Theoretical comparison of MWIR and LWIR laser diode structures

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The ideal performance of interband and intersubband active regions for III-V laser diodes emitting from 3-11 microns (MWIR and LWIR) are compared. The principal figure of merit is the maximum net gain per unit volumetric current. Material properties determining this figure of merit, including optical gain, carrier recombination via Auger recombination, and intersubband absorption, were calculated for bulk, quantum well, and superlattice active regions. Based on these calculations, optimal thicknesses for active regions were evaluated assuming a separate confinement region design.

Whereas a variety of claims have been made concerning the relative *ideal* performance of active regions of various types in the MWIR and LWIR, evaluation of these claims has been hampered by the lack of a common figure of merit. As an example, consider Auger coefficients: different conventions seem appropriate for superlattices and quantum wells (i.e. whether the barrier region is included in the definition of the carrier density). A more appropriate quantity used for evaluation of active region materials has been the volumetric threshold current density for a particular gain, but that is not flexible enough to compare laser designs based on different thicknesses of active region, or for comparing cascade to noncascade designs. An appropriate figure of merit is required that can be used to compare quantum well, superlattice, and bulk active region lasers. Ideally it would also allow fair comparison between traditional and cascade structures, and interband and intersubband active regions.

Here figures of merit [1-4] are described which allow fair comparison of the active regions of MWIR and LWIR systems under certain reasonable assumptions. The optimal thickness of an active region for a particular cavity can also be determined via these figures of merit. Once the figures of merit have been identified, calculated values are presented for several laser diode structures emitting in the MWIR and LWIR, representative of those under current consideration.

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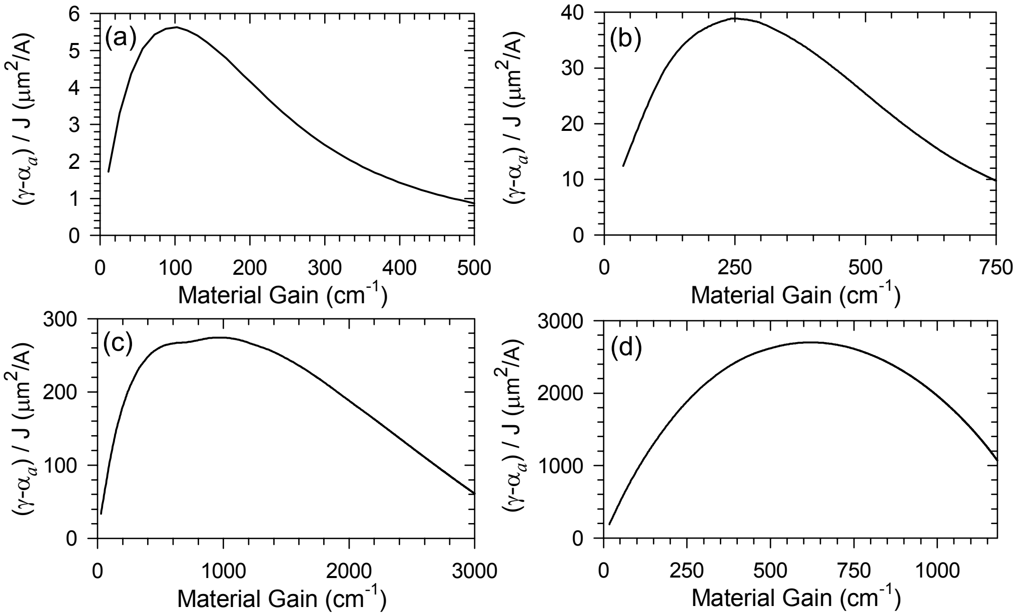

Figure 1: Net gain per unit volumetric current, $[(\gamma-\alpha_a)/J]$, as a function of gain at 300K for (a) bulk InAs, (b) an InAsSb/InAsP quantum welI, (c) an InAs/GaInSb/InAs/AlGaInAsSb superlattice, and (d) an optimized multiple-layer structure. Note the different scales. Regardless of the laser cavity design, the active region should be operating at the optimum value of this figure of merit for the lowest threshold current requirements.

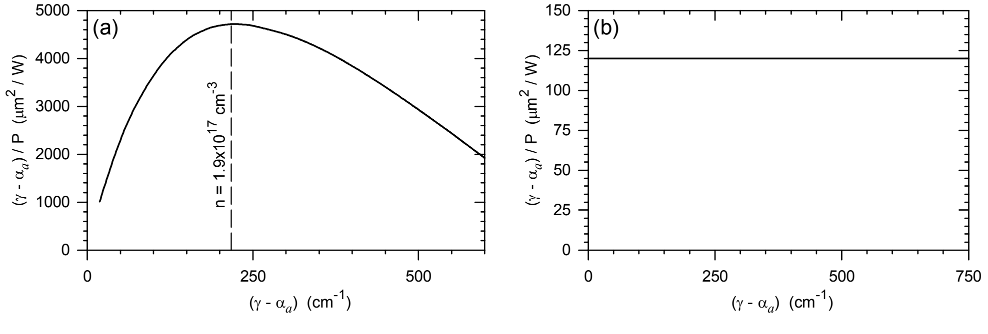

Figure 2: Net gain per unit volumetric power dissipation density, $[(\gamma-\alpha_a)/P]$, as a function of net gain at 300K for (a) an optimized interband and (b) an intersubband active region. Note the different scales. The density corresponding to the optimum $[(\gamma-\alpha_a)/P]$ is indicated on (a). The net gain at these densities is the optimum material net gain for these systems.