A metamorphic GaAs HEMT Distributed Amplifier with 50 GHz Bandwidth and low Noise for 40 Gbits/s optical receivers

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***Abstract* — An eight stage distributed amplifier with 12.5 dB ± 0.45 dB gain and 50 GHz bandwidth has been demonstrated in a commercially available 0.1 µm metamorphic GaAs HEMT (MHEMT) technology. The amplifier has a minimum noise figure lower than 2.5 dB in the bandwidth. The group delay variation from 9 to 40 GHz is ± 7.5 ps and circuit consumption is 0.4 W. Such amplifier has been packaged with a high responsivity photodiode into a fiber pig-tailed module. Eye diagrams measurements demonstrate the successful high-speed operation of the photoreceiver.**

***Index Terms* — distributed amplifiers, metamorphic HEMT, MMICs, photoreceiver, fiber optic communication, microstrip circuits.**

I. INTRODUCTION

In recent year the development of multimedia communications has generated a strong demand for high speed and high capacity systems. If now the 10 Gbit/s is strongly developing, 40 Gb/s will be highly desirable to reduce cost and increase capacity per channel. In the same time, electrical time division multiplexing (ETDM) and wavelength division multiplexing (WDM) have been developed to increase the number of channels per fiber.

The increasing of bit rates is very challenging for analog designer. High speed optical transmission systems require high performance amplifiers with bandwidth ranging from few kHz up to maximum bit rate, low group delay variation to limit distortion of the pulse waveform and low noise to achieve high sensitivity receivers. Distributed amplifiers (DA) have proved to be optimum choice for such amplifier [1].

Until now, distributed amplifier fabricated on InP substrate have achieved higher performances than GaAs amplifiers [1]-[3]. However metamorphic HEMT technology is able to provide InP based HEMT performances with GaAs based HEMT levels of manufacturability and cost [4]-[5]. Moreover metamorphic HEMT consume less than pseudomorphic HEMT, with higher performance. In this way power circuit consumption can be reduced [4]-[7].

In this paper we describe the design, the characterization, and integration in a photoreceiver module of a MHEMT trans-impedance amplifier (TIA), for 40 Gbits/s operations. The circuit optimization is made as well in term of gain, bandwidth, and group delay.

II. TECHNOLOGY

Circuits were fabricated using a commercially available D01MH process developed by OMMIC. This process is based on low noise 0.1 µm metamorphic HEMT devices with current cut-off frequency Ft of 150, maximum transconductance Gm of 750 mS/mm, breakdown voltage of -8.0 V, and pinch-off voltage of -0.8 V. The microstrip lines implies via holes technology with a 100 µm substrate thickness.

III. DA CIRCUIT DESIGN

The distributed amplifier presented in this paper, is based on cascode cells. This topology, instead of a single common source transistor, provide many advantages such as high gain, high bandwidth due to the compensation of drain line losses, and improvement of the input/output isolation by cancelling Miller-effect [8-9].

However, the induced negative resistance of the cascode cells has to be controlled to avoid possible oscillations. With this aim, we have inserted a source inductance ls (Fig.1) between the source terminal of the common source transistor and ground [3].

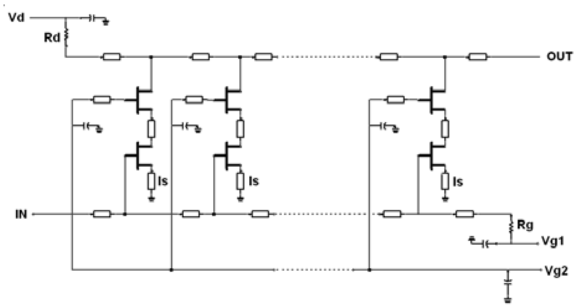

Fig.1. Schematic of the distributed amplifier circuit

The circuit stability has been studied using the normalized determinant function (NDF) approach which is appropriate to the analysis of circuits “with loops” [10].

