Study of polymer micro-ring resonator based filter in system experiment at 10 Gbit/s

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***Abstract*—In this paper, the design and the fabrication process of a micro-ring resonator using polymer waveguides is reported. After static tests results, report on transmission test at 10 Gbit/s is given.**

Keywords: micro-ring resonator, polymer waveguides, optical filter

I. Introduction

Polymer materials, with their large available optical indexes, are potentially a basis to develop optical functions at low cost and high integration level for applications in the telecom access network. For these applications a low cost, a small footprint and flexibility are known as important issues. Other advantages of polymer materials are a good transparency at the telecom wavelengths and the ability to tune their properties by thermo-optic or electro-optic effects.

The next generation access network will use WDM technology. A tunable optical filter at the home's premises is able to provisioning the flexibility and could be an interesting alternative to AWG. The requirement for the device studied in this paper is a tunable filter on eight ITU channels at 100 GHz based on a polymer micro-ring resonator suitable for this application. Micro-ring resonators have been extensively studied for numerous applications including the filtering [1, 2]. In section II the design and the fabrication process are reported. In section III the static measurements and the dynamic response at 10 Gbit/s are presented.

II. Filter Design and fabrication

A. Polymer micro-ring design

The filter structure we consider is a ring resonator coupled to two straight bus waveguides. The ring and the straight guides have the same section size. The first step is to calculate the section of the waveguide that must be a trade off between the loss in the ring, the single mode conditions and the ring/ bus waveguide coupling. Considering an index contrast of 0.15 between the core and the cladding, a square waveguide of 1.5 x 1.5 μm^2 is determined. The free scale range (FSR) of the resonator is related to the effective index and the ring round-trip length. The Full Width at Half Maximum (FWHM) is determined by the round-trip loss and the power coupling with the straight guides. The index contrast leads to a minimum radius for the ring of 100 µm to have an acceptable bend loss in the ring. In another side the bandwidth must be low enough to limit the inter-channel crosstalk. We set the objective to have a FSR of 2.04 nm and a FWHM from 0.08 nm to 0.4 nm, which lead to a ring radius of 120 µm and gaps from 0.5 to 1 µm.

B. Implementation

The core structure was performed using the polymer PVCi poly(Vinyl Cinnamate) [3] (n = 1.555 at λ = 1550 nm). This polymer was irradiated by UV for stabilization. Lower and higher claddings were made with PMATRIFE (Poly(2,2,2 MethAcrylate of TRIFluoro-Ethyle)) (n= 1.409 at λ = 1550 nm). Polymer layers were performed by spin coating. The techniques used in the process were photolithography at 365 nm and Reactive Ion Etching (RIE).

In order to improve the resolution, two masking layers were used (Fig 1). The photolithography step allows achieve photo-resist patterns. These patterns are useful for masking SiO_2 during SF_6 plasma etching. Then SiO_2 patterns serve as mask to etch polymer during O_2 plasma etching. 40 nm thickness of silica is enough to etch up to 1.5 µm of PVCi layer. In fact, effective improvement is due to the very thin photo-resist layer of 0.13 µm. This thickness can be obtained by spin-coating a commercial photo-resist under particular conditions (diluted solution) optimized in our laboratory [4].

Fig. 2 is a SEM photo of PVCi micro-ring resonator. It shows the high resolution in the definition of the gap size between the straight waveguide and the ring. The gap of fig 2 is about 0.8 µm. Finally, a layer of PMATRIFE was spin coated and then micro-ring resonators were optically characterized.

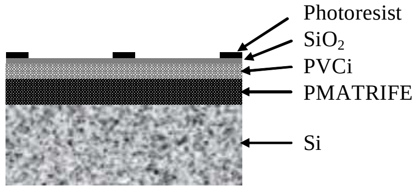

Figure 1. Representation of different layers before photolithography step

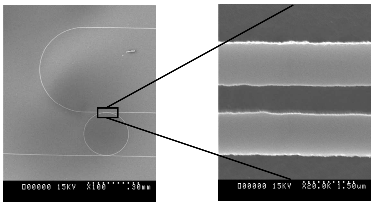

Figure 2. SEM photos of PVCi etched structure

III. Results and Discussion

A. Filter measurements

The transmission spectra are measured by means of a tunable laser source and a power meter. The input coupling fiber has a micro-lens at the end, and the output fiber is a standard SMF. The measurements have been done on the through port and the drop port in the wavelength range 1528 – 1538 nm with a step of 2.5 pm. Fig 3 shows the drop output power for TE and TM mode for the micro-resonator with a ring diameter of 120 µm and a gap of 0.8 µm To resolve more precisely the resonant peak and the bandwidth the filter has also been measured with a step of 1 pm (Fig 4).

