Role of Non-Effective Intraband Relaxation Time on the Photon Assisted Polarization Amplitude in InGaAs/GaAs QD Laser

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Abstract. We study the effect of ineffective relaxation time at the levels of the quantum dot (QD) laser system (p-shell and s-shell) on the temporal behaviour of the system of interesting variables (photon-assisted polarisation, number of carriers in pumping and emission levels) of a QD laser system. We also study its effect on the ineffective relaxation time of the temporal behaviour of photon-assisted polarisation. We rely on the master equation system by solving it numerically with specifying experimental values for the control and system parameters of InGaAs/GaAs QD semiconductor laser output lasing with a continuous wave wavelength of 1.3 μm.

Keywords. Quantum dot laser, photon-assisted polarisation, temporal behaviour, ineffective relaxation time.

1. INTRODICTION

Compound semiconductors have unique properties, such as high electron mobility and effective small masses [1–3], due to narrow gaps. Thus, these materials are suitable for interesting device applications, such as mid-range cascading infrared lasers [4], engineering magnetic resistors [5, 6] and spintronic devices [7–11]. Materials with a narrow gap are not only suitable for hardware applications from a fundamental physics perspective but also have interesting unusual properties and exotic states and properties. These III–V semiconductors have recently been platforms for Majorcan fermion and topological edge states [12, 13]. In topologically protected quantum computation scheme applications, Majorcan fermions are proposed. For the development of optoelectronic devices, examining the carrier dynamics in femtosecond timescales is necessary. By using time spectroscopy, we can understand the relaxation dynamics of excited pho-carriers [3]. The unbalanced population of electrons and holes relax after optical excitation by several scattering mechanisms including the carrier phonon and carrier impurities. The carriers can be photo-excited within a narrow energy range using femtosecond pulses. With the progress of time, the carrier–carrier interaction produces a heat carrier distribution function [14, 15]. On a longer time scale, electron–phonon scattering results in quasi-equilibrium in the system. With quasi-Fermi holes and separate electron levels, the hot holes in this system at the top of the valence band feature thermal distribution functions. In slow electrical recombination, holes through the gap return the system to its initial thermal equilibrium state on a longer time scale. Successful reviews have been made on ultrafast photoexcitation of hot carriers in semiconductor heterostructures and their subsequent relaxation back to thermal equilibrium in pump–probe spectroscopy [16, 17].

As information of the time-magnitude of the different relaxation process, the semiconductor heterostructures examine the dynamics of photo-excited carriers in several based QWs (intraband and interband dynamics) [18], and important for the development of devices operating in terahertz (THz) and mid-infrared (MIR). Investigations have been conducted on the relaxation of photo-excited carriers through the use of multiple pump/probe time differential transport schemes. Given the discrete nature of their density of state, quantum dot (QD) lasers are a superb choice for future high-speed communication and are superior to quantum well (QW) lasers in temperature stability, threshold current, feedback insensitivity and chirp [19].

In semiconductor QDs, three-dimensional electronic confinement occurs in the emergence of a complete spectrum. That is let investing of typical effects of atomic physics in a solid-state environment. The data transfer rate and frequency should be further improved for industrial applications. Therefore, understanding the basic dynamics at the microscopic level is necessary [20]. The goal of this modelling is to study the non-effective intraband relaxation time on polarisation amplitude role through the master equations model (MEM). The behaviour of dynamic semiconductor microcavity QD is not clear or easily dissolvable. Physicists and mathematicians resort to