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Photonic Integrated Circuit for Channelizing RF Signals

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Abstract: A new highly-functional photonic integrated circuit for the channelization of wideband RF signals is presented. This chip includes integrated ring resonator filters, electro-absorption modulator, and a tunable laser. The operation of the integrated laser and filter are shown.
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1. Introduction

Advanced digital signal processing techniques cannot be applied directly to real time analysis of wideband RF signals due to limits in the ability to perform analog to digital conversion at high frequencies and limits in compute resources and power required to perform real time computation on these signals. Channelizers fragment the wideband spectrum into a series of sub-bands that can be down-converted to frequencies compatible with analog to digital converters. Existing microwave channelizers are physically large and have fixed frequency characteristics which seriously limit the application space.

We present a monolithically integrated photonic channelizer which reduces the size of the channelizer components by orders of magnitude over conventional electronic channelizers, and has adjustable filter characteristics. These features permit wideband RF digital signal processing in new applications which were heretofore impossible. This photonic integrated circuit (PIC) is composed of an integrated distributed Bragg reflector (DBR) laser, electro-absorption modulator (EAM), a filter bank and an optical wavelength monitor. One primary advantage of using an InP-based material platform is the ability to integrate the filters monolithically with light sources and modulators which eliminates coupling losses, reduces the chip size and increases the mechanical robustness. Since passive waveguide losses using InP-based materials are too high for the required filter quality-factor and insertion loss, each integrated ring resonator contains an integrated optical amplifier. Active filter design details for insertion loss, noise and distortion are reported in reference [1].

2. Design and Operation

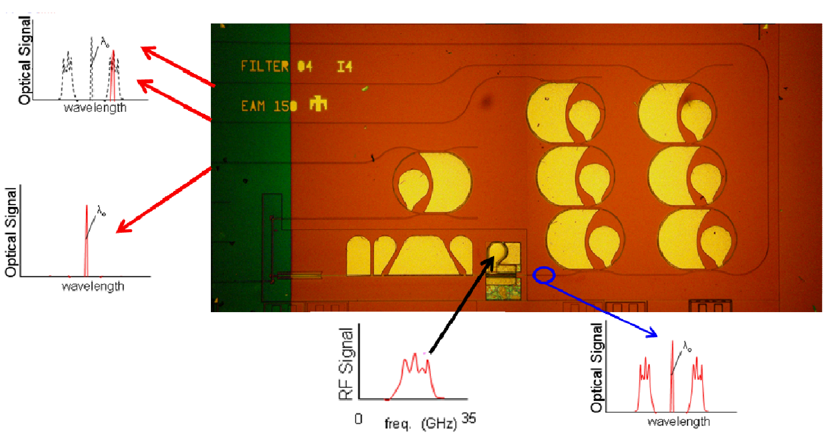
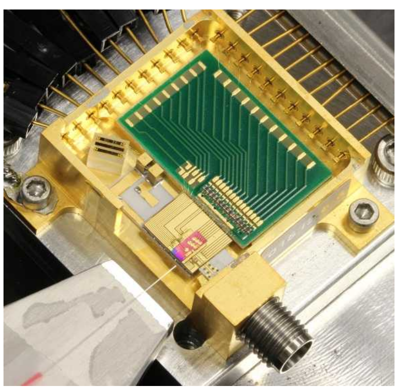


Figure 1: Optical image of the channelizer chip and representative signals at various points

An optical micrograph of the chip along with signals at various points is shown in Figure 1. The laser provides a continuous-wave (CW) carrier wavelength. The CW-laser light is then modulated by an EAM using the RF signal of interest which creates laser carrier wavelength sidebands. Slices of these sidebands are then pulled off by the third-order ring resonator filters which follow the EAM. The signals are then coupled off chip to a fiber or photodetector. The integrated laser is a DBR laser continuously tunable by more than 0.25 nm by only changing the phase section bias and over several nanometers by adjusting the mirror biases as well. The three ring filters for channelizing utilize identical designs that should have the same resonance frequency within fabrication tolerances. The filter resonances are tuned post fabrication using passive phase tuning sections for each ring to place the resonances at the desired frequency to be channelized. Single ring filters of similar designs have been shown to be tunable by as much as 110 GHz [2]. In addition to the channelizing filters there is a wavelength monitor consisting of a low quality-factor single ring filter. Since the wavelength monitor is in close proximity and of the same design (except for the coupler strength) as the channelizing filters, the resonance shifts due to environmental changes will be similar. Therefore, the laser wavelength can be tracked to the filter shift which is easier than tracking the filters to the laser.

