AlGaAs/GaAs HBT Limiting Amplifier for 10Gbps Optical Transmission System

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Abstract

A 10Gbit/s limiting amplifier IC for optical transmission system was implemented with AlGaAs HBT technology. Amplifier was designed to support differential input and output. Small signal performance of the packaged IC achieves 26dB gain and f_{3dB} of 8GHz. A single output has 800mV$_{p-p}$ swing with more than 26dB dynamic range. The performance of the limiting amplifier was verified through single mode fiber 320km transmission link test.

Introduction: High speed limiting amplifier is widely used in optical transmission system, radar receiver system, satellite communication system, and so on. In optical transmission system application limiting amplifier must have high gain and wide bandwidth with frequency response from DC range. Also low phase shift deviation and crossing point fluctuation must be insured over wide input dynamic range. AlGaAs/GaAs HBT is a potential candidate for this application with its inherent capability for high speed and high gain use. Recently AlGaAs/GaAs HBT technology has been matured with improved reliability and reproducibility.

Several papers have been reported about AlGaAs/GaAs HBT limiting amplifier which works at or above 10Gbps fiber optic transmission system[1,2]. However the reported result was of on-wafer RF probe test in most cases. This paper describes design and performance of a packaged AlGaAs/GaAs limiting amplifier for 10Gbps optical repeater and result of 10Gbps transmission test over 320km SMF using this amplifier.

Circuit Design: The block diagram of limiting amplifier is shown in Fig. 1. It is composed of input buffer, two gain cell for high gain, output buffer and feedback circuit for DC offset control. It is designed to operate with single or differential input and output. Inside direct-coupled differential amplifier structure was used for frequency response from DC range and for reduced phase shift deviation. A pair of DC port was provided at input side for external slicing level control.

The input buffer uses an emitter follower with 50Ω thin film resistor to ensure input impedance matching. The gain cell employs parallel feedback transistor(PFT) to achieve higher gain and wider bandwidth than a conventional differential circuit[3]. With PTF acting as a buffer, gain can be controlled keeping DC output voltages constant and cascading of gain cell becomes easier. The differential pair is followed by emitter follower for level shift. The output buffer uses an emitter coupled pair with emitter degeneration resistors. Each block operates with its own reference current source to reduce crosstalk. HBTs with emitter size of $2x10\mu m^2$ and $6x20\mu m^2$ are used in design. The cutoff frequency f_T of both HBTs is 35GHz in the operation at a bias point of the circuit. A single supply voltage(-7V) is used with 1.4W power consumption.

After circuit level optimization, layout was carried out preserving the symmetry of the differential amplifier to reduce offset from layout and processing. At the operating speed of 10Gbps and above, effects of parasitic phenomena such as stray capacitance and inductance due to the interconnection line should be included for better optimization. Hence all the connection lines in the preliminary layout were handled as a distribution network and optimization was carried out again with circuit parameters and other parasitics due to the packaging including bonding wire. Several iterations of circuit and layout level optimization were performed for final layout for mask generation.

Performance: The limiting amplifier was fabricated on MOCVD-grown wafer using self-aligned emitter/base and sidewall dielectric passivation. The backside of the wafer was lapped and grounded through backside via hole to reduce the effects of parasitics due to ground bonding wire. The chip size is $0.95x1.4mm^2$ as shown in Fig. 2. Amplifier chip is mounted on microwave substrate for packaging as shown in Fig. 3. The amplifier module with SMA connectors was tested for frequency response and limiting performance. Fig. 4 shows the frequency dependence of scattering parameter. Top four traces are S_{21} of amplifier with increasing input level by 10dB step. The small signal gain is about 26dB with f_{3dB} of 8GHz. With increasing input level, the gain decreases by 10dB step with broadening bandwidth more than 10GHz. The bottom traces show the return losses which are less than -10dB below the small signal f_{3dB}. Using 10Gbps NRZ PRBS limiting performance of amplifier was measured as shown in Fig. 5 with increasing input level from 10 to $500mV_{p-p}$. Output signal is limited to 800mVp-p from $50mV_{p-p}$ to more than $1V_{p-p}$ input level, which is 26dB dynamic range. The inserted eye diagrams are the measured output eyes with input of $50mV_{p-p}$ and $1V_{p-p}$ 10Gbps signal. For optical transmission system application limiting amplifier must have low phase shift deviation and crossing point fluctuation over wide input dynamic range. Measurement of input DC bias drift and output phase deviation are shown relatively in Fig. 6. DC bias drift is only 1.5mV and the phase deviation is as low as 6.5ps over more than 20dB dynamic range. Using 10Gbps pattern generator and bit error detector V-curve of limiting amplifier was measured at BER of $1x10^{-10}$. As shown in Fig. 7, V-curve has so wide bottom that amplifier performance can be insensitive to input bias over wide dynamic range of input power. The input ambiguity level reads as $16mV_{p-p}$ and $19mV_{p-p}$ for PRBS 2^7-1 and 2^{23}-1 respectively.

