Electro-Optical and Temperature Tunable WDM Filter

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We present a new concept of a tuneable WDM filter. With this device we demonstrate that tuning over the complete C or L band is feasible by using either Temperature or the Electro-Optic effect. We have simulated and designed a device in the InP-based material system with capacity for two channels spaced 15 nm. Design, simulation, and the preliminary experimental results are presented in this paper.

Introduction

The spectral behavior of components that are wavelength dependent, such as filters or (de) multiplexers, is of vital importance in an optical network. Tuning is one solution that would make it possible to avoid spectral mismatches. Some tuning strategies offer the possibility of reducing the crosstalk and shaping the pass-band [1]. In addition we can reduce the number of elements in a WDM network by including the tuning capabilities in them.

Several techniques can be used to make a device tunable. For our implementation we have decided to use the Electro-Optic and the temperature effects in our device. The choice is made depending on the characteristics of the layer stack, the speed requirements and the experience in the field. The Electro-Optic effect provides a fast response and is widely used in many devices. However, there are layer stacks where this effect is low. In this case the Temperature effect can be implemented.

We have made use of the Array Waveguide Grating (AWG) technology to implement our filter. In order to make it tunable we will influence the delay in the individual arms of the array. The independent phase shifters, implemented on each of the arms, do this. In this way, if the maximal phase shit required to tilt the equi-phase plane of the AWG overcomes $2p$, we can make an equivalent shift with the modulo $2p$, as shown in Fig. 1. This kind of procedure is called Fresnel-lens type operation.

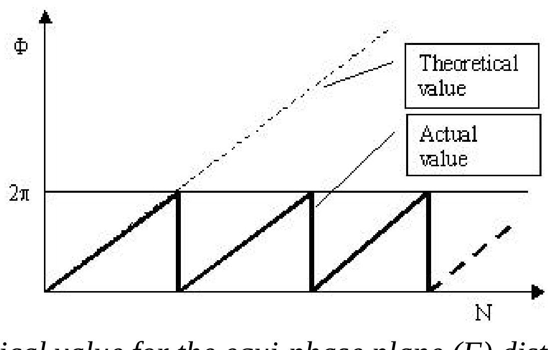

Figure 1: The theoretical value for the equi-phase plane (F) distributed over individual array arms (N) is transformed in an equivalent module $2p$.

Design

In Fig. 2 we show the photograph of the device. An AWG has been design such that it can select a group of WDM channels. The design parameters of the device are 30 nm for the FSR, and 15 nm as channel spacing for both devices, respectively. The phase shifting sections have a length of 4.3 µm in order to provide low voltages for a $2p$ phase shift without significant losses.

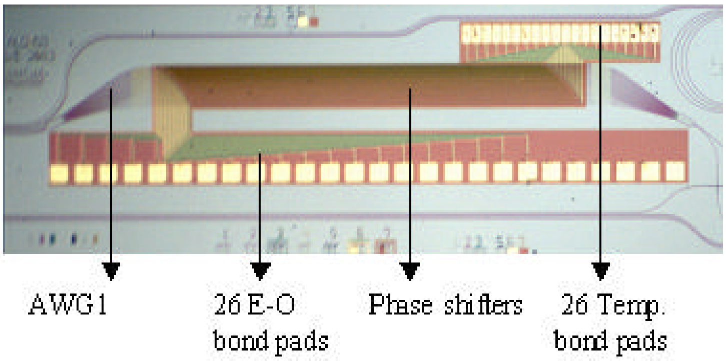

Figure 2: picture of the complete device and schematic description of its functionality.

The main questions about the Temperature tuning are the capability of reaching $2p$ phase shift in one waveguide by heating, and the relative temperature crosstalk, percentage of heat that propagates to the waveguides neighboring the heated one. From the Temperature simulations we expect a growing refractive index change as the power increase, such that for a 3 µm wide shallow waveguide with a metal contact with a resistivity of 1 µΩ·cm and a width of 5 µm can obtain a 392 deg/mm phase shift when 250 mA are going through the metal heater.

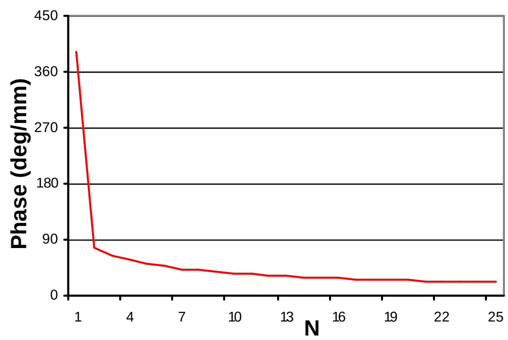

Figure 3: phase distribution on the shifting sections, depending on the power.

From Fig. 3 we conclude that the thermal crosstalk is sufficiently low as to allow a $2p$ phase difference between two adjacent arms. As result, 21% of the power is transmitted from the heated waveguide to the neighbouring one.

Fabrication

The Tunable AWG was fabricated in a layer-stack consisting of a 600 nm InGaAsP ($l_{bandgap}$=1.25 µm) waveguide layer sandwiched between an n-doped InP and an InP non-intentionally doped layer, which are 1000 and 180 nm respectively. A 50-nm SiN layer served as an etching mask for the waveguides. The pattern was defined using contact illumination with positive photo-resist and transferred in the SiN-layer by reactive ion etching (RIE), which is used to etch the shallow region too. After the etch-depth for the shallow region was reached, a photo-resist mask was deposited, windows were opened at the regions where a deep etch is required, and the etching was using again a RIE process but this time optimized for photo-resist masking.

