Coupling evanescently low loss Silicon-on-insulator (SOI) ridge waveguides(WGs) including high Q nanocavities: for light control

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Abstract

We have fabricated a multislotted optical nanoresonator with several spatial field distributions which are all addressable by the wavelength. The reported structure consists in an array of evanescently coupled single mode photonic crystal nanocavities. By using a scanning near-field optical microscope, we quantify the morphology of the different optical mode volumes and show that they consist in grids of light confined at the subwavelength scaleOver the last recent years, optical microcavities have proven their ability to slow down, control and even trap light inside an ultra small volume. Several approaches have led to quality factor (Q) records allowing to reach high photon life-time for optical information processing . Optical nanocavities are also very efficient sensors for biological or chemical detection inside ultra small volumes. In such applications, the detection mechanism is based on a small change of the resonance wavelength due to the modification of the cavity optical near-field. In order to improve the sensing efficiency of such systems, it has also been proposed to fabricate air-slotted nanocavities in which the field is confined in an air sub-wavelength volume. In this configuration, the overlap between the cavity optical near-field and the analyze can be greatly improved.

1. Introduction

The optical cavities miniaturized at the submicrometer scale have enabled a wide range of applications ranging from quantum information processing[1–3] to biological sensing[,4] . Their ability to confined the light in an extremely small volume where the light matter interactions are enhanced,[5] where the light is trapped[6] or slowed down[7] has motivated extensive researches over the past decades. In these systems, the two properties that are desired, but often incompatible, are very high quality factors Q and very small mode volumes V. Among the potential optical cavities operating at this cale[,8] the photonic crystal _PC_ cavities[6,9–11] offer a good compromise between these two features and confinement volumes at the wavelength scale are achieved thanks to their photonic band gap. Over the past decade, the advances in the field of nanotechnology fabrication facilities and in the understanding of the confinement processes inside PCs have led to cavities with Q-factors as high as several millions. Among these cavities, the one-dimensional PC nanocavities integrated on a single mode dielectric waveguide[9,12–14] also combine to the previous features an extremely small mass and intense optical forces in the surrounding free space, which are of a great interest in the emerging fields of optomechanics[,15–18] optical trapping,[19] and optical sensing at the nanoscale.[20,21]

2. multislotted optical nanoresonator

In this work, we propose an innovative way to achieve an air-slotted nanocavities by coupling evanescently low loss Silicon-on-insulator (SOI) ridge waveguides(WGs) including high Q nanocavities exhibiting an ultrasmall modal volume V. We first show that coupling two WGs allows us to achieve a field confinement within the air slot as low as lambda/30 while preserving a

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high group index of the guided modes. Then we demonstrate that merging such coupled WGs with state-of-the-art high-Q/small V nanocavities is a robust way to achieve a single compact (1 µm * 3 µm) air-slotted resonator on substrate [22-25].

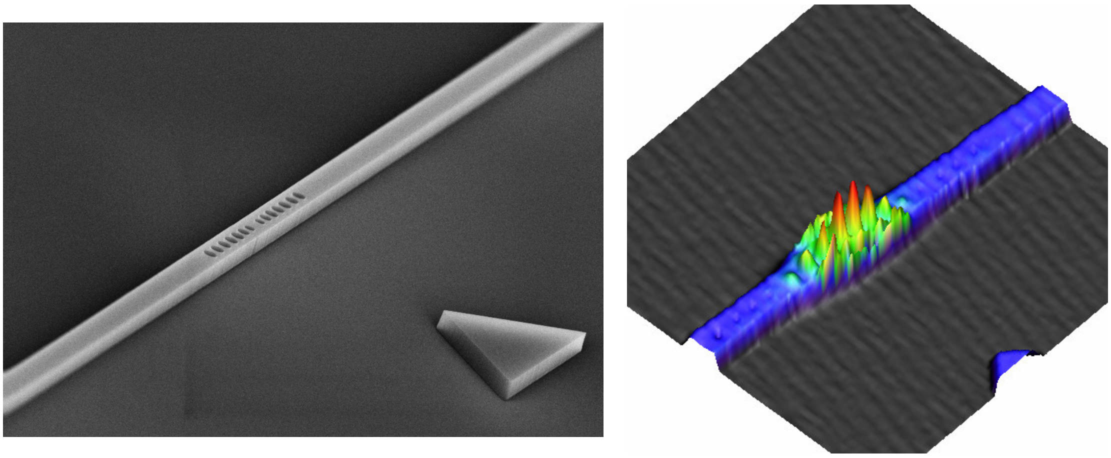

Fig1. Cavity and Mode field distribution inside a small volume cavity : V~0.6(l/n)3~0.1µm^3

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Finally, we extend the concept to multiple air-slotted resonator systems and evaluate their potential of such structures to produce sub-wavelength field localization and distribution on demand [26-27].

