Enhancement of Resonance Frequency in a DFB-LD with Internally Incident Modulated Light

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Abstract-**A DFB-LD with internally incident modulated light is proposed and simulated. The resonance frequency is enhanced to 43.68 GHz when the injected current is 3.5 times the threshold current.**

I. INTRODUCTION

High resonance frequencies in semiconductor lasers are very important to achieve high speed direct modulations of semiconductor lasers.

To date, to achieve high speed direct modulations of semiconductor lasers, push-pull modulations of semiconductor lasers have been studied [1]-[4]. In push-pull modulations, semiconductor lasers are divided into two regions along cavity axes and the anodes for the two regions are electrically separated to modulate the two regions with anti-phase. Enhancement of modulation bandwidth has been successfully reported, but the modulation scheme has been relatively complicated [1]-[4] or $\kappa L=6$ with second-order grating has been required [4] where κ is a grating coupling coefficient and L is cavity length. Recently bandwidth enhanced operation of a single mode semiconductor laser has been reported by injecting intensity modulated signal light externally [5]. If intensity modulated signal light is generated in the laser cavity, modulation schemes of DFB-LDs are expected to become simple.

In this paper, to obtain a high resonance frequency and stable SLM operation simultaneously, a DFB-LD with internally incident modulated light is proposed and simulated. In the proposed DFB-LD, the resonance frequency of 43.68 GHz is obtained when the injected current is 3.5 times the threshold current.

II. LASER STRUCTURE AND SIMULATIONS

Figure 1 shows an analytical model of the DFB-LD with internally incident modulated light where an optical cavity is divided into two regions along the cavity axis. Region 1 has phase-shifted gratings with the grating coupling coefficient κ_1=40 cm^{-1}, the region length L_1 =300 μm, the corrugation pitch Λ_1=238.45 nm, and the phase-shift $\Delta\Omega_1= -\pi$ at the center of Region 1. Region 2 has phase-shifted gratings with the grating coupling coefficient κ_2=40 cm^{-1}, the region length L_2 =300 μm, the corrugation pitch $\Lambda_2=\Lambda_1-\Delta\Lambda$, and the phase-shift $\Delta\Omega_2 =-\pi$ at the center of Region 1. Both facets are anti-reflection coated and the power reflectivities R_1 and R_2 are assumed to be zero. Undoped active layers consist of five 7.5 nm-thick $In_{0.557}Ga_{0.443}As_{0.982}P_{0.018}$ strained quantum wells, which are sandwiched by 23 nm-thick $In_{0.738}Ga_{0.262}As_{0.568}P_{0.432}$ barriers. The substrate is n-InP with impurity concentration of 10^{18}cm^{-3}. The upper cladding layer is p-InP with impurity concentration of 5×10^{17}cm^{-3}. The waveguide is 1.5 μm wide.

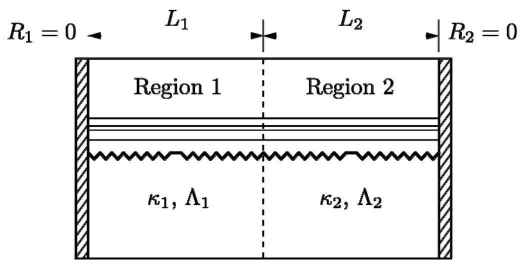

Fig. 1 Analytical model of a DFB-LD with internally incident modulated light. Both facets are anti-reflection coated.

In Region 1, a main-mode oscillates at Bragg wavelength of $2n_{\mathrm{eff}}\Lambda_1$ where n_{eff} is the effective refractive index of the cavity. In Region 2, a sub-mode oscillates at Bragg wavelength of $2n_{\mathrm{eff}}\Lambda_2$ and this sub-mode is used as the internally incident modulated light. Region 1 and Region 2 have a common anode; Region 1 and Region 2 have a common cathode. As a result, the main-mode and the sub-mode are modulated in phase, contrary to the push-pull modulation. Therefore, it is expected that modulation scheme for the DFB-LD with internally incident modulated light is simpler than that for the push-pull modulation of DFB-LDs.

Lasing characteristics are simulated by a commercial simulator, PICS3D (Crosslight), which solves Poisson's equation and two-dimensional Helmholtz equation self consistently with a finite element method.

III. SIMULATED RESULTS AND DISCUSSIONS

Figure 2 shows the resonance frequency f_r as a function of the grating pitch difference $\Delta\Lambda$ for the injected current I=20 mA. It is found that the resonance frequency f_r has a peak at $\Delta\Lambda$=1.6 nm where the resonance frequency f_r is 23.2 GHz, which is 3.04 times of f_r =7.64 GHz at $\Delta\Lambda$=0 nm.

