Analytical Model of Nonlinear Gain in Strained Ge

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Strained germanium attracts a lot of attention as a potential gain medium for monolithically integrated laser sources compatible with Si technology. The first observation of lasing in strained germanium was reported almost a decade ago [1]. However, the mechanism of lasing is still not clear. Indeed, the measured amplification on inter-band transitions in Ge with strain corresponding to that of [1] and high pumping levels (about 10^{20} cm^{-3}) was found to be more than an order of magnitude smaller than pump-induced absorption [2], while low temperature lasing from strained germanium have been obtained at pumping levels as low as 10^{17} cm^{-3} [3]. The latter result has been attributed by the authors to the non-equilibrium distribution of electrons. On the other hand, numerical simulations [4] show that non-monotonous pump power dependence of the total gain is possible in strained germanium in the case of quasi-equilibrium distribution of electrons and holes.

We build an analytical model which explains the non-monotonous dependence of the total gain in strained germanium under conditions of quasi-equilibrium distribution of electrons and holes by non-linearity of the dependence of the inter-band gain and inter-valence band absorption on the chemical potential of holes. The model is based on the factorization of the quasi-equilibrium difference of populations between the valence and conduction band states. This model allows us to identify several regimes of dependence of the interband gain on the effective dimensionless chemical potentials of electrons and holes, derive simple analytical expressions for the boundary of the generation zone in the plane of dimensionless chemical potentials, determine the threshold strain level as a function of temperature and the minimum doping as a function of strain and temperature.

References

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