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Photonic crystal surface emitting laser (PCSEL)

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Abstract:

Molecular beam epitaxy (MBE) is investigated as a method of fabrication for photonic crystal surface emitting lasers (PCSELs). The influence of regrowth to photonic crystal morphology is documented. PCSEL devices are demonstrated by optical pumping and electrical injection.

PCSELs represent a new class of semiconductor laser that fulfills an industry need for high-power high-quality beams from a monolithic form factor. Traditional semiconductor lasers, edge emitting lasers and vertical cavity surface emitting lasers (VCSELs), make compromises between high-power and high-quality emission. For instance, edge emitting lasers are commonly chosen for high power applications, however, their oblong emission surface yields wide divergent ovular beams. VCSELs produce narrower circular beams but large device areas necessary for increased power enable high-order transverse modes that break coherent emission and sacrifice this advantage. PCSELs employ a 2D photonic crystal resonant cavity that isolates a single lasing mode and creates vertical emission. In this way, PCSEL devices can power scale with area whilst maintaining single-mode emission for high-quality beams.

Early PCSELs were fabricated by way of wafer fusion where two wafers, one containing the active region and the other containing a photonic crystal layer, are joined together. Because it is impossible to match the two wafers in terms of atomic order, wafer bonding leaves a high density of light absorbing defects at the bonded interface. In the present research we investigate epitaxial regrowth as a method of PCSEL fabrication.

By epitaxial regrowth, an initial epitaxy constructs the body of the PCSEL and terminates with the active region and photonic crystal layer. The photonic crystal is patterned by electron beam lithography and ICP etch. The surface is cleaned, and the device is reintroduced to the reactor for growth of top clad and contact layers. Epitaxial regrowth maintains the crystalline structure of the substrate throughout the entire device, thereby mitigating defects at the interface when compared to wafer bonding. Regrown 980 nm InGaAs quantum well PCSELs are demonstrated by optical pumping and electrical injection using the regrowth method.