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Optoelectronic Technology Consortium

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Prepared by:

Dr. Mary Hibbs-Brenner (PI)
Honeywell Technology Center
(612) 954-2806
fax: (612) 954-2504
Hibbs-Brenner_Mary@htc.honeywell.com

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OPTOELECTRONIC TECHNOLOGY CONSORTIUM
Quarterly Technical Report No. 7

January 1 to March 31, 1994
Honeywell, Inc.

1.0 Introduction.

The Optoelectronic Technology Consortium has been established to position U.S. industry as the world leader in optical interconnect technology by developing, fabricating, integrating and demonstrating the producibility of optoelectronic components for high-density/high-data-rate processors and accelerating the insertion of this technology into military and commercial applications. This objective will be accomplished by a program focused in three areas.

> Demonstrated performance: OETC will demonstrate an aggregate data transfer rate of 16 Gb/s between single transmitter and receiver packages.
>
> Accelerated development: By collaborating during the precompetitive technology development stage, OETC will advance the development of optical components and produce links for a multiboard processor testbed demonstration.
>
> Producibility: OETC's technology will achieve this performance by using components that are affordable, and reliable, with a line BER$<10^{-15}$ and MTTF$>10^{6}$ hours.

Under the OETC program Honeywell will develop packaged AlGaAs arrays of waveguide modulators and polymer based, high density, parallel optical backplane technology compatible with low-cost manufacturability. The scope of the program has been modified, such that the number of packaged waveguide modulator arrays to be fabricated under the program will be reduced, and efforts are initiated in the development of Vertical Cavity Surface Emitting Lasers.

The packaged AlGaAs modulator arrays will consist of a single fiber input, a 1x4 fanout circuit, four waveguide modulators, and four fiber outputs, all mounted on a ceramic header. The primary benefits to this approach are enhanced system reliability, particularly at high temperatures, and a device design that is highly producible due to the inherent process tolerance. Combined with the demonstrated high density of these devices when fabricated in arrays, this allows the development of compact and reliable transmitter components.

The objective of the polyimide backplane development effort is to demonstrate a practical high density (>20 lines or channels per mm) parallel optical backplane facilitating (bandwidth x length/power) interconnect figures of merit between one and two orders of magnitude greater than would be attainable with state-of-the-art electrical interconnects. The effort will address both development of an ultimately manufacturable and environmentally tolerant optical backplane, and the optical interface concepts required for practical board-to-backplane optical connection. The key functionalities, and compatibility with standard multiboard assembly practices will be demonstrated in a laboratory evaluation system.

Technical progress achieved during the current reporting period, and plans for the next reporting period, are summarized in the following sections.

2.0 Progress Summary.

2.1 AlGaAs Modulator Array Development. Task leader: Dr. Mary Hibbs-Brenner

The effort during this reporting period was concentrated on measuring the high speed characteristics of the waveguide modulators, and measuring parameters required to tune the driver circuit to the modulator.

The high frequency or microwave characteristics of the modulator were determined experimentally in the 50MHz-20GHz range. Since the modulator layout did not incorporate RF probe pads, it could not be directly tested using the standard Cascade Microtech probes. It was thus necessary to provide a temporary package for the modulator to enable the measurements to be performed. Figure 1 shows such a package layout wherein standard coplanar RF probe pads on a GaAs chip were placed in close proximity to the modulator chip. The GaAs and modulator chips were both soldered onto the gold plated brass base plate and the pads connected by means of 0.0007" diameter gold wires. Several gold wires were bonded together to reduce pad-to-pad lead inductance, whereas vias to ground ensured a low coplanar ground impedance for the RF probe pads on GaAs. Since the coplanar RF probe pads on GaAs were measured to exhibit an insertion loss of -0.1 dB and return loss of-25dB over 50MHz-40GHz range, we concluded that this type of packaging provides accurate RF measurements of the modulator characteristics without needing to first de-embed the coplanar RF probes.

