Theory of Semiconductor Laser Cooling at Low Temperatures

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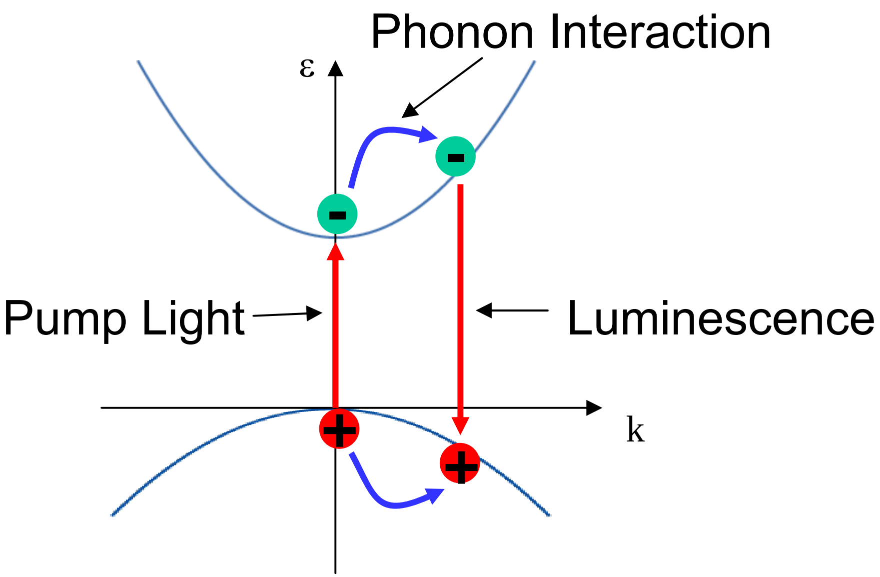
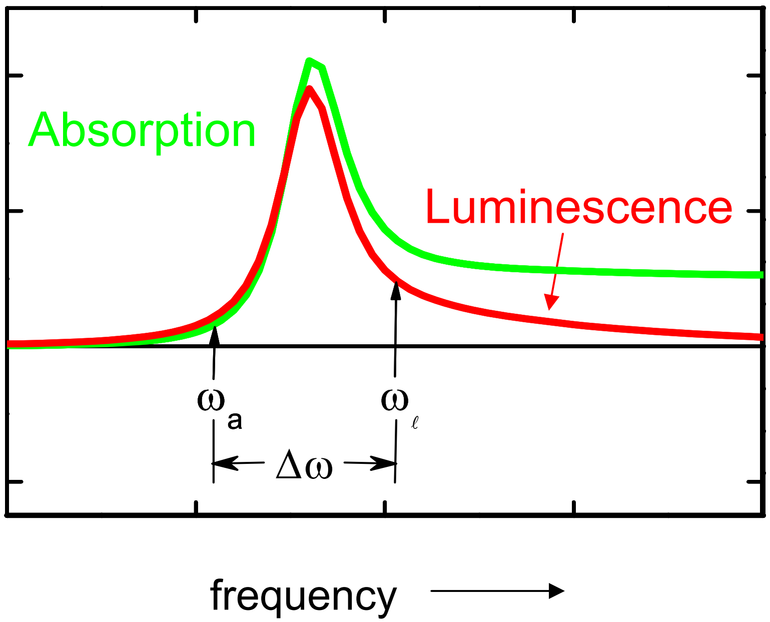
Semiconductor: basic cooling principle

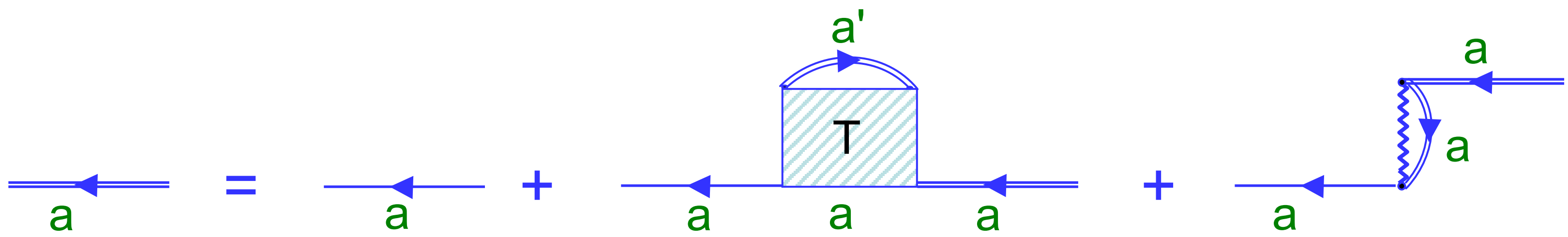
mean frequency of emitted light higher than absorbed light

