Compact integrated photonic crystal demultiplexer for emitting and receiving InP photonic integrated circuits

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Abstract

Photonic-crystal-based demultiplexers, compact and versatile, are successfully used to demonstrate a polarisation-diversity receiving InP-based chip and a laser with integrated wavelength monitor. Selectivity improvements are discussed.

Introduction

We have worked in a collaborative fashion (cf. acknowledgement) to provide key demonstrations of the on-chip integration of InP-based functions that benefit from photonic crystal technology.

We highlight here two of our major integrated achievements :(i) a polarization diversity demux receiver and (ii) a laser integrated with a wavelength monitor. Both rely on a photonic crystal demux exploiting the "mini stopband" (MSB) of photonic crystal waveguides made of n missing rows, nicknamed "Wn" [1-3].

Polarization diversity demux

We show in Figure 1 an overall sketch of a polarization diversity demux receiver. It exploits vertical fiber coupling through a 2D grating, as developed in [4] on InP or SoI platforms. Here the chip is a thin InP membrane, with a dedicated technology allowing the co-existence of PhC and monolithic telecom-compatible receiver photodiodes. This is described in more details in [5-8].

The demux performances on four channels are shown in Figure 2, for 10 nm spaced channels. Its core operation in the PhC waveguide is shown at the top of Fig.2, we call it "TAMIS", french word for "sieve". The cross-talk is modest (-4 dB to -6 dB) among them, but more acceptable if one has a 20 nm CWDM grid in mind, reaching then -7 to -13 dB. We showed elsewhere that existing PhC losses accounted well for all details of these spectra.

As said in [2-3], the spectral "TAMIS" response is dictated by the Fabry-Perot-like resonance of the higher order mode, whose tails are of Lorentzian nature. Hence it is a first-order filter type, with a standard slope related to its spectral width. To improve it and go to the -20 dB crosstalk range, we have to implement a 2nd order

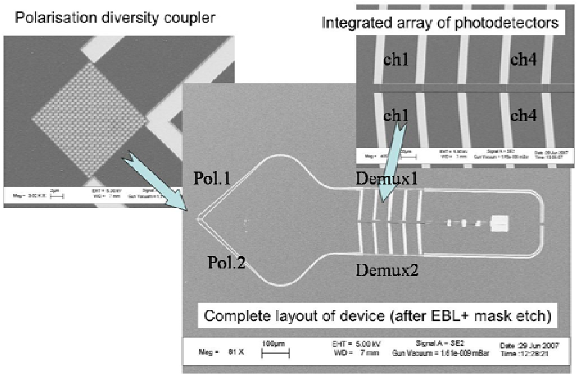

Figure 1: Overview of the polarization diversity demultiplexer receiver, the four channels are separated by the white trenches

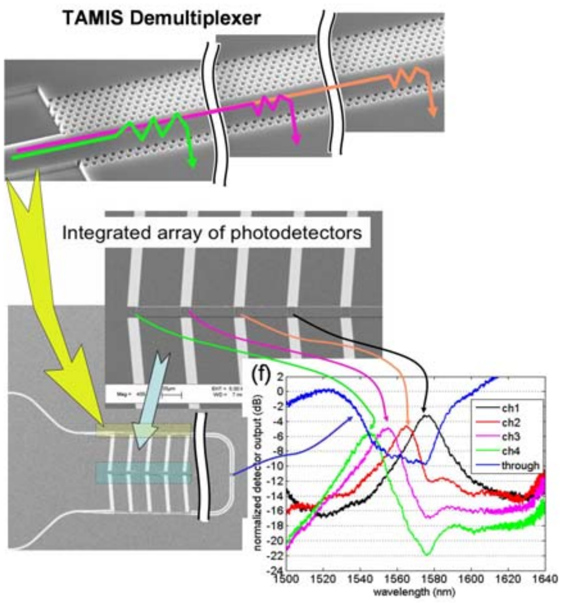

Figure 2 : Zoom on the "TAMIS" demux (top) and spectra showing its performances (bottom, 4 channels, 10 nm spacing), adapted to CWDM

filter effect. We shall discuss this along the scheme shown in Fig.3, whereby a second waveguide similar to the first one is used, but to avoid coupling to its fundamental mode, its symmetry class is swapped from A type (symmetrical) to B type (anti-symmetric). Fabrication robustness should ease the proper operation of this system. The use of smaller holes at the edge of PhC regions could also lower losses.

