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ORIGINAL ARTICLE

Optimized Perturbation Effect of Photonic Crystal Nano Cavities

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ABSTRACT

Photonic crystals (PhC) symbolize a developing class of periodic nanomaterials that offers flexibilities in succeeding novel plans. Based on the research of the high-Q resonance mode energy distributions, we optimized the nano-scale tip for optimal perturbation effect with low loss resonance control in the optical near field regime. In this study to do larger spectral resonance, a doubly nano-scale perturbation tip to achieve optimal accurate photonic crystal has been proposed. Such method may be driven by a nano-electromechanical (NEMS) system that may be fabricated with monolithic approaches.

Keywords: *nano cavity, nano-electromechanical, Photonic crystals.*

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INTRODUCTION

Silicon photonics is the study and application of photonic systems which use silicon as an optical medium [1]. The increasing interests in silicon photonics and its commercialization are not unexpected given the current trend of exponential growth in high density integrated circuits and increasing demand for high speed information retrieval. A photonic integrated circuit (PIC) or integrated optical circuit is a device that integrates multiple (at least two) photonic functions and as such is analogous to an electronic integrated circuit [2].The most commercially utilized material platform for photonic integrated circuits is indium phosphide, which allows for the integration of various optically active and passive functions on the same chip [3, 4]. All optical communication integration has proven to revolutionize computing platforms whereas maintaining the use of traditional silicon manufacturing methods. Silicon is presently widely used in existing semiconductor processes, a hybrid integration of electronics and photonics have been extensively shown to further achieve faster data transfers with lower cross talk with lower heat dissipation [5]. Current interests in nanophotonics are compact, efficient, integrated semiconductor lasers [6]. Much emphasis placed allows single tunable device to replace an array of fixed devices. Tunable photonic devices have the potential to increase the flexibility and capacity of communications with an vast reduction in complexity, inventory costs and time [7-9]. Applications such as [10], tunable wavelength filters[11]. Optical switches and reconfigurable OADM for, active sensors for chemical and physical sensing would applaud the development of a high Q, small mode volume, easily integrated and cheap tunable device [7, 12, 13].

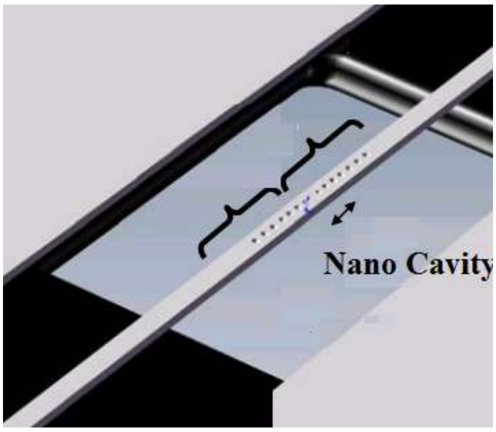

Figure 1. Schematic of nano cavity system

A wide range of methods proposed such as electro-optics, liquid crystal anisotropy tuning, thermo-optic tuning, magneto tuning [14]. In this research mechanical based tunable mechanisms enabled by utilizing an innovative (NEMS) system approach has been demonstrate in combination with photonic crystal nanocavities utilizing a doubly nano-scale perturbation tip approach.