Adopted in optical transmission system[4], the performance of the limiting amplifier was verified in 10Gbps SMF 320km transmission test in link setup shown in Fig. 8. Optical transmitter uses a DFB-LD and an $LiNbO_3$ external modulator as light source[5]. A optical booster amplifier and three optical line amplifiers with dispersion compensation fiber were used to transmit 10Gbps optical signal over SMF 320km with 80km span. Receiver system is composed of EDFA optical preamplifier, PIN-HBT preamplifier[6], limiting amplifier and clock and data recovery(CDR) circuit[7]. In Fig. 9 eye diagrams of optical input signal to preamplifier and electrical output signal from limiting amplifier were compared after transmission. By increasing the optical fiber length from back-to-back to 320km, the shape of input optical signal is distorted with increasing jitters and dispersion. However the eye diagrams of limiting amplifier output are always in same shape and level with accumulated jitters only. Fig. 10 shows the bit error rate of this optical transmission system using the fabricated limiting amplifier at various length of fiber link. The sensitivity is -31dBm at BER of $1x10^{-12}$ in case of back-to-back and the penalty for 320km transmission is -4dB.

Conclusion: 10Gbps AlGaAs/GaAs HBT limiting amplifier was designed and fabricated. Small signal performance of 26dB gain with 8GHz bandwidth was achieved in microwave packaged amplifier. Large signal performance has the bandwidth extended to more than 10GHz and 26dB dynamic range with return loss of less than -10dB. Phase deviation of 6.5ps was achieved over 20dB input dynamic range. The performance of amplifier was verified in 10Gbps SMF 320km transmission test.

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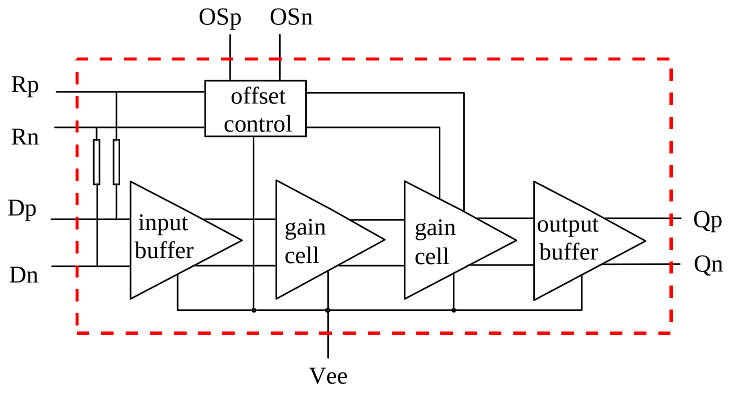

