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Design of integrated optics all-optical label swappers for spectral amplitude code label swapping optical packet networks on active/passive InP technology

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ABSTRACT:

In this paper the designs of optical label swapper devices, for spectral amplitude coded labels, monolithically integrated on InP active/passive technology are presented. The devices are based on cross-gain modulation in a semiconductor optical amplifier. Multi-wavelength operation is enabled by means of arrayed waveguide gratings and ring resonators.

Keywords: optical burst/packet networks, label swapping, integrated optics, monolithic integration, InP devices

1.- Introduction

The actual optical network infrastructure, that supports modern telecommunications (voice and data) is based in connection oriented networks (circuit), after the legacy plain old telephone system networks. In these optical networks, a light path is established permanently between network nodes. However most of the traffic conveyed in telecommunication networks since nearly 15 years ago is data (packet, burst) traffic [1]. Despite this, the optical network infrastructure is still circuit oriented. One of the major drivers for a change from circuit to packet/burst optical networks will be the availability of cheap and power efficient components for these networks, able to perform the different network functions over data packets. Amongst these functions, operations over the packet headers (labels) is crucial for packet/burst optical networks to succeed. One approach for packet switched optical networks is optical code multi-protocol label switching (OC-MPLS). In the recent years several labeling implementations for optical networks have been subject of research [2]; a simple but yet effective approach is the so called Spectral Amplitude Coded (SAC) label swapping [3,4]. In SAC label swapping, a spectral band is reserved for labels, and divided into N wavelength slots, therefore enabling 2^N-1 labels. This is shown in Fig. 1.

A key component in a OC-MPLS network node is the label swapper (LS), which strips the incoming label, attaches a new label, and reinserts it with the payload. Devices using cross-gain modulation (XGM) in ring cavities have previously been demonstrated which have several attractive characteristics for a LS; namely, high extinction and conwafer, and likely in different orientations, therefore the spectral responses will be misaligned. To overcome by design this misalignment, the use of a single AWG and mirrors is proposed. In this case, the device is a linear laser between the mirrors of SOAs $\lambda_{out,1}$ to $\lambda_{out,4}$ and SOA_2.

Finally the LS topology in Fig. 4 uses ring resonators (RRs) as wavelength selective elements.

No XGM intermediate stage is included. The configuration is a ring laser in which SOA_1 provides the gain medium and SOAs $\lambda_{out,1}$ to $\lambda_{out,3}$ will enable the different label wavelengths at the output. The ring resonators are coupled to the SOAs by means of two bus waveguides, in such a way that wavelengths $\lambda_{out,1}$ to $\lambda_{out,3}$ will circulate between SOA_1 and SOAs 1 to 3 respectively.

For all the topologies, physical design details are given in the next section.

Parameter	[6]	[8]
Cavity length	8.9 m	8 mm
Operating frequency	80 kHz	1.25 GHz
Rise/fall time	270 ns/570 ns	295 ps
Static contrast ratio	> 33 dB	> 41 dB
Dynamic contrast ratio	> 10 dB	> 25 dB
Extinction ratio	> 40 dB	---
Size	1 m^2	8.2 mm^2

Table 1: Table top experimental results vs. integrated LS simulation results

3.- Design details

The devices will be integrated monolithically in InP active/passive technology from the JePPIX platform [10]. Full technology details are given in [11], where the layer stack, waveguide types (deep, shallow) and devices realizable in the platform are summarized.

The AWGs were designed such a way that two diffraction orders [7] are available at in/out device couplers. Hence the 50:50 power splitting/combining operations in Figs. 2 and 3 can be performed without the need of an additional power splitter/coupler.

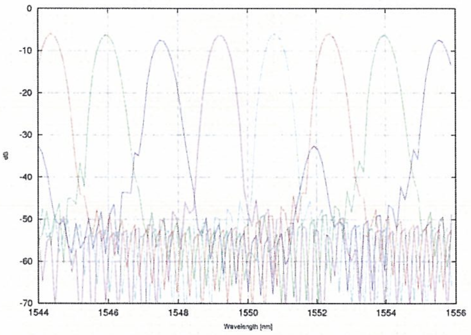

Fig. 5. Spectral response of the AWGs used in the LS from the two input waveguides to the five outpus

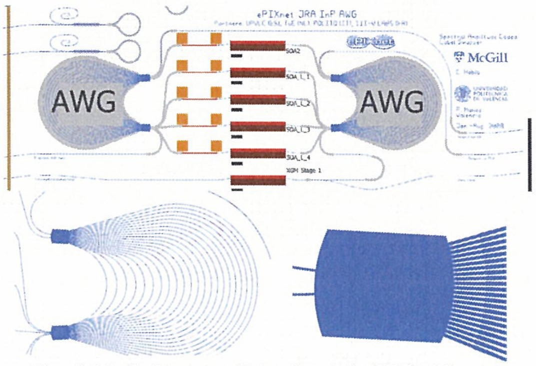

Fig 6 Mask layout of the (top) 2 AWG LS and (bottom) detail of the out coupling from the AWGs.