The device is fabricated on an MOCVD grown epitaxial base structure and requires a single regrowth. Quantum well intermixing was used to tailor the quantum well band edge with very low optical reflections allowing for active, passive and intermediate bandedges [3]. A discussion of the fabrication process can be found in reference [2]. The ring resonators for the filters utilize buried heterostructure waveguides to aid in coupling and reduce loss due to sidewall roughness. However, the laser and modulator use a ridge waveguide structure. To couple between the two waveguide types a tapered coupler is used. The coupler is formed by abruptly transitioning from a ridge to buried waveguide and then gradually tapering down the waveguide core width from 3.5 µm to the final 1 µm waveguide width over 200 µm. These couplers were measured to have 0.13±0.05 dB of loss. The chips were packaged with a thermal electric cooler for testing (Figure 2).

It is a challenge to characterize the individual device components separately due to the highly integrated nature of the chip. Therefore, the filter shape and response was characterized using the on chip laser. The wavelength of the laser was mapped out as a function of phase and front mirror current. From this map a phase current sweep was selected for the characterization experiment to provide continuous tuning. The light out of the filter was then monitored with a photodetector while the phase current was swept. The resonances of the three rings were aligned by applying current to the individual ring tuning sections. The three ring active filters showed greater than a 20 dB optical extinction and a linewidth of 3.8 GHz (Figure 2).



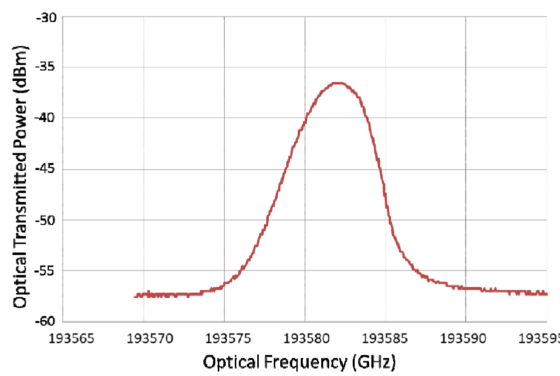


Figure 2: left: Optical image of packaged channelizer chip for testing.
right: Filter output spectra showing the resonance with a 3.8 GHz linewidth and >20 dB extinction.

4. Summary

A new highly-functional PIC for the channelization of wide band signals is presented. This chip included the integration of optical ring resonator filters, EAMs, and tunable laser. The operation of the integrated laser and filter with 20 dB of optical extinction was described. Future work will include a more through characterization of the chip performance including filter tenability and channelization of signals applied to the EAM.

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[1] G.A. Vawter. A. Tauke-Pedretti. E.J. Skogen," Wide Dynamic Range of Ring Resonator Channel-Dropping Filters with Integrated SOAs", 2011 Optical Fiber Communications Conference, paper OThW2, Los Angeles, CA, March 6-11 (2011).
[2] A. Tauke-Pedretti, G.A. Vawter, E.J. Skogen, G. Peake, M. Overberg, C. Alford, D. Torres, F. Cajas, "InP Tunable Ring Resonator Filters," SPIE Optoelectronic Integrated Circuits XV Conference Proceedings, February 2013, 8628-23
[3] E.J. Skogen, J.S. Barton, S.P. DenBaars, and L.A. Coldren, "A Quantum-Well-Intermixing Process for Wavelength-Agile Photonic Integrated Circuits," IEEE Journal of Sel. Topics in Quantum Electronics, Vol. 8, No. 4, 863-869 (2002).