Fig. 1. Block diagram of limiting amplifier

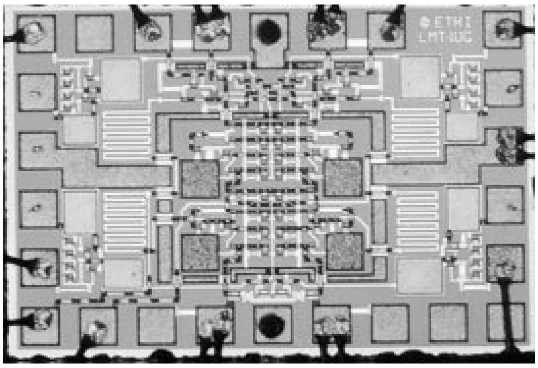

Fig. 2. Microphotograph of Limiting amplifier

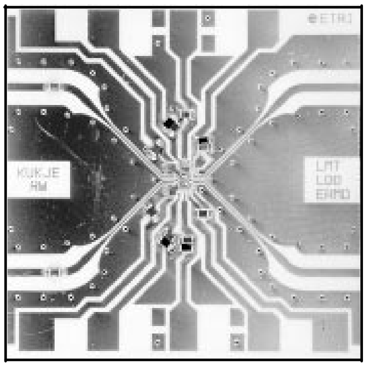

Fig. 3. Limiting amplifier on 1x1in^2 alumina substrate

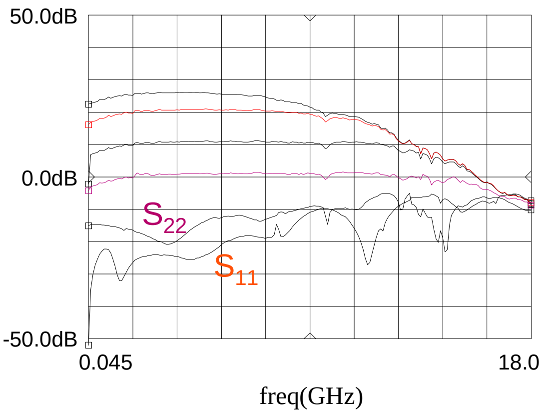

Fig. 4. Frequency dependence of limiting amplifier

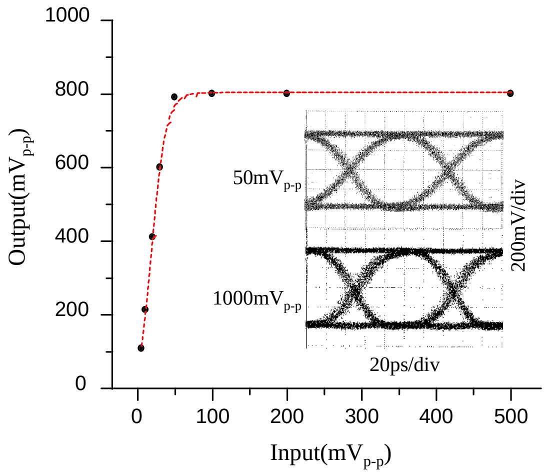

Fig. 5. Limiting characteristics

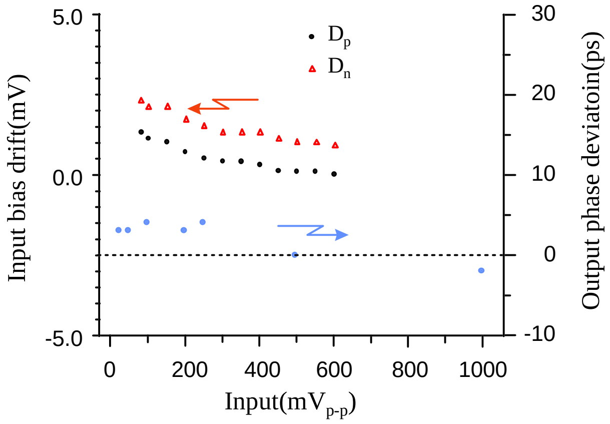

Fig. 6. Input bias drift and output phase deviation

