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# Dynamics and their effects on quantum-dot laser

M.O.Oleiwi C.A.Emshary

Physics Department . Education College for pure sciences . Basrah University. Basrah . Iraq

**Abstract:**

In this article a detailed dynamical study of the InAs/InGaAs quantum dot emitting 1.3$\mu m$ under the excitation with a signal lasting for 5ns is given. Temporal behavior of electron and hole densities in the QD and photon density at constant current injection density are studied .The in-scattering rate of electrons and holes against number of electrons and holes densities respectively at different temperature i.e (70-400)K are studied too.

## Introduction:

Quantum dot, QD, lasers are new generation semiconductor lasers including several million nano-sized crystals called QDs in the active region as light emitters , and as a result of their unique properties like low threshold current ,low bet-error rate ,and temperature stability QD are expected to revolutionize optical transmitters for optical communications with their robustness to environment such as extreme temperature insensitivity ,low power consumption ,and high temperature operation over $100\,^{o}C$ .Their high –performance was first predicted by Arakawa and Sakaki in 1982[1] through theoretical modeling of semiconductor lasers to clarify the quantum effect on their temperature characteristics .The three-dimensional confinement of electrons and holes in a QD semiconductor profoundly changes its density of states compared to a bulk semiconductor or thin –film quantum well. In practical ensembles of QDs ,the ideal delta –function density of states of a single dot is modified into a nearly Gaussian contour that is determined by the degree of inhomogeneity in the QD sizes and shapes [2].The temperature of the carrier plasma in an optical device may change for example with varying injection strength due to Joule heating or due to free carrier absorption (FCA) within the conduction and valence bands. Therefore it is crucial to study the temperature dependence of carrier-carrier scattering [3].In this work ,a detailed microscopic analysis of the turn on dynamics of InAs/InGaAs quantum dot lasers pumped by a nanosecond current pulse is presented .The results obtained are based on the models of Ludge et al [3].

## Basic model :

The nonlinear rate equations that describe the dynamics of the charge carrier densities in the QD ground state , $n_e$ and $n_h$, the carrier densities in the quantum well, $w_e$ and $w_h$ (e and h stands for electrons and holes respectively) ,and the photon density $n_{ph}$ of the ground state transition can be written as[3,4]:

$$\dot{n}_e = -\frac{1}{\tau_e} n_e + S_e^{in} N^{QD} - \Gamma R_{sim}(n_e, n_h, n_{ph}) - R_{sp}(n_e, n_h) \quad (1)$$

$$\dot{n}_h = -\frac{1}{\tau_h} n_h + S_h^{in} N^{QD} - \Gamma R_{sim}(n_e, n_h, n_{ph}) - R_{sp}(n_e, n_h) \quad (2)$$

$$\dot{w}_e = \eta \frac{j(t)}{e_0} + \frac{n_e}{\tau_e} \frac{N^{sum}}{N^{QD}} - S_e^{in} N^{sum} - \tilde{R}_{sp}(w_e, w_h) \quad (3)$$

$$\dot{w}_h = \eta \frac{j(t)}{e_0} + \frac{n_h}{\tau_h} \frac{N^{sum}}{N^{QD}} - S_h^{in} N^{sum} - \tilde{R}_{sp}(w_e, w_h) \quad (4)$$

$$\dot{n}_{ph} = -2\kappa n_{ph} + \Gamma R_{sim}(n_e, n_h, n_{ph}) + \beta R_{sp}(n_e, n_h) \quad (5)$$

Where

$\tau_e = (S_e^{in} + S_e^{out})^{-1}$: is the scattering time for electron .

$S_e^{in}$ :is the carrier –carrier scattering rate for electron (capture into the QD levels).

$S_h^{in}$ :is the carrier –carrier scattering rate for hole (capture into the QD levels).

$\tau_h = (S_h^{in} + S_h^{out})^{-1}$: is the scattering time for holes

$S_e^{out}$ : is the carrier –carrier scattering rate for electron ( escape from the QD levels).

$S_h^{out}$ : is the carrier –carrier scattering rate for hole ( escape from the QD levels).

$R_{sim}(n_e, n_h, n_{ph}) = WA(n_e + n_h - N^{QD})n_{ph}$ : is the linear gain.