Ultra-compact multistage interferometric devices for optical communication

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***Abstract*—Densification of photonic functionality is important as the optical communication industry strives to achieve higher levels of integration. We present a new approach for folding multistage interferometric devices such that waveguide density reaches its theoretical limit. The feasibility of the approach is validated by a demonstration of a CWDM multiplexer, which was realized in a silica-on-silicon platform in a footprint of 0.18 cm^2 and exhibits state-of-the-art optical performance characteristics.**

Keywords—planar lightwave circuit, silica-on-silicon, waveguide, densification, integrated optics

I. Introduction

Planar lightwave circuit (PLC) technology has grown into a powerful platform that is able to meet the challenging demands of today's high-speed optical communication systems [1][2]. PLCs provide integrated solutions that offer compact form factor, lower cost and higher reliability compared to bulk optics solutions. Here we present a new approach for achieving highly-optimized, ultra-dense layouts of multistage interferometric devices that is suitable for both low- and high-refractive index contract PLC platforms.

II. Our Work

PLCs provide economical, high-capacity solutions for systems using wavelength-division multiplexing (WDM). WDM systems that are based on optical lattice filters [3] are essentially lossless components. However, these systems typically require a large footprint due to the serial nature of the cascaded interferometric stages. We describe a generalized architecture that allows a compact arrangement of interferometric chains, resulting in an ultra-dense layout with waveguide density close to the theoretical limit. Previously, we applied this architecture to realize a LAN-WDM multiplexer [4]. Here we extend this work to CWDM systems.

A. *Generalized Spiral Architecture*

The presented architecture relies on the generalized spiral pattern, shown in Fig. 1(a). A Mach-Zehnder interferometer requires two couplers and a physical delay between two waveguides. A waveguide ribbon spiral can realize such an interferometer by providing physical delays at the bends, and by implementing directional couplers within the straight regions of the spiral. The incremental cost of adding an additional interferometric stage to the spiral is very low, both in terms of the footprint and the excess insertion loss, thus long cascaded multistage interferometric chains can be readily formed.

B. *CWDM Multiplexer*

To validate the approach, we designed and fabricated a 4-channel CWDM multiplexer that is based on optical lattice filters, shown in Fig. 1(b). We used a silica-on-silicon PLC platform with a refractive index contrast of $\Delta n = 2.0\%$. Typical characteristics of our platform include ultra-low waveguide propagation losses (< 1 dB/m), efficient fiber-to-waveguide coupling (~0.5 dB facet), temperature-stable optical performance, and polarization-invariant operation with zero birefringence. The relatively low refractive index contrast restricts the maximum waveguide curvature to 1 mm.

Fig. 1(c) shows the transmission spectra of a fiber pigtailed 4-channel CWDM multiplexer, for TE and TM polarized light. The device exhibits worst channel insertion loss of 1.5 dB. Most of the insertion loss is due to two fiber couplings, with on-chip loss estimated at 0.3 dB. A single-mode spectral response of each channel is flat with a 1-dB bandwidth of 16.4 nm (greater than 82% of the channel pitch). The device has worst case adjacent crosstalk of 19 dB and polarization dependent loss of less than 0.2 dB.

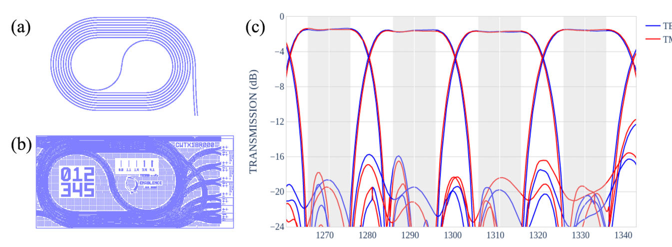

Fig. 1. (a) Generalized spiral used as a basis for the described architecture. (b) A 4-channel CWDM multiplexer chip. (c) Measured transmission spectra of the multiplexer, including two fiber couplings.

III. Conclusion

We proposed a methodology to achieve ultra-dense folding of long interferometric chains that is suitable for densification of optical functionality in PLCs in any refractive index platform. The approach was validated by a demonstration of an ultra-compact 4-channel CWDM multiplexer. Despite the relatively low refractive index contrast of our silica-on-silicon platform, the footprint of the multiplexer was only 0.18 cm^2 and it exhibited exceptional optical performance characteristics.

References

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