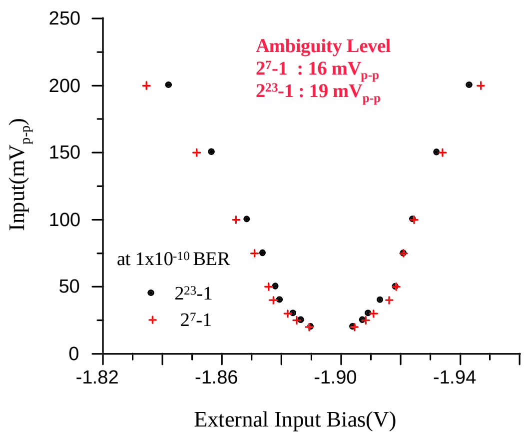

Fig. 7. V-curve and ambiguity level of amplifier

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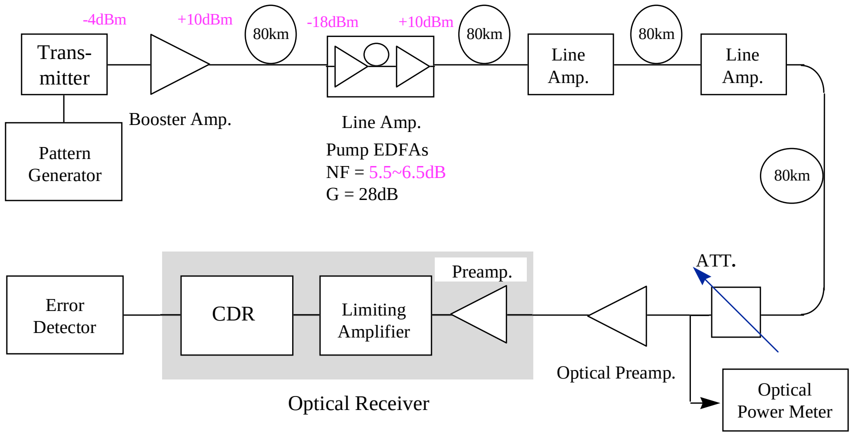

Fig. 8. Setup for SMF 320km transmission test

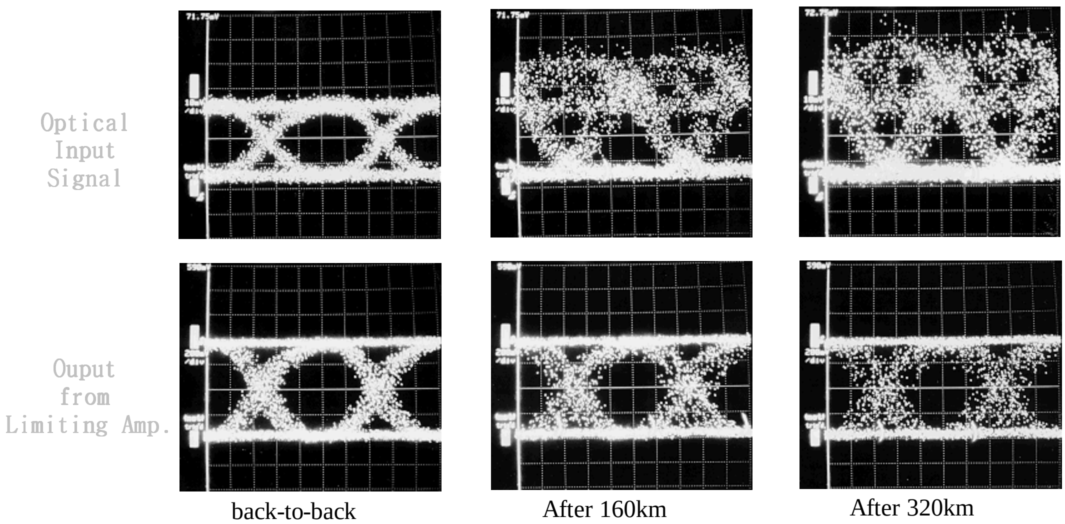

Fig. 9. Comparison of input optical signal and output signal of limiting amplifier

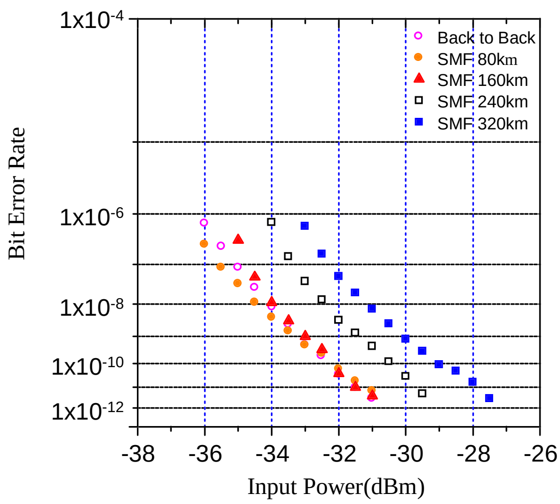

Fig. 10. Sensitivities of receiver after transmission of single mode fiber