0.5nm narrow channel spacing of microring resonator Add/Drop filter array controlled by the UV trimming technique

Shuichi Suzuki[1)], Yutaka Hatakeyama[1)], Yasuo Kokubun[1)], and Sai Tak Chu[2)]

1. Yokohama National University, Graduate School of Engineering,
Dept. of Electrical and Computer Engineering
79-5 Tokiwadai, Hodogayaku, Yokohama, 240-8501 JAPAN
Phone +81-45-339-4237, Fax +81-45-338-1157,
Email kokubun@dnj.ynu.ac.jp
2. Little Optics Inc.
9020 Junction Drive, Suite, Annapolis Junction, MD 20701, USA
Email sai@littleoptics.com

Abstract: In the multi-channel microring resonator filter, the wavelength channel spacing was limited to 5.7nm due to the resolution limit of photomask(50nm). Therefore, we developed a new technique to control precisely the channel spacing by a UV-trimming technique using polysilane as the over-cladding layer. As a result, we successfully decreased the channel spacing to 0.5nm, and also controlled the channel spacing precisely to 1.0nm using the same trimming technique.

1. Introduction

Microring resonator devices are attractive as Add/ Drop wavelength filters for wavelength multiplexed access networks, due to their functionality and compactness. We have proposed and demonstrated a vertically coupled microring resonator (VCMRR) filter array[1] by concatenating cross-grid VCMRR elements, as shown in Fig.1. However, the channel spacing of the Add/Drop filter array realized by changing the radius of each ring is about 5.7nm, because the differences of ring radius are limited by the resolution of the photomask, i.e. 50nm. In this study, we demonstrated a precise control of channel spacing of multi-channel Add/Drop filter array using the UV-trimming technique of center wavelength of the filter[2].

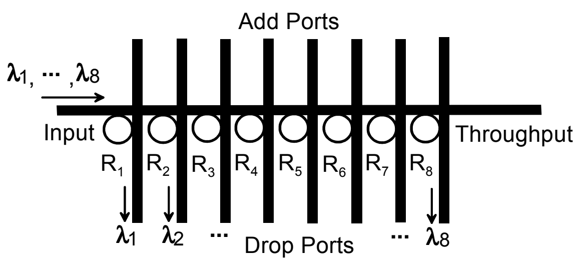

Fig.1: VCMRR filter array

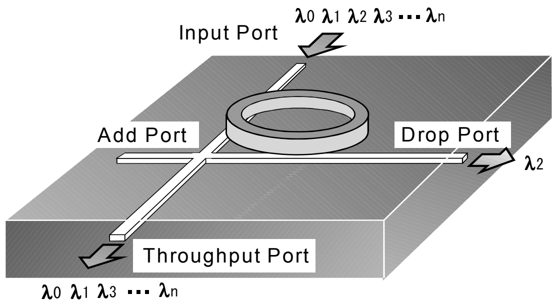

Fig.2: Structure of VCMRR filter element

2. Design of trimming range

Fig.2 shows the structure of the basic VCMRR filter element. Due to the stacked configuration, the upper and lower waveguides play different roles, i.e., the lower buried channel waveguides serve as input/output busline waveguides while the upper ring functions as the frequency selective element.

Fig.3 shows the cross-sectional structure of the VCMRR filter, in which the over-cladding is formed by a UV sensitive polymer. When the index of over-cladding is reduced by UV irradiation, the equivalent index of the ring waveguide is also changed and the center wavelength of the filter is shifted. The polymer used in this study is polysilane $(MeSi)_n[Me(EtO)Si]_m$(n/m:mixture ratio). The refractive index change of polysilane by UV irradiation is shown in Fig.4. The wavelength of the UV light in this experiment was 370nm and the intensity was 20mW/cm^2. The refractive index was decreased from 1.51 to 1.43 by 400sec irradiation. We calculated the amount of center wavelength sift and the bending loss of ring waveguide when the index of over-cladding was assumed to be reduced from 1.51 to 1.43. The parameters used in the calculation are given in Fig.3. The calculated result of the wavelength shift and the bending loss for the ring radius of 15μm is shown in Figs.5 and 6, respectively. It can be seen that when the core thickness of ring waveguide is smaller, the range of center wavelength shift by trimming is larger. However, since the bending loss is also larger as the decrease of core thickness, we designed the thickness of the ring core to be 1.6μm, so that the bending loss of the ring waveguide is the same level as the value for which we could previously obtain a clear spectrum response[3]. For this designed structure, the trimming range of 8nm can be realized, while the bending loss is kept to be smaller than the allowable loss level (0.3 dB/turn).

