MMIC GaAs TRANSIMPEDANCE AMPLIFIERS FOR OPTOELECTRONIC APPLICATIONS

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ABSTRACT

This paper demonstrates the feasibility of MMICs able to improve the global performances of an optical link, over a typical 1 to 20 GHz frequency range. A distributed laser driver and a photodiode Bootstrap follower provide active matching between 50Ω and optoelectonic transducers.

INTRODUCTION

For Radar, Electronic Warfare and Telecommunications applications, optical links are regarded as very promising solutions. Associated to the optoelectronic devices (photodiodes and lasers), Microwave Transimpedance Amplifiers represent key components in terms of performance optimization (dynamic range, noise figure, consumption, losses....). In particular, in Electronic Warfare applications, where wide frequency range operations are required, transimpedance Amplifiers are a real challenge allowing matching between 50 Ω RF impedance and both high impedance of a photodiode and low impedance of a laser diode over a typical 1 - 20 GHz frequency range.

This paper describes two types of wide band Microwave "Transimpedance" circuits using advanced and novel concepts :

- A distributed transimpedance amplifier dedicated to laser direct modulation
- A specific transimpedance amplifier, used for photodiode matching.

These amplifiers have been designed by DASSAULT ELECTRONIQUE and manufactured with the VLN02 HEMT 0.25 µm gate process from THOMSON/TCS (France). Application of a powerful Design methodology led to a successful first foundry run.

DISTRIBUTED TRANSIMPEDANCE AMPLIFIER (DTA, laser driver)

Distributed (or traveling wave) amplifiers have already been used as photodiode amplifiers, either with a conventional 50 Ω input impedance [1] or with a low input impedance (25 Ω, [2]) to improve the input RC-bandwidth. Low output impedance distributed amplifiers have also been done for power purposes [3]. Here is reported for the first time a Distributed Amplifier with a low output impedance designed for the direct modulation of a laser. The well known distributed configuration has been adapted to low output impedance by setting the drain line characteristic impedance near 5 Ω instead of classical 50 Ω impedance. This allows to avoid the commonly used 45 Ω series resistance that matches the low laser diode input impedance (typically 5 Ω up to 20 GHz) but creates 10 dB losses at the very beginning of the transmission link. The laser bias current is supplied through a on-chip bias-T. The circuit is shown on the photograph of Figure 1.

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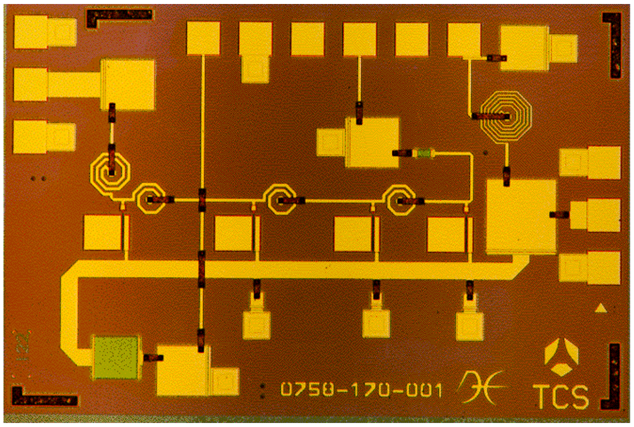

Figure 1: Distributed Transimpedance Amplifier. Input: 50Ω. Output: 10Ω. (1.8mm x 1.3mm)

A 7 ± 0.5 dB gain with less than 8 dB input and output return losses have been obtained over the 1-18 GHz range, with 50 Ω at the input and 10Ω at the output as reference impedances. On wafer measurements show a very good agreement to predicted values.

France Telecom Cnet has presented an enhanced optical harmonic upconverter, for mm-wave radio applications[4], based on an hybrid integration of the wideband DTA with a high speed MQW DFB laser. The submount is 2X3.5X6mm3 copper-tungsten plate on which the components are either indium-soldered or epoxy-glued. Capacitors are placed along the device to ensure DC voltage decoupling. The DTA and the laser are connected together through a very short gold bonding wire (<300μm) to minimize parasitics.

By using the nonlinear effects in the MQW DFB laser, fourth or higher order harmonics can be used to generate millimeterwave frequencies. Due to the wideband matching and amplifying capabilities of the DTA, the device can cover a wide millimetric range from 20 to 40 GHz with a reduced input driving power (<10dBm) in the frequency range of 5-10 GHz .

