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Anticompetition of Laser modes in Quantum Dot Lasers

Yi-Shin Su and Ching-Fuh Lin*
Graduate Institute of Electro-Optical Engineering
** also with Department of Electrical Engineering and Graduate Institute of Electronics Engineering*
National Taiwan University
Taipei 106, Taiwan ROC
Email: cflin@cc.ee.ntu.edu.tw

Abstract: Laser-mode anticompetition is observed in a quantum-dot laser. The laser is operated at 1168.5nm and 1262.3nm wavelength simultaneously using a grating-controlled external cavity. Increasing the power of 1168.5nm, the power of 1262.3nm also increases.

OCIS Codes: (140.3600) Lasers, tunable; (140. 5960) Semiconductor lasers

1. Introduction

The gain bandwidth of semiconductor lasers can be increased to over 200nm by several ways like combining first and second quantized states of a single QW [1,2], combining quantum wells of different composition and width[3] as well as utilizing the first and second quantized states of quantum dots [4]. The gain competition between different lasing modes is considered as an inevitable phenomenon for almost all kinds of lasers. However, experiments show that anticompetition behaviours can be observed in devices, which combine quantum dot of different sizes or quantum wells of different composition and width [5].

2. Experiment

The devices have InAs QDs as the active layer and is grown on GaAs substrate. The fabricated device has double channel ridge waveguide, PECVD SiO_2 passivation layer, Ti/Pt/Au p-metal contact and AuGe/Ni/Au n-metal contact. Figure 1 shows the emission spectra of the QD semiconductor optical amplifier (SOA) with a tilted waveguide. The peak emission intensity of first quantized states is at 1.25 μm. The peak emission intensity of second quantized states is at 1.17 μm. Due to inhomogeneous broadening caused by dot size distribution, the EL emission spectrum covers more than 200nm wavelength.

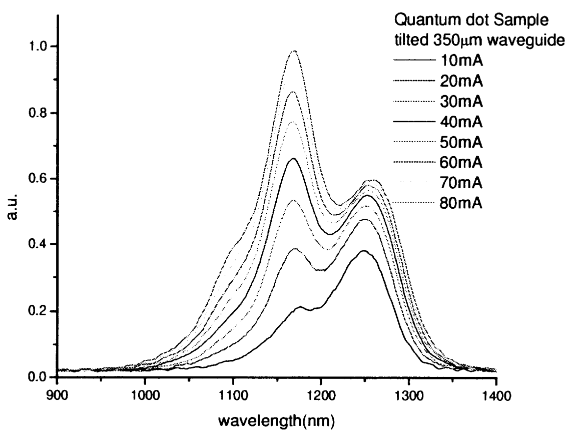

Fig. 1 The EL spectrum of a QD device with tilted waveguide.

CThH5

The anticompetition behavior is observed in an external cavity laser controlled by the grating, shown in Figure 2, to oscillate at two different wavelengths. The operating wavelength is tuned to 1262.3nm for first quantized states, and 1168.5 for second quantized states. This external-cavity laser uses a Fabry-Perot laser diode (LD) fabirctaed on the QD substrate with a length of 613 μm. A single layer SiO_2 is coated at one facet for anti-reflection (AR) to prevent the device from oscillating at the first quantized state. In Figure 2, gray line is the optical path of 1262.3nm light, while black line is the optical path of 1168.5nm light. Lights of the two wavelengths are separated by grating 1 and reflected back to the device by two mirrors. The feedback efficiency of 1262.3nm light is fixed at optimum. Tilting the mirror in vertical direction varies the feedback efficiency of 1168.5nm light, and the optical power of 1168.5nm light is varied. Output power of the two wavelengths are separated by grating 2 and collected by two InGaAs photodiodes simultaneously. The light – output power curve is recorded with different feedback amount of the 1168.5nm light.

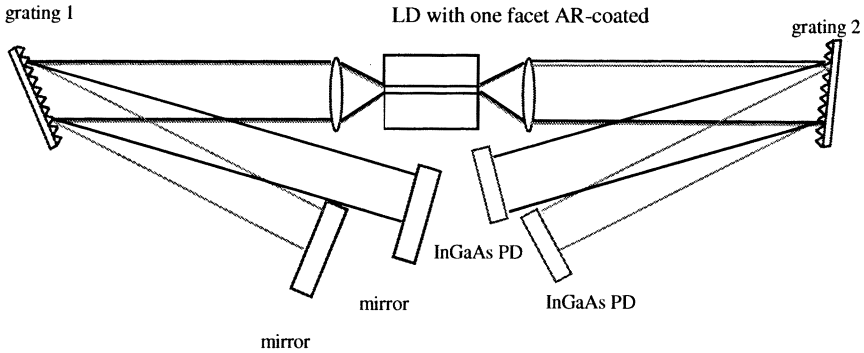

Fig. 2 Two wavelength external-cavity configuration and setup for monitoring the power of both wavelengths..

Figure 3 shows the recorded 1262.3nm wavelength power vs. the 1168.5nm wavelength power. With 65mA injection current, the output power of 1168.5nm wavelength increases by 1.7mW, when feedback amount of 1168.5nm wavelength is increased. The output power of 1262.3nm wavelength also increases by 0.3mW. At this current level, anticompetition behavior is observed for a large range of 1168.5nm wavelength power.

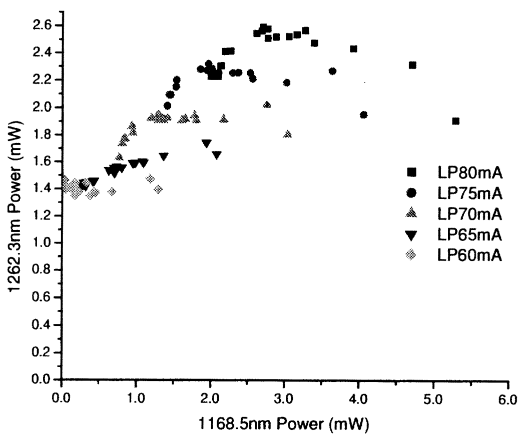

Fig. 3 1262.3nm wavelength power vs. 1168.5nm wavelength power

When the injected current is increased to 70mA, the increase of 1262.3nm wavelength power with 1168.5nm wavelength power is faster. However, anticompetition behavior is not observed when 1168.5nm wavelength power exceeds 1mW. Comparing the data points of 70mA, 75mA and 80mA, we can observe the following two trends. First, anticompetition occurs at higher 1168.5nm wavelength power for increased current. Second, competition behavior, which occurs at high 1168.5nm wavelength power, is increasingly severe with increased current. The data points with 65mA and 60mA injection currents show that anticompetition strength increases with the increased injection current and no competition behavior is observed.

3. Results and discussions

In conclusion, anticompetition effect is observed in a quantum-dot laser. The laser is operated at 1168.5nm and 1262.3nm wavelength simultaneously. Increasing external feedback increases the power of 1168.5nm wavelength. The power of 1262.3nm will also increase. The phenomenon of anticompetition occurs when the quantum dots which contribute to 1262.3nm light is able to absorb the 1168.5nm light. Because the carrier density of quantum dots which contribute to 1262.3nm light is suppressed by laser oscillation, it's second quantized state does not have population inversion. Thus, these quantum dots are absorber for 1168.5nm light. The gain of 1168.5nm oscillation is contributed by quantum dots, which do not contribute to 1262.3nm oscillation. Thus, the laser oscillation at 1168.5nm helps carriers transfer from quantum dots that do not contribute to 1262.3nm oscillation to quantum dots that contribute to 1262.3nm oscillation. The detail will be discussed in the presentation.

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