Demonstration of nano-pixel 9:1 asymmetric power splitter

(Student paper)

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Asymmetric power splitter was realized using nano-pixel configuration. The implemented device was realized in an area of 3.2 µm × 3.4 µm. It demonstrated asymmetric splitting ratio of 9:1 with excess loss of 4 dB at 1550 nm.

Keywords: *Power splitter, Nano-pixel*

INTRODUCTION

Power-splitter is one of the fundamental optical devices. Especially waveguide-based power-splitter is attractive as it offers several applications including: 1) Mach-Zhender interferometer, 2) output power monitor, and others. As to our purpose, we have been researching and developing an optical integrated circuit to realize a compact breath sensing system (see Fig. 1). As is shown in the figure, power-splitter is, anyway, one of the key-elements [1]. In this case most of the light power must be returned back into the loop whereas slight portion must be monitored apart from the loop. This requirement arises "asymmetric" power-splitter. This is because the monitored power may be sufficient with relatively low power, on the other hand, most of the propagating light must be returned back into the loop to achieve high sensitivity. As to the power splitter, Y-junction and MMI (multi-mode-interference) have been widely used; however; there is insufficient design theory to realize asymmetric splitting [2]. Directional coupler has a potential of asymmetric splitting; however; the length of the device is relatively long (close to around mm) and relatively less robust in general [3]. In this paper, we demonstrate a new potential of using nano-pixel [4-9] for asymmetric splitting. The implemented device was realized in an area of 3.2 µm × 3.4 µm. It demonstrated highly asymmetric splitting of 9:1 with propagation loss of 4 dB at 1550 nm.

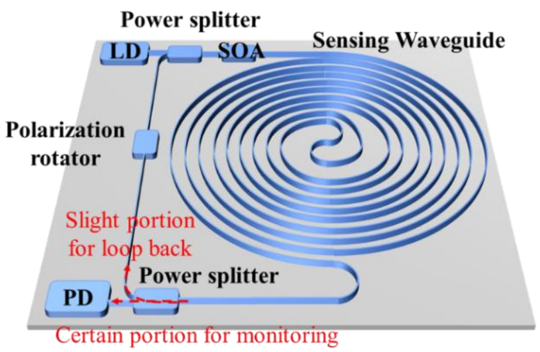


Fig. 1. Photonic integrates circuit for breath sensing

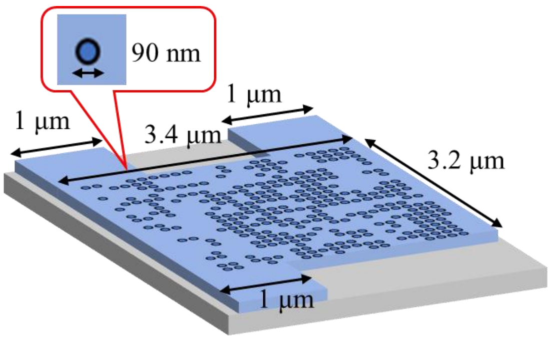
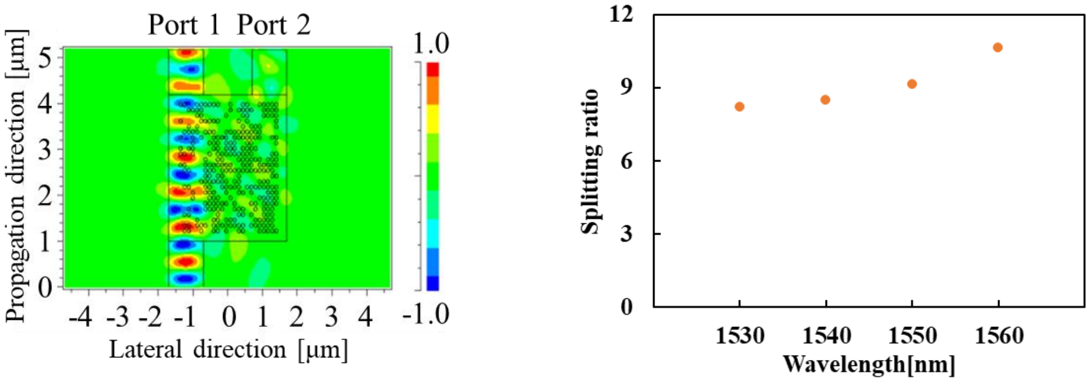


