# 반도체 광증폭기의 광변조응답을 이용한 Carrier Lifetime 과 α-Factor 측정

# A Novel Technique of Measuring SOA Differential Carrier Lifetime and α-Factor using SOA Optical Modulation Response

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Abstract

We demonstrate a new technique of measuring differential carrier lifetime and linewidth enhancement factor of a semiconductor optical amplifier. In our measurement, the optical responses and fiber transfer functions of a self-gain modulated SOA are used. From these, values of differential carrier lifetimes and linewidth enhancement factors for various SOA input optical powers are determined.

## 1 Introduction

Semiconductor optical amplifiers are widely used in many optical signal processing applications such as wavelength conversion and optical switching. In order to model nonlinear characteristics of SOA for these applications, it is essential to have accurate parameters like differential carrier lifetimes and linewidth enhancement factors. In the previous studies, these parameters have been determined from the self heterodyned beat spectrum caused by the bias current modulation [1-2] or the frequency response of a cross gain modulated probe beam [3]. However, electrical parasitics are involved for the method given in [1-2] and two optical sources are needed for [3].

In this paper, we propose a simple method which uses the frequency response of optically modulated input signals for determining differential carrier lifetimes. In addition, we derive the fiber transfer function from a small signal analysis of SOA and from this the linewidth enhancement factors are determined.

## 2 Experiment and Results

By injection MZ-modulated signals into the SOA and measuring the frequency response of SOA-amplified signals, the SOA optical frequency response is measured. By subtracting the frequency response without SOA, the response can be normalized and with this, any extrinsic effects do not have to be considered. The measured frequency response data are shown in Fig. 2 for several input powers. At the low frequency, the modulation index is compressed because the carrier density and gains change as the input signal changes. However, as the modulation frequency increase, this self gain modulation is limited by carrier lifetime and the modulation index reaches a stable value. The data in Fig. 1 are fitted to Eq. (1), the analytical SOA optical frequency response, derived from the small signal analysis of the SOA rate equations.

$$T(\omega)=\left(1-\frac{1}{P_{sat}/G_{cw}P_0(1-i\omega\tau_s)+1}\right) \quad (1)$$

Since the equation involves $\tau_s$, differential carrier lifetime, by fitting the data to the equation, the numerical values of $\tau_s$ can be determined. In our investigation, the fitting is done with the least mean square method for two parameters, $P_{sat}/G_{cw}P_0$ and $\tau_s$ , where $G_{cw}$ is static gain, $P_0$ is input optical power and $P_{sat}$ is saturation power. The resulting parameter values are shown in Table 1. The measured differential carrier lifetime is increased because the carrier density is depleted with the increasing input optical power.

We also measured fiber transfer functions, by subtracting the frequency response after a fiber transmission (63.2km) to that before the transmission. The fiber transfer function is the frequency response of a fiber when the intensity and phase modulated signal goes through the fiber chromatic dispersion. The wavelength of tunable laser is set to 1550nm and the chirp of a single electrode Mach-Zehnder modulator is negligible. Fig. 2 is the measured results and fitted results with Eq. (2) which is derived from the small signal analysis following the procedure in [4].

$$H(\omega) = \cos(\theta) - \frac{\alpha}{P_{sat} / G_{cw} P_0 (1 - i\omega\tau_s)} \sin(\theta) \quad (2)$$

In the above equation, θ is given as $\theta = \omega^2 \pi \lambda^2 DL / 4\pi c$ . For the values of $P_{sat}/G_{cw}P_0$ and $\tau_s$, measured values are used. The fitted linewidth enhancement factors are listed in Table. 1. The value of the linewidth enhancement factor increases as the input optical power to SOA increases. This is due to the compression of the differential gain.

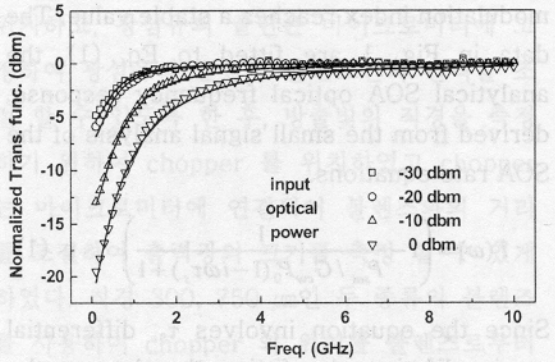


Fig. 1. Optical modulation Response

## 3 Conclusion

We demonstrated a new method measuring differential carrier lifetime and linewidth enhancement factor of a semiconductor optical amplifier. We used the optical modulation response and the fiber transfer function for the measurement. This simple measurement method will be useful in modeling semiconductor optical amplifiers.

[1] N. Storkfelt, *et al.*, *IEEE Photon. Technol. Letter*, Vol. 3, No. 7, pp. 632-634, 1991

[2] H. Dupont, *et al.*, *IEEE Photon. Technol. Letter*, Vol. 6, No. 8, pp. 942-944, 1994

[3] K. Kikuchi, *et al.*, *IEEE Internat. Semiconductor Laser Conf.*, Davos, Switzerland, pp. 130-131, 1990

[4] J. Wang, *et al.*, *Journ. of Lightwave Technol.*, Vol. 10, No. 1, pp. 96- 100, 1992

| Input power | $G_{cw}P_0/P_{sat}$ | $\tau_s$ (ps) | α |
|---|---|---|---|
| -30dbm | 0.89 | 422 | 1.34 |
| -20dbm | 1.26 | 476 | 2.74 |
| -10dbm | 3.80 | 531 | 4.10 |
| 0dbm | 10.68 | 725 | 4.30 |

Table 1. Measured differential carrier lifetime and linewidth enhancement factor

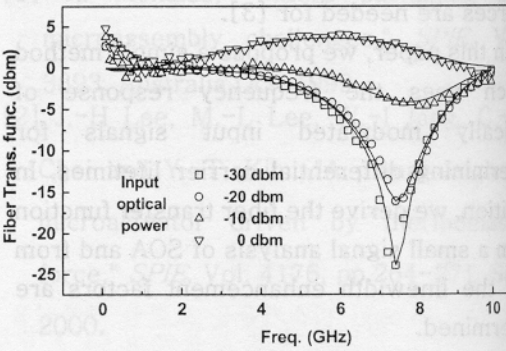


Fig. 2. Fiber transfer function