The circuit is biased through the gate and drain termination resistor Rd and Rg and the bonding pads are provided to supply drain (Vd), gate of the common-source transistor (Vg1) and gate of common-gate transistor (Vg2). In this way the amplifier is well suited for packaging.

A photograph of the fabricated distributed amplifier is shown in Fig.2. The eight-stage amplifier has a chip size of 3.2 x 1.2 mm².

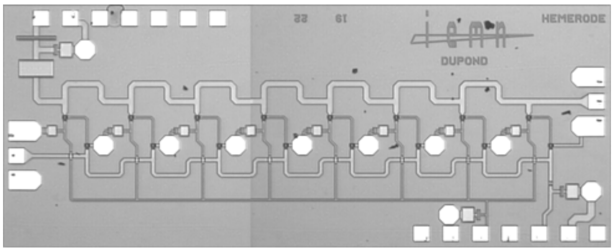

Fig.2. Photograph of the MHEMT distributed amplifier.

IV. Distributed Amplifier Characterization

The on-wafer characterization of the amplifier is made using HP8510XF network analyzer, in the frequency range [0.5-110 GHz]. The RF probes were calibrated using the line-reflect-reflect-match (LRRM) method.

The on-wafer S-parameters are shown in Fig.3. This amplifier achieved a gain of 12.5 dB and a 3-dB bandwidth of 50 GHz. The transimpedance of the distributed amplifier reaches as high as 48-dBΩ. The biased conditions are Vdrain_line=6 V, Vgate_line=-0.3 V and Vcommon-gate=1.45 V. Under these bias conditions, the power consumption is about 0.4 W and the gain flatness is within ± 0.45 dB from 5 to 40 GHz.

S21 parameters show a low frequency perturbation due to resonance between on chip shunt capacitances, used for ac grounding the 50 Ω termination resistors, and inductance of the dc-biasing probes. This has been verified by simulation using a model for dc probes and by measuring the amplifier directly through the RF probes using a bias network. In this case, the power consumption is less than 0.17 W.

The input return-loss is below -15 dB and the output is below -10 dB up to 65 GHz.

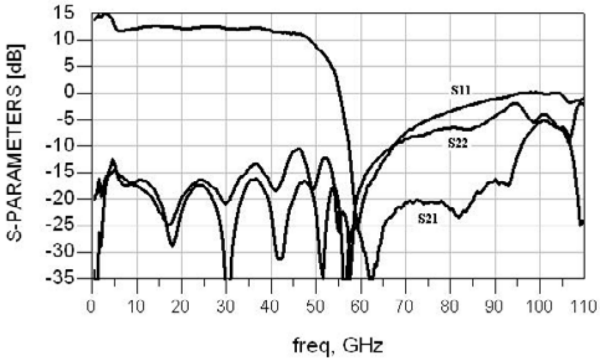

Fig. 3. S-parameters measurement.

The group delay from 0.5 to 50 GHz is shown in Fig. 4. The peak-to-peak variation from 9 to 40 GHz is ± 7.5 ps. The ripple below 9 GHz, like the gain variation at lower frequency, is also related to the on-wafer measurement, where the DC probes are not sufficiently bypassing.

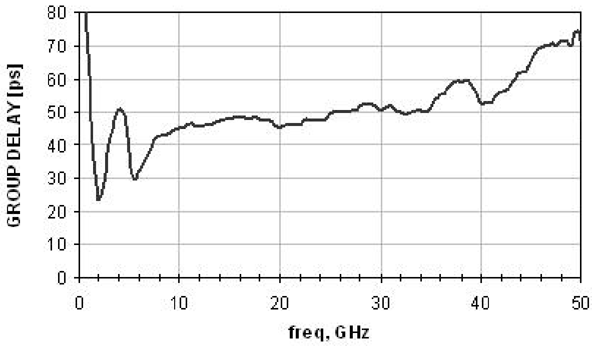

Fig. 4. Group Delay versus frequency

Figure 5 shows the 50 Ohms noise figure measured from 6-20 GHz and 26-40 GHz. Noise figure lies between 4.5 and 2.5 dB which led on an average value of 3 dB over the bandwidth.

