Silicon Photonic Band Gap, Microcavity and Waveguide Structures

Personnel

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Tunable photonic crystals are key devices for microphotonics, especially for future WDM applications. Since the first introduction of Photonic Band Gap structures(PBG), also known as photonic crystals, new concepts and designs are proposed, which could be building blocks for next generation photonic integrated circuits. When defects are formed in the PBG materials, localized state could be introduced and light is strongly confined around the defect. The confinement of light to small volumes as wavelength scale will lead to large reduction of photonic circuit size and numerous useful devices, especially for Si microphotonics. Realization of the tunability of the photonic crystal, which makes it an active component, will play the key role as switching, modulation and wavelength conversion. This project is in collaboration with Profs. Joannopoulos, Ippen, Haus, Kolodziejski, and Smith.

Here we demonstrate a tunable one dimensional photonic crystal with large air defect size in silicon based PBG materials. Multiple localized resonance modes are observed within the photonic band gap at 1.402µm, 1.582µm, 1.792µm and 2.072µm. The observed photonic band gap is from 1.19µm to 2.18µm, which has 1000nm bandwidth. The Free Spectral Range (FSR) is larger than 100nm. Employing the electrostatic force, low voltage tuning of the localized modes are achieved simultaneously around two telecom wavelength 1.3um and 1.55µm. At 10V, almost 60nm mode shift is achieved. This is the lowest as we know so far.

Fig. 29: The illustration of the one dimensional photonic crystal with large air defect.

Fig. 30: SEM picture of the one dimensional photonic crystal with large air defect.

While fabrication of 3D photonic crystal by CMOS compatible process is still challenging, the 1D omnidirectional PBG is easily incorporated into CMOS process, and still keep some important features of 3D PBG structures. Tunability can also be realized. Here we utilize the Micro-Electro-Mechanical-System (MEMS)method to realize the low voltage tuning of the 1D PBG structure with large air defects. As the top Si/SiO_2 mirror and bottom mirror forms an air gap (cavity) by membrane which is suspended by supporting beams. Apply a voltage between the membrane and substrate can tune the cavity thickness, i.e, can shift the multiple resonance modes within the PBG. Here we emphasize the low voltage can be used to tune large wavelength. We concentrate on the windows from 1.2µm to 1.7µm. We plot the wavelength shift vs. voltage square in Fig. 3 and Fig. 4. around 1.402µm and 1.582µm which are close to two telecom wavelength 1.3 and 1.55µm. The almost perfect linear relationship between the wavelength shift and voltage square confirms the electrostatic tuning of the localized modes. We notice that, at 1.582µm resonance, almost 60nm shift is realized with up to 10 volts. This is the lowest as we have known. Switching and modulation mechanism can be realized with such shift.

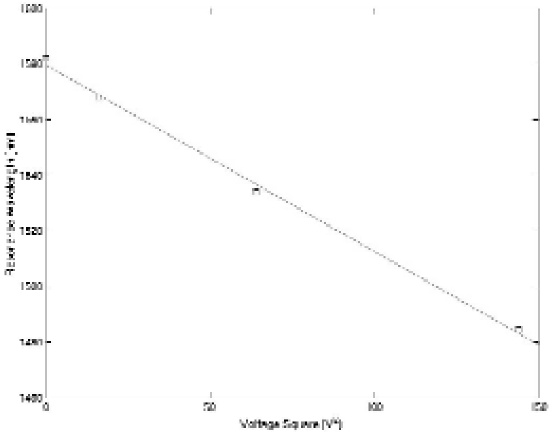

Fig. 31: The resonance wavelength shift with voltage square at 1.582µm.

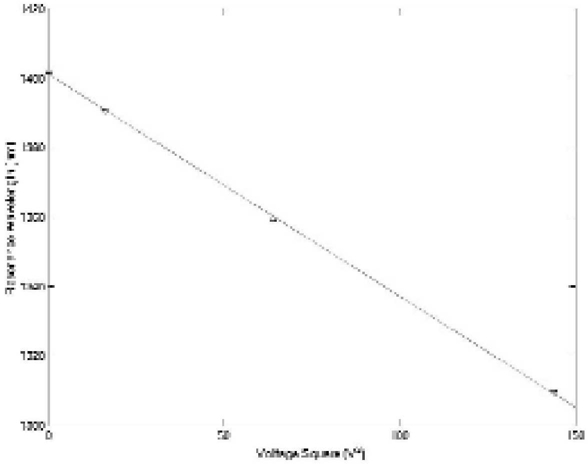

Fig. 32: The resonance wavelength shift with voltage square at 1.402µm.