Integrated multiplexing and switching in wavelength, polarization and mode

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Abstract: We review recent results on integrated silicon photonic chips for (de)multiplexing and switching, which operate in wavelength, polarization, and mode dimensions. © 2020 The Authors

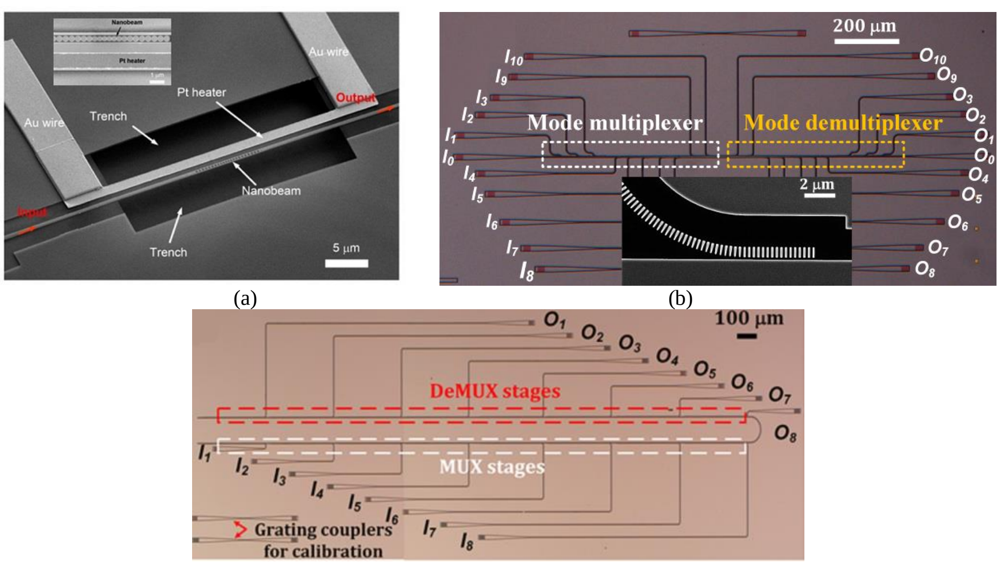
1. Introduction

Multiple physical dimensions of an optical carrier can be leveraged to multiplex data. While wavelength and polarization were extensively exploited, mode has become an interesting dimension to increase the system capacity and spectral efficiency without needing more laser sources. On the other hand, switching of data streams with fine granularity in a network node requires a prior de-multiplexing stage for the aggregated data, i.e., a reverse operation of the multiplexing process [1]. In this paper, we review our recent results on integrated (de)multiplexing and switching devices on silicon chips, which operate in the wavelength, mode, and polarization dimensions.

2. Integrated multi-dimensional (de)multiplexing chips

We first demonstrate a compact wavelength-tunable filter based on a photonic crystal nanobeam (PCN) with a high thermo-optic (TO) tuning efficiency of 21 nm/mW [2]. The device shows a single resonance in C band with a continuous tuning range of ~43.9 nm. The results are enabled by the ultra-small mode volume (~0.34 μm^3) of the PCN cavity and a suspended waveguide structure surrounded by the air, resulting in a small heat capacitance.

We then discuss a high-order mode (de)multiplexer [3]. Subwavelength grating (SWG) structure is introduced to engineer the access waveguide so it has the same effective refractive-index property as that of a high order mode in the bus waveguide. An 11-mode (de)multiplexer on single polarization was realized (TE_0 ~ TE_{10} modes) in Fig 1(b) with the SWG for the TE_{10} channel shown in the inset.



(c)

Fig. 1. (a) A wavelength-tunable filter based on PCN, (b) a mode (de)multiplexer SWG couplers, and (c) a wavelength-mode-polarization (de)multiplexer employing contra-directional SWG couplers.

We further attempt to realize a three-dimensional (de)multiplexer in wavelength, mode, and polarization [4]. An SWG exhibits wavelength selectivity if placed in a contra-directional configuration in parallel to a bus waveguide. A proof-of-concept experiment was performed with an 8-channel (de)multiplexer with 2 wavelengths (1540 and 1550 nm), 2 polarizations and 2 modes (TE_0, TE_1, TM_0, TM_1) with the device shown in Fig. 1(c).

