Measurement of SOA Differential Carrier Lifetimes and α-Factors using SOA Optical Modulation Responses

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Abstract - We demonstrate a new technique of measuring differential carrier lifetimes and linewidth enhancement factors in semiconductor optical amplifiers (SOAs) using the modulation responses of a self-gain modulated SOA with and without fiber transmission for various SOA input optical powers.

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 SOA characteristics for these applications, it is essential to have accurate information on SOA differential carrier lifetimes and linewidth enhancement factors. In previous studies, SOA carrier lifetimes have been determined from the SOA frequency response to the bias current modulation or to two optical input signals closely spaced in wavelength [1], or SOA frequency response to a cross gain modulated probe beam [2]. However, electrical parasitics are involved for the first method and two optical sources are needed for the second and third methods. For measurement of linewidth enhancement factor, α, relative sideband strength of optical spectrum of AM and FM modulated signals is observed by self-heterodyned technique [1, 2] or by high resolution optical spectrum analyzer [3].

In this paper, we demonstrate a simple method of SOA carrier lifetime and linewidth enhancement factor measurement by measuring SOA frequency responses to optically modulated input signals with and without fiber transmission.

2 Experiment and Results

Fig. 1 shows the experimental setup used for our investigation. First, varying the modulation frequency of the input intensity modulated optical signal, we measured the frequency response of SOA-amplified signals. Then, subtracting the frequency response without SOA, extrinsic effects of the modulator and the photo-detector are cancelled and the SOA frequency response to the optical input signal can be obtained. The measured frequency response data normalized to static gain, G_{cw}, are shown in Fig. 2 for several input powers. When the modulation frequency, ω, is small, the SOA carrier density changes in the opposite manner to the change in SOA input signal intensity, and consequently, small signal SOA gain is suppressed compared to the static gain. However, when ω becomes large, the small signal SOA gain approaches G_{cw}.

The data in Fig. 1 are fitted to Eq. (1), the analytical SOA frequency response to the optical input signal, derived from the small signal analysis of the SOA rate equations.

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

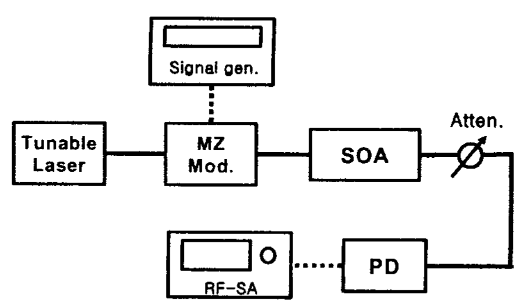

Fig. 1. Experimental Setup

Since the equation involves τ_s, differential carrier lifetime, by fitting the data to the equation, the numerical values of τ_s can be determined. In our investigation, the fitting is done with the least mean square method for two parameters, $G_{cw}P_0/P_{sat}$ and τ_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 as the input optical power increases because differential carrier lifetime is inversely proportional to the differential carrier recombination rate and the carrier density is depleted with the increasing input optical power.

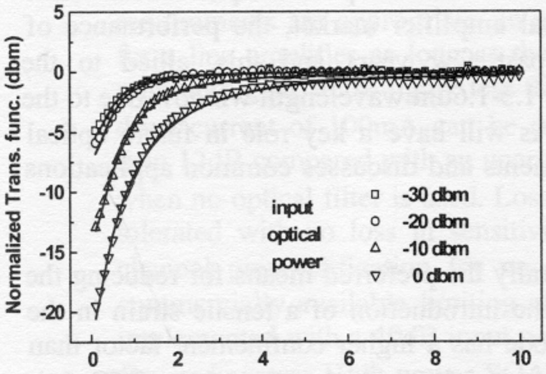

Fig. 2. Optical modulation response

We also measured the fiber response of SOA output signals by subtracting the frequency response after a fiber transmission (63.2km) to that before the transmission. When the intensity and phase modulated signal after SOA goes through the fiber chromatic dispersion, phase modulation is converted to intensity modulation. Using this, we can measure the linewidth enhancement factor which is related to the phase modulation. The chirp of the Mach-Zehnder modulator can be ignored. The input optical power to the fiber is attenuated to suppress fiber nonlinearities and the fiber loss is compensated with EDFA. Fig. 3 is the measured results and fitted results with Eq. (2) which is induced from small signal analysis following the procedure in [4].

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

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

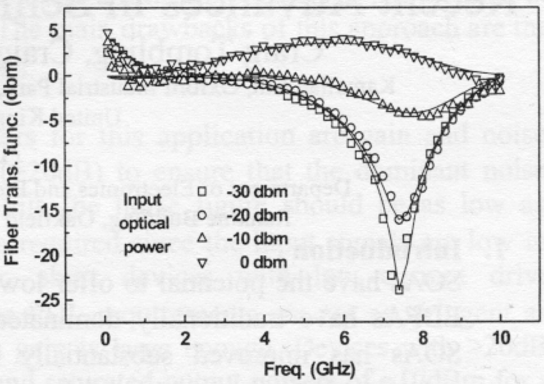

Fig. 3. Fiber response of SOA output signals

Input power	$G_{cw}P_0/P_{sat}$	τ_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

3 Conclusion

We demonstrated a new measurement method for SOA differential carrier lifetimes and linewidth enhancement factors. We used a single optical source and simple fiber-optic elements for the measurement of SOA optical modulation response with and without fiber transmission. This measurement method will be useful in extracting parameter values for modeling SOAs.

References

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