The AWG was designed to work at λ_0=1550 nm, with 2 x N_{ch} = 5 spectral channels spaced $\Delta\lambda_{ch}$= 1.6 nm. The FSR was designed for the two input waveguides to have the same spectral transfer function, as mentioned above. The spectral response of the AWG is shown in Fig. 5. The layout for the two AWG LS topology from Fig. 2 is shown in Fig. 6. For scale reference, the SOA sections in the middle are 500 microns long.

The loop mirrors for the second LS topology on last section are Sagnac interferometers [12] with a 2x2 MMI coupler [13]. The layout of the LS with Sagnac loop mirrors is shown in Fig. 7. Again the SOA sections have a length of 500 microns. For the mirror just one waveguide is used, the other one is terminated in a pigtail/spiral shaped waveguide to minimize unwanted reflections, though ideally no light should reach that path coming back from the Sagnac loop.

[3] N. WADA and F. KUBOTA, *"Cutting-edge technologies on broadband and scalable photonic networkpacket switched networks based on all-optical label processing,"* Optical Review, vol. 11, pp. 106–112 (2004).

[4] P. SEDDIGHIAN, J. B. ROSAS-FERNÁNDEZ, S. AYOTTE, L. A. RUSCH, S. LAROCHELLE, and A. LEON-GARCIA, *"Low-cost, scalable optical packet switching networks with multi-wavelength labels,"* in Proc. OFC/NFOEC '07. Optical Society of America, 2007, p. OthF5.

[5] R. E. GORDON and L. R. CHEN, *"Demonstration of all-photonic spectral label-switching for optical MPLS networks,"* IEEE Photon. Technol. Lett., vol. 18, no. 4, pp. 586–588, (2006)

[6] C. HABIB, V. BABY, L. R. CHEN, A. DELISLE-SIMARD, and S. LAROCHELLE, *"All-optical swapping of spectral amplitude code labels using non-linear media and semiconductor fiber ring lasers,"* IEEE J. Sel. Topics Quantum Electron., vol. 14, no. 3, pp. 879-888 (2008).

[7] P. MUÑOZ, D. PASTOR, J. CAPMANY, *"Modeling and design of arrayed waveguide gratings",* J. Lightwave Technol., vol. 22, no. 4, pp. 661-674 (2002)

[8] C. HABIB, P. MUÑOZ, L. CHEN, J. CAPMANY, *"Design of a Monolithically Integrated All-Optical Label Swapper for Spectral Amplitude Code Labels Using",* In Proc. ECIO, vol. 1, pp. 265-268 (2008)

[9] B.E. LITTLE, S.T. CHU, W. PAN, Y. KOKUBUN, "*Microring resonator arrays for VLSI photonics*," IEEE Photonics Tech,. Lett., vol.12, no.3, pp.323-325, (2000)

[10] Joint European Platform for InP-based Photonic Integrated Components and Circuits (JePPIX), http://www.jeppix.eu/

[11] E.A.J.M. BENTE, M.K. SMIT, "*Ultrafast InP optical integrated circuits*,", Proc. SPIE vol. 6124, pp. 6124219-1 – 10 (2006)

[12] B.E.A. SALEH, M.C. TEICH, "*Fundamentals of Photonics,*" chaper 2, 2nd ed., Wiley (2007)

[13] L.B. SOLDANO; E.C.M., PENNINGS "*Optical multi-mode interference devices based on self-imaging: principles and applications*," J. Lightwave Technol., vol. 13, no. 4, pp.615-627 (1995)

[14] M. BACHMANN, P. BESSE, H. MELCHIOR, "*Overlapping-image multimode interference couplers with a reduced number of self-images for uniform and nonuniform power splitting*," Appl. Opt. 34, 6898-6910 (1995).

[15] RSoft Design, http://www.rsoftdesign.com/

[16] A. YARIV, "*Universal relations for coupling of optical power between microresonators and dielectric waveguides*," Elect. Lett. , vol. 36, no. 4, pp.321-322 (2000)