Structural nonlinear effects in In$_{0.53}$Ga$_{0.47}$As/GaAs heterostructure bipolar transistor lasers

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The effects of carrier capture on nonlinear gain of In$_{0.53}$Ga$_{0.47}$As/GaAs heterostructure bipolar transistor (HBT) lasers have been investigated. Calculations show that the gain of transistor laser (TL) for this structure depends on the parameters such as the initial electron energy, structure size, capture time and pump photon energy.

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1. Introduction

The transistor laser (TL) is a heterojunction bipolar transistor that employs a quantum well in its base region that causes emissions of light in a large wavelength range. The intensity of light output increases by using the quantum well in TL [1]. The TL which operates as a transistor and a laser at the same time provides both a high impedance output with current gain at the base-collector junction and laser emission from stimulated base electron-hole recombination. The TL has opened a novel way for higher speed applications in optical communication and interconnects, and optoelectronic integration. They can output ultrafast optical and electrical signals with high bandwidth and power. Wide bandgap semiconductor heterojunction bipolar transistors (HBTs) are suitable for applications in high frequency switching, communications and radar. The TL or heterojunction bipolar junction transistor laser (HBJTL) is made by embedding a quantum-well (QW) in the base of a heterojunction bipolar junction transistor (HBJT) that acts as an optical collector.

The laser output of the TL works when the quantum well in the base region captures electrons that would normally be sent out through the electrical output. These electrons then undergo a process of radiative recombination, during which electrons and positively charged holes recombine in the base [2]. The TL was initially constructed out of layers of InGaP, GaAs and InGaAs, which prevented the device from running without being cooled with liquid nitrogen. The TL allows for operation at room temperature and continuous wave operation [3]. The TL can produce laser output without any resonance peak in the frequency response.

Room-temperature lasing at 2.55 μm is reported for InP-based GaInAs/GaAsSb type-II quantum well lasers in pulsed mode up to 42 °C [4]. Applying highly strained In(Ga)As quantum well (QW) active regions, wavelengths up to 2.33 μm have been reported [5,6]. The GaN/AlGaN system is particularly attractive because of its outstanding transport properties and the experience base that has developed as a result of the success of light-emitting diodes, diode lasers [7–9], Carrier dynamics in the TL is different from either conventional HBJTs or laser diodes and due to its unique carrier dynamics; the transistor laser has the potential of high-speed direct modulation [10]. In [11] authors used a model to explain the large increase in the high-speed performance of the TL operating on the first excited state compared to ground state. Experiments indicate that the carrier transport effects as a dominant factor limits the modulation response of semiconductor lasers. In this work the effect of carrier dynamics as a nonlinear structural effect on gain and modulation bandwidth has been investigated [12]. In this paper we study a theoretical model in effects of the nonlinear gain in In$_{0.53}$Ga$_{0.47}$As/GaAs heterostructure bipolar quantum well TL in...