# Telecoms-Wavelengths Cavity-enhanced Devices Based on Type-II GaSb Quantum Rings

S. Jones, G. Acar, P. D. Hodgson and M. Hayne
*Department of Physics, Lancaster University, Lancaster LA1 4YB, United Kingdom*
m.hayne@lancaster.ac.uk

The demand for compact, low-cost and efficient devices emitting at telecoms wavelengths (1260 to 1675 nm), continues unabated. Whilst vertical-cavity surface-emitting lasers (VSCELs) are ubiquitous in datacoms (<1000 nm), their widespread availability at longer wavelengths remains an unfulfilled goal. In addition to the merging of datacoms and short haul telecoms (~1310 nm), other applications are emerging such as upstream lasers for fibre to the premises (1270 nm), below screen facial and gesture recognition (>1380 nm) in mobile devices and 'eye-safe' light detection and ranging (LiDAR >1400 nm). The principal reason for the lack of >1000 nm VCSELs is that established commercial VCSEL technology uses $GaAs/Al_xGa_{1-x}As$ distributed Bragg reflectors (DBRs). Due to lattice mismatch and strain, this limits the In in the InGaAs quantum well emitter. Alternative approaches use, *e.g.* dilute nitrides or InAs quantum dots (QDs), and/or other material systems for DBRs, but moving away from the monolithic epitaxial growth increases production costs. In terms of technological challenges, by far the most demanding is low-cost, C-band (~1550 nm) single photon sources capable of operating at room temperature.

We report a unique approach to cavity-based telecoms devices using type-II self-assembled GaSb quantum rings (QRs) for photon generation. GaSb QDs are formed by the Stranski-Krastanow growth on GaAs but are transformed into QRs on capping [1]. They emit deep into the telecoms band at room temperature [2] and are fully compatible with $GaAs/Al_xGa_{1-x}As$ DBRs. A deep-hole localization potential of 609 meV [3] ensures hole capture well above 300 K. However, at first sight their type-II character and broad emission from 1000 nm to 1600 nm seems disadvantageous for a laser, let alone a single-photon light-emitting diode (SPLED). Our counterintuitive approach hypothesizes that these disadvantages combine to be advantageous, *i.e.* that intrinsically slow spontaneous recombination allows effective generation of cavity-enhanced emission at a wavelength deep into the telecoms band that is determined solely by the cavity resonance. Recent GaSb QR VCSEL devices [4] show cavity peaks in the telecoms 'O' band, a threshold in room-temperature light emission at 0.15 $kAcm^{-3}$ in a 10-µm-mesa device and a notable 77 K threshold for quenching of stimulated emission, which we attribute to the electric field sweeping unconfined electrons through the active region. However, to date, QR VCSEL output intensity (and efficiency) is very low. Our approach to SPLEDs is even more radical. Rather than trying to isolate a specific QD or QR, we again exploit cavity effects to engineer emission from an ensemble of rings, with the intention to ensure single photon emission by injection of a single electron using a layer of highly non-uniform ($GaAs/Al_xGa_{1-x}As$) QDs [5]. With low-cost manufacture of a device capable of operating at or above room temperature as a starting point, we are currently studying the emission of devices with smaller and mesas. Single photon emission is the final goal, rather than the starting point. Recent results show cavity-enhanced O-band emission, with an encouraging decrease in background emission with decreasing excitation current relative to the cavity peak. Interestingly, both VCSEL and SPLED devices show a decrease in background (spontaneous) emission with increasing temperature relative to cavity emission, which we attribute to non-radiative processes.

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