Silicon-based photonic crystals for the control of light propagation and emission

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Abstract

In this project we shall employ Silicon-based photonic crystals of different dimensionalities, realized by the proposing groups, in order to study various effects related to the control of light propagation and emission on a sub-micrometric scale. The available fabrication technologies combine growth by chemical-vapour deposition and by sedimentation in colloidal solutions, electron-beam and X-ray lithography, wet and dry etching (electrochemical- and reactive-ion etching via plasma and focused-ion-beams). These techniques allow producing various kinds of systems: one-dimensional (microporous Silicon), two-dimensional (macroporous Silicon, planar waveguides) and three-dimensional (opals, Yablonovite). Moreover the materials will be infiltrated with active media, both globally and locally. In particular, the following systems and phenomena will be studied:

1) One-dimensional porous Silicon photonic crystals: multilayers and coupled microcavities
- We shall determine the phase dispersion and the slowing down of group velocity at the band-edge resonances and, for coupled microcavities, in the mini-band resulting from the coupling of single-cavity modes.
- We shall perform time-resolved experiments of pulse propagation in these systems.

2) Two-dimensional and waveguide-embedded photonic crystals: macroporous Silicon, Silicon-on-Insulator, suspended Silicon membranes, Silicon Nitride
- We shall determine the dispersion of photonic modes by means of angle-resolved reflectance and, for truly guided modes below the light line, by attenuated total reflectance. With the same technique we shall measure the energies of modes associated to linear defects (photonic wave-guides) and point defects (nano-cavities).
- We shall measure the waveguide transmission of linear defects, also containing 120 degree bends, and of more complex structures like cavities and add-drop filters.
- We shall study tuning and switching effects obtained by photo-excitations. Moreover we shall measure third-harmonic generation with resonance effects on photonic modes.
- We shall measure frequency-resolved and/or spatially-resolved emission spectra from periodic lattices and from photonic nano-cavities infiltrated with Erbium ions, dyes and colloidal quantum dots. We shall study gain effects in these systems.

3) Three-dimensional photonic crystals: opals and inverse opals, Yablonovite
- We shall measure the dispersion of photonic bands in the direction of light propagation (by interferometry) and in a plane parallel to the sample surface (by angle-resolved reflectance).
- We shall study phenomena related to disorder by means of time-resolved propagation and diffusion of light and by coherent back-scattering.
- We shall realize switching effects induced by a magnetic field in opals infiltrated with liquid crystals.

These experimental activities will by supported by a theoretical study of photonic bands, optical response and spontaneous emission in the investigated photonic crystals. In particular, the most novel theoretical aspects will concern linear defects and nano-cavities, also by considering the effects of structural disorder and the emission properties related to infiltration with active media.