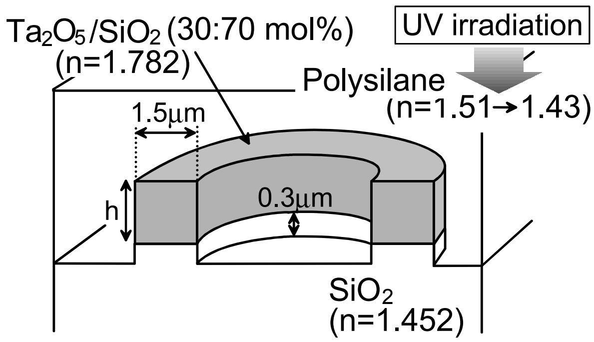

Fig.3: Principle of UV trimming

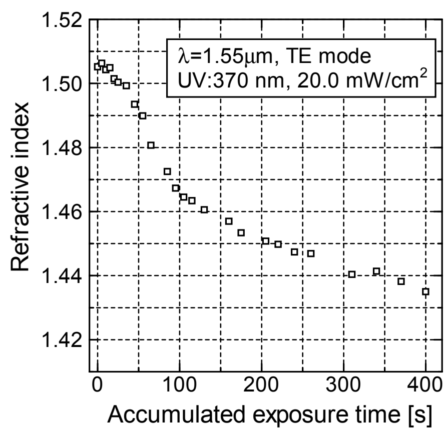

Fig.4: Measured refractive index change of polysilane vs UV exposure time

3. Fabrication and measurement of VCMRR filter array

We fabricated an 1×8 filter array as shown in Fig.1, in which the ring radii (15μm) and ring core thicknesses (1.6μm) are identical for all ports, respectively. The channel spacing between adjacent ports is 250μm. The lower cladding and separation layers are made of SiO_2(n=1.452 at λ=1.55μm). The ring and busline waveguides are made of the Ta_2O_5/SiO_2(Ta_2O_5 30mol%) compound glass to give a refractive index of 1.782. The

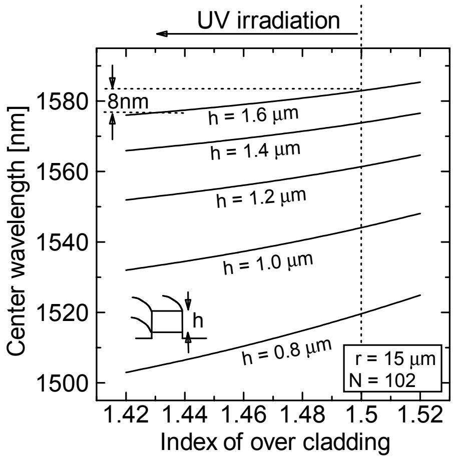

Fig.5: Calculated center wavelength shift by trimming

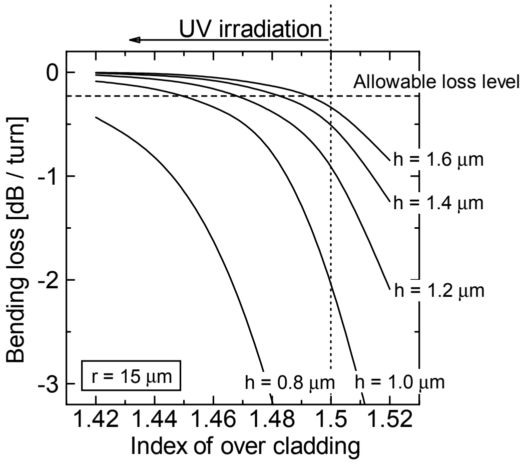

Fig.6: Calculated radiation loss of ring vs index of over-cladding

microring cores were covered by the polysilane with the thickness of 10μm. Other sizes of the device are shown in Fig.3.

Each ring was irradiated by UV-light with different exposure time by shifting a mask using a manipulator. Fig.7 shows the change of the spectrum response of the VCMRR filter for different irradiation time. The center wavelength was shifted over 9.7nm by 220sec irradiation. Fig.8 shows the spectrum responses of R2 and R7, before controlling the channel spacing. Although eight filter elements were integrated in this device, we used the R2 and R7 for the demonstration of the precise control of channel spacing. This is because the initial channel spacing between these two was the largest due to the nonuniformity of waveguide size and core index, and was suitable for the demonstration of large amount of trimming. The channel spacing between R2 and R7 is about 2.5nm. To reduce this spacing, we irradiated UV light only on R2 which has a longer center wavelength than that of R7. The exposure condition of the UV light source used in this experiment was the same as used for the measurement of index change of the polysilane film, i.e. the power density was 20mW/cm^2 and the peak wavelength was 370nm. The spectrum responses after 140sec irradiation only on R2 are shown in Fig.9. Comparing Fig.9 with Fig.8, it can be seen that the channel spacing between R2 and R7 was successfully reduced from 2.5nm to 0.5nm. Next only the R7 was exposed to UV light for 15sec, and the channel spacing was increased to 1nm as shown in Fig.10.

