2008

Reconfigurable Multi-Passband Optical Filter Using Opto-VLSI Processor

Muhsen Aljada
Edith Cowan University

Kamal Alameh
Edith Cowan University

10.1109/OECCACOFT.2008.4610564
This is an Author's Accepted Manuscript of: Aljada, M. , & Alameh, K. (2008). Reconfigurable Multi-Passband Optical Filter Using Opto-VLSI Processor. Proceedings of Joint conference of the Opto-Electronics and Communications Conference, 2008 and the 2008 Australian Conference on Optical Fibre Technology. OECC/ACOFT 2008. (pp. 1-2). Sydney, Australia. IEEE. Available here

Reconfigurable Multi-Passband Optical Filter Using Opto-VLSI Processor

Muhsen Aljada, Kamal Alameh
Centre of Excellence for Microphotonics Systems, Electronics Science Research Institie, Edith Cowan University
Email: m.aljada@ecu.edu.au, k.alameh@ecu.edu.au

Abstract – A reconfigurable multi-passband optical filter of 0.5nm linewidth and a tuning range of 8 nm is demonstrated using an Opto-VLSI processor. The wavelength tunablility is performed using digital phase holograms uploaded on the Opto-VLSI processor.

Introduction

Wavelength division multiplexing (WDM) have been a potential approach that meets the emerging needs of broad-band telecommunications thereby increasing transmission capacity, switching and routing optical signals, providing new services, and improving network modularity, scalability, and flexibility [1]. One of the most important components for WDM networks is a tunable wavelength filter. Such a filter can serve as the tuning element, either at the receiving end or the transmitting end of a WDM system. Moreover, a tunable optical filter is also required for channel monitoring, dispersion equalization, as well as improving the spectral purity, and the tunablility of an optical source. In addition, a tunable optical filter can be used in other laser-based applications such as laser printing, optical data storage, and biomedical applications [2]. Various tunable filters have been demonstrated, including, fiber Fabry-Perot (FFP) filters [3], and acousto-optic tunable filters (AOTF's) [4], optical micro-electro mechanical system (MEMS) [5], and fiber Bragg gratings [6].

Recently, reconfigurable opto-VLSI processors have been demonstrated to be attractive active devices for WDM networks and systems [7-9]. An Opto-VLSI processor comprises an array of liquid crystal (LC) cells independently and electronically driven by a Very-Large-Scale-Integrated (VLSI) circuit that generates multi-phase digital holographic diffraction gratings capable of steering and/or shaping optical beams. A computer-generated blazed grating of arbitrary pitch can be synthesized by digitally driving a block of LC pixels with appropriate voltage levels (the optical phase shift of a pixel is voltage dependent) so that an incident optical beams can be dynamically steered along an arbitrary direction. The steering performance of Opto-VLSI processors has previously been reported in [7-9]. In this paper, we experimentally demonstrate a reconfigurable optical filter based on the use of an opto-VLSI processor. The attractive features of the proposed structure include reconfigurability, the ability to operate as a single-pass or multipass, and the potential to realize a wide tuning range.

Filter Demonstrator and Experiment Setup

A reconfigurable multi-passband optical filter demonstrator, employing an opto-VLSI processor was implemented as shown in Figure 1. A fiber-pigtailed broadband amplified spontaneous emission (ASE) source, whose spectrum is also shown in Figure 1, was used in conjunction with an optical spectrum analyzer to obtain the spectral response of the optical filter. The fiber-coupled ASE was collimated using a 1-mm-diameter fiber collimator and launched onto a 1200 lines/mm diffractive grating plate that spread the wavelength components of the collimated ASE along different directions and mapped them onto the active window of the Opto-VLSI processor.

The Opto-VLSI processor used in this experiment was one-dimensional having 1×4096 pixels, 256 phase levels, 1μm pixel size, and 0.8μm spacing between pixels. The active window of the Opto-VLSI processor was partitioned into different pixel blocks driven by optimised digital phase holograms, which steer the incident wavelength components along arbitrary directions within the steering range of the Opto-VLSI processor (~ ±4˚).

A collimated optical beam incident on a pixel block of the Opto-VLSI processor could either be coupled back, through beam steering, into the fiber collimator with minimum attenuation, or steered off-track, hence attenuated. Depending on the required spectral response of the filter, selected wavelengths were coupled into the fiber collimator and routed into a semiconductor optical amplifier (SOA) to compensate for the coupling loss caused by the fiber to free-space and free-space to fiber light transmission. Wavelength tuning was achieved by changing the phase holograms that drive the various pixel blocks of the Opto-VLSI processor.

To demonstrate the functionality and flexibility of the proposed optical filter structure, the wavelength tunablility and the number of simultaneously synthesized wavelength passbands were investigated.

At first, the Opto-VLSI processor was loaded with the digital phase hologram shown in Figure 2(a), which coupled a single wavelength, namely 1532.7nm, back into the fiber collimator. Figure 2(b) shows the measured spectrum at the output of the SOA. Optimized phase holograms were generated to couple different wavelengths into the fiber collimator, thus realizing a tunable optical filter with a single passband with a tuning range of 8 nm, as illustrated in Figure 2(c).