The mean FSR is 2.01 nm, the shift of resonant wavelength for TE and TM is around 0.7 nm. The extinction ratio is about 20 dB and the FWHM is 0.12 nm (15 GHz). The finesse (FSR/FWHM) of the filter reaches 17 and the quality factor about 12,000. These results are in good agreement with the theory.

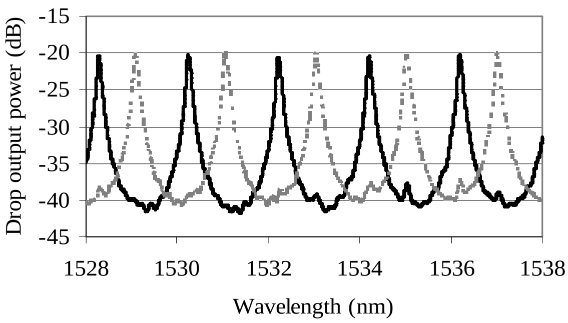

Figure 3. Drop output power with 2.5 nm step wavelength (TE / TM)

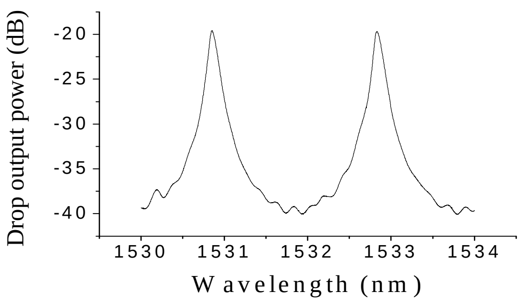

Figure 4. Drop output power with 1 nm step wavelength

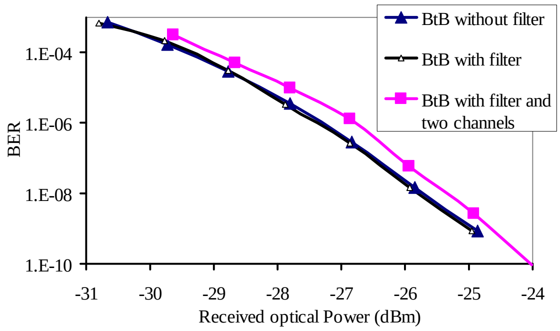

Figure 5. Experimental results at 10 Gbit/s

B. Experimental results at 10 Gbit/s

The precedent structure has been tested in system experiment. The transmitter (Tx) produces an NRZ optical signal modulated at 10 Gbit/s with a 2^{31}-1 bits PRBS at 1550.5 nm. To align the resonant wavelength of the filter with the transmitter wavelength, the temperature of the device is controlled by a thermo-electric cooler. The dependence of the resonant wavelength of the resonator with the used polymers has been measured at 0.11 nm/K. At the reception, the signal is directly detected by an avalanche photodiode (APD) having 10 GHz bandwidth.

Fig 5 shows there is no penalty for the Bit Error rate (BER) measured in back to back configuration (BtB) with and without the filter. Next, a second wavelength emitter corresponding to the adjacent channel of the 100 GHz ITU grid (1549.7 nm) is inserted in the line test to characterize crosstalk channel. With this neighbor channel a penalty of 0.5 dB has been measured.

IV. Conclusions

We have described the design and the fabrication process of a polymer micro-ring filter. In this paper, the emphasis is on the experimental results in system at 10 Gbit/s which show that the filter bandwidth is enough for this rate.

Acknowledgment

Authors acknowledge support from ANR and Pôle Images@réseaux in the project SELECTACESS and the Regional project, PONANT including FEDER funds.

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