The role of Nanostructures in Integrated Photonics

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The potential gains of integrating multiple photonic devices to realize photonic integrated circuits (PIC) and electronics with photonic devices to realize optoelectronic integrated circuits (OEIC) have been obvious for many years. The challenge has been how to realize the integration of different materials and very different device structures. Many of the first attempts involved pick and place with In bump bonding or wafer bonding at the device level, but alignment tolerances, expansion coefficient differences, optical coupling between fiber, waveguides and devices and overall yield limited the gains one hoped to realize from integration. The first real change in integration was realized with vertical cavity surface emitting lasers (VCSELs) with large (100 x 100) laser arrays being realized. While this was largely a result of surface vs. edge emitting devices, it was more fundamental in that the mirrors used in VCSELs are 1-dimensional photonic crystals realized by periodic nanostructuring of materials and set a new direction in thinking for PICs and OEICs. I will describe work on 1 and 2-dimensional photonic crystals that enable waveguides, high Q resonators, sub-wavelength apertures and plasmonic structures that we have integrated with active devices or combined with passive non-linear devices to perform functions that could not previously be realized. I will also describe work on Ge/SiGe quantum well detectors and modulators that are Si based and Si technology compatible that offer for the first time the potential for true optoelectronic integration and the use of optics on-chip for clock distribution and ultra-high bandwidth signal channels.