# GaAs/GaAlAs HETEROJUNCTION BIPOLAR PHOTOTRANSISTOR FOR MONOLITHIC PHOTORECEIVER OPERATING AT 140 Mbit/s

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## Abstract

The first monolithic integrated photodetector-preamplifier implemented with GaAs-GaAlAs heterojunction phototransistor and transistors has been fabricated and tested. A heterojunction phototransistor (HPT), two heterojunction bipolar transistors (HBT's) and four resistors are integrated in a 0.5 x 0.5 $mm^2$ GaAs chip. The photoreceiver with a 26 kΩ external feedback resistor has a bandwidth of 80 MHz with a transimpedance gain of 7000V/A. The noise measurements indicate that a minimum detectable power of -30 dBm is obtained at 140 Mbit/s for an error rate of $10^{-9}$.

## Introduction

The heterojunction phototransistor (HPT) is very attractive in optical fiber communications for its sensitivity at high bit-rate compared to other photodetectors such as PINFET and APD. For HPT with classical structure, its performance is limited by the main noise parameter Cinput/$\sqrt{\beta}$, and the high sensitive range is located above 1 GHz [1]. High current gain-low capacitance characteristics which are relevant to a diffused structure HPT [2] permit to increase the signal to noise ratio by reducing this main noise parameter, and consequently to extend the interesting range of HPT to bit-rates around and above 140 Mbit/s [3].

## Design

The first monolithic photoreceiver using HPT presented in this paper is a 0.5 x0.5 $mm^2$ monolithic GaAs chip implementing a HPT, two heterojunction bipolar transistors (HBT's) and four resistors [Fig.1].
The photoreceiver has been designed to have a low sensitivity on the variations of the resistors and other parameters related to HBT's and HPT ($f_t$,β,etc) [4].
Fig.2 shows the circuit diagram of the monolithic photodetector-preamplifier in the transimpedance configuration. The transimpedance configuration is preferred according to its advantages over the high input impedance design for obtaining high stability and large dynamic range. In the present stage of the fabrication process, the feedback resistor $R_f$ is an external resistor. The stability of the circuit is ensured by the local serie feedback resistor $R_E$.
The layout of the circuit is based on 4 μm design rules. The photosensitive area of the HPT has an equivalent diameter of 56 μm, compatible with the dimension of multimode fibers.

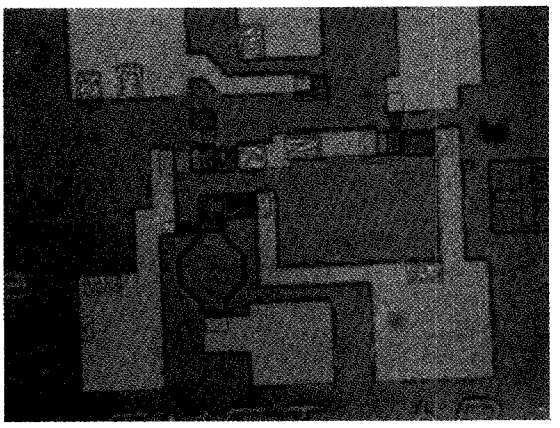

Fig.1 : Microphotograph of the monolithic photoreceiver

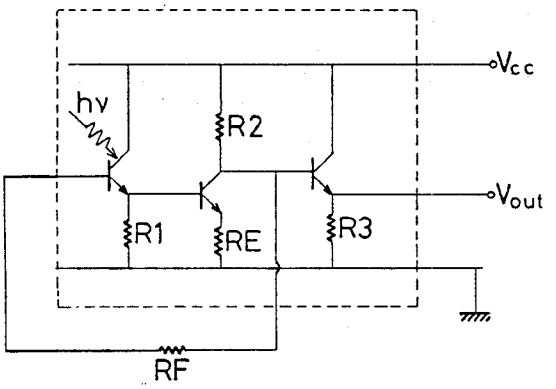


Fig.2 : Circuit diagram of the monolithic photoreceiver



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## Fabrication Technology

The multilayer was grown by the molecular beam epitaxy. Very high current gain up to 3000 have been obtained with similar epitaxial structures [4] [Fig.3].

