Experimental Demonstration of a WDM-based Integrated Optical Decoder for Compact Optical Computing

Chenghao Feng [1], Jiaqi Gu [2], Hanqing Zhu [2], David Z. Pan [2], and Ray T. Chen [1*]
[1]Microelectronics Research Center, The University of Texas at Austin, Austin, Texas 78758, USA
[2]Computer Engineering Research Center, The University of Texas at Austin, Austin, Texas 78705, USA
[*] e-mail address: chenrt@austin.utexas.edu

Abstract: We propose and experimentally demonstrate a 3-8 wavelength-division-multiplexing (WDM) based optical decoder using microring-based add-drop switches and filters. The proposed decoder has a smaller footprint and consumes lower power compared with previous designs.
OCIS codes: (200.4660) Optical logic; (250.3750) Optical logic devices; (130.3120) Integrated optics devices

1. Introduction

Optical computing is intriguing because of some unique features of light, which are low latency, high bandwidth and low power consumption. Various photonic circuits are proposed to replace transistor-based electric circuits to do computation as the continuation of Moore's law has become problematic[1][2]. Numerous approaches have been made to enhance the performance of optical computing architectures. For instance, recent work utilizes multiplexing techniques in photonic computing architecture design to shrink the size and improve the energy efficiency [3].

Decoder is a fundamental building block of combinational logic circuits and is widely used for data transportation, addressing and code conversion in modern processors. Previous work discloses that the WDM-based electronic-photonic optical decoder using high-speed microdisk modulators outperforms electronic counterparts in both speed and energy efficiency [4]. We believe these performance metrics can be further improved by using more suitable optical components to construct the decoder.

In this paper, we devise a new scheme to further enhance the performances of the WDM-based electronic-photonic decoder such as the footprint and the power consumption. In addition to applying WDM to lessen the number of logic gates, we use add-drop microresonator-based modulators in substitution for all-pass microresonator-based modulators used in previous work to scale down the size of the module as well as reduce the optical propagation loss. The functionality of the 3-8 (3 inputs, 8 outputs) decoder is experimentally demonstrated, revealing one can reduce more than forty percent of active optical components compared with previous designs.