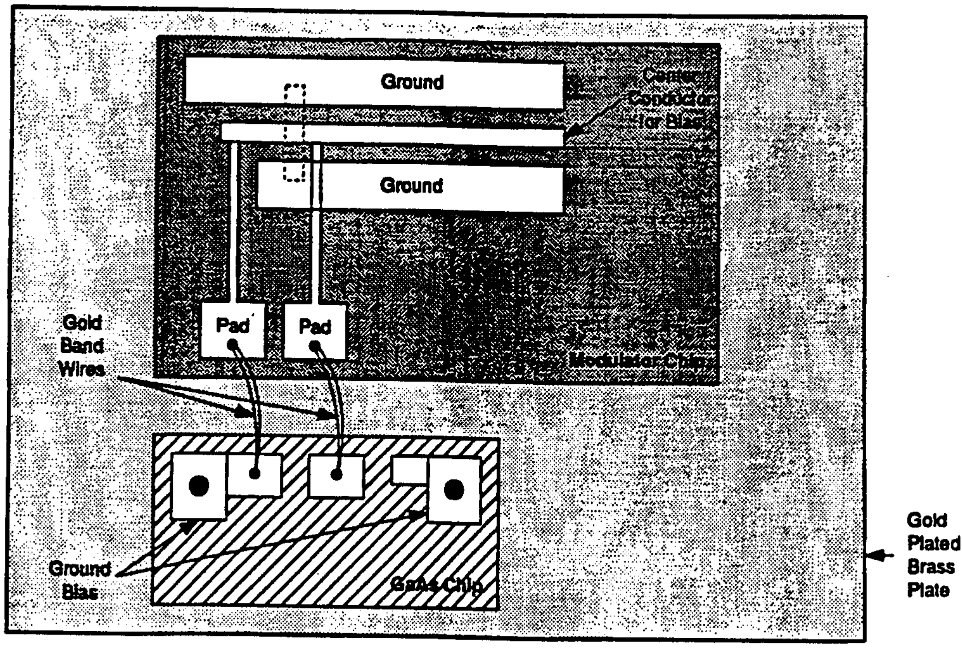
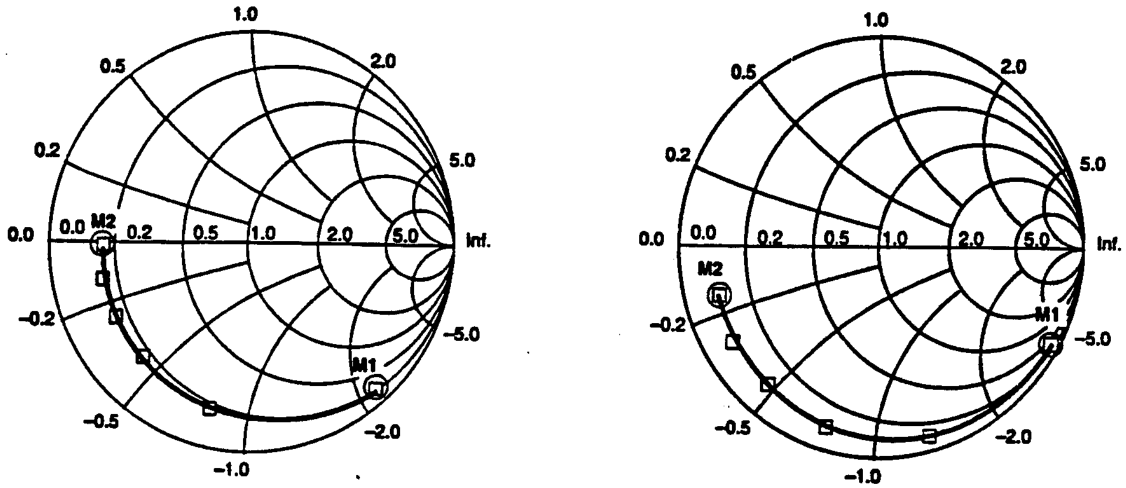


Fig 1: Modulator packaged for on-wafer RF measurements

The first step in determining the microwave characteristics of the modulator was to measure its small signal input impedance. This was accomplished using a standard Cascade

Microtech probe and an HP 8510B network analyzer in the 50MHz-20GHz range, with the modulator biased at each of several different bias voltages. Figure 2(a) and(b) show the measured input impedance of the modulator of length 3m at bias levels of -7.6V and -2.8V, respectively. It is clear from these measurements that at lower microwave frequencies the modulator behaved like a lossy capacitor (Figure 3(a)), whereas, at high frequencies it behaved more like a transmission line. Thus for all practical purposes, the modulator can be modeled as a transmission line (Figure 3(b)). Table I shows details of characteristics of this physical transmission line at various bias levels.



