Realisation of Multi-Mode Reflector Lasers for Integrated Photonics

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The epitaxial growth of III-V materials on silicon is an alternative approach to combining silicon photonics with the active laser source. Substantial progress has been made to reduce the defects created at the III-V / Si interface to a level that has a negligible impact on laser operating current and lifetime, providing quantum dot gain materials are utilized [1,2]. A number of issues remain for the integration of III-V structures with silicon, not least that of reducing the footprint and ensuring the fabrication required is as simple as possible. While the laser reflectors can be fabricated in the silicon here we focus on using the III-V material, which removes the need to have the III-V / Silicon interface and its associated losses within the laser cavity.

Here we describe the modelling and design, fabrication and characterization of multi-mode interference reflector MMIR lasers based on InAs QDs grown on GaAs, where both the laser active region and the reflector components are made from the same material, as a means to qualify the performance of these reflectors for use with lasers. This offers advantages with regard to reflectivity, footprint, and is effective reducing the threshold current of InAs QD lasers. The principle of a single port MMIR is shown in Fig l (a), and it possible to create this type of device with low loss (~ 0.1 dB) and in a format that is relatively insensitive to wavelength and polarization [3].

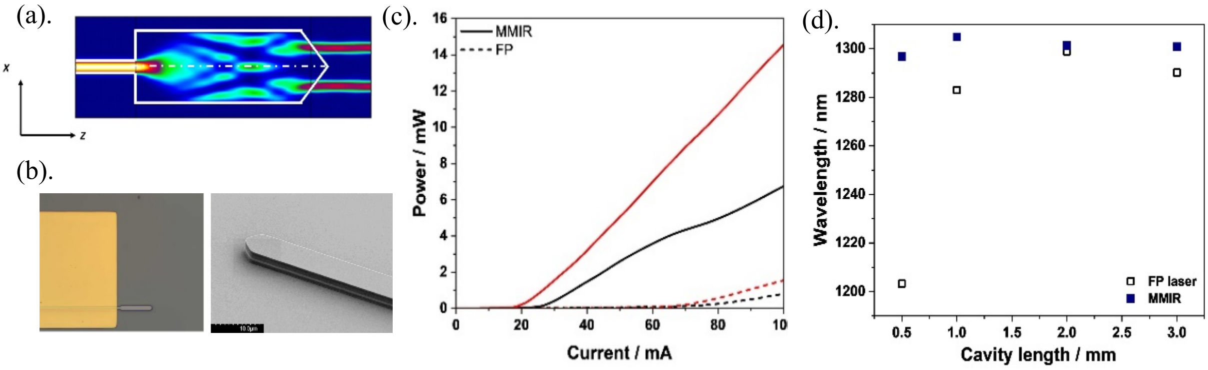

Fig. 1 (a). operation principle: field distributions simulation of a 1×2 MMI with position of two angled facets marked. (b). Optical microscopic image of InAs QDs based MMIR laser (left), FESEM micrograph of zoomed area of MMIR (right). (c). Pulsed P-I curves for MMIR (solid) and FP (dashed) 0.5mm (black) and 1 mm (red) cavity length lasers 25 °C, (d). Peak lasing wavelength for MMIR and FP lasers at 25 °C .

To investigate fabrication tolerances we made InGaAs-InAs QD MMIR lasers with 6 µm MMI width terminated with 45 degree angled etched mirrors and used a simple cleaved edge to provide the other laser mirror. The active device length and input to the MMI section comprised a ridge of 3 µm width and 0.5 mm length and we compared the performance of these lasers with simple cleaved facet ridge waveguide lasers of the same ridge width. Fig. 1 (c) shows that MMIR lasers typically show more than 40% lower threshold current for the same cavity length compared with FP lasers, and Fig. 1 (d) shows that MMIR lasers operate on the QD ground state down to 0.5mm cavity length, even at elevated temperature, while ground state emission is only maintained down to 1mm cavities for the FP lasers. From the threshold comparison we estimate an MMIR reflectivity of ~92 %.
In summary, we achieved high reflectivity on-chip reflectors with a single waveguide etch step and with high fabrication tolerances. Low threshold current and operation on the QD ground state were maintained for 0.5 mm cavity length MMIR lasers.

References

[1] S. Chen, W. Li, J. Wu, Q. Jiang, M. Tang, S. Shutts, S. N. Elliott, A. Sobiesierski, A. J. Seeds, I. Ross, P. M. Smowton, and H. Liu, Electrically pumped continuous-wave III-V quantum dot lasers on silicon. Nature photonics. 2016;10(5):307-11

[2] J. C. Norman, Z. Zhang, D. Jung, C. Shang, M.J Kennedy, M. Dumont, R. W. Herrick, A. C. Gossard, and J. E. Bowers, The Importance of p-Doping for Quantum Dot Laser on Silicon Performance, IEEE J. Quant. Elec., 55, (6), 2019 2001111

[3] L. Xu et al., "MMI-reflector: A novel on-chip reflector for photonic integrated circuits," in 2009 35th European Conference on Optical Communication, 20-24 Sept. 2009 2009, pp. 1-2.