The optoelectronic upconverter can also behave as a mixer, if another modulation is pathed on the on-chip bias T port of the device. The available bandwidth on this port remained quite flat from 10kHz to 800 MHz. The open baseband eye diagram detected at the photodiode end confirmed the good behavior of the on-chip bias T path of the DTA. The device mixing capability has been confirmed up to 622Mbit/s over the harmonic generated millimeterwave carrier at 38 GHz [5].

THE BOOTSTRAP PHOTODIODE AMPLIFIER

The concept of this amplifier is based on the fact that, for a medium power photodiode, the parasitic capacitor is the main limiting factor in terms of frequency band. For the first time in the microwave domain, the Bootstrap technique is used to create an active feedback loop aimed at canceling the voltage across the photodiode. This leads the current across the parasitic capacitance to be canceled and the photodiode to act ideally as a pure current source. Basic theory and photograph are shown Figures 2 and 3:

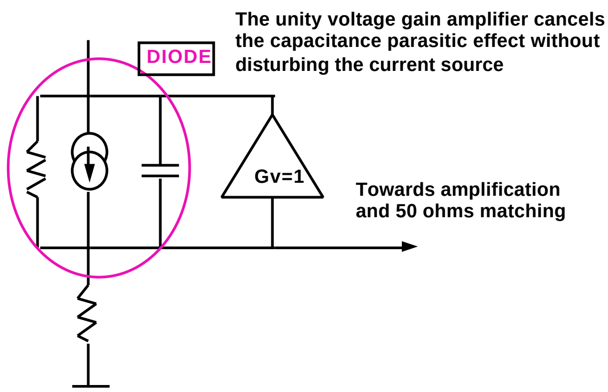

Figure 2: Bootstrap basic diagram

The ideal amplifier that cancels the voltage across the photodiode is fabricated in practice by using a FET in a common drain configuration. A second common drain stage is used to improve the gain and the 50 ohms output matching.

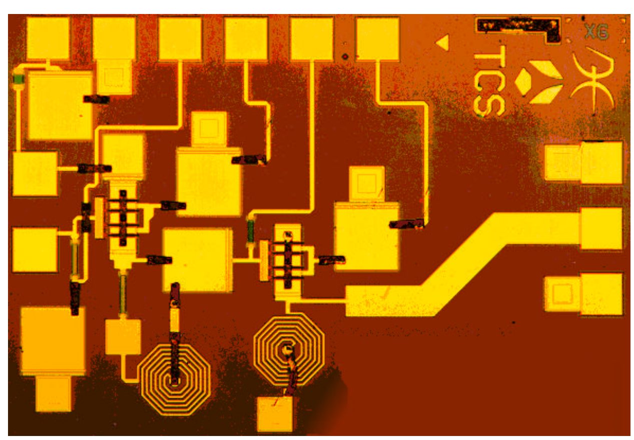

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Figure 3: Bootstrap Amplifier chip (1.3mm x 0.9mm) - Input connected to photodiode. Output to 50 Ω

Experimentation on this device is in progress at IEMN (University of Lille, France). The first results were obtained with relatively large Photodiode components. The reasons for choosing large Photodiodes are the following:

The cut off frequency of photodiodes depends on the size of their active surface. The smaller is the surface, the higher is the frequency. If, in order to reach high frequencies, small active surface is used, the alignment problems will be less suitable for low cost and volume production. In addition, surface illuminated photodiodes have a better conversion efficiency if the active surface is large. Furthermore, wide band photodiodes with large active surface are suitable for combiner's implementation. Combiners are particularly convenient for optical signal summation and consist of several fiber cores joined in front of the photodiode.

We performed microwave optical link measurements with GaInAs/InP PIN photodiode which diameter is 80 µm. The total capacitance (including parasitics) is 0.7 pF. This diode was biased at 5V and measured on 50 Ω and associated to the bootstrap MMIC. For this experiment we used a 1.3 µm high speed ORTEL laser which cut off frequency is 18 GHz at 85 mA bias current. Results are given figure 4. Comparison between the frequency responses shows an improvement of the microwave transmission by up to 7 dB between 1 and 12 GHz. The 3 dB cut-off frequency has been moved from about 3 GHz to about 7 GHz.

