Band structure engineering in dilute bismide semiconductor lasers

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Highly mismatched semiconductor alloys such as $\text{GaN}_x\text{As}_{1-x}$ and $\text{GaBi}_x\text{As}_{1-x}$ have several novel electronic properties, including a rapid reduction in energy gap (E_g) with increasing x and also, for $\text{GaBi}_x\text{As}_{1-x}$, a strong increase in spin-orbit-splitting energy (Δ_{SO}) with increasing Bi composition. Furthermore, it has been demonstrated that for sufficiently large x ($\gtrsim 10\%$) in $\text{GaBi}_x\text{As}_{1-x}$ that we enter a $\Delta_{\text{SO}} > E_g$ 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 $\mathbf{k}\cdot\mathbf{p}$ 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 $\text{GaBi}_x\text{N}_y\text{As}_{1-x-y}$/(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 $\text{GaBi}_x\text{As}_{1-x}$ layers) as x is increased towards the $\Delta_{\text{SO}} > E_g$ 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 $\Delta_{\text{SO}} > E_g$, 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

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