A Silicon-on-Insulator 120° Optical Hybrid Based on 3x3 Multimode Interference Coupler

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Abstract—A 120° optical hybrid based on 3x3 multimode interference coupler is reported. The device exhibits less than 10° phase deviation over 55 nm in the C- and L-band.

Keywords—120-degree hybrid; multimode interference coupler;

I. INTRODUCTION

Coherent optical detection system provides high receiver sensitivity, excellent spectral efficiency and elongated unrepeated transmission distance. In conventional coherent detection system, the incoming optical signal is mixed with the local oscillator using a 90° optical hybrid which is then detected with a pair of balanced photodetectors per polarization. Coherent detection scheme can also be implemented using 120° optical hybrid with three single-ended photodetectors [1]. Although balanced detection is favored in long-haul communication systems due to its superior performance in suppressing different noise sources, single-ended detection is less expensive due to simpler transimpedance amplifiers and less number of required RF connections. Furthermore, 120° optical hybrids can extenuate imperfections caused by analog to digital converters and digital signal processors [2-3].

In this paper, we experimentally demonstrate a 120° optical hybrid based on 3x3 multimode interference (MMI) coupler in silicon-on-insulator (SOI) platform for TE mode. Optical bandwidth (BW) of a MMI coupler is proportional to the square of the ratio between waveguide width and MMI width [4]. Therefore, a 3x3 MMI coupler based 120° hybrid intrinsically has broader optical BW than a 4x4 MMI coupler based 90° hybrid. Optical hybrids with broader BW are preferred in long-haul communication systems since colorless detection is desired over the whole telecom BW. The reported 3x3 MMI coupler based 120° hybrid shows <3.5 dB excess loss in the C-band and <10° phase deviation over 55 nm.

II. DESIGN AND MEASUREMENT

The 3x3 MMI is designed using eigenmode expansion solver of Lumerical MODE solutions [5]. The device is fabricated by electron-beam lithography using a single-etch process. The SEM image of the fabricated 3x3 MMI coupler with device dimensions is shown in Fig. 1(a). The setup for measuring the relative phase of the 3x3 MMI coupler is presented in Fig. 1(b). The injected light is split using a 3-dB directional coupler and a Mach-Zehnder interferometric structure is implemented at the input of the hybrid. This results in a free spectral range (FSR) characteristic at the three output ports from where the relative phase differences can be determined using the following relation

\[ \Delta \phi / \Delta \lambda = 2\pi / \text{FSR} \]

The measured relative phases of the three output ports are shown in Fig. 1(c). Each output port exhibits <10° phase deviation for the wavelength range of 1530-1585 nm. The transmission responses of the three output ports for each of the input ports are shown in Fig. 1(d). An excess loss of <3.5 dB is observed in the C-band.

III. CONCLUSION

A 3x3 MMI coupler based 120° hybrid is demonstrated in SOI platform with <10° phase deviation over 55 nm BW.

REFERENCES

Fig. 1. (a) SEM image of the fabricated device with dimensions, (b) Relative phase measurement method, (c) Measured relative phase differences at the 3 output ports, and (d) Measured splitting ratios at the 3 output ports for each input port.