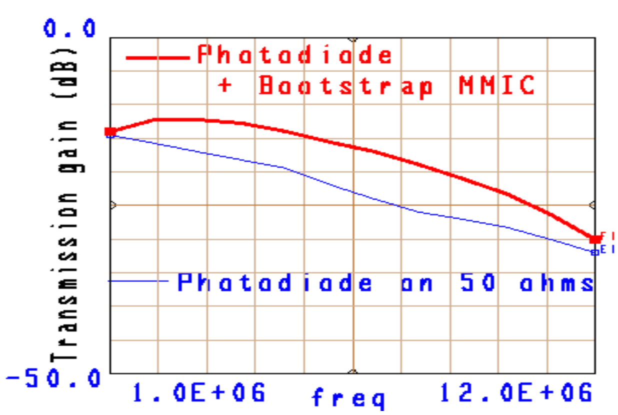

Figure 4: Optical link measurement

In order to eliminate the phenomena that are not directly due to the parasitic capacitance, it is interesting to plot (Figure 5) the difference between the frequency response with the bootstrap and the response without the bootstrap. The resulting curves show a good agreement between theory and measurement.

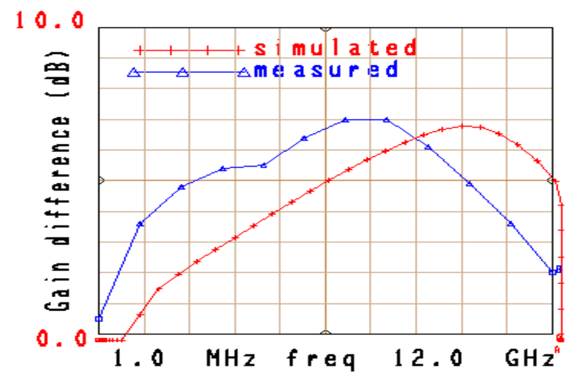

Figure 5: Difference between a link including the bootstrap and a link with a direct connection on 50 Ω.

Similar results were obtained with other photodiode capacitances (up to 1 pF). This shows the capability of a single bootstrap MMIC to work with a large range of optical fiber communication PIN photodiodes.

GLOBAL LINK PERFORMANCES

Figure 6 shows simulated curves comparing the overall performances of a link comprising a laser diode, a fiber and a photodiode (having a 0.2pF parasitic capacitance) in five configurations :

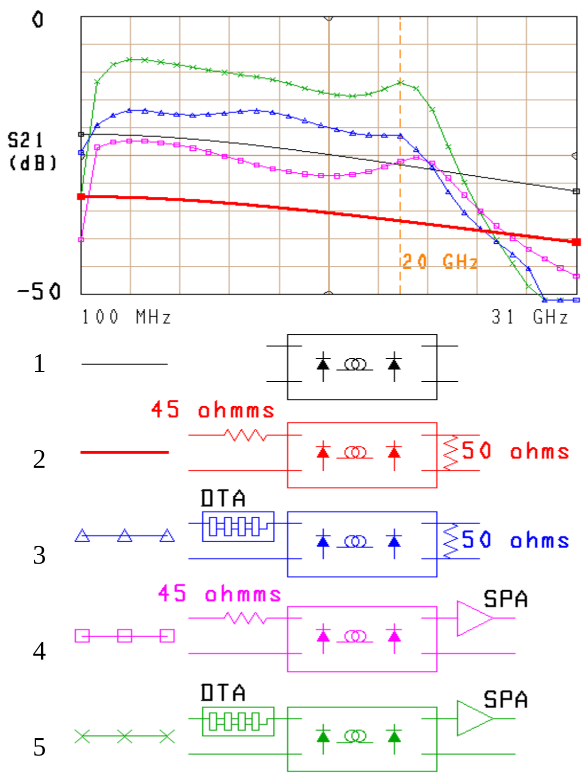

Figure 6: Simulated link performances

1. The diodes are connected directly to the 50 Ω ports: the I/O mismatch make this configuration unsuitable for practical use.
2. A passive matching, leading to very high losses.
3. The DTA, allows about 20 dB improvement.
4. The Specific Photodiode Amplifier (Bootstrap) allows about 10 dB improvement.
5. The final proposed configuration that combines the advantage of the DTA and the Bootstrap.

More sophisticated models developed and extracted by the CNAM provide enhanced information, in particular on the nonlinear and noise behavior of the link. Examples will be given during the conference.

CONCLUSIONS

These very promising devices, obtained after a single foundry run, are key components for Digital and Analogue Optical Links. They have demonstrated the feasibility of high efficiency optical links in real integration situations. A high density packaging is being developed to integrate a complete set of devices, including additional 50 Ω MMIC amplifiers. The resulting T/R modules are aimed to achieve a full 0dB loss optical link. Work on further improvements of the MMICs, in terms of bandwidth, matching, overall gain and integration, is currently being supported by the French Administration. The goal is to convince users to prefer this means of microwave transportation for a lot of applications.

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