Recombination Processes in Type I GaInAsSb Lasers

T. Eales[1], I. Marko[1], B. Ikyo[1], A. R. Adams[1], S. Arafin[2], S. Sprengel[2], M.-C. Amann[2], S. J. Sweeney[1]*

[1] *Advanced Technology Institute and Department of Physics, University of Surrey, Guildford, GU2 7XH, United Kingdom*

[2] *Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany*

Mid-infrared optical devices between 2 and 3 µm are motivated by a diverse array of applications which include trace gas detection and communications [1]. Type-I quantum well (QW) laser structures, based on the GaInAsSb/GaSb material system are the standard approach for this wavelength range. However, loss processes such as Auger recombination, inter-valence band absorption and carrier leakage all effect the temperature stability of these devices. In this work we study the dominant recombination mechanisms affecting the operating characteristics of type-I GaInAsSb based lasers emitting at 2.3, 2.6 and 2.9 µm [2]. The characteristic temperature (T_0) is a measure of the temperature sensitivity of the threshold current density. The temperature dependence of T_0 for the three wavelength devices is presented in Fig. 1. The same qualitative behaviour is observed in each device with T_0 decreasing rapidly (decreasing stability), approaching, and then exceeding the predicted temperature sensitivity of a device dominated by Auger recombination ($T_0 \sim T/3$). These processes can be explored in more detail using hydrostatic pressure since the different loss processes have distinctive behaviour as a function of pressure. In a device dominated by the CHCC process the threshold current would be expected to decrease exponentially with increasing pressure (increasing bandgap) while a device dominated by the CHSH process is expected to increase exponentially as the bandgap increases and approaches resonance with the spin-orbit splitting energy (Δ_{SO}). This work can be supplemented with previous high hydrostatic pressure measurements on GaInAsSb lasers, extending the wavelength range to 1.83 µm [3]. To account for structural differences the non-radiative component of the threshold current density in each device was independently normalized, generating a smooth dependence with lasing energy. This is shown Fig. 2. Modelling the experimental data provides clear evidence of the dominance of the CHCC process at longer wavelengths and the importance of the spin orbit split off resonance in enhancing the CHSH process.

References

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*corresponding author: s.sweeney@surrey.ac.uk

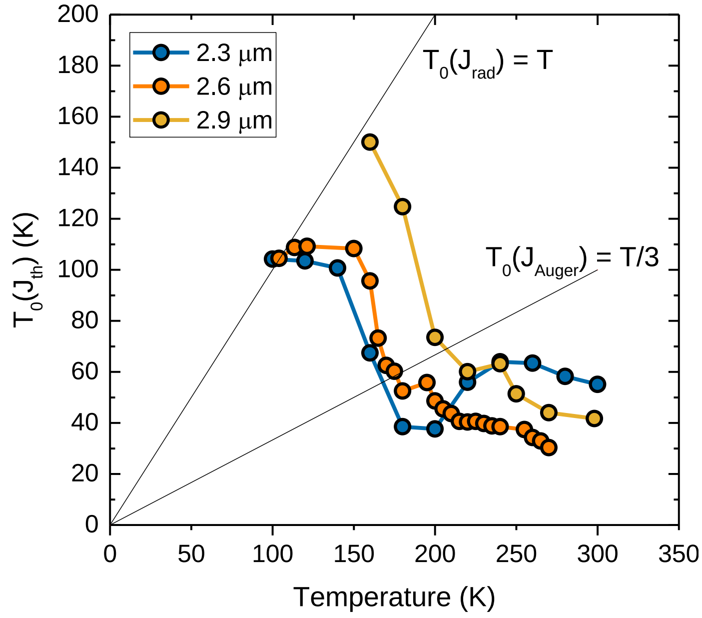

Fig.1. T_0 for the three devices as a function of temperature. The dotted lines indicate highest theoretical T_0 for a device dominated by radiative and Auger recombination.

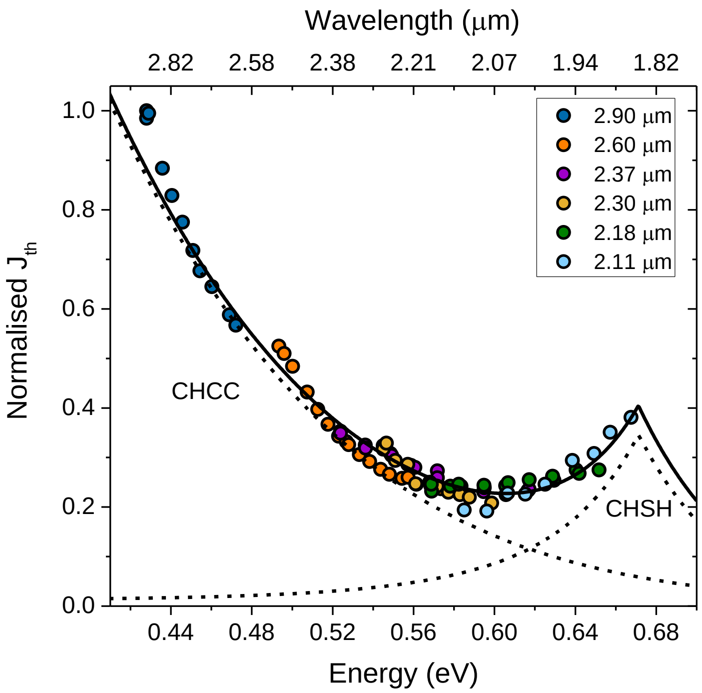

Fig.2. The normalized non-radiative component of the threshold current density as a function lasing photon energy. The dotted lines show the modelled contribution from the CHCC and CHSH processes.