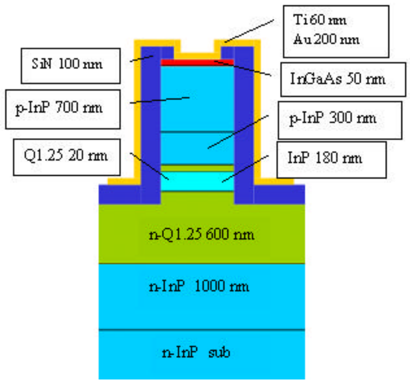

Figure 4: Layer stack of the phase shifters.

Experimental results

Optical measurements were performed by coupling the broad EDFA spontaneous emission spectrum into the AWG. At the output side a tapered fiber, connected to an optical spectrum analyzer, collects the light. We have made no attempt of making the device polarization independent, thus only the TE polarization results are presented.

The tuning capability is demonstrated in Fig. 5. We have measure the pass-band of the coarse AWG, finding till 22 nm tuning without significant degradation of the pass-band. The pass-band is centered at 1565 nm if no tuning is applied. And it is shifted to 1554 nm and 1576 nm when a negative and a positive equi-phase plane are applied to the phase shifting sections. The metal lines connected to the shifting sections (see Fig. 2) provide the tuning voltage, which is made available by two 16-channel analog output voltage cards. A flat cable with 26 wires connects the cards with a 25 pins multiprobe, which is situated over the bond pads of the device.

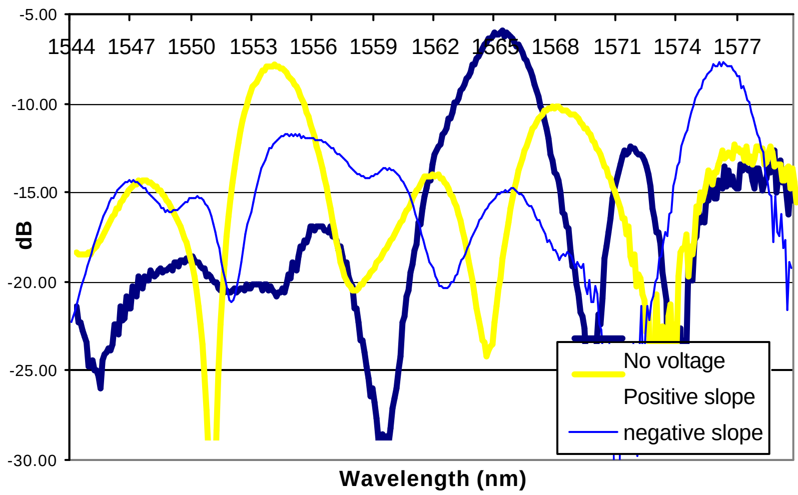

Figure 5: Pass-band shift under tuning conditions.

The side lobes of the channels are generated by the inhomogeneity of the different phase shifting sections. This affects the interaction of the light in the last star coupler of the AWG. By influencing the delay of the AWG's arms, these side lobes can be reduced and the pass-band shaped in order to obtain a square shape [2]. As example of this influence we show Fig. 6. As first attempt, we made a linear correction of the inhomogeneities in the phase shifters. We have applied –5 V to each of the phase and linearly change this value until the last phase shifter that has –5.9 volts. This approximation gives us a first approach to the possible improvement in the pass-band, increasing the peak power. A more complete demonstration can be found in [2].

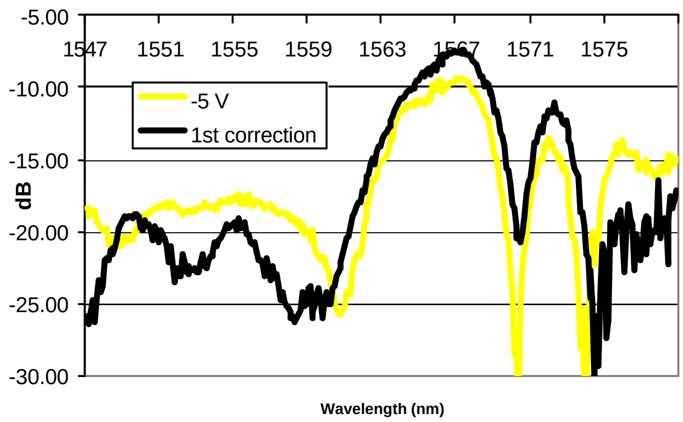

Figure 6: Pass-band shaping when linear corrections are applied.

Conclusions

We have experimentally demonstrated an integrated In-P based filter, which makes a complete device with capacity of two channels with a channel spacing of 15 nm and a tuning range of 22 nm.

References

[1] D.H.P. Maat, F.H. Groen, R.C. Horsten, Y.C. Zhu, P.E.W. Kruis, C.G.P. Herben, X.J.M. Leijtens, and M.K. Smit, "Tunable phased array demultiplexer on InP featuring wide-range tuning and pass-band shaping", *Proc. 9th Eur. Conf. on Integr. Opt. (ECIO '99), postdeadline papers*. April 14-16 1999, pp. 25-28, Torino, Italy.

[2] A. Guarise, X.J.M. Leijtens, M.K. Smit, D.H.P. Maat, R.C. Horsten, and F.H. Groen, ``Crosstalk reduction in a tunable PHASAR", *Proc. IEEE/LEOS Symposium (Benelux Chapter)*. 2000, pp. 187-190, Delft, The Netherlands.