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# Designing Nanowire Based Honeycomb Photonic Crystal Surface Emitting Lasers

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**Abstract :** Photonic Crystal Surface Emitting Lasers (PCSELs) are structures which are made up of a periodically repeating patterns with a unit cell consisting of changes in refractive index. The variation in refractive index can be achieved by etching air holes in a semiconductor material to get hole based PCSELs or by growing nanowires to get nanowire based PCSELs. As opposed to hole based PCSELs, nanowire based PCSELs can be integrated on silicon platform without threading dislocations, thanks to the small area of the nanowire that is in contact with silicon substrate that relaxes the strain. Nanowire based PCSELs reported in the literature have been designed using a triangular, square or honeycomb patterns. The triangular and square pattern PCSELs have limited degrees of freedom in tuning the design parameters which hinders the ability to design high quality factor (Q-factor) and/or variable wavelength devices. Nanowire based PCSELs designed using triangular and square patterns have been reported with the lasing thresholds of 130 kW/□cm□^2 and 7 kW/□cm□^2 respectively. On the other hand the honeycomb pattern gives more degrees of freedom in tuning the design parameters, which can allow one to design high Q-factor devices. A deformed honeycomb pattern device was reported with lasing threshold of 6.25 W/□cm□^2 corresponding to a simulated Q-factor of 5.84X□10□^5.Despite this achievement, the design principles which can lead to realization of even higher Q-factor honeycomb pattern PCSELs have not yet been investigated. In this work we study how the resonance wavelength and the Q-factor of three different resonance modes of the device vary when their design parameters are tuned. Through this study we establish the design and simulation of devices operating in 970nm wavelength band, O band and in the C band with quality factors up to 7X□10□^7 . We also investigate the quality factors of undeformed device and establish that the band edge close to 970nm can attain high quality factor when the device is undeformed and the quality factor degrades as the device is deformed.

**Keywords :** honeycomb PCSEL, nanowire laser, photonic crystal laser, simulation of photonic crystal surface emitting laser
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