Photonic-Crystal-Based Optical Functions for Metropolitan Area Networks: Polarisation Control, Linear Amplification, Wavelength Selection

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Abstract *The FUNFOX European IST-project exploits photonic crystals and nanophotonic concepts to elaborate functional applications of InP-based devices for metropolitan-area-network applications, among which a polarization rotator, a linear amplifier, and a wavelength monitoring device.*

Introduction

The FUNFOX IST-04582 European project started in 2004 with the aim of applying several photonic crystal (PhC) and nanophotonic concepts to functional applications for InP-based chips and photonic circuits operating into the metropolitan area network.

We focus here on three applications: (1) We first discuss the ultra-compact polarization rotator presented in Ref. and introduce an improved process for the key angled-etching technology in this device; (2) Next, we present first results on in-plane gain clamping operation of in-plane optical amplifier schemes. The perspective is to achieve low-cost in-plane "linear optical amplifiers" (LOA's), similar to the Genoa proposal of 2001 , but entirely in an in-plane geometry. This configuration can take advantage of existing optimized SOA epitaxial structures and tames gain saturation; (3) Last, we present a demultiplexing device based on mode interaction in a photonic crystal waveguide (Ref.). Thanks to a largely improved design, a cross-talk of –15 to –18 dB between CWDM-type channels is obtained.

Perspectives for the integration of these InP-based devices are discussed on the basis of other works currently carried out within the FUNFOX consortium on fibre (SMF) in/out coupling through compact grating structures.

Ultra-compact polarization rotator

To obtain ultra-compact polarization rotation on an InP-based waveguide, we exploited previously angled thin slots etched along the waveguide axis as explained in , resulting in a conversion length of less than 2 µm. Obtaining an optimal thickness and of regular slots is important to improve the performances of this device and to minimize its losses when inserted for example in a network trunk to allow polarization diversity schemes. However, one critical step is the hard mask.

The strategy of was to produce it by standard non angled etching. The vertical walls of this mask then erode differentially in the CAIBE-type semiconductor etching process (Fig. 1.a). In the improved process, an angled RIE etching was performed on the hard mask to obtain slanted walls already in this mask, and thus a better transfer of fine features towards large depths.

Figure 1.b presents the new technology results with respect to the morphology of the mask. The evaluation of this new process is in progress and will be reported at the Conference (conversion length, insertion performances, etc.).

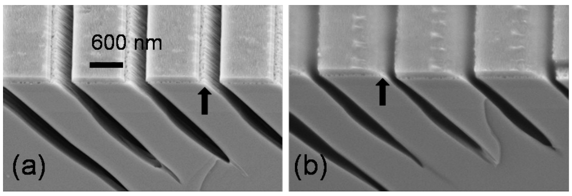

Figure 1: CAIBE etching of slanted slots in InP-based waveguides for ultra-compact polarization rotation. (a) Vertical mask etching; (b) Slanted mask etching allowing a deeper and more precise overall semiconductor etching, notably at the location of the arrow.

Linear optical amplifier

Linear amplification in SOA's rests on gain clamping. Longitudinal gain clamping is not desired as the laser has to be strongly filtered in the signal channel. The Genoa solution of transverse clamping oscillation can be implemented in an in-plane fashion, as done in our FUNFOX project.

The first realization was performed between photonic crystal mirrors very deeply etched by ICP-RIE in an adequate 6 QW laser structure operating around 1.5 µm, with a width of around 10 µm and a length over 300 µm. The large free spectral range for transverse oscillation (>20 nm) is a good start before more stringent wavelength selection schemes are used to force the clamping oscillation to lie outside the amplified CWDM desired channels. The reflectivity of photonic crystal mirrors for a relatively deeply buried waveguide should be conserved to operate the transverse lasing oscillation in favourable conditions.

Figure 2 shows that lasing oscillation is indeed obtained. More data on the gain and performances of this "IPLOA" (In-Plane Linear Optical Amplifier) will be given at the Conference.

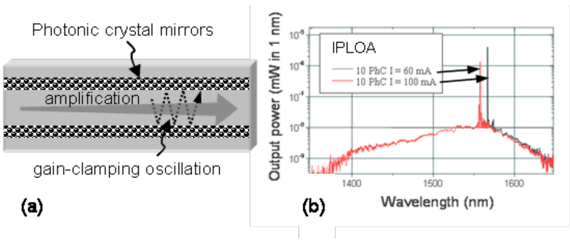

Figure 2: (a) Principle of in-plane gain clamping oscillation; (b) First electrically pumped transverse operation at 60 and 100 mA (side collection). Note the large FSR.

A complementary device for wavelength conversion may also be obtained if the amplified beam consumes enough carriers to extinguish the laser oscillation. The system then functions as a compact inverting wavelength converter, if one channels a fraction of the lasing beam at some side output. See also Ref. [4] for operation in optically pumped fashion.

Compact Demultiplexing function

A novel scheme for a demultiplexing (Demux) device has been proposed in [3]. It relies on a coupling between selected modes of a photonic crystal 1–2 µm-wide waveguide to extract selected wavelengths sideways. This results in a compact, easy-to-integrated scheme. The PhC structure, that requires e-beam and etching, remains compact and of limited extent. Furthermore, the possibility to operate this scheme on "substrate"-type photonic crystals makes its integration with photodetectors easier. The wavelength selectivity of such devices has been poor in the preliminary attempt. We shall show here that by proper choice of the extraction parameters (viz. length and strength of the mode coupling in each section), a performance compatible with CWDM grids is obtained, with a cross-talk that can reach –20 dB in the third generation design presently foreseen. The present status of this device is shown in Fig. 3 and readily exhibits a –15 to –18 dB cross-talk, and a flat-top response.

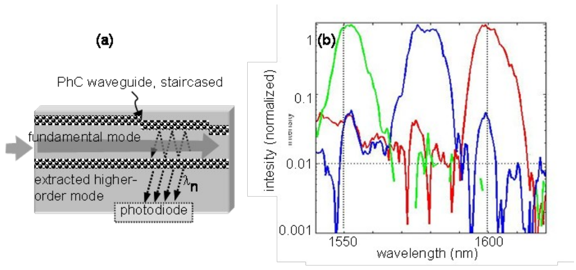

Figure 3: Demultiplexing/wavelength monitoring. (a) Principle of operation based on multimode waveguide. (b) Measured response of three adjacent channels, with a flat top and a good cross-talk.

As another part of this FUNFOX European project, the IMEC team with St Andrews team is implementing a surface coupler adapted to InP. It consists of an InP membrane, incorporating a structured grating region. It was shown to have efficiency over 50 % (for in- or out-coupling to single-mode fibres). We intend to integrate the Demux device shown above with these couplers and detectors to produce an integrated device.

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