amplifier in CRDS system, however, may result in self-lasing at specific wavelength in case of high pumping condition. Figure 2 (a) is the spectrum when self-lasing happens. Once self-lasing happens, signal light loose its gain from amplifier. Figure 2 (b) is the cavity ring-down waveform with only 3 pulses.

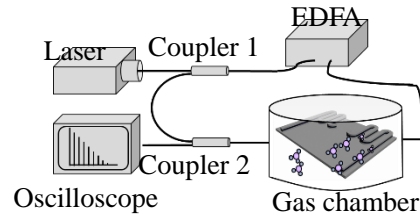


Fig. 1. Experiment set-up configuration of gas sensing system utilizing waveguide.

We proposed the scheme of polarization direction control to suspend the self-lasing. Figure 3 (a) is the spectrum after polarization direction control. It illustrates that the self-lasing power is suppressed down below -50 dBm. We estimated that a gain of 24 dB is improved at signal. Figure 3 (b) is the cavity ring-down waveform after polarization direction control. In this waveform, more than 200 pulses is achieved, which corresponds to the ability for 10 ppm-order CH₄ detection^[4].

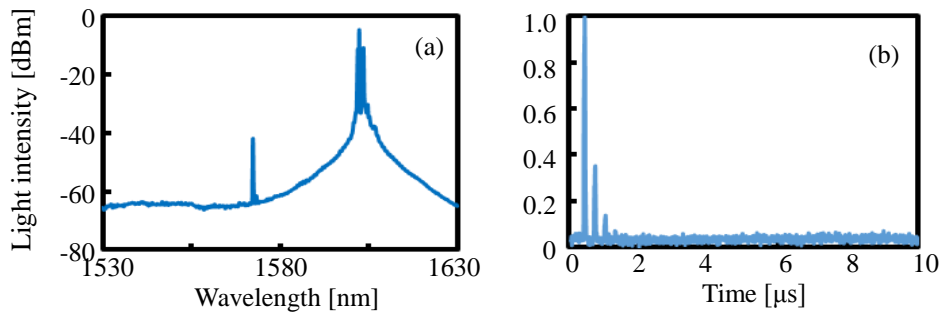


Fig. 2. Amplifier assisted CRDS system with self-lasing occurs (a) spectrum and (b) cavity ring-down waveform.

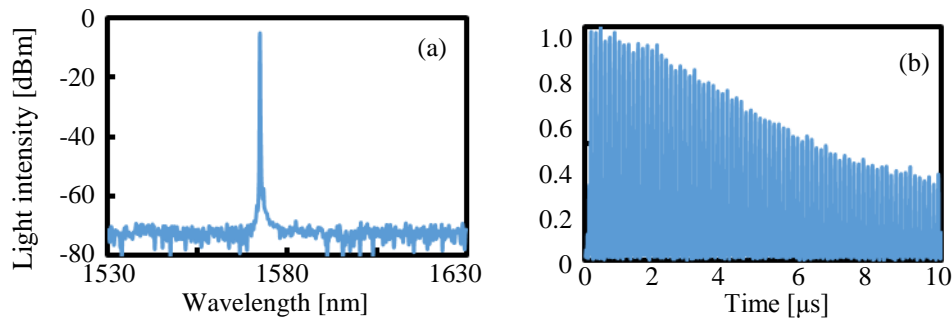


Fig. 3. Amplifier assisted CRDS system with polarization direction control, (a) Spectrum and (b) cavity ring-down waveform.

Reference

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Proposal of Two Tangent Air Hole Structure for Higher Sensitivity Gas Sensor

Zan Hui Chen, Wenyin Li, Yu Han, Haisong Jiang and Kiichi Hamamoto

Breath gas analysis emerged as a promising technique which is serving as biomarkers [1]. The optical method is a very sensitive and accurate method for the analysis of a variety of biomarkers. In this way, the use of PhC resonators as gas refractive index (RI) sensors is concerned, a strong light-matter interaction between the optical field and the analytes is preferred. However, in typical PhC-based sensors, the optical resonance mode is strongly confined to the high-index material (dielectric region) in order to achieve a high-quality factor ($Q \sim 10^6$) [2]. For these structures, the sensitivity (S) is low because the analyte is located in the air or liquid region where the strength of the confined light field fully overlaps with the analytes. Therefore, the RI sensitivities of most geometries are generally limited to around 100-200 nm/RIU (RIU, refractive index unit) [3-4].

