Numerical Modelling of Injection-Locked Fabry-Perot Laser Diode for WDM-PON System

Suhyun Kim[1], Ho Lee[2], Gun Woo Kim[2], Seung Hyun Lee[2], and Youngchul Chung[2]

[1]Korea Institute of Science and Technology
39-1 Hawolgok, Seongbuk, Seoul, Korea

[2]Department of Electronics and Communications Engineering, Kwangwoon University
447-1 Wolgye-Dong Nowon-Ku, Seoul, 139-701, KOREA, ychung@kw.ac.kr

***Abstract*—Wavelength-locked Fabry-Perot laser diodes are good candidates for low-cost WDM-PON sources, and some trial systems are commercially deployed. Nevertheless, a detailed modelling of the injection-locking process has not been presented. In this paper, the influence of reflectivity at facet on lasing characteristics of Fabry-Perot laser diodes, into which spectrum-sliced broadband light is injected, are analyzed using a time-domain modelling.**

I. Introduction

In order to provide video services such as internet protocol television (IPTV), high-speed subscriber networks faster than 100 Mbps become essential [1], and wavelength division multiplexing passive optical networks (WDM-PONs) are expected as a ultimate solution [2].

For economical deployment of WDM-PON, it must be accomplished that the cost of optical components such as arrayed waveguide gratings and optical sources should be lowered further. In order to realize low-cost sources for WDM-PON, researches on a colorless optical source which selects one of Fabry-Perot LD (FP-LD) modes close to the injection wavelength of filtered amplified spontaneous emission(ASE) source have been done. Subsequently, 155Mbps WDM-PON systems with colourless optical sources have been commercialized recently.

But, even though the possibility of color less source in the system has been presented in experiments, a research about detailed numerical analysis for lasing characteristics of these type of colorless source is insufficient yet. In this paper, we investigate the injection-locked lasing characteristics of these lasers using time-domain modelling.

II. Numerical Analysis

For analysis of this characteristic, the modellings of wavelength sliced ASE optical source and Fabry-Perot laser diode are needed. The ASE optical source in the system is assumed to be conventional broadband sources such as semiconductor optical amplifier (SOA) or erbium doped fiber amplifier (EDFA) and it is modelled by introducing random phases with 200 femto-second coherence time. In order to numerically model wavelength-sliced ASE optical source through the AWG at remote node the time-domain signal of the broadband source is converted to wavelength-domain by the Fourier transform and then it is filtered with Gaussian filter. Fig. 1 shows the calculated optical spectra of the broadband ASE source and filtered output. The 3-dB bandwidth and crosstalk of the Gaussian filter are 50 GHz and 30 dB, respectively. The filtered signal is converted to time-domain signal by inverse Fourier transform and injected into one of the facets of the FP-LD.

For the analysis of the injection-locked Fabry-Perot laser diode, we used a time-domain large signal model, which is proven to be an effective model for the simulation of various laser diode structures [4]. The conditions of simulation are as follows. We assumed that the power of ASE optical source is 10 mW and the injection power into the FP-LD laser diode is attenuated as 1/30 by link losses such as insertion loss in circulator, connector loss and various losses in the system. The bandwidth of the filter for spectrum splicing is 0.4 nm. Injection current into FP-LD is 1.2 I_{th}, where I_{th} is the lasing threshold current. Laser diode parameters are listed in Table 1. Fig. 2 shows simulation results for injection-locked FP-LDs. The injected optical waves force the FP-LD to oscillate at a quasi-single mode. The side-mode suppression ratio is about 25 dB. The lasing wavelength of injection-locked FP-LD is shifted toward longer wavelength side, even if the center wavelength of the narrow-band ASE source corresponds to a specific mode of free-running FP-LD. The shift of the lasing wavelength is originated from plasma effect due to the external injection, where the increase of the carrier density decreases the refractive index of the active region. This effect is also observed in the experiment [5].

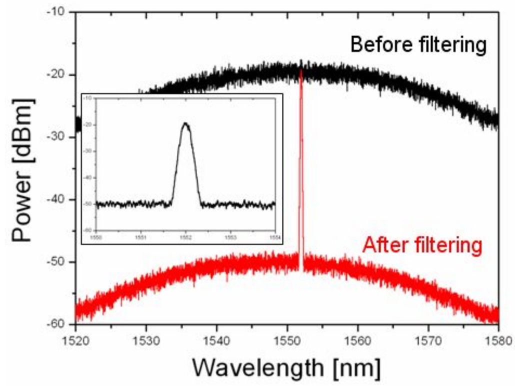

Fig. 1. Filtered ASE optical source.

