1.3 μm In(Ga)As/GaAs Quantum-dot lasers and their dynamic properties

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ABSTRACT

In(Ga)As/GaAs quantum-dot lasers with emission wavelength at 1295 nm at room temperature are fabricated. The highest relaxation oscillation frequency measured at room temperature is 1.8 GHz, corresponding to a modulation bandwidth of 2.8 GHz.

INTRODUCTION

Since proposed in 1982 [1], quantum-dot (QD) lasers have attracted much attention due to their superior properties compared with quantum-well lasers [2]. Recently, there was much interest in 1.3 μm In(Ga)As/GaAs quantum-dot lasers [3-5], because they show very low threshold current density and they serve as a candidate for light sources in fiber communication systems. Concerning the dynamic properties of QD lasers, there were several studies in the literature [6-9]. But only very few of them are for QD lasers in 1.3 μm wavelength range [9]. In this work, In(Ga)As/GaAs quantum-dot lasers with emission wavelength at 1295 nm are fabricated and their dynamic properties will be investigated through the measurement of relaxation oscillations (RO).

EXPERIMENTAL RESULTS AND DISCUSSION

The sample designed for 1.3 μm QD lasers is grown using gas-source molecular beam epitaxy (GSMBE) on Si-doped n⁺ (100) GaAs substrate. In the center of the waveguide, there are three stacks of QD layers. For each QD layer, 2.3 monolayer (ML) InAs was firstly deposited and followed by a 9.0 ML In_{0.33}Ga_{0.67}As capping layer. These three stacks of QD layers are then embedded in a 200-nm-thick waveguide layer with In_{0.49}Ga_{0.51}P serving as upper and lower cladding. A heavily p⁺-doped ($1.5 \times 10^{19} \text{ cm}^{-3}$) 200-nm-thick GaAs layer is grown as contact layer. After the epitaxial growth, the wafers were processed into 8- μm -wide ridge waveguide lasers with different cavity lengths by using standard photolithography, wet etching, and metallization techniques. The fabricated lasers were tested under pulsed mode with a pulse width 500 ns and a repetition rate of 5 kHz to measure the static properties. In Fig. 1, ground-state lasing at 1295 nm at room temperature with nominal threshold current density of 152.5 A/cm^2 is demonstrated from a laser structure of 3.5 mm long and 8 μm wide. With this low threshold current ($I_{th} = 42.7 \text{ mA}$), it is possible to investigate the relaxation oscillations.

For the dynamic measurement, we use an ultra-high speed pulse generator, a photo detector, a pre-amplifier, and a 50GHz oscilloscope to observe the relaxation oscillations. Fig. 2 shows a linear dependence of RO frequencies on the square root of normalized current, as predicted theoretically [10]. The highest relaxation oscillation frequency measured is 1.8 GHz, corresponding to a modulation bandwidth of 2.8 GHz.

To summarize, In(Ga)As/GaAs quantum-dot lasers with emission wavelength at 1295 nm at room temperature are fabricated. The highest relaxation oscillation frequency measured at room temperature is 1.8 GHz, corresponding to a modulation bandwidth of 2.8 GHz. For 1.3 μm QD lasers, this is one of the best values in the literature. Thus, the application potential of long-wavelength QD lasers for fiber communication is demonstrated.

Fig. 1. L-I curve of a QD laser with emission wavelength at 1295 nm..

Fig. 2. Relaxation oscillation frequencies v.s. square root of normalized current. The highest RO frequency is about 1.8 GHz.

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