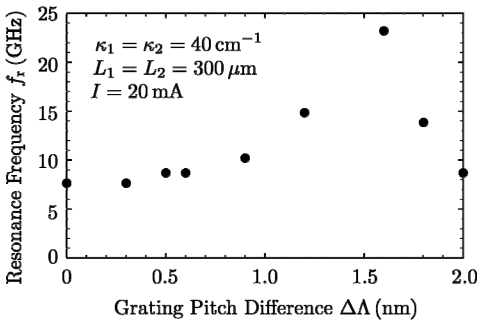

Fig. 2 Resonance frequency f_r as a function of the grating pitch difference $\Delta\Lambda$.

Figure 3 shows the resonance frequency f_r as a function of the relative bias current $I/I_{th}-1$ at $\Delta\Lambda$=1.6 nm where I_{th} is the threshold current. With an increase in $I/I_{th}-1$, the resonance frequency f_r increases and the resonance frequency f_r is 43.68 GHz when $I/I_{th}-1$=2.5 where the injected current I is 3.5 times the threshold current I_{th}.

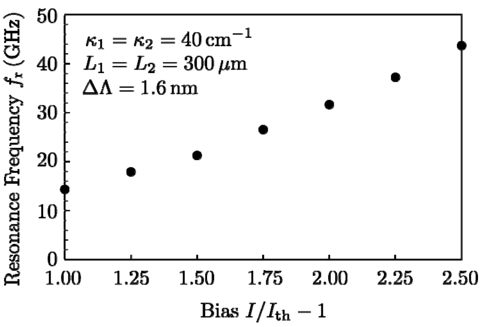

Fig.3 Resonance frequency f_r as a function of the relative bias current $I/I_{th}-1$.

Figure 4 shows frequency response when $\Delta\Lambda$=1.6 nm and $I/I_{th}-1$=2.5. The resonance peak is clearly observed at the modulation frequency of 43.68 GHz.

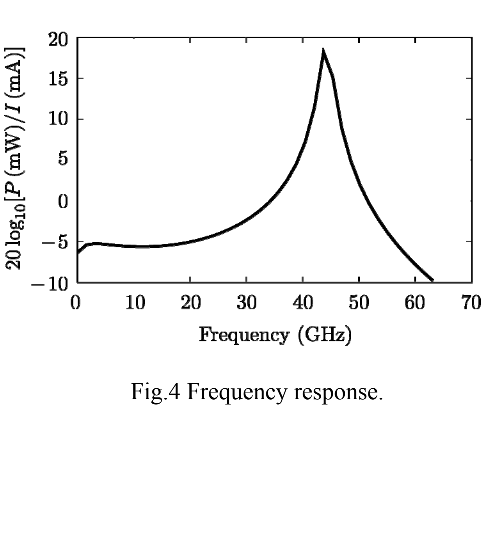

Fig.4 Frequency response.

Figure 5 shows oscillation spectrum when $\Delta\Lambda$=1.6 nm and $I/I_{th}-1$=2.5. The main-mode oscillates at 1.524418 μm which is Bragg wavelength in Region 1. The sub-mode generated in Region 2 is observed at the shorter wavelength side of the main-mode. It should be noted that this side-mode contributes to enhancement of the resonance frequency.

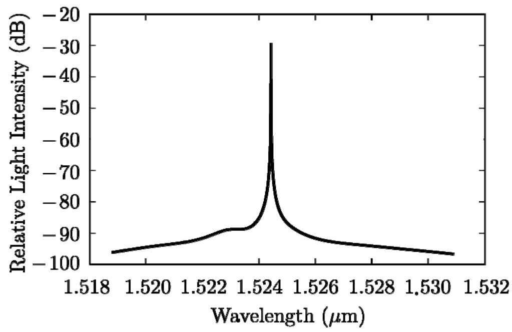

Fig.5 Oscillation spectrum.

IV. CONCLUSIONS

To enhance the resonance frequency of semiconductor lasers, a DFB-LD with internally incident modulated light was proposed and simulated. When the grating pitch difference $\Delta\Lambda$ between Region 1 and Region 2 is 1.6nm and the injected current I is 20 mA, the resonance frequency f_r was 23.2 GHz, which is 3.04 times of f_r =7.64 GHz at $\Delta\Lambda$=0 nm. When $\Delta\Lambda$=1.6 nm and $I/I_{th}-1$=2.5, the resonance peak was enhanced to 43.68 GHz. These resonance frequencies were obtained at the grating coupling coefficient $\kappa_1 = \kappa_2$=40 cm^{-1} and the region length L_1 = L_2 =300 μm, which are modest values for fabrication processes.

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