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Abstract. In this work, we make a step forward in the manipulation of light on the surface of one-dimensional photonic crystal through Bloch Surface Waves (BSW) within resonant structures of various types. Linear Fabry-Perot cavities eventually combined with diffraction gratings allow to directly couple BSW from free-space radiation. Design, fabrication and experimental characterization are provided.

1 Introduction

With the development of integrated photonics, Bloch Surface Waves (BSW) are attracting more and more attention as an alternative to plasmonic platforms. Being evanescently bound to a surface, BSW require energy and momentum matching for coupling from free-space radiation. Generally, oil immersion optics and diffraction gratings [1-2] are the two main methods used to this aim.

In this work, we introduce resonant structures equipped with grating couplers on the surface of one-dimensional photonic crystal (1DPC) to provide BSW excitation. We show experimental characterization of linear Fabry-Perot cavities inscribed within thin polymeric film tailoring all-dielectric 1DPC.

2 Computational model

The dielectric 1DPC is constituted by alternating layers of SiO_2 and Ta_2O_5 as described elsewhere [3]. A thin polyphtalamide (PPA) layer with nominal refractive index n_{pol}=1.595 is topping the 1DPC surface. Thickness of the PPA film ranges from 40 to 60 nm. A linear modulation is inscribed into the PPA layer. In Fig. 1(a), the modulation is periodical and implements a Distributed Bragg Reflector (DBR) for BSW, carrying a linear defect (so-called a spacer) in the middle. Such a configuration mimics a two-dimensional version of a planar Fabry-Perot cavity. By changing the period, grating couplers for diffracting radiation from/to the structure can be obtained as well. Here we focus our attention to the Fabry-Perot cavity only, possibly surrounded by a linear grating coupler.

We employ a code based on the Rigorous-Coupled Wave Analysis (RCWA) to carry out design tasks. Illumination is provided from the glass substrate, in a conical mounting, when the angle of incidence θ and the angle ϕ with respect to the grating vector can be arbitrarily varied. In Fig. 1(b,c) we show the reflectivity at different photon energies and different incidence conditions represented by $\beta_x = n_{glass} \cdot \sin(\theta) \cdot \cos(\phi)$ and $\beta_y = n_{glass} \cdot \sin(\theta) \cdot \sin(\phi)$, where n_{glass} is the refractive index of the glass substrate. The cavity mode and the DBR edge modes are clearly visible, as indicated. The gap opened by the DBR is proportional to the refractive index contrast introduced by the DBR modulation. The width of the linear defect within the DBR affects the spectral position of the cavity mode across the forbidden band opened by the DBR.

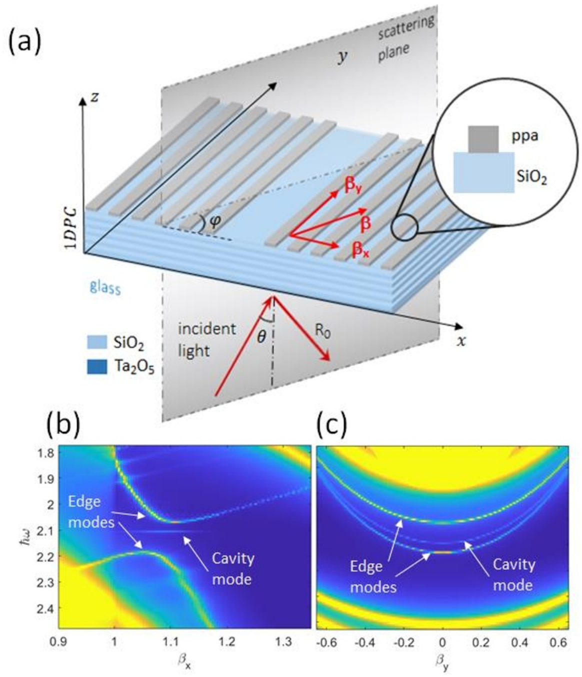

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Fig. 1. (a) Sketch of the geometry of a linear cavity on a dielectric 1DPC, with illumination in the so-called conical mount; (b,c) dispersion of the cavity and edge modes as a function of the in-plane momentum components parallel (β_x) and perpendicular (β_y) to the DBR vector.