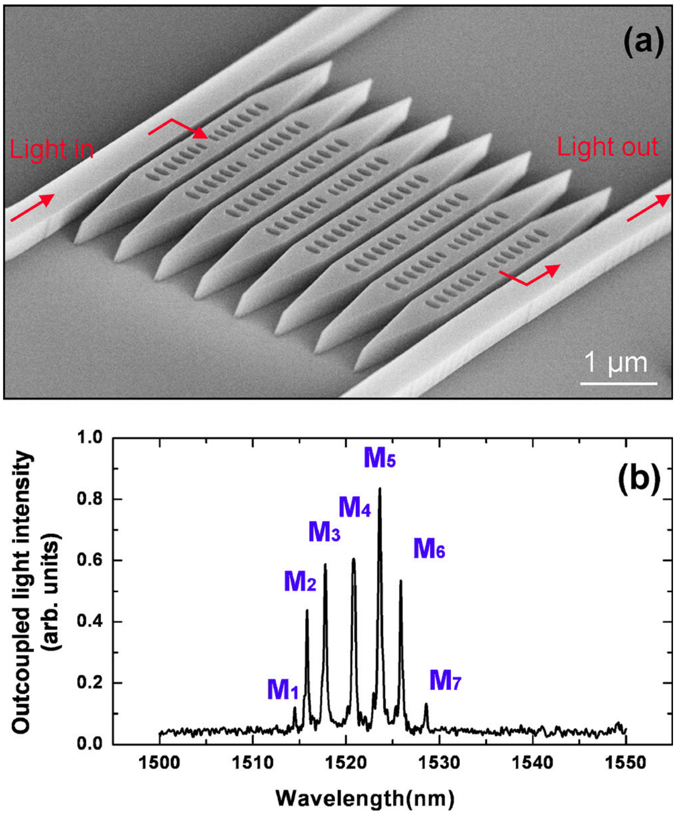

Fig 2_a_ Scanning electron microscope view of the multislotted resonator made of coupled nanocavities. The view includes the rib waveguides for light input and output. The arrows provide a schematic illustration of the light path through the structures. _b_ Experimental spectrum of the light transmitted through the structure and outcoupled into the output waveguide

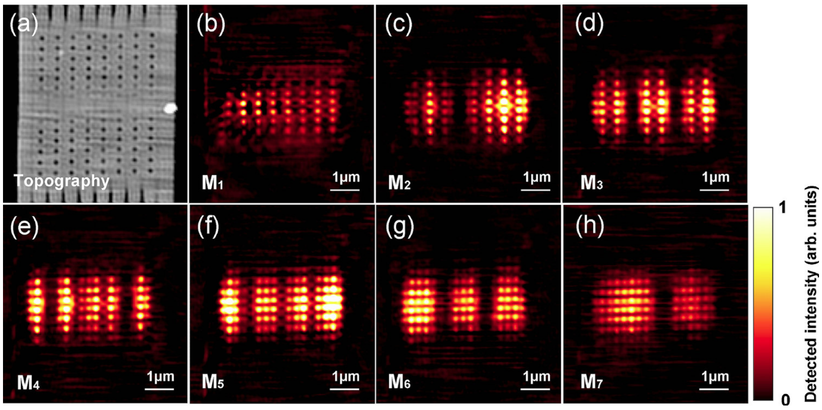

Fig.3 Experimental near-field images of the multislotted resonator. –a- Topographical image recorded using a shear-force feedback and –b to –h- corresponding optical near-field images of the seven resonant modes of the system recorded using the interaction s we reported here the optical near-field properties of a multislotted optical resonator made of height coupled nanocavities integrated on silicon waveguides.

The far-field transmission spectrum of the structure has enabled to identify its resonance wavelengths and high resolution near-field images of the field distribution within the coupled cavity system have been systematically performed.

3. Conclusion

The analysis of the reported results has revealed that each resonance is associated to a well defined grid of confined ligh with a specific subwavelength structure. All these subwavelength grids of light are addressable by changing the wavelength which offers perspectives to achieve on a chip anactive control of the spatial distribution of optical forces, traps, detection volumes, and to develop a new class of configurable optomechanical nanosystems.

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