Temperature and Band Structure Dependent Properties of GeSn Double Heterostructure Lasers

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The development of monolithically integrated group-IV lasers remains a key challenge in realising Si-based integrated optoelectronic circuits [1]. With its direct bandgap and the possibility for wavelength tuning through strain and composition engineering, GeSn has emerged as an interesting approach. However, GeSn lasers have been primarily limited to low temperature operation. Understanding the carrier recombination behavior is therefore vital to develop improved devices with higher operating temperatures. Here, we investigate bulk $Ge_{0.89}Sn_{0.11}$ lasers grown using chemical vapor deposition [2]. In this study, high pressure, low temperature measurements are used to vary the electronic band structure for a fixed thermal carrier distribution, enabling purely band structure dependent mechanisms to be probed. Analysis of the threshold current density with pressure indicates an L-valley occupation of ~1% at 85K, determined from the fit in Fig. 1 a). Above this temperature, the fractional L-valley occupation increases strongly, indicated by a sharp rise in the threshold carrier density (assuming only mirror losses), illustrated by the red line in Fig. 1 b). This increases the pump threshold leading to device heating, increasing the L-valley occupation further and heightening free carrier absorption losses. The implications for this in terms of optimising the laser design for ambient temperature operation will be discussed.

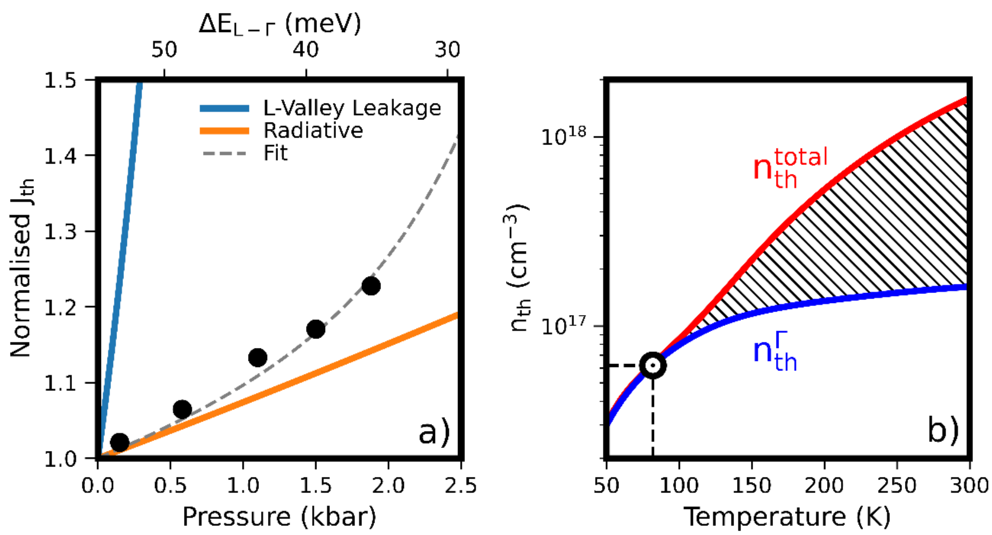

Figure 1. a) Normalised variation of threshold current density with pressure and **Γ**-L separation, $\boldsymbol{\Delta E_{L-\Gamma}}$, showing the effect of L-valley leakage. b) Increase in total threshold carrier density with temperature above the 80K break point due to enhanced fractional L-valley occupation.

[1] Wang, B. *et al.* *Light Sci Appl* **10**, 232 (2021).
[2] Zhou, Y. *et al.* Optica **7**, 924-928 (2020).

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