Band structure engineering in dilute bismide semiconductor lasers

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Highly mismatched semiconductor alloys such as GaN\textsubscript{x}As\textsubscript{1−x} and GaBi\textsubscript{x}As\textsubscript{1−x} have several novel electronic properties, including a rapid reduction in energy gap (\(E_g\)) with increasing \(x\) and also, for GaBi\textsubscript{x}As\textsubscript{1−x}, a strong increase in spin-orbit-splitting energy (\(\Delta_{SO}\)) with increasing Bi composition. Furthermore, it has been demonstrated that for sufficiently large \(x (\gtrsim 10\%)\) in GaBi\textsubscript{x}As\textsubscript{1−x} that we enter a \(\Delta_{SO} > E_g\) regime in the alloy [1, 2]. This band structure condition has been identified as promising for opening the route to efficient temperature-stable telecomm and longer wavelength lasers with significantly reduced power consumption [3]. It is proposed that this is to be achieved by suppressing the non-radiative CHSH Auger recombination path, a loss mechanism which strongly dominates the threshold current of conventional InP-based lasers above room temperature [4].

In this work we apply modified 12 and 14-band \(\textbf{k} \cdot \textbf{p}\) Hamiltonians that we have recently derived for dilute bismide and bismide-nitride alloys [5] to study the effect of Bi and N incorporation on the optical gain and inter-valence band absorption (IVBA) in ideal GaBi\textsubscript{x}N\textsubscript{y}As\textsubscript{1−x−y}/(Al)GaAs lasers. We observe that although Bi incorporation degrades the optical gain and increases IVBA at low \(x\) (due in part to weak confinement of electrons in the GaBi\textsubscript{x}As\textsubscript{1−x} layers) as \(x\) is increased towards the \(\Delta_{SO} > E_g\) regime the optical gain recovers to a level comparable to that of a standard InGaAs/GaAs laser. This is accompanied by the added benefit of suppressed IVBA losses when \(\Delta_{SO} > E_g\), confirming the promise of dilute bismides for telecomm laser applications [?]. Quantification of the effects of Bi incorporation on Auger recombination in dilute bismide lasers is the subject of ongoing investigation.

References