The designed higher sensitivity gas sensor based on two tangent air hole structure is shown in Fig. 1. The structure is designed via the following two phases. First, the photonic crystal cavity region has a 21-tangent air hole defect consisting of a quadratic decreasing in hole radius, decreased from $R_1 = 120$ nm on both ends to $R_2=100$ nm in the center. Second, on each side of the cavity is the mirror region, which consisting of 10 tangent air-hole mirrors with the same radius of $R_1=120$ nm. The separation distance (Λ period) of each tangent air hole arrays is 600 nm. The width of bus waveguide is 500 nm wide and 24 μm long. Figure 2 shows the resonance peak shift of the proposed tangent air hole structure with increased methane gas concentration. As seen, the methane gas detection sensitivity is 2.16 nm/%, which corresponding to the RI sensitivities is 353 nm/RIU. The proposed two tangent air hole structure improves sensitivity to 2.16 nm/% compared to the single air hole structure (0.67 nm/%) [5].

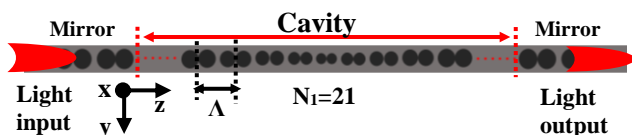


Fig. 1. Device configuration

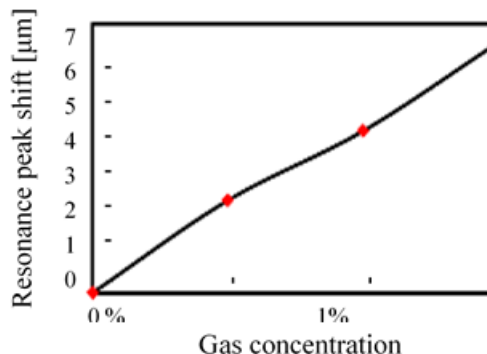


Fig. 2. Methane gas detection sensitivity

Reference

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Mode Crosstalk Evaluation in Mode Selective Active Multimode Interferometer Laser Diode

Bingzhou Hong, Tomotaka Mori, Shingo Murakami, Haisong Jiang and Kiichi Hamamoto

The lateral mode selective light source has been demonstrated with over 40 GHz bandwidth [1]. As the emission wavelength of 0th and 1st order mode locates at different range, accurate crosstalk evaluation method is obtained from spectrum analysis [2]. In this work, mode crosstalk between 0th and 1st order mode was evaluated based on spectrum analysis. As a result, Mode crosstalk of -13.7 dB -12.5 dB for 0th and 1st mode have been confirmed, respectively.

Figure 1 shows the fabricated device structure. 0th mode and 1st mode have individual propagation paths [3]. The bending waveguides left side act as the mode selector each mode. The straight access waveguide and multimode section consist the pumping section. By controlling current injection into the mode selector region, output modes are selected [4]. Figure 2 (a) and (b) shows the measured near field pattern (NFP) of only 0th and 1st order mode operation. Figure 3 (a) and (b) show the emission spectrum of 0th mode and 1st order mode, respectively. As can be seen from the figures, the 0th mode component mainly locates at wavelength range shorter than 1560 nm. On the other hand, 1st order mode component locates at wavelength range longer than 1560 nm. Thus, for quick and simple evaluation method, wavelength components below 1560 nm are attributed to 0th mode. The range from 1560 nm to 1580 nm are attributed to component of 1st order mode. By integrating the wavelength components, power of each mode is evaluated. As a result, in Fig. 3 (a), mode crosstalk of 0th mode is -13.7 dB. In Fig. 3 (b), 1st mode mode crosstalk is -12.5 dB.