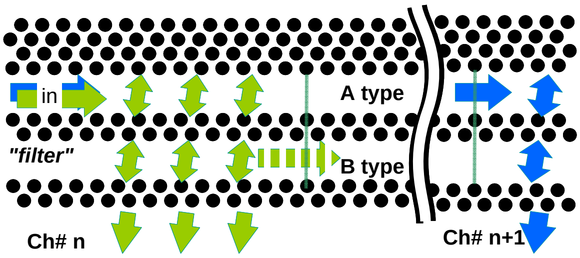

Figure 3: Principle of design improvement.

Wavelength monitor monolithically integrated on a laser

We successfully demonstrated the feasibility of on-chip wavelength monitoring and locking of tuneable lasers exploiting PhC. Based on the existing design for a PhC tuneable two-section laser at Würzburg [9], we introduced at its back a wavelength monitor.

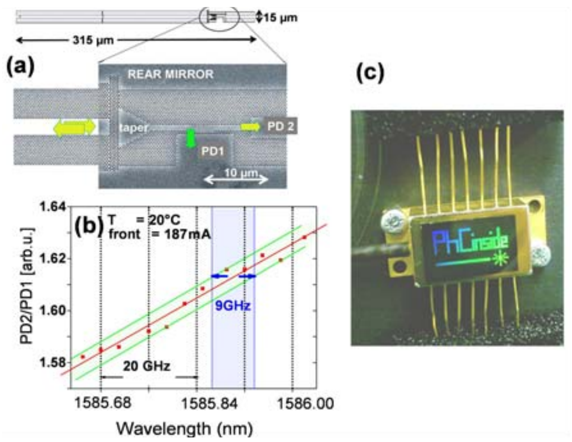

Figure 4: View (a), performance (b), and packaging (c), of a monolithic wavelength-controlled PhC tuneable laser.

The basic design (Fig.4a) is to divert the signal to a lateral photodiode when it hits the MSB of a short PhC waveguide section. The end of this PhC waveguide is another photodiode. The idea is to monitor the signals (photocurrents) of the two diodes, and more particularly their ratio, which is independent (ideally) of the laser power.

Both photodiodes are defined by properly insulated area of the lasing heterostructure, used in reverse-bias configuration. The attainment of good electrical insulation from the laser and among the diodes themselves demanded specific technology/photonic design steps. Avoiding excessive wavelength-dependent laser feedback was another important issue : would the monitor's photonic operation result in back scattered signal with a exactly the same spectral dependence as the selective response of the monitor, changes in the laser operation could then prevent reliable laser wavelength locking.

The monitoring operation can be seen to be successful (9 GHz) for the nm-range explored in Fig.4b. Such a range may be useful in PIC chips with a large set of integrated lasers. Monitoring on a broader range will also be discussed, up to 30 nm range. Packaging is shown to be possible on a similar chip (Fig.4c).

Conclusions

We have invested specific efforts to demonstrate the feasibility of integrated functionalities on InP photonic telecom chips exploiting photonic crystals and more generally nanophotonic approaches (e.g. for polarisation diversity, polarisation rotation, etc.).

The wavelength selectivity of the "TAMIS", a broad photonic crystal waveguide with a thinned wall on one side, proved very advantageous in this context. It could be exploited firstly for a CWDM-oriented demultiplexer receiving device, integrated with polarisation diversity and vertical fibre coupling.

It could also be exploited to implement on-chip laser monitoring and locking capability based on recent PhC two-section laser designs. We also indicated ways to improve the performances of the core device.

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