InAs Quantum Dot Laser Diodes Grown on on-axis Silicon

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Self-assembled InAs quantum dots are a promising light source for silicon photonic devices with low power consumption and superior temperature-dependent performance. Lasers employing quantum dots as the active region demonstrated the lowest threshold current densities and highest lasing temperatures of any semiconductor laser diodes [1-2]. Recently, integrating InAs quantum dot lasers onto silicon has been actively investigated for large scale/low cost fabrication and photonic integrated circuits, and showed high performance lasing at 1.3 μm with low threshold current (16 mA) and high output power (176 mW) at room-temperature, high operating temperature (119 °C), and improved reliability (mean-time to failure of ~4600 hours) [3-4]. This improved lifetime was mainly enabled by the fact that, compared to conventional quantum well technology, quantum dots are much less sensitive to high density of non-radiative defects (2-3×10^8 cm^{-2}) that occur during III-V growth on silicon. These 1.3 μm InAs/GaAs lasers were grown on off-cut (~6 °) silicon

In this invited talk, we will present recent progress on 1.3 μm InAs/GaAs lasers grown on on-axis silicon wafers, which will enable this technology to be more compatible with standard silicon processing. To minimize formation of high defect densities that arise from III-V growth on on-axis silicon, two approaches were taken; 1) pseudomorphic GaP on Si and 2) V-groove patterned silicon. The InAs quantum dot laser diodes grown on GaP/Si template demonstrated promising results, showing high continuous wave lasing up to 90 °C. Also, the lasers grown on V-groove patterned silicon showed relatively low threshold current of 45 mA under room-temperature continuous wave operation. Note that this is the first demonstration of InAs quantum laser diodes epitaxially grown on on-axis silicon, operating above room-temperature under continuous wave mode. We expect that the device performance could be further improved by optimizing the initial GaAs buffer growth conditions and by reducing the defect densities below ~10^7 cm^{-2}.

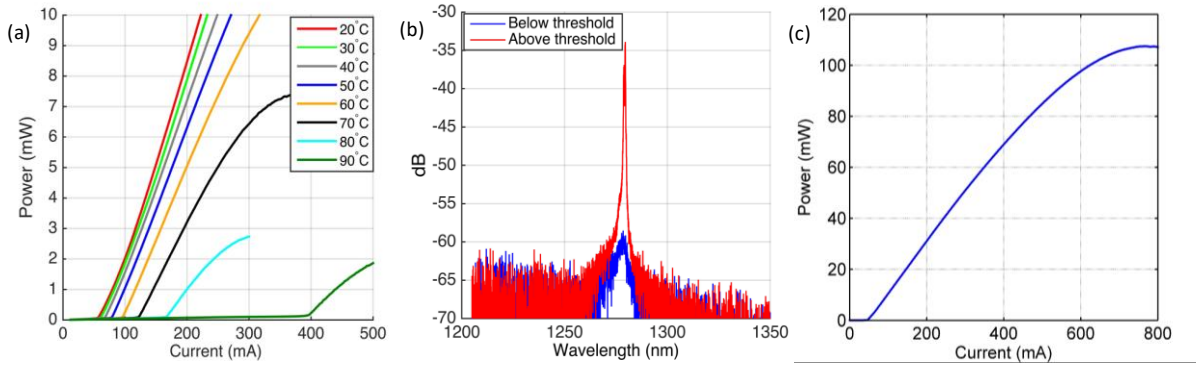

Figure 1 (a) temperature-dependent L-I curves and (b) laser spectra from InAs quantum dot lasers on on-axis GaP/Si substrates, (c) L-I curve measured at room-temperature continuous wave operation for a laser diode grown on V-groove patterned on-axis silicon.

References:

[1] T. Kageyama *et al.*, The European Conference on Lasers and Electro-Optics, (Optical Society of America, Germany, 2011).

[2] B. Dieter and U. W. Pohl, Mater. Today **14**, 388 (2011).

[3] A. Y. Liu, C. Zhang, J. Norman, A. Snyder, D. Lubyshev, J. M. Fastenau, A. W. Liu, A. C. Gossard, and J. E. Bowers, Appl. Phys. Lett. **104**, 041104 (2014)

[4] A. Y. Liu, R. W. Harrick, O. Ueda, P. M. Petroff, A. C. Gossard, J. E. Bowers, IEEE Jour. Sel. Top. Quan. Elec. **21**, 1900708 (2015)