| | | |
|---|---|---|
| CONTACT GaAs n+ | 4e18 | 2600 A |
| EMITTER GaAlAs N | 5e17 | 4700 A |
| BASE GaAs p | 8e17 | 500 A |
| COLLECTOR GaAs n− | 3e16 | 10500 A |
| BUFFER GaAs n+ | 2e18 | 10000 A |
| SEMI−INSULATING SUBSTRATE | | |

Fig.3 : Multilayer structure for monolithic photoreceiver

The fabrication process from a multilayer wafer is composed by the following steps [Fig.4] : a) emitter mesa etching to eliminate the emitter contact layer.

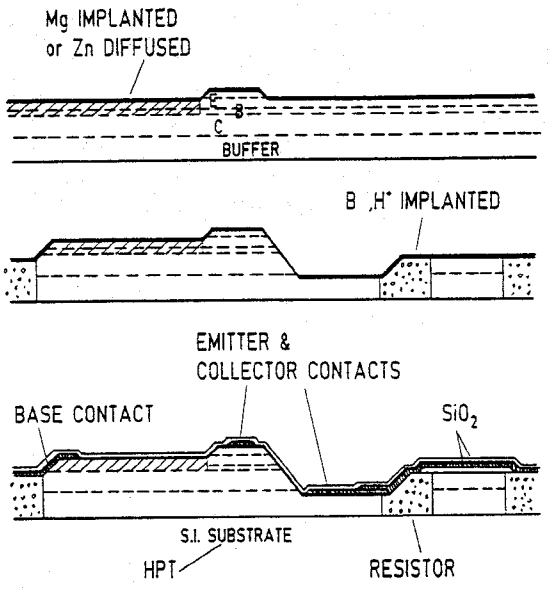


Fig.4 : Schematic drawings of the fabrication process of the monolithic photoreceiver

b) localised Zn diffusion to reach the base layer. c) base mesa etching to eliminate the base layer outside the active area. d) $H^+$ and $B^+$ implantation for isolation. e) collector via-hole etching to reach the $n^+$ buffer layer. f) dielectric ($SiO_2$) deposition for isolation between resistor and metal-line. g) n-type contact. h) p-type contact. i) metallisation of interconnexion. j) antireflecting coat deposition.

## Experimental Results

The photoreceiver with a 26 k Ω feedback resistor operates from a single 7 V supply voltage. The transimpedance gain has been measured as 7000 V/A, and the noise measurements with a low-pass filter of 70 MHz have shown at output a NEP = -61 dBm. The measured NEP does not depend on the incident optical power as long as it is in the microwatt range. The pulse measurement using a GaAs laser operating at 0.82 μm and emitting optical pulses of about 100 ps durations has been performed [Fig.5], the exponential falling edge has a time constant of 2 ns which corresponds to a first order pole of the transfer fonction of 80 MHz.