→ energy removed from semiconductor





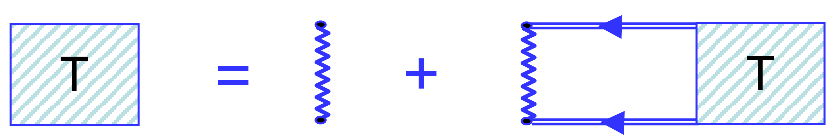
Dyson equation (↔ quasi-particles, energy renormalization, damping and dephasing, chemical potential, density, ionization degree)



T-selfenergy includes electron bound to hole as exciton

quasi-statically screened Hartree-Fock selfenergy
+
Coulomb hole selfenergy

T-matrix (↔ non-perturbative e-h, e-e, h-h correlation)



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cf. Schmielau et al., phys. stat. sol. (b) 221, 215 (2000); Piermarocchi, Tassone, Phys. Rev. B 63, 245308 (2001)

Cooling analysis

$$P_{net} = I\left[\alpha(\omega_a, n) + \alpha_b + \sigma_{fca} n\right] - \hbar\omega_\ell \eta_e B(n) n^2$$

$$\frac{dn}{dt} = \frac{\alpha(\omega_a, n)}{\hbar\omega_a} I - An - \eta_e B(n) n^2 - Cn^3 = 0$$

absorption — luminescence

from microscopic theory

An - Non-radiative recombination rate

Bn^2 - Radiative recombination rate

η_e - Extraction efficiency

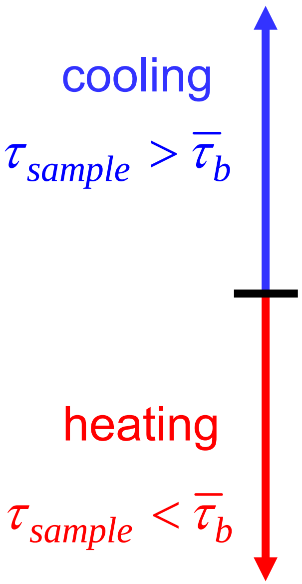
Cn^3 - Auger recombination rate

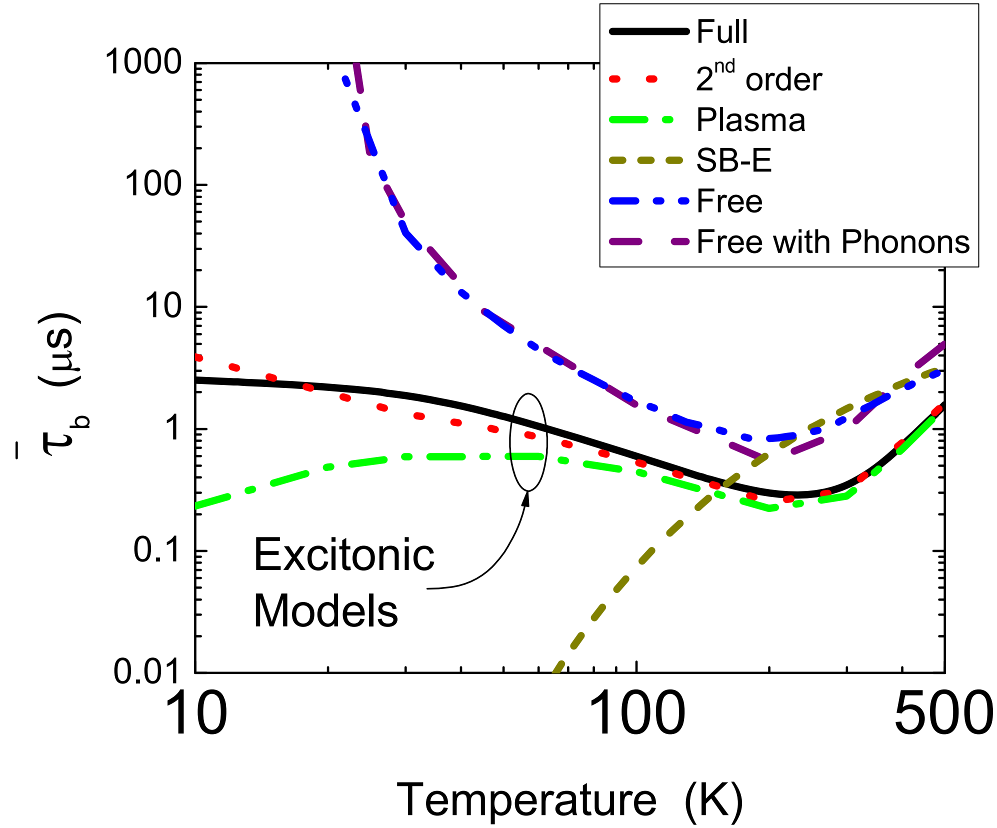
α_b - Parasitic background absorption

σ_{fca} - Free carrier absorption

Reference: Sheik-Bahae, Epstein PRL 92, 247403 (2004)

Threshold non-radiative lifetime





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