Intrinsic intermodulation distortion characteristics of Linear Optical Amplifier

Dennis T.K. Tong
Department of Electrical and Electronic Engineering, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong SAR.
eetong@ust.hk

Ming C. Wu
Electrical Engineering Department, University of California, Los Angeles, CA, USA
wu@ee.ucla.edu

Sol P. Dijaili
Genoa Corporation, Fremont, CA, USA
sdijaili@genoa.com

Abstract: We experimentally investigate the use of Linear Optical Amplifier (LOA) in microwave photonic systems and its intrinsic intermodulation distortion characteristics. Amplifier-induced spurious-free dynamic range (>100 dB-Hz$^{2/3}$) is obtained for the first time.

OCIS codes: (250.5980) Semiconductor optical amplifiers; (060.4080) Modulation

Recently, linear optical amplifier and its implementation in WDM networks have been demonstrated [1, 2]. In LOA, gain clamping is achieved through lasing action perpendicular to the propagation of the amplified signal, and nonlinear distortion due to gain saturation can be effectively suppressed. Such feature also makes LOA an attractive alternative for microwave photonic systems. Previously, microwave photonic systems implemented with gain-clamped semiconductor optical amplifier (GC-SOA) have been reported [3, 4]. Composite intermodulation distortion (IMD) characteristics of the entire link are dominated by the external modulator nonlinearities [4]. As the performance requirements for these systems become more stringent, various linearized modulation techniques are applied and intrinsic IMD properties of the amplifiers become critical. In this paper, we investigate the intrinsic IMD characteristics measurement of LOA. By using a two-wavelength approach, LOA-induced spurious-free dynamic range of is measured for the first time.

The experimental setup is shown in Fig 1. Two lasers at λ_1 = 1555.27 nm and λ_2 = 1560.07 nm were modulated separately via external modulators at RF frequencies of f_1 and f_2, respectively. The two modulated wavelengths have equal power and are combined through a WDM multiplexer, amplified by EDFA, and fed through the LOA. Variable optical attenuators are employed to control optical powers at inputs of the LOA and the photodetector. When operates at 245 mA, the LOA used in this experiment exhibits a constant fiber-to-fiber gain of 12 dB at the tested wavelengths up to an output optical power of +9 dBm.

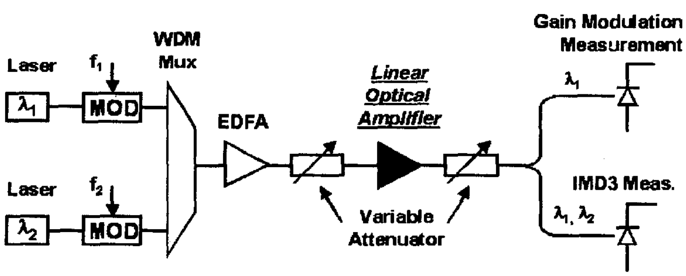

Fig. 1. Experimental setup for measuring intrinsic intermodulation distortion characteristics of LOA

The gain modulation responses of the LOA at various output optical powers are first measured using a calibrated network analyzer. This is achieved by leaving λ_1 unmodulated while sweeping the modulating frequency on λ_2 from 45MHz to 15GHz. The two wavelengths are separated after the LOA. Responses at λ_1 are then measured at fixed received optical power. In Fig.2, resonance peaks due to gain clamping are observed at around 2 GHz and the response increase as the square of LOA output power. When the LOA output exceeds +9dBm, gain clamping no longer exists, responses at low frequencies experience significant increases and the curve exhibits a typical "low-pass" properties of conventional SOA. In a regular microwave photonic system, multiplying the gain modulation response by the square of modulation index yields the second order IMD (IMD2) originated from the LOA at $f_1 \pm f_2$.