4.Conclusion

We demonstrated the precise control of channel spacing of vertically coupled microring resonator Add/Drop filter array by using a UV trimming technique. In the analysis, we found the structure that satisfies both wide trimming range ($\sim$8nm) and low bending loss of the ring waveguide ($\leq$0.3dB/turn). In the fabrication, we improved the lift-off process and reduced the dent on the top of the lower waveguide. By the step-by-step UV irradiation on the ring resonator in the filter array, a narrow channel spacing (0.5nm) was successfully obtained and the channel spacing was inversely increased to 1.0nm by exchanging the filter under exposure. Thus we successfully demonstrated the precise

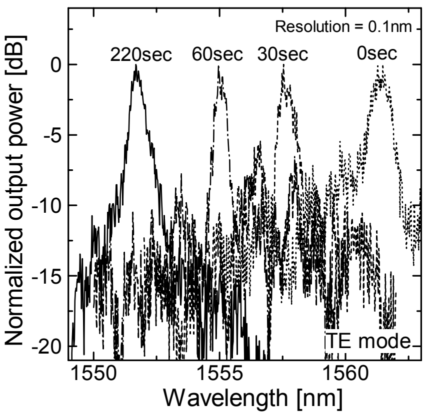

Fig.7: Change of spectrum response by UV irradiation

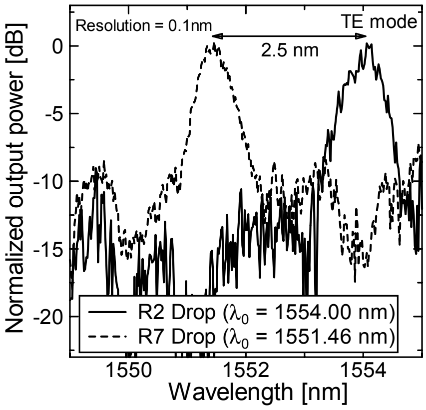

Fig.8: Mearured spectrum responses of R2 and R7 before channel spacing control

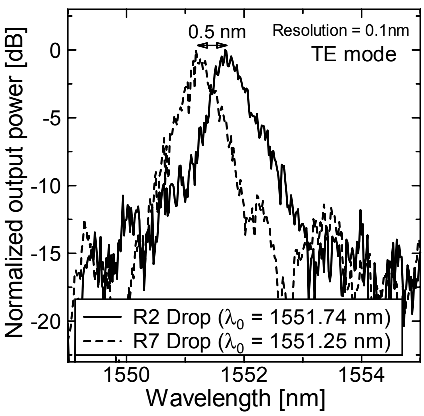

Fig.9: Measured spectrum responses of R2 and R7 after UV irradiation on R2

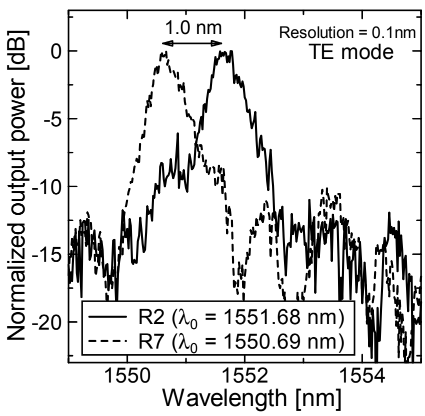

Fig.10: Measured spectrum responses of R2 and R7 after UV irradiation on R7

control of center wavelength and the channel spacing.

Acknowledgments

The authors express their sincere thanks to Drs. T. Imai, T. Fujimoto, and K. Ando of GE Toshiba Silicones, Co., Ltd. for supplying polysilane. This work was partly supported by Grant-in-Aid for Scientific Research (A) No.11305028 by Japan Society for the Promotion of Science, Research for the Future by Japan Society for the Promotion of Science, and International Communication Foundation.

References

[1] S. T. Chu, B. E. Little, W. Pan, T. Kaneko, S. Sato and Y.Kokubun: "An eight-Channel Add/Drop filter using vertically coupled microring resonators over a cross grid" *Photo. Tech. Lett.*, **11**, pp.691-693, 1999

[2] S. Sato, W. Pan, S. T.Chu, S. Endo, S. Suzuki, and Y. Kokubun: "59-nm trimming of center wavelenth of ARROW-type vertical coupler filter by UV irradiakon" *Photo. Tech. Lett.*, **11**, pp.358-360, 1999

[3] S. T. Chu, W. Pan, S. Suzuki, B. E. Little, S. Sato and Y.Kokubun: "Temperature insensitive vertically coupled microring resonator Add/Drop filters by means of polymer overlay" *Photo. Tech. Lett.*, **11**, pp.1138-1140, 1999