Multichannel Si Photonic Crystal filters with Fine-Tuning Capability of Individual Channels for WDM optical interconnects

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Summary

We demonstrate a simple, low-cost solution for a single multi-channel WDM (Wavelength Division Multiplexing) filter with fine-tuning capability at the level of the individual channels. The filter is based on silicon photonic crystal and microfluidic technologies and can be integrated with CMOS processes.

Introduction

Although fabrication technology of silicon photonics WDM systems has significantly advanced over the last decade, the most difficult challenges are currently posed by accurate wavelength control, wavelength drifts and slow optical switching times. Fabrication tolerances for modern e-beam lithography are usually assumed to be a minimum of about 5% of the nominal target dimensions. This crucially affects the optical characteristics of multi-channel filter devices. It changes the precise wavelength dependencies of individual channels; it increases the out-of-band reflection and causes attenuation of the maximum intensity, resulting in a lowering of the quality factor, Q. One of the most promising solutions to these problems could be a filter device with low-power and low-loss capability to compensate for the optical filter deviations. This would allow fine-tuning of individual channels in the filter system by varying the temperature or by applying an electric field. However, one of the main challenges in the realisation of tunable multi-channel devices remains the fixed channel spacing or free spectral range which cannot be easily tuned due to the strong inter-channel coupling [1].

Discussion

In this paper we propose a novel design of a multichannel integrated filter based on silicon-on-insulator (SOI) photonic crystal (PhC) concepts and liquid crystal optofluidics technology (Fig 1a). By infiltration of specific periods of a PhC with a liquid crystal (LC) filler, an efficiently coupled Fabry-Pérot micro-resonator can be realised in which the wide stop band (SB) is used for frequency channel separation (Fig 1b). Using an example of a coupled triple-cavity PhC filter operated using the first SBs, we have developed a simple model for facile manipulation of the LC within individual cavities, enabling the independent fine tuning of each channel in the overall system. We note

that the model suggested can be extended to a higher number of coupled cavities (defects) and, therefore, to a higher number of resonances, with a correspondingly improved Q factor.
By using the commercial nematic liquid crystal 5CB [1], we reviewed electro-optical switching time in the range of 30–50 nanoseconds and we demonstrate the continuous tuning of the individual channels by up to 30% of the channel-spacing. The fabricated multichannel filters have bandwidths of 0.1–0.9nm with a high extinction ratio of 20 dB at high modulation of reflection/transmission coefficient. Using the gap map approach as a core engineering tool allows prediction of the formation and separation of transmission channels within the SBs and, thus, effective determination of the exact design parameters of the optical device. The obtained experimental spectral characteristics in the
NIR range around 1.31 and 1.55 µm validated the proposed method and its applicability for use in wavelength selective switching as well as for WDM in silicon chip optical interconnects.

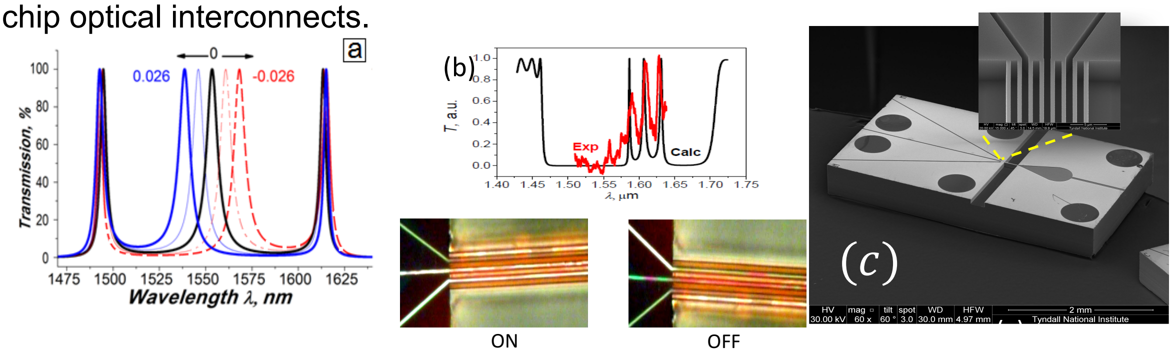

Figure 1. (a) Continuous tuning of the central channel in triple channel filter realized through the refractive index tuning in one of the triple cavities of FP resonator. (b) FP resonator triplet demonstrated within the SB region in experimental (red line) and calculated (black line). Polarized optical microscopy images showing a top view on the channels without applied voltage and under applied voltage (c) SEM image of the fabricated defect-free 1D PhC with three electrically tuneable microfluidic channels.

To experimentally demonstrate the proposed idea, the triple-channel resonator device was fabricated on <100> p-type SOI wafer with a silicon device layer thickness of 4.5 µm, and a 1 µm thick buried oxide (Fig 1a). The design parameters of the 1D PhC structures were selected from the calculations using a transfer matrix method and gap map approach for one of the selected types of tuning discussed above. Electron-Beam Lithography followed by the plasma etching was used to fabricate the nano-scale structures.

Conclusions

Different options for position control of individual transmission channels in a triple-cavity resonator device are discussed. The resonator design is based on a silicon-air 1D PC. Optofluidic materials(Ferrofluids, nematic LC) integrated as a tunable cladding on an efficiently coupled Fabry-Pérot resonator can be realized in which a wide stop band is used for broad frequency channel separation.

References

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