Monolithic Growth InAs Quantum Dots Lasers on (001) Silicon Emitting at 1.5 µm

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III-V Quantum dot (QD) possess capabilities such as low sensitivity to material defects and operation temperature, whilst providing broad optical gain and thus have been considered as a promising candidate to achieve monolithic integration of III-V lasers on a silicon platform. In the past few years, InAs QDs with GaAs-based materials monolithically grown on silicon have been achieved, lasing at 1310 nm (O-band). To extend the lasing wavelength to 1550 nm range (C-band) will bring more possibilities and flexibilities in real applications, such as optical communication and sensing. However, to integrate such C-band lasers on silicon still has many challenges in which the most important limitation is associated with the materials. To achieve laser operation at 1550 nm InP-based materials must be incorporated, making good material quality and QD formation very difficult. Only recently, electrically pumped broad-area 1.55 µm QDs lasers on silicon have been reported [1]. Using the same material published in [1], we have fabricated both broad-area stripe lasers and multiple segmented contact devices to extend the study on the optical properties of this material system.

In this laser structure, the silicon (001) substrates were first patterned with v-grooves to inhibit anti-phase boundaries and block threading dislocations during III-V growth. A GaAs buffer layer and strained superlattice defect filter layers were then grown respectively, followed by the growth of laser structure [2]. The active region was formed by three layers of InAs QDs grown in InGaAs quantum-wells covered with InAlGaAs quantum-barrier layers and sandwiched by InP cladding layers. These materials were then fabricated into broad-area devices which have 100 µm wide mesas, 50 µm wide top p-contact and co-planar n-contact. For segmented contact devices, each contact was 292 µm long separated by an 8 µm gap. Figure 1 gives the Light-Current (L-I) features of a stripe laser with a 2.1 mm cavity length driven by a pulsed source (5 kHz duty cycle and 1 µs pulse width) running at different temperature. Figure 2 shows the optical gain and absorption properties of this silicon-based 1.55 µm QD laser material measured at 21 ˚C. The maximum gain of 10 cm^{-1} was observed under a current density of 2.05 $kAcm^{-2}$ with the peak gain at 1518 nm. Absorption at the long wavelength region corresponds to the material internal optical mode loss α_i, which is approximately 20 cm^{-1}. This study can further promote the improvement in growth technique and more efficient laser design for silicon-based C-band lasers.

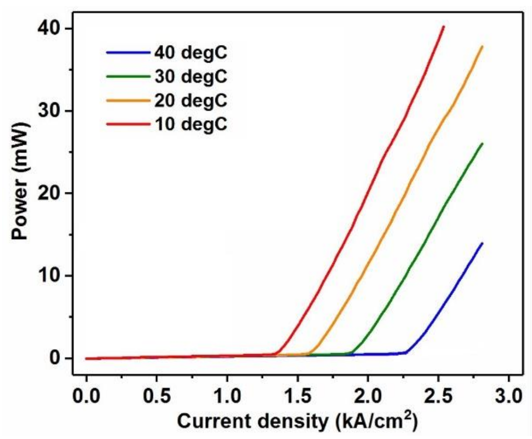

Figure 1, Temperature- dependent L-I curve of a 2.1 mm stipe laser

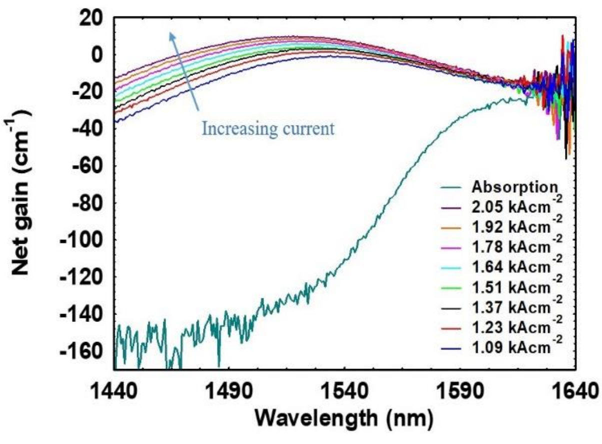

Figure 2, Optical gain and absorption measured at 21 ˚C

[1] Si Zhu, et al., 1.5 lm quantum-dot diode lasers directly grown on CMOS-standard (001) silicon, Applied Physics Letters, 113, 221103 (2018)

[2] Qiang Li and Kei May Lau, Epitaxial growth of highly mismatched III-V materials on (001) silicon for electronics and optoelectronics, Prog. Cryst. Growth Character. Mat. 63, 105-120, 2017.