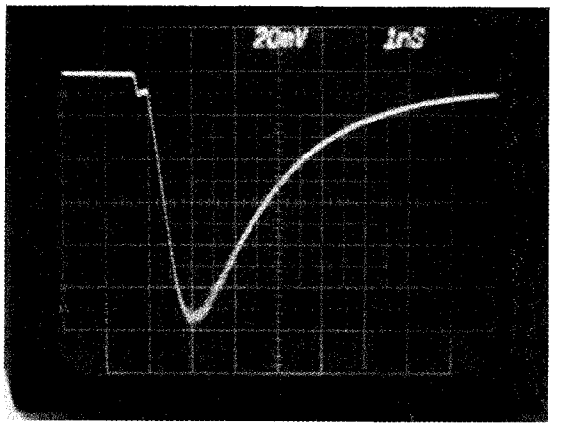


Fig.5 : Pulse response of the monolithic photoreceiver

The discrete Fourier Transform computation of the pulse response exhibits a 6dB roll off and a band-width about 100 MHz. Optical measurements with a 0.85 μm LED have shown an electro-optical gain of 1500 V/W. From these experimental results on signal and noise power, one can infer the variations of signal to noise ratio with optical power. This, together with the bandwidth of the receiver (the value of 80 MHz is used in our calculation) leads to an estimated sensitivity for the receiver of - 30 dBm at 140 Mbit/s transmission rate for an error rate of $10^{-9}$ [5].

## Electrical characterization and Comparison to theoretical performances

S parameters measurements have been carried out on discrete devices (HBT and HPT) located on test area of the same wafer. A transition frequency larger than 8 GHz for the HBT and close to 2 GHz for the HPT have been obtained. These measurements are performed with an extended deembedding technique which allows to reduce the parasite of the test fixture to less than 0.1 dB. From these measurements, the electrical equivalent circuits of HPT and HBT have been established by a CAD program [Fig.6].

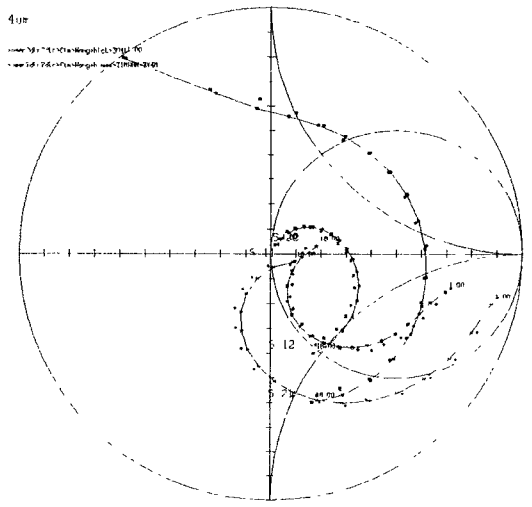

Fig.6a : S parameters measured and calculated from the equivalent circuit of HBT.

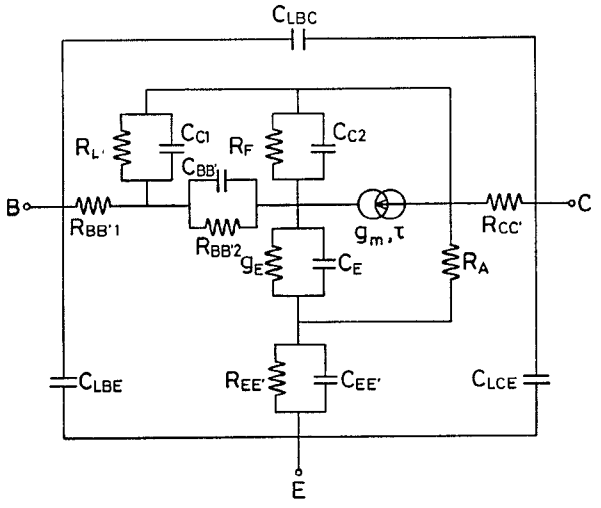


Fig.6b : Equivalent circuit of the HBT

It appears that if very low junction capacitances are effectively obtained, relatively high serie resistances are observed for the emitter ($R_E$ = 30 Ω). The contact resistance seems to be the only origine of this high resistance value. TLM measurements on test structures confirm this prediction.

## Conclusion

The first monolithic photoreceiver implemented with HPT has been fabricated and tested. The experimental results show that taking advantages of the compatibility between HBT and HPT, the monolithic photoreceiver with heterojunction bipolar devices can achieve high reliability and low parasitic noise. Although the performance obtained is already one of the best results reported on monolithic photoreceiver at 0.85 μm, an improvement on available technology will lead to a higher sensitivity and higher gain-bandwidth product.

## REFERENCES


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