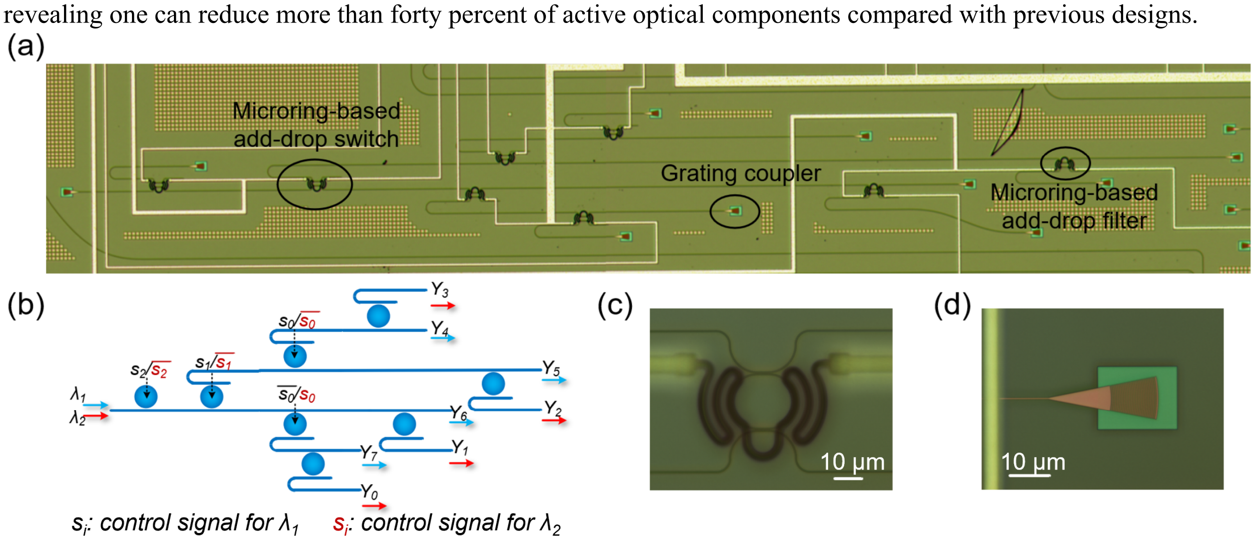


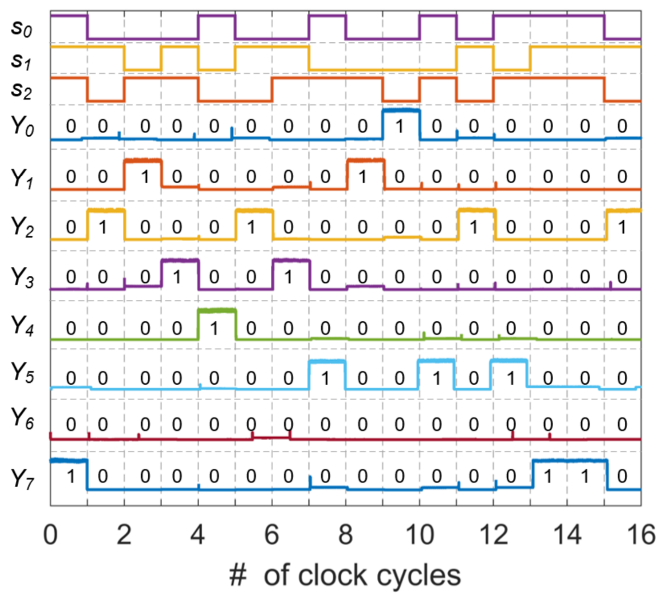
Fig. 1. (a) Micrograph of the fabricated optical decoder chip. (b) The schematic of the optical decoder. (c)(d) Close-ups of the add-drop switch and the grating coupler.

2. Results

Figure 1(a) shows a micrograph of the optical decoder chip fabricated in Advanced Micro Foundry(AMF). Four microresonator-based add-drop thermal-optic (TO) switches (shown in Fig. 1(c)) function as electrooptic (EO) logic gates, which can achieve modulation by manipulating the flow of light and direct light to different optical paths. Shown in Fig.2(b), we use two wavelengths λ_1 and λ_2 according to the transmission spectrum of the switch as well as the operating voltage. As a result, the two light beams can share the EO logic gates and be controlled by two different signals that are inverse codes to each other. For example, when voltage V_1 is applied on the switch, light beam λ_1 will transmit the through port while λ_2 will transmit the drop port. Add-drop microring resonators also function as demultiplexers to split λ_1 and λ_2 to different output ports. Compared to the previous design of 3-8 optical decoder [4], where seven all-pass microdisk modulators are used as EO logic gates, this work uses 43% fewer modulators to realize the same logic function. Furthermore, less laser power is required since splitters are no longer needed in our design, which will bring 3 dB splitting loss each.

Here we experimentally demonstrate the functionality of our decoder by comparing the output waveforms with the truth table of the circuit. In the testing, the input lights with different wavelengths are generated by a tunable laser. Pseudorandom non-return-to-zero (NRZ) signals are generated by a multi-channel digital-analog converter (DAC) and are operated on the thermal pads of the add-drop switches simultaneously. An add-drop microring filter will separate these two lights at the output. Finally, light is coupled out and received by an oscilloscope for logic analysis. Part of the testing results is shown in Figure 2(a), which fits well with the truth table shown in Fig. 2(b). The clock period in Fig. 2(a) is 20 ms, which is limited by the set-up time of the DAC. It should be noted that the operating speed of our decoder can reach tens of GHz by replacing TO modulators with high-speed carrier-depletion microresonator-based modulators [5]. More data at higher clock rate along with detailed performance analysis will be shown in the presentation.

(a)



(b)

Input	Output
$\bar{s}_2\bar{s}_1\bar{s}_0$	Y_0
$\bar{s}_2\bar{s}_1 s_0$	Y_1
$\bar{s}_2 s_1\bar{s}_0$	Y_2
$\bar{s}_2 s_1 s_0$	Y_3
$s_2\bar{s}_1\bar{s}_0$	Y_4
$s_2\bar{s}_1 s_0$	Y_5
$s_2 s_1\bar{s}_0$	Y_6
$s_2 s_1 s_0$	Y_7

Fig. 2. Testing results of the decoder (a) Testing waveforms of different outputs, the operating wavelengths are 1550nm and 1552.5nm. (b) The truth table of the 3-8 decoder.

In conclusion, we have proposed a 3-8 optical decoder in experiments using microresonator-based add-drop switches. WDM and add-drop switches are used to optimize the number of modulators and power consumption. We believe this design could contribute to future ultracompact optical computing with low power consumption and high computation speed.

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