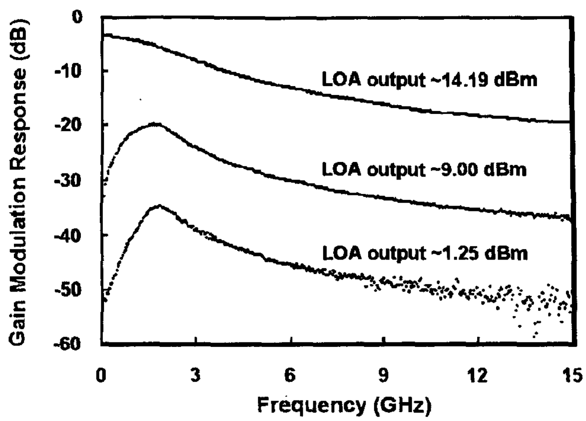

Fig. 2. Gain modulation response of LOA at various output powers

Two-tone third order IMD (IMD3) is measured at ~ 2.5 GHz, near the peak of gain modulation response in Fig. 2, with the two RF frequencies spaced 10 MHz apart. Here, both wavelengths are received by the photodetector. The photocurrent consists of the fundamental and the third order mixing products at $2f_1 - f_2$ and $2f_2 - f_1$. The two-wavelength approach has been employed to measure IMD3 of a HBT optoelectronic mixer [5]. By modulating the two wavelengths separately, we ensure the IMD3 are originated from the LOA, and not from the external modulators. In addition, total received optical power is maintained at +3dBm to avoid nonlinearity of the photodetector. Figure 3 shows the IMD3 measurement when the LOA output at +9dBm. The third order mixing products generated by the LOA are two orders magnitude lower than that calculated for a typical Mach-Zehnder modulator. The spurious-free dynamic range (SFDR) is measured to be 92 dB-Hz$^{2/3}$. We should note that the measured SFDR represents the worst case near the peak of the LOA gain modulation response and at the high end of its linear operating range. In our experiment, for example, IMD3 at 100 MHz and > 5 GHz are not measurable, indicating SFDR of > 100 dB-Hz$^{2/3}$ is feasible.

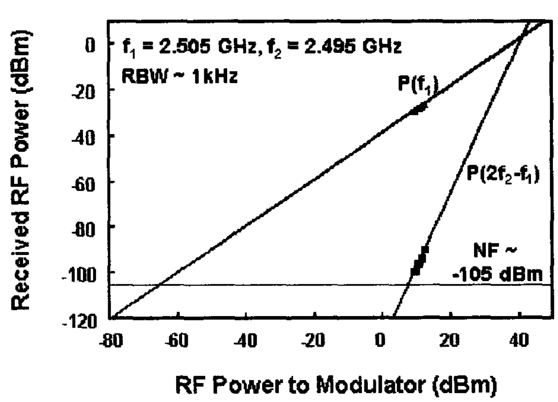

Fig. 3. Intrinsic third order intermodulation distortion of LOA at +9dBm output power.

CThD6

In conclusion, we have experimentally investigated the intrinsic intermodulation characteristics of linear optical amplifier using a two-wavelength approach. Spurious-free dynamic range of >100 dB-Hz$^{2/3}$ is obtained except for frequencies near the gain modulation response at 2 GHz. The results indicate that LOA offer potentially low cost and compact amplification solution for high-performance microwave photonic links.

1. D.A. Francis, S.P. DiJaili, and J.D. Walker, "A single-chip linear optical amplifier," *OFC 2001*, Anaheim, CA, USA, paper PD13.
2. J.J.J. Crijns, L.H. Spiekman, G.N. van den Hoven, E. Tangdiongga, and H. de Waardt, "Static and dynamic switching performance of a metro WDM ring using linear optical amplifiers," *IEEE Photon Technol. Lett*. vol. 14, pp. 1481-1483, 2002
3. V.G. Mutalik, G. van den Hoven, and L. Tiemeijer, "Analog performance of 1310-nm gain-clamped semiconductor optical amplifiers," *Proc. Opt. Fiber Comm. Conf. 1997*, Dallas, TX, USA, paper ThG4.
4. R. Boula-Picard, M.-B. Bibey, and N. Vodjdani, "Semiconductor optical amplifiers for microwave photonics links," *MWP 2001*, Long Beach, CA, USA, paper Tu-4.11
5. C.P. Liu, A.J. Seeds, Y. Bester, V. Sidorov, D. Ritter, and A. Madjar, "Two-tone third-order intermodulation distortion characteristics of an HBT optoelectronic mixer using a two-laser approach," *MWP 1999*, Melbourne, Vic., Australia, paper T-5.4