3. Integrated multi-dimensional switching chips

In general, switching process consists of three steps: de-multiplexing of input data to multiple streams in one or more physical dimensions, routing of the data streams on multiple layers to desired output ports, and multiplexing of the switched data to interface with output fibers. Fig. 2(a) illustrates a three-dimensional switching architecture [1].

Fig. 2(b) is a scanning electron microscope (SEM) image of a 2 × 2 wavelength switch. It consists of two suspended PCN cavities in a Mach-Zehnder interferometer (MZI) configuration. A low TO tuning power of 0.16 mW is achieved [5]. In [6] we demonstrate an on-chip silicon 2 × 2 mode and polarization selective switch (MPSS) with two mode channels and two polarizations, as shown in Fig. 2(c). Mode (de)-multiplexers and polarization combiners/splitter are employed. A proof-of-concept three-dimensional 2 × 2 mode-polarization-wavelength selective switch (MPWSS) is proposed and demonstrated in [1] with 2 modes, 2 polarizations, 1 wavelength, and 2 ports. The MPWSS is scalable in wavelength by cascading more add-drop filters and employing more mode channels.

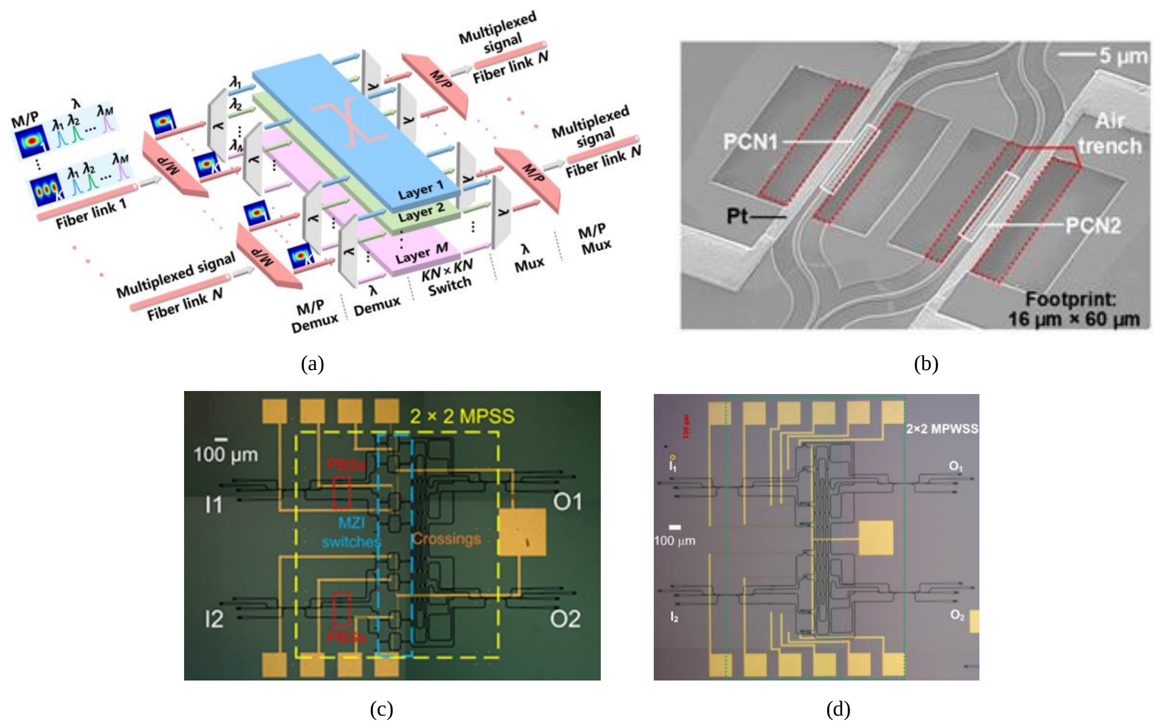


Fig. 2. (a) A general architecture for multi-dimensional switching, (b) a wavelength switching employing PCNs, (c) a mode-polarization selective switching, and (d) a proof-of-concept mode-polarization-wavelength switch.

4. Conclusion

We demonstrated 6 on-chip (de)multiplexing and switching chips, including a high efficiency wavelength tunable filter, an 11-channel mode (de)multiplexer, a three-dimensional (de)multiplexer, a low-power-consumption wavelength switch, a mode-polarization selective switch, and a proof-of-concept three-dimensional switch.

References

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