High-performance InAs/GaAs quantum-dot laser didoes monolithically grown on silicon for silicon photonics

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III-V lasers grown on Si is the most promising solution to light sources on Si platform. The silicon-based telecommunications-wavelength III-V lasers with low threshold current density, high output power, and long lifetime will be presented. As a future driving force technology, Si photonics can improve the low-cost and high speed inter-chip communication by using optical transmission instead of electrical connection. However, Si based light-emitting sources have been considered as “holy grail” for silicon photonics due to Si has in-direct bandgap. By using InAs/GaAs quantum dots (QDs) as active region in laser structure, III-V laser monolithically grown on silicon is a promising solution to be the role of active region on Si platform, which has been proved on GaAs substrate [1, 2]. The challenge of monolithic growth is that high density of threading dislocations (TDs) will propagate into laser active region due to the lattice mismatch between GaAs and Si. To stop the TD propagation, defect filter layers (DFLs) formed by InGaAs/GaAs strained-layer superlattices (SLSs) have been applied, which significantly reduce the density of TDs from ~10^{10}/cm^2 at the interface between III-V and Si to <10^6/cm^2 in III-V active region [2, 3]. As a zero-dimensional material, QD has three-dimensional quantum confinements, which create delta function like density of states. QD lasers thus have low threshold currents, temperature insensitive operation, and less sensitivity to threading dislocations. Therefore QD is the ideal candidate to form active region in III-V lasers grown on group IV substrates. High performance QD lasers grown on GaAs substrates have been well-established, which proves its potential of growing on group IV platforms [1].

In this presentation, we will review our development of InAs/GaAs QD lasers monolithically grown on Ge, Se/Si, and Si substrates in last few years [2-10]. Low threshold current density of 62.5 A/cm^2, which corresponds to 12.5 A/cm^2 for each of the five QD layers, has been demonstrated under cw operation at room temperature. The lasing wavelength is at 1315 nm. The output power is as high as 105 mW at an injection current density of 650 A/cm^2, with no evidence of power saturation up to this current density. The ageing test was performed at a fixed temperature of 26 ^{o}C, with the output power monitored for a constant cw drive current of 210 mA. An extrapolated mean time to failure (MTTF) of over 100,158 hours was demonstrated here. These results are a major step towards silicon-based photonics and photonic-electronic integration, and provide a route towards cost-effective monolithic integration of III-V devices on Si platform.

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