High Resonance Frequency in a Coupled Cavity DFB-LD with Phase-Shifted/Uniform Gratings by Photon-Photon Resonance

Takahiro Numai, *Senior Member, IEEE*

Department of Electrical and Electronic Engineering, Ritsumeikan University
1-1-1 Noji-Higashi, Kusatsu, Shiga 52-8577, Japan
Phone: +81-77-561-5161 E-mail: numai@se.ritsumei.ac.jp

Abstract- **Enhancement of resonance frequency in a coupled cavity DFB-LD with phase-shifted /uniform gratings by photon-photon resonance is reported. The resonance frequency is 40.45 GHz and the 3-dB down band width is 57.4 GHz when the injected current is 3 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 [1]-[4], injecting intensity modulated signal light externally [5], photon-photon resonance [6], [7] have been studied.

In this paper, to obtain a high resonance frequency and stable SLM operation simultaneously, a coupled cavity DFB-LD with phase-shifted/uniform gratings by photon-photon resonance is numerically studied. When the injected current is 3 times the threshold current, the resonance frequency is 40.45 GHz, which is much higher than 31.64 GHz [7]. The 3-dB down band width is 57.4 GHz.

II. LASER STRUCTURE AND SIMULATIONS

Figure 1 shows an analytical model of the coupled cavity DFB-LD with phase-shifted/uniform gratings 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=2038.45 nm, and the phase-shift $\Delta\Omega_1 = -\pi$ at the center of Region 1. Region 2 has uniform gratings with the grating coupling coefficient κ_2=40 cm^{-1}, the region length L_2 =310 μm, the corrugation pitch $\Lambda_2=\Lambda_1-\Delta\Lambda$. 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.

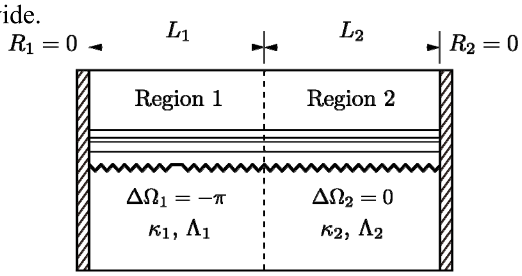

Fig. 1 Analytical model of a coupled cavity DFB-LD with phase-shifted /uniform gratings. Both facets are anti-reflection coated.

Region 1 and Region 2 form a coupled cavity. When the corrugation pitch difference $\Delta\Lambda$ is large enough, a main-mode oscillates at Bragg wavelength in Region 1, and sub-modes are other resonance modes of the coupled cavity. Bragg wavelength in Region 1 is $2n_{\mathrm{eff}}\Lambda_1$ where n_{eff} is the effective refractive index of the cavity. Region 1 and Region 2 have a common anode; Region 1 and Region 2 have a common cathode. As a result, Region 1 and Region 2 are modulated in phase, in contrast to the push-pull modulations [1]-[4] where two regions are modulated with anti-phase. Therefore, it is expected that modulation scheme for the coupled cavity DFB-LD with phase-shifted/uniform gratings 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

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injected current I =20 mA. It is found that the resonance frequency f_r has a peak at ΔΛ=1.7 nm where the resonance frequency f_r is 38.83 GHz, which is 5.08 times of f_r =7.64 GHz at ΔΛ=0 nm.

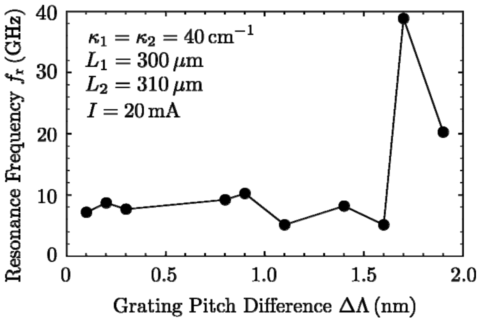

Fig. 2 Resonance frequency f_r as a function of the grating pitch difference ΔΛ.

Figure 3 shows the resonance frequency f_r as a function of the relative bias current I/I_{th}−1 at ΔΛ=1.7 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 40.45 GHz when I/I_{th}−1=2.0 where the injected current I is 3 times the threshold current I_{th}.

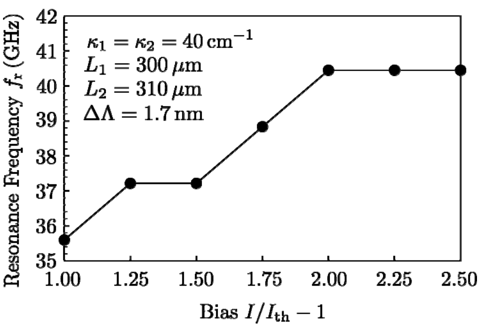

Fig.3 Resonance frequency f_r as a function of the relative bias current I/I_{th}−1.

Figure 4 shows frequency response when ΔΛ=1.7 nm and I/I_{th}−1=2.0. The resonance peak is clearly observed at the modulation frequency of 40.45 GHz. The 3-dB down band width is 57.4 GHz.

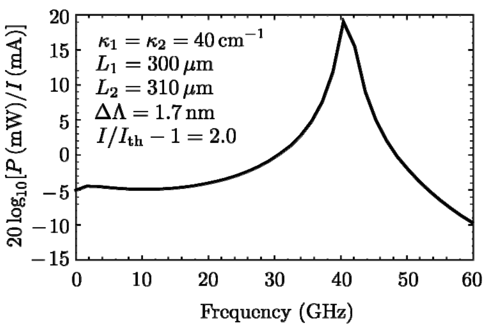

Fig.4 Frequency response.

Figure 5 shows oscillation spectrum when ΔΛ=1.7 nm and I/I_{th}−1=2.0. The main-mode oscillates at 1.52446 μm which is Bragg wavelength in Region 1. The sub-modes generated by the coupled cavity, which are composed by Region 1 and Region 2, are not clearly observed, but several slight peaks exist in the side lobes of the main-mode. The resonance frequency was enhanced due to photon-photon resonance among the main-mode and sub-modes.

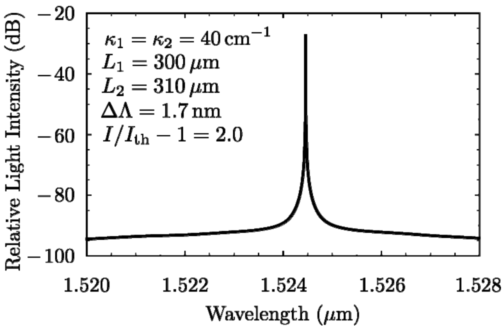

Fig.5 Oscillation spectrum.

IV. CONCLUSIONS

To enhance the resonance frequency of semiconductor lasers, the coupled cavity DFB-LD with phase-shifted/uniform gratings was simulated. When the grating pitch difference ΔΛ between Region 1 and Region 2 was 1.7 nm and the injected current I was 20 mA, the resonance frequency f_r was 38.83 GHz, which is 5.08 times of f_r =7.64 GHz at ΔΛ=0 nm. When ΔΛ=1.7 nm and I/I_{th}−1=2.0, the resonance frequency and the 3-dB down bandwidth were enhanced to 40.45 GHz and 57.4 GHz, respectively. These resonance frequencies were obtained at the grating coupling coefficient κ_1= κ_2=40 cm^{-1} and the region length L_1 =300 μm and L_2 =310 μm, which are modest values for fabrication processes.

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