3 Experimental

Fabrication of the surface corrugations is performed by means of a probe-assisted technique (NanoFrazor, Heidelberg) that uses an atomic force microscopy (AFM) heated probe to induce a local evaporation of the polymer layer at high spatial resolution. The PPA film is spun with a thickness of approximately 60 nm and then patterned with linear cavities that are eventually surrounded by linear grating couplers.

The optical characterization is performed on a modified inverted microscope, equipped with oil-immersion optics. Both illumination and collection are performed through a NA=1.49 objective. Illumination is provided by using polarization-controlled white-light from a halogen lamp. In order to assure a better control on the BSW coupling, the illumination beam can be selectively moved across the objective back focal plane, in order to steer the incidence angle on the 1DPC. In this way, BSW can be coupled in Kretschmann-like fashion, exploiting the objective as a cylindrical prism, with no need of grating couplers. Instead, an almost-normal incidence can be used in case grating couplers are present. Collected light is Fourier-filtered with a beam blocker in order to let only light propagating at large angles to reach the image plane. In Fig. 2(a) the dark-field of a linear cavity is shown, with the central bright line representing the scattered light from the cavity mode. This image is projected onto the entrance slit of the spectrometer, which is aligned with the spacer, thus allowing space-dependent spectral measurements.

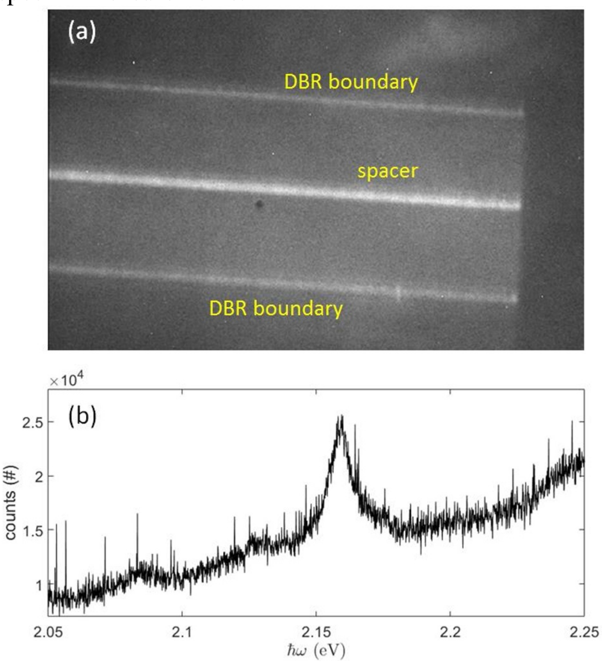

Fig. 2. (a) Dark-field image of the linear cavity upon illumination through BSW coupled through oil-immersion objective; (b) scattering spectrum measured corresponding to the bright spacer appearing in the centre of the cavity.

In Fig. 2(b), a typical spectrum of the cavity mode is shown, with a peak at 2.16 eV that is well matching the resonance expected from calculations (2.11 eV). In this case, illumination is provided as BSW incident onto the DBR with ϕ=0.

4 Concluding remarks

We have explored the spatial and spectral confinement of BSW within resonant structures, which can be fabricated together with proper grating couplers onto a polymeric film spun on 1DPCs. Despite the low effective refractive index contrast produced by such ultra-shallow patterning/modulations of the 1DPC surface, BSWs can be made resonantly confined within sub-micrometric regions. Cavity mode exhibits a narrow-peaked spectrum of about 1 nm Full Width Half Maximum [4].

These results contribute to advancing knowledge on BSW-based platforms. We anticipate future applications in the perspective of integrated quantum devices, with single emitters properly located within such nanostructures

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