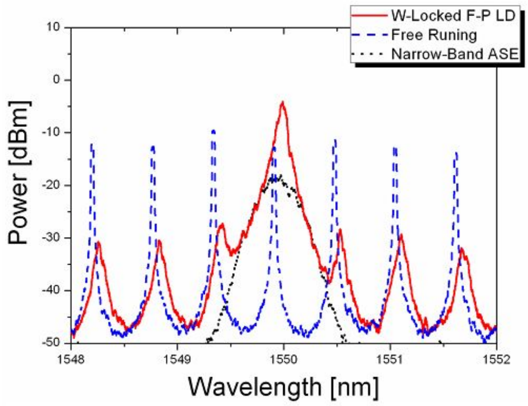

Fig. 2. Spectrum of injection-locked FP-LDs.

TABLE I
PARAMETERS USED IN THE MODEL

Spontaneous recombination coeff.	B	$1.0 \times 10^{-10}cm^3s^{-1}$
Auger recombination coeff.	C	$4.0 \times 10^{-28}cm^6s^{-1}$
Transparency carrier density	N_0	$1.0 \times 10^{18}cm^{-3}$
Waveguide loss	α	$30cm^{-1}$
Confinement factor	Γ	0.3
Nonlinear gain suppression coeff.	ε	$1.0 \times 10^{-17}cm^3$
Group index	n_g	3.5
Linewidth enhancement factor	α_m	3
Differential gain	g_N	$4.5 \times 10^{16}cm^2$
Spontaneous coupling factor	β	$5.0 \times 10^{-4}cm^{-1}$
Laser length	L	600μm
Strip width	w	1.5μm
Reflectivities at facets	r	input facet : 1 % rest facet : 30%

Fig. 3 shows the calculated lasing spectra of injection-locked FP-LDs with asymmetric reflectivity at the facets the reflectivities of which are 0.1% and 30%, respectively, when 32 channel narrow band ASEs with 100 GHz span are injected into the FP-LD. The power at each wavelength is shown to be fluctuating. The power fluctuations come from difference between input wavelength span and mode spacing of the FP-LD. The side mode suppression ratios in this case are shown in Fig. 4.

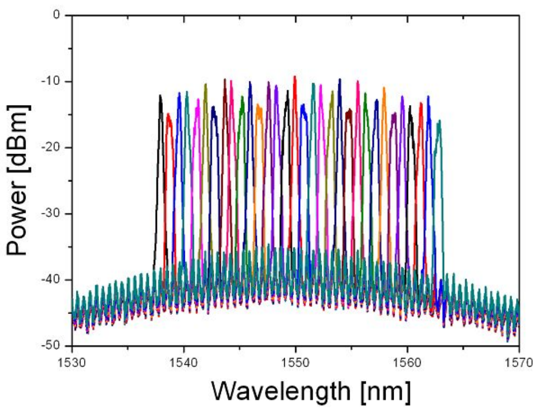

Fig. 3. Calculated lasing spectra of injection-locked FP-LD with 0.1% reflectivity at the input facet.

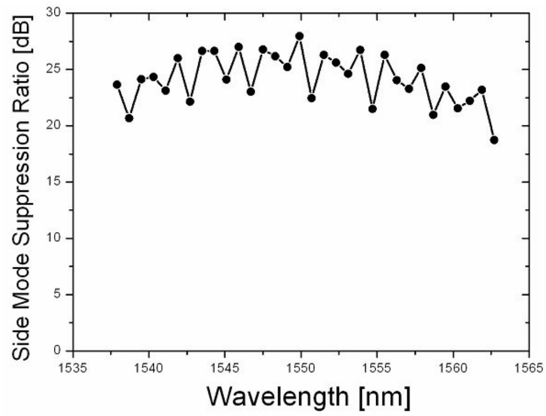

Fig. 4. Calculated side-mode suppression ratio.

III. CONCLUSIONS

In this paper, we analyze the lasing characteristics of injection-locked FP-LD with asymmetric facet reflectivity by a large-signal time domain model, which is known to be useful in analyzing single or multi-mode laser diodes such as DFB-LD, DBR-LD, FP-LD, etc. It is shown that the modeling results are similar to the experimental results. The simulation results also show that the reflectivity at the input facet affects the lasing characteristics of the injection-locked FD-LD. We expect that the model can be used for the detailed analysis and advanced design of the injection-locked FP-LDs

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