2025 Conference on Lasers and Electro-Optics Europe & European Quantum Electronics Conference (CLEO/Europe-EQEC) | 979-8-3315-1252-1/25/$31.00 ©2025 IEEE | DOI: 10.1109/CLEO/EUROPE-EQEC65582.2025.11110796

A Novel Surface-Emitting Laser Using Coupled InGaAs/GaAs Nano-Ridges on Si: Insights from Cathodoluminescence

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Nano-ridge engineering (NRE) is a promising solution to address the challenges facing current micro-laser technologies [1]. It allows the growth of high quality, defect free active materials on silicon substrates without the need for thick buffer layers [2]. Here, we present a novel laser design based on an array of nano-ridges arranged in a photonic crystal configuration, where each nano-ridge is spaced with a period of 380 nm and has three quantum wells (Fig. 1a). This architecture supports a bound state in the continuum (BIC) mode across the nano-ridge array, providing both strong in-plane confinement and surface emission. To gain insight into the underlying physics of the lasing mechanism, we use cathodoluminescence (CL) measurements to construct experimental band-structure maps [2]. The angle- and spectrally-resolved CL data enable us to visualize the photonic modes and directly confirm the presence of the BIC mode. Although CL uses an electron beam to locally excite only a single nano-ridge, the observation of the complete band structure in our measurements highlights that the laser action arises from collective coupling across the nano-ridge array. The experimentally measured band structure obtained from CL exhibits excellent agreement with FDTD simulations along both the k_x and k_y directions, including a close match in the frequency of the lowest band mode at the Γ point as well as in the curvature of the band (Fig. 1b). Under optical pumping, a prominent lasing peak emerges near the predicted wavelength of around 990 nm. As shown in Fig. 1c, when increasing the pump power, the device displays a distinct threshold at about 10 kW/cm^2 , confirming robust laser action near the designed operating wavelength. This new approach to achieving lasing combined with in depth characterisation through CL offers unprecedented flexibility, as the BIC mode can be tuned by adjusting key design parameters—such as the array period and nano-ridge width. This versatility not only enables operation at wavelengths in the near-infrared, but also paves the way for cost-effective, integrated, mass-manufactured lasers on standard silicon wafers.

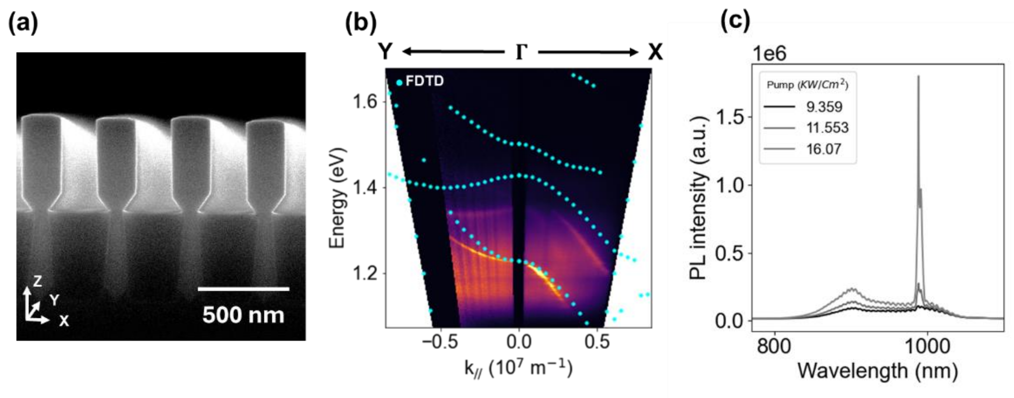

Fig. 1 (a) Scanning electron microscope (SEM) image of an array of optically coupled nano-ridges forming the laser device. (b) Angle-resolved cathodoluminescence measurement showing the band structure of the coupled nano-ridge array, obtained by locally exciting a single nano-ridge with an electron beam. The measured data is overlaid with the band diagram simulations from FDTD simulations (cyan dots) (c) Lasing spectrum under different pump powers, measured using a micro-PL setup with a 532 nm pulsed laser as the pump source. A strong peak at 986 nm is observed, with a threshold pump power of approximately 10 kW/cm².

Example References

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