Slow light engineering by chirped photonic crystal waveguides

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Slow light is expected to allow optical buffer memory, strong light-matter interaction, and so forth. In photonic crystal waveguides, slow light propagation occurs due to the large structural dispersion at band edges and local flat bands. The constraint between the speed reducing ratio and the frequency band is moderately expanded by the chirped structure [1]. The large dispersion accompanied by the slow light is well compensated by a directional coupler [2] and/or fine structural tuning [3]. Thus, the distortion-free slow optical pulse is obtained. Since no unrealistic conditions are required in these structures, the expected effect will be observed in the standard photonic crystal slab. The tuning of refractive index profile is an important challenge, which gives the tunability for the optical delay. The optical loss will also be compensated by efficient optical amplification for the slow light. In this case, a relatively large leakage loss can be acceptable in a deep hole waveguide structure, which is advantageous for the electrical pumping and heat sinking.

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2D PCs for spontaneous emission and mode control, and vice-versa

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While the initial motivation for photonic crystal was spontaneous emission control, the need to miniaturize optical signal has led to contemplate the use of 2D photonic crystals. Fig.1 shows an example of compact PhC-based device for wavelength monitoring. The unique ability of this system to combine momentum conservation in all directions, without sacrificing confinement, will be discussed.

Yet, the same systems help pursuing the more fundamental quest of emission control. In particular, their dispersion relation and density of states (Fig.2) indicates that extended systems may support the Purcell effect due to their singular photon DOS. Various evidences of this spontaneous emission enhancement will be discussed, based on photoluminescence measurements. Last, the possible good use of gain, of its enhancement and of nonlinearities with active medium inserted in these waveguides will be discussed in the framework of the FP6-IST-004582 FUNFOX European project.

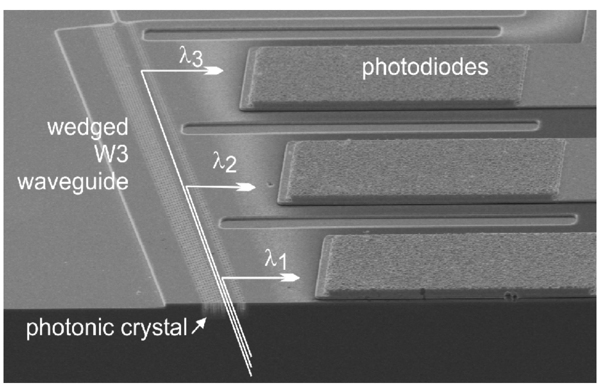

Figure 1 : demultiplexer with integrated photodiodes

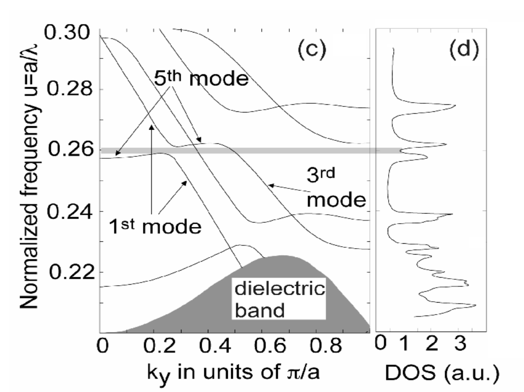

Fig.2: Dispersion relation (c) and in-plane density of states (d) of the W3 waveguide

The Wannier function approach to photonic crystal circuits

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Over the past years, the fabrication of Photonic Crystals has matured to a point where the complex functional elements can be realized. This leads to serious challenges for the modeling of these systems and conventional electromagnetic solvers very quickly find themselves at the limits of their capabilities.

The Wannier function approach [1] provides a novel route to the efficient modeling of Photonic Crystals-based integrated optical circuits. Within this technique, the electromagnetic field is expanded into an orthogonal basis of Wannier functions which are derived from the Bloch functions of the underlying Photonic Crystal. This results in extremely small and sparse matrix problems and allows the efficient determination of cavity mode frequencies, waveguide dispersion relations, and transmission/reflection characteristics of multi-port functional elements[1, 2]. Together withefficient low-rank adjustment schemes and sensitivity analysis techniques[3], the Wannier function approach facilitates the design and optimization of devices with robust performance characteristics[2, 3, 4].In particular, based on this Wannier function approach, a novel type integrated Photonic Crystal circuits based on the infiltration of low-index materials such as polymers or liquid crystals into selected void regions has been suggested[2]. This concept facilitates the design of a basic set of inherently tunable wave guiding structures for broad-band telecommunication applications[2, 4].

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Electrooptically Tunable Photonic Crystal

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A long standing challenge in photonics is the implementation of a nanophotonic circuit into a noncentrosymmetric medium which exhibits a second order nonlinear optical susceptibility based on electronic displacement polarization [1]. The inherent quasi instantaneous response of the nonlinear polarization in such media generates the potential of ultrafast electrooptical submicrometer photonic devices with switching bandwidths well beyond 100 GHz. Such functionalities will play a vital role in next generation computer technologies.
We report on electrooptical modulation with a sub 1 Volt sensititivity in a photonic crystal slab waveguide resonator which contains a nanostructured second-order-nonlinear optical polymer. The electrooptical susceptibility in the core was induced by high-electric-field poling. A square lattice of holes carrying a linear defect was transferred into the slab by electron-beam-lithography and reactive-ion-etching [2], creating a photonic crystal slab based resonator. Applying an external electric modulation voltage to electrodes leads to a linear electrooptical shift of the resonance spectrum and thus to a modulation of the transmission at a fixed wavelength based on the electronic displacement polarization in a noncentrosymmetric medium (Pockels-effect). This effect is therefore inherently faster than other reported electrooptic modulation effects in nanophotonics [3].

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