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Modeling defect level occupation for recombination statistics[1]

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— Measurements of luminescence intensity as a function of temperature and laser illumination can provide considerable insight into the energy level distribution and recombination statistics of a semiconductor. Since the radiative recombination rate is proportional to the product of carrier densities in the valence and conduction bands, measurements of radiative efficiency vs. photoexcitation reveal how nonradiative, defect-related recombination mechanisms vary with band occupation. In this context, recent experimental results for a high-quality GaAs/GaInP double heterostructure contain two informative features. First, the radiative efficiency increases with temperature, indicating that shallow nonradiative recombination centers are being thermally depleted. Second, the defect-related recombination rate increases unusually slowly against the band carrier density product. Using a sophisticated model for non-equilibrium band and defect level occupation, we show that this latter result requires an asymmetric distribution of defect levels within the gap. Trap filling produces a rapid increase in that carriers band occupation, while the density of carriers in the band responsible for defect-related recombination remains nearly constant, such that the product increases without augmenting the recombination rate appreciably.

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