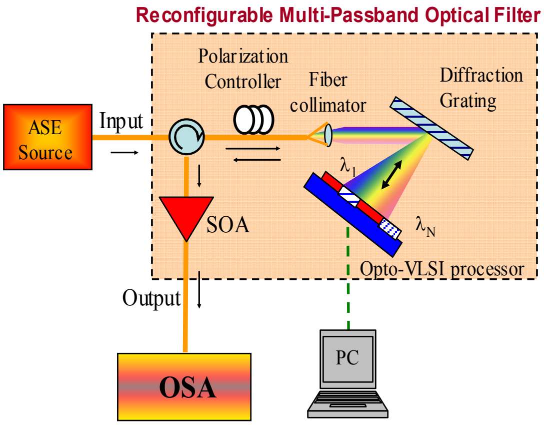

Fig. 1. Experimental setup for demonstrating the proposed reconfigurable multi-passband optical filter. Inset: Spectrum of the input ASE source.

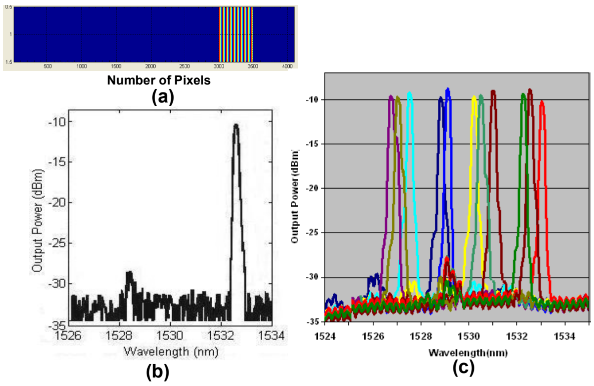

Fig. 2. (a) Digital phase hologram loaded onto the Opto-VLSI processor. (b) Output spectrum for generating an output wavelength at 1532.7nm. (c) Measured filter responses, demonstrating single-wavelength tuning through hologram optimization.

The synthesis of a multi-passband filter response with arbitrary spacing between the passbands was also demonstrated through digital phase hologram optimization. Digital phase holograms were loaded onto the Opto-VLSI processor to realize tunable optical filter responses with 2, 3, and 5 passbands, respectively, with non-uniform spacings. Figs 3(a-b), Figs. 3 (c-d), and Figs. 3 (e-f) demonstrate a multi-passband filter response with a bandwidth as narrow as 0.5nm and show the loaded digital phase holograms and the corresponding measured spectra at the SOA output for 2, 3, and 5 wavelength, respectively.

In this experiment, the tuning range was limited by the small window size of the Opto-VLSI processor used that restricted some of the ASE wavelength components to be mapped within the active window of the Opto-VLSI processor, thus prevented the wavelength components to be steered back into the SOA. Therefore, by using an Opto-VLSI processor with a large active window size (20mm) and small pixel pitch (~ 2 microns), a tuning range of 40nm and a larger number of simultaneously generated wavelengths can be achieved.

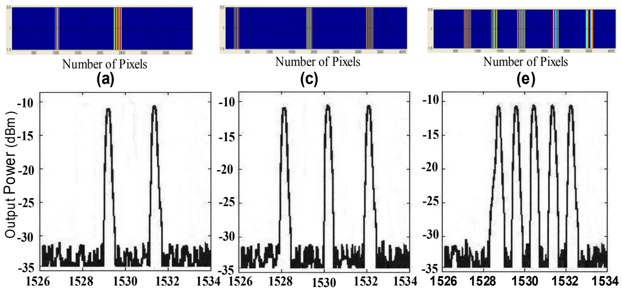

Fig. 3. (a ,c, e) Digital phase holograms loaded onto the Opto-VLSI processor to synthesize two, three, and five passbands respectively. (b, d, f) Corresponding measured output spectra.

Conclusion

A reconfigurable multi-passband optical filter based on the use of an Opto-VLSI processor has been proposed and experimentally demonstrated. The Opto-VLSI processor has been used to generate phase holograms that steer selected wavebands and couple them into a fiber collimator, thus realizing tunable optical filter with arbitrary passbands and 0.5nm linewidth over a tuning range of 8nm. However, a large-aperture Opto-VLSI processor is capable of realizing a tuning range in excess of 40 nm.

References

[1] B. Glance and M. Karol, IEEE Photon. Technol. Lett. **6** (1994) p.872
[2] B. Saadany et al, J. Sel. Top. Quantum Electron. **12** (2006) p.1480
[3] J. Stone and L.W. Stulz, Electron. Lett. **23**, (1987) p.781
[4] D. A. Smith et al, Electron. Lett. **25** (1989) p. 398
[5] A. Lipson, E.M Yeatman, J. Microelectromechanical Systems **16** (2007) p. 521.
[6] M. Rochette et al, IEEE Photon. Technol. Lett. **17** (2005) p.1680
[7] M. Aljada, et al, *J.* Lightwave Technol., **24** (2006) p.2779
[8] M. Aljada, R. Zheng, K. Alameh, and Y.-T. Lee, Opt. Express **15** (2007) p. 9666
[9] M. Aljada, K. Alameh, Y.-T. Lee, and I.-S. Chung, Opt. Express **14** (2006) p. 6823