Fig. 2. 9:1 power splitter using nano-pixel

Device Design

Asymmetric splitting device was designed using 3.2 µm × 3.4 µm pixel waveguide (see Fig. 2). The layer structure consists of 100 nm Si- core on top of 1 µm SiO_2 cladding. Each pixel in the nano-pixel waveguide was in a size of 120 nm ×120 nm square. In some pixels, 90 nm radius circular-void are arranged so as to realize the desired 9:1 splitting. The layout of the pixel-pattern was arranged using machine-learning including deep-learning and direct binary search (DBS) [10-11]. There are two issues when highly asymmetric splitting is designed. One is the way to find the initial pattern before starting DBS, and the other is as to criteria setting in DBS. As to the initial pattern finding, we exploited machine-learning. As to the criteria setting, we introduced vector criteria including excess loss and splitting ratio and carried DBS in forward direction. Normally in DBS process, inverse design is used as this scheme leads simple criteria. It becomes sufficient to monitor only the excess loss at the input in this case. In case of designing highly asymmetric splitting, however, this process seems not appropriate even in case of perfect 9:1 combined light power injection is used from two output waveguides simultaneously (and the excess loss is monitored at the input in this case.). We noticed that the power balance of 9:1 was not completely secured and was sacrificed rather than the total excess loss when we verified the splitting performance after the regular DBS design process. To overcome this issue, we relied on DBS in forward direction with vector criteria in this work. As a result, relatively ideal performance was confirmed in FDTD (finite-difference time-domain) simulation. Figure 3 shows the results. As Fig. 3 (a) shows clearly, most of the light propagated toward main output (port 1), whereas slight portion of the injected light comes out from monitor-port (port 2). Figure 3 (b) shows the splitting ratio as a function of wavelength. 9:1 splitting was secured at entire C-band.



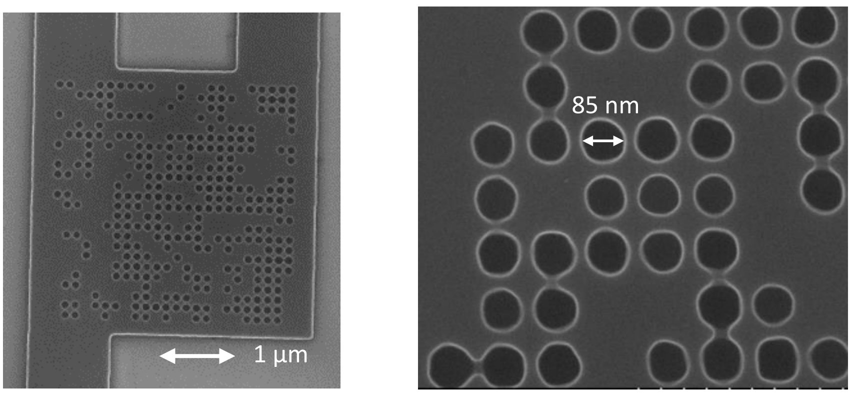
(a) *(b)*

Fig. 3. FDTD simulation result

(a)Counter map, (b) Wavelength dependency of splitting ratio

RESULTS AND DISCUSSION

We fabricated the asymmetric power splitter using SOI wafer. EB-lithography was used for air-hole patterns as well as side-wall formation mask, and ICP (inductively coupled plasma) dry-etching was used for the nano-pixel and the waveguide implementation. Figure 4 shows the top view of the fabricated device. The realized air-hole diameter is estimated to be around 85 nm which is slightly narrower, but not too small, rather than the design. To help the characterization especially asymmetric splitting, S-bend waveguides were integrated at both sides of the device. 1550 nm light was used and coupled through the cleaved facet using hemi-spherical lensed fibre. The light output from the device was measured using IR (infra-red) camera. Figure 5 shows NFP (near-field-pattern) of the device. As shown clearly in the figure, asymmetric power splitting was confirmed successfully. To make the precise splitting ration estimation, we verified the power portion monitored in NFP. Figure 6 shows the results. As shown in the figure, a splitting ratio of 9:1 was confirmed successfully at 1550 nm. In addition, we also verified the wavelength dependency at entire C-band. As is also shown, the ratio was kept almost similar along entire C-band (except 1530 nm case) that mostly agrees with the simulated results. The evaluated propagation loss was estimated to be 4 dB including S-bending waveguide loss.



(a) *(b)*

Fig. 4. Fabricated device

(a) 9:1 power splitter, (b) Nano-pixel region

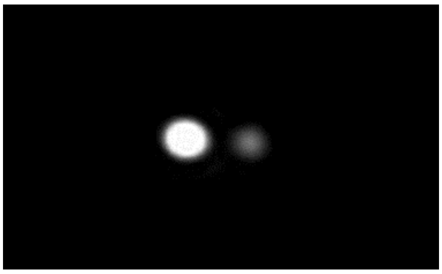


Fig.5. Near field pattern

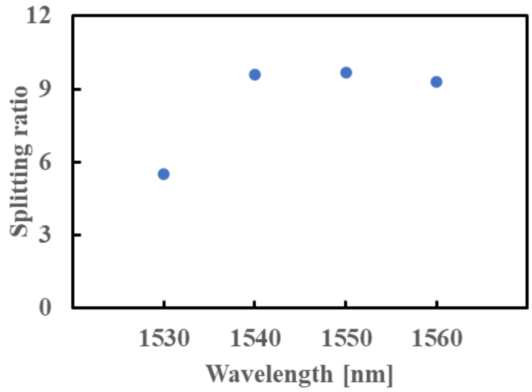


Fig. 6 Wavelength dependency of splitting ratio

Conclusion

We demonstrated nano-pixel asymmetric power splitter with the area of 3.2 µm × 3.4 µm. It demonstrated asymmetric splitting ratio of 9:1 successfully with propagation loss of 4 dB at 1550 nm. We believe that we can realize fully integrated breath-sensing circuit with this asymmetric power splitter soon in the future.

Acknowledgments

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