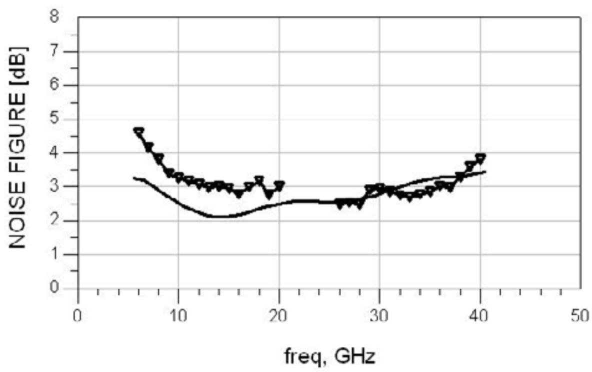

Fig. 5. Noise figure measurement (▽) and simulation versus frequency

Basing on the agreement between simulation and measurement of noise figure, the equivalent input noise current density [11] is calculated and shown in figure 6. Input noise current density is less than 20 pA/√Hz in the bandwidth.

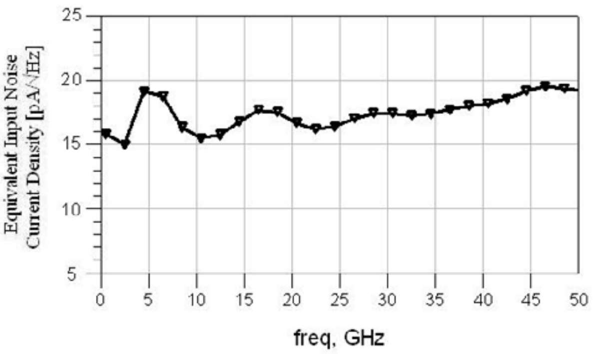

Fig. 6. Calculated Equivalent Input Noise Current Density versus frequency

V. Photoreceiver module

An equivalent amplifier has been packaged in a hybrid photoreceiver. using bond wire interconnects. It consists of a 55 GHz bandwidth, 45.6 dB.Ω transimpedance gain distributed amplifier and a photodiode with responsivity of 0.7 A/W.

The small signal frequency response of the photoreceiver module, evaluated with an lightwave component analyzer, is shown in Fig. 7. A 3-dB bandwidth of 35 GHz with an optical/electrical conversion factor of 130 V/W is obtained. The low frequency perturbation is reduced using external circuit decoupling.

Fig. 7 shows an example of 40 Gb/s NRZ output eye diagram obtained with this photoreceiver module. This result demonstrates that such photoreceiver is appropriated for 40 Gbit/s operations.

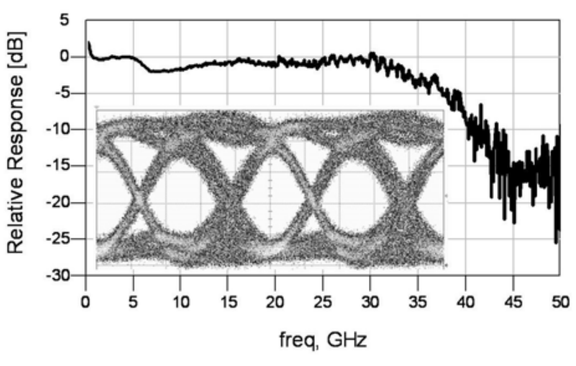

Fig. 7. Frequency response and NRZ eye diagram

VI. Conclusion

A metamorphic HEMT distributed amplifier with 12.5 dB 50 GHz bandwidth, and 48 dB.Ω transimpedance has been presented. Minimum noise figure is 2.5 dB from 6 to 40 GHz. The amplifier provides InP like performances on a GaAs substrate. Integration of such amplifier into a 40 Gbit/s hybrid photoreceiver has been successfully demonstrated.

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