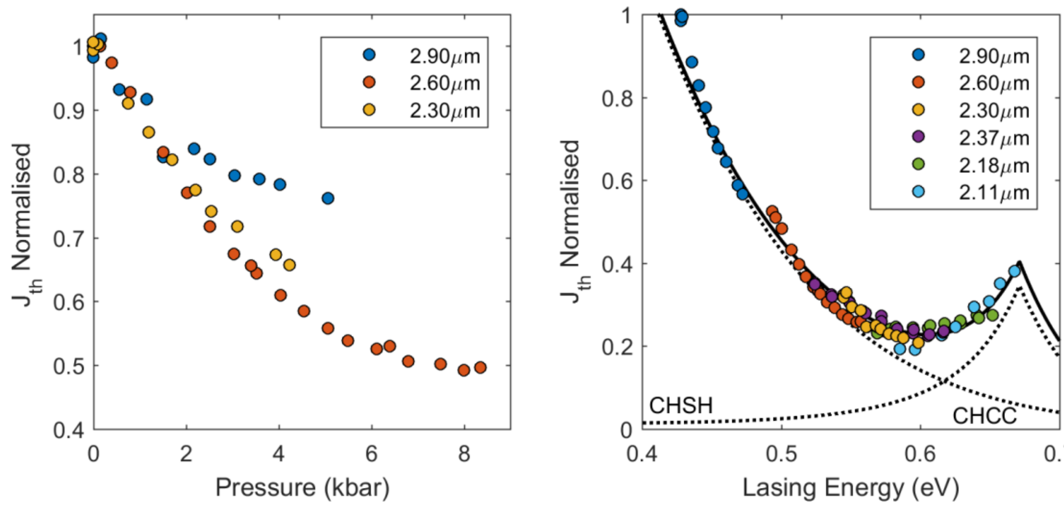
Physical Properties of Type I GaInAsSb/GaSb lasers emitting in the Mid-infrared range of 2.3-2.9 μm

Timothy Eales[1], Igor P. Marko[1], Barnabas A. Ikyo[1], Alf R. Adams[1], Stephen J. Sweeney[1], Shamsul Arafin[2], Stephan Sprengel[2] and M.-C. Amann[2]

[1]*Advanced Technology Institute and Department of Physics, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom*
[2]*Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany*

The pursuit of semiconductor lasers operating at room temperature in the 2-3 μm region is motivated by a variety of applications which include environmental monitoring, non-invasive medical diagnosis and industrial processing.[1] Type-I quantum well (QW) laser designs, based on the GaInAsSb/GaSb material system have received significant attention for this purpose. The operational instability observed in type-I infrared inter-band lasers are primarily attributable to the effects of non-radiative Auger recombination, inter-valence band absorption and carrier leakage.[2] As the spectral range of type I QW lasers has expanded, these limitations have become more apparent.[3] In this work using high hydrostatic pressure we study the Auger recombination mechanisms affecting the operating characteristics of type-I GaInAsSb based lasers emitting at 2.3 μm, 2.6 μm and 2.9 μm wavelengths and the extent to which these influence device performance.

High hydrostatic pressure reversibly alters the fundamental bandgap of semiconductors providing a useful method to investigate bandgap dependent recombination mechanisms such as the Auger processes. In the 2.3-2.9 μm wavelength range the CHCC process is expected to decrease exponentially with the bandgap increase (increasing pressure) while the CHSH process increases exponentially with increasing bandgap as the bandgap approaches resonance with the spin-orbit splitting energy (Δ_{SO}). If either of these processes is a dominant recombination path then the associated bandgap dependent behaviour should be represented in the threshold current density dependence on pressure.



The obtained high pressure results (see the figure on the left) have been supplemented with our previous measurements on GaInAsSb lasers to extend the wavelength range from 2.9μm to 1.8 μm (see the figure on the right). The radiative component is removed from the threshold current density using spontaneous emission measurements at atmospheric pressure and assuming $J_{rad} \propto E_g^2$. To account for the structural variability in the devices the nonradiative component of each device was independently normalised to generate a continuous dependence of the threshold current density against the lasing photon energy.

A simple model for the CHCC and CHSH processes was used to fit the high pressure measurements. Two important regimes are evident. The nonradiative current decays approximately exponentially with lasing photon energy, before reaching a minimum around 0.6 eV. The non-radiative current then increases exponentially up to 0.67 eV reaching the region where the bandgap is in resonance with Δ_{SO}. This coupled exponential behaviour is indicative of two Auger processes.

References

[1] A. Joullié and P. Christol, Comptes Rendus Phys. **4**, 621 (2003).
[2] K. Vizbaras and M.-C. Amann, Electron. Lett. **47**, 980 (2011).

[3] R.G. Bedford, G. Triplett, D.H. Tomich, S. W. Koch, J. Moloney, and J. Hader, J. Appl. Phys. **110**, 073108 (2011).