InAs/GaAs quantum-dot photonic crystal bandedge lasers monolithically grown on on-axis Si (001) substrates

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Abstract: A room-temperature continuous-wave optically pumped lasing operation at 1.3 μm with an ultra-low threshold has been demonstrated from an InAs/GaAs quantum dot (QD) square-lattice PhC bandedge laser monolithically grown on on-axis Si (001) substrates.

OCIS codes: 050.5298, Photonic Crystals.

1. Introduction

Photonic crystal (PhC) laser integrated on Si is a promising candidate as coherent light sources in silicon photonics platforms because of its ultrasmall mode volume, high quality-factor and the large Purcell factor properties. A room-temperature continuous-wave optically pumped lasing operation at 1.3 μm with an ultra-low threshold has been demonstrated from an InAs/GaAs quantum dot (QD) square-lattice PhC bandedge laser monolithically grown on on-axis Si (001) substrates. [1–8]

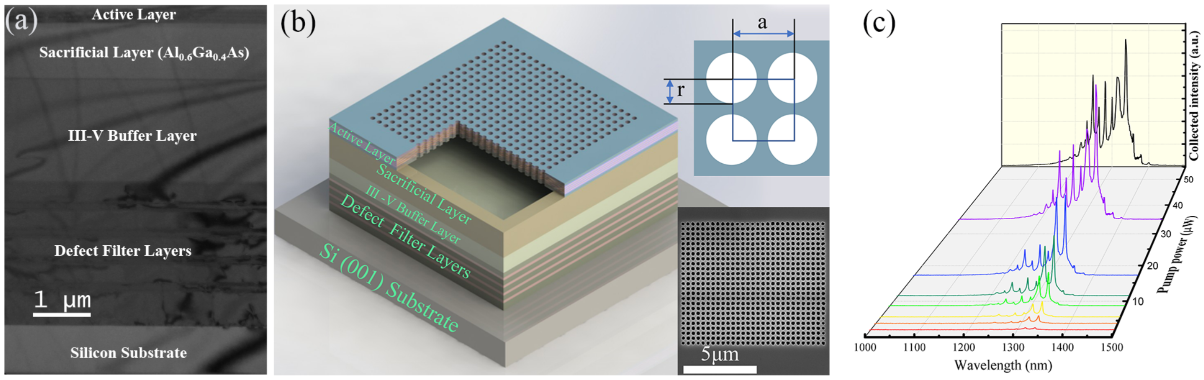

Fig. 1. (a) TEM image of the QD epitaxy structure grown on on-axis Si (001) substrate. (b) Schematic diagram of a square lattice PhC bandedge laser grown on planar on-axis Si (001) substrate. (inset: a top-view SEM image of the fabricated device) The radius of the air hole is indicated as r, and the lattice constant is ex-pressed as a. (c) Emission spectrums of the fabricated bandedge laser under different pump powers.

2. Experimental Results

The InAs/GaAs QD PhC bandedge lasers were monolithically grown on on-axis Si (001) substrates without any intermediate buffer layer. Figure 1.(a) shows the cross-sectional transmission electron microscope (TEM) images of the visible defect free four stacked grown InAs/GaAs QD layers on Si substrate. The bandedge photonic crystal cavity was designed with parameters r/a=0.35, and defined by EBL onto the wafer. After the dry etching and wet etching, the device were characterized by optical pumping using a He-Ne laser. Figure 1.(c) shows the emission spectrums of the fabricated bandedge laser under different pump powers. Apparent lasing peaks can be observed when increasing the pumping power.

In conclusion, we have demonstrated the InAs/GaAs QD 2D square-lattice PhC bandedge lasers monolithically grown on on-axis Si (001) substrates. The lasers operated under continuous-wave optical pumping under room-temperature. Three lasing modes were realized at the bandedge points on the photonic band structure and identified by their spectral positions, working at wavelengths around 1.3μm.

References

1. M. Asghari and A. V. Krishnamoorthy. Silicon photonics: Energy-efficient communication. *Nature photonics*, 5(5):268, 2011.
2. S. Chen, W. Li, J. Wu, Q. Jiang, M. Tang, S. Shutts, S. N. Elliott, A. Sobiesierski, A. J. Seeds, I. Ross, et al. Electrically pumped continuous-wave iii–v quantum dot lasers on silicon. *Nature Photonics*, 10(5):307, 2016.
3. D. Liang and J. E. Bowers. Recent progress in lasers on silicon. *Nature Photonics*, 4(8):511–517, Aug. 2010.
4. A. Rickman. The commercialization of silicon photonics. *Nature Photonics*, 8(8):579, 2014.
5. M. Tang, S. Chen, J. Wu, Q. Jiang, V. G. Dorogan, M. Benamara, Y. I. Mazur, G. J. Salamo, A. Seeds, and H. Liu. 1.3-μm inas/gaas quantum-dot lasers monolithically grown on si substrates using inalas/gaas dislocation filter layers. *Optics express*, 22(10):11528–11535, 2014.
6. D. Thomson, A. Zilkie, J. E. Bowers, T. Komljenovic, G. T. Reed, L. Vivien, D. Marris-Morini, E. Cassan, L. Virot, J.-M. Fédéli, et al. Roadmap on silicon photonics. *Journal of Optics*, 18(7):073003, 2016.
7. Y. Wan, J. Norman, Q. Li, M. J. Kennedy, D. Liang, C. Zhang, D. Huang, Z. Zhang, A. Y. Liu, A. Torres, D. Jung, A. C. Gossard, E. L. Hu, K. M. Lau, and J. E. Bowers. 13 μm submilliamp threshold quantum dot micro-lasers on Si. *Optica*, 4(8):940, Aug. 2017.
8. T. Zhou, M. Tang, G. Xiang, X. Fang, X. Liu, B. Xiang, S. Hark, M. Martin, M.-L. Touraton, T. Baron, Y. Lu, S. Chen, H. Liu, and Z. Zhang. Ultra-low threshold inas/gaas quantum dot microdisk lasers on planar on-axis si (001) substrates. *Optica*, 6(4):430–435, Apr 2019.