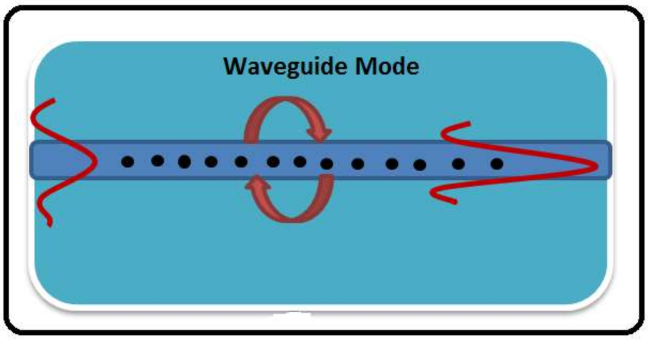

Figure 2. Tapering Design

METHODOLOGY

In this study, the PhC nanocavity is designed theoretically by a series of FDTD numerical approach. The layout of free suspending air bridged PhC nanocavity is proposed as shown in Figure 1. A series of holes are patterned to function as Bragg stack mirrors on a free suspending 500nm wide, 260nm thick silicon nanowire waveguide. The nanowire waveguide is connected to a strip waveguide sitting on a 1 μm thick buried oxide. The thickness of oxide sufficiently isolates the confined light from the silicon substrate and chosen based on the specifications of the SOI wafer (SOITEC). Various tapered holes are investigated to boost the transmissibility and the Q of the nano cavity. We utilized a series of periodically tapered holes between the mirrors to achieve a progressive transition of mode matching as illustrated in Figure 2. The difference between the fundamental mode distributions and the Bloch mode field distributions are also illustrated in the inset. Such designs have been reported to decrease radiative losses, leading to a cavity with higher Q-factor and improved transmission of the cavity mode. The nano cavity is basically a defect that is present between Bragg reflectors, forming a region where certain energies are allowed to exist. Light can evanescently couple in and out of the nanocavity. Tapering of the Bragg holes makes the introduction of Bragg mirrors gradual and thus incurring less radiative loss and higher transmission and higher Q factor. In this method, an source has been placed in an arbitrary position near the PhC nanocavity with thick cladding of perfectly matched layers (PML) absorbing conditions. The resonant mode quality factors (Q) are obtained from the fast harmonic analysis which yields good accuracy results and high spatial resolutions with relatively short convergences temporal iterations needed.

RESULTS AND DISCUSSION

In order to demonstrate the response of the nanocavity, a FDTD calculation has been performed on nano scale perturbation tips are positioned at the far field regime from the edge of the nano cavity. Figure 3 shows Theoretical wavelength shift of nano scale perturbation tip. A single resonance wavelength has been observed at approximately λo=1.5 μm, demonstrate dipole like fundamental mode within a wide bandgap of 330 nm. The optical characteristics of a doubly nano scale perturbation tip on a PhC nanocavity has been explained in this study. The width of the doubly perturbation tip to a dimension is optimized where near field probing at 80nm. will induce a degradation of Q of not lower than 330nm. The width of the doubly perturbation tip was chosen to be 330 nm with a thickness of 260 nm. To ensure that the large area region of the doubly perturbative tip actuating mechanism does not affect the nanocavity, the length was chosen 1.5μm before linearly tapering the probe structure to a width of 2μm. A summary of the results is shown in Fig. 2. We found a polynomial increment in the spectral shift as the offset gap between the both nano scale perturbation tip and the PhC nanocavity are reduced. Both nano scale perturbation tip are assumed to displace at a same rate, hence achieving identical offset gap at both sides. Negligible spectral shifts were observed from 30-330 nm. Less than 200 nm gap, a 40 nm spectral shift in resonance is observed. . Also most of energy concentration of the fundamental mode is distinctively seen to be concentrated around the nanocavity region while slowly decaying into the Bragg stack mirror. Effectively increasing the width of the tip will induce a larger spectral resonance shift with the expense of larger Q degradation.

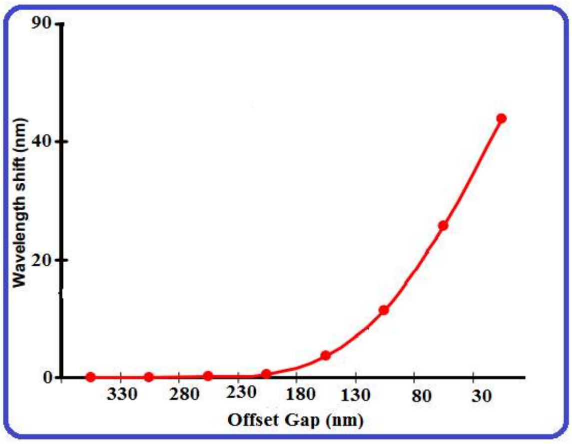

Figure 3. Theoretical wavelength shift of nano scale perturbation tip

CONCLUSION

In conclusion, we investigated a novel doubly perturbation tip to achieve a large resonance control of PhC free suspending nano cavities. Such devices are investigated and found to have a 20nm resonance shift whilst in perturbation a near field distance of 80nm. Such design is feasible as a low power compact approach for resonance control and fine-tuning in PhC.

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