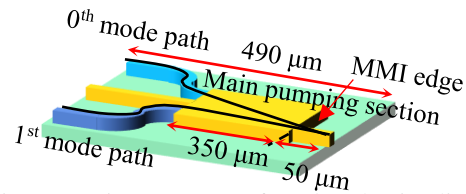


Fig. 1. Device structure of mode selective light source



Fig. 2 NFP of (a) 0th mode and (b) 1st order mode

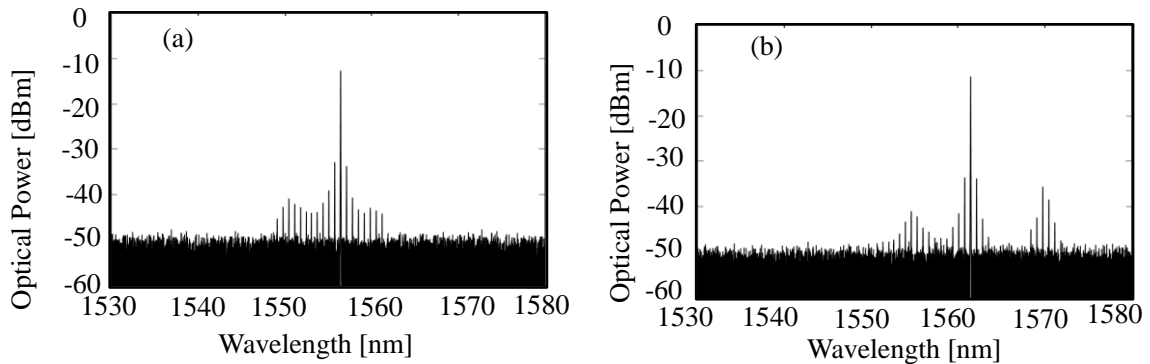


Fig. 3. Spectrum of single lateral mode lasing cases. (a) Measured 0th mode spectrum, and (b) measured 1st mode spectrum.

References

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Spatial Single Dimensional Mode Demultiplexer Based on Slab Waveguide

Mahmoud Nasef, Kantaro Fujimoto, Haisong Jiang, Kiichi Hamamoto

Spatial multiplexing transmission technology is highly researched to enhance transmission capacity in single fiber [1]. LP (Linearly Polarized) mode based multiplexing, however, require MIMO processing due to its difficulty of mode de-multiplexing caused by the mode degeneration and the mode crosstalk [2]. In order to solve this problem, spatial multiplexing transmission using spatial single-dimensional mode has been proposed [3]. We are studying phase control type multiplexer / demultiplexer using slab waveguide that can multiplex / demultiplex single-dimensional spatial mode [4]. Figure 1 shows the schematic of our mode de-multiplexer. Our de-multiplexer is similar to AWG which is widely used in WDM, and is structurally composed of a strongly coupled waveguides part, a phase control part, and slab waveguide part. As shown in Fig. 2, the field profiles and phase profiles of coupled modes have a phase difference of π between v th order mode and $(v+1)$ th mode [5]. And as shown in Fig. 3, slab waveguide has a light focusing function. The focusing position is different if the light of equivalent wavefronts injected from the array waveguide. Based on this principle, we can realize mode de-multiplexing. As a preliminary study of a phase control type multiplexer / demultiplexer, it was confirmed that the focal position of single dimensional space modes with different equiphase planes are different and can be clearly observed in the slab waveguide.

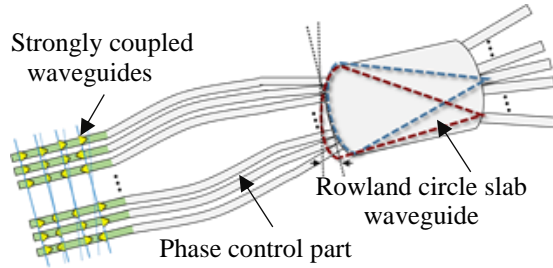


Fig. 1. The schematic of our mode de-multiplexer.

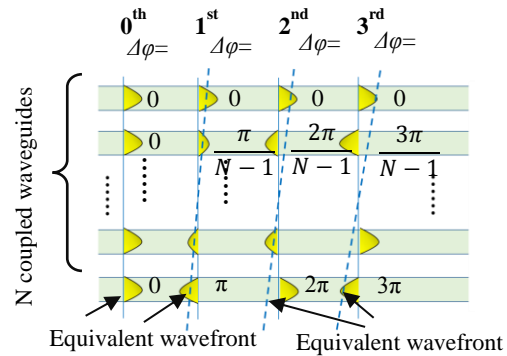


Fig. 2. Field profiles and phase profiles of coupled modes.

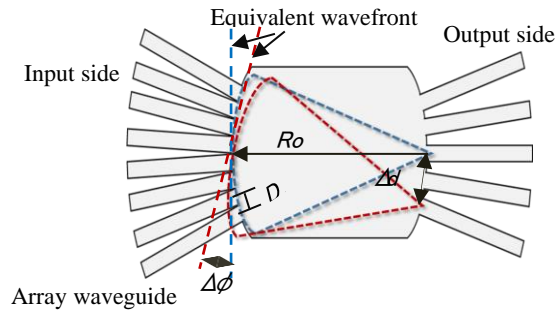


Fig. 3. Schematic of light focus using slab waveguide.

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