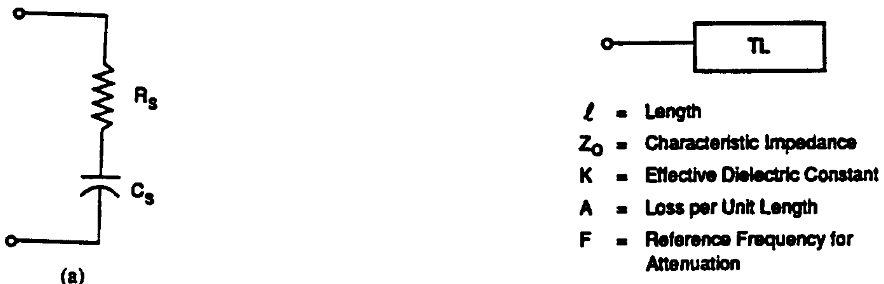
Frequency 0.5 to 5.0 GHz

(a)

Frequency 0.5 to 5.0 GHz

(b)

Figure 2: (a) Measured input of the modulator at a bias of -2.8 V. (b) Measured Impedence of the Modulator at a Bias of -7.6 V.

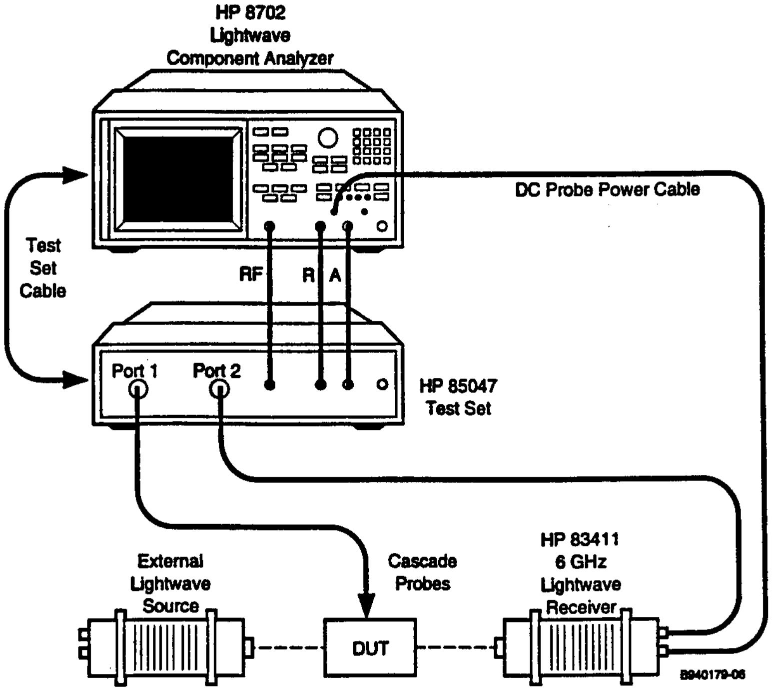


(a)

(b)

Fig. 3: (a) Low frequency nad (b) High frequency equivalent circuit model of the Modulator

The next step in characterizing the modulator was to evaluate its microwave performance under normal operating conditions. This was accomplished by using an HP 8702 Lightwave Component Analyzer together with the HP test set in the experimental setup shown in Figure 4.



DUT = Modulator

Figure 4: Experimental setup for measuring the Microwave/Optical response of the modulator

The system was first calibrated by using an external light source and the standard HP lightwave receiver. Next the GaAs modulator was inserted into the optical path as shown, with the microwave signal being injected into the modulator using Cascade Microtech probes. The response of the optical receiver then indicated the RF response of the GaAs modulator. Figure 5 shows this response at bias levels of -2.8V and -7.6V, respectively. Studying the results shown in Figure 5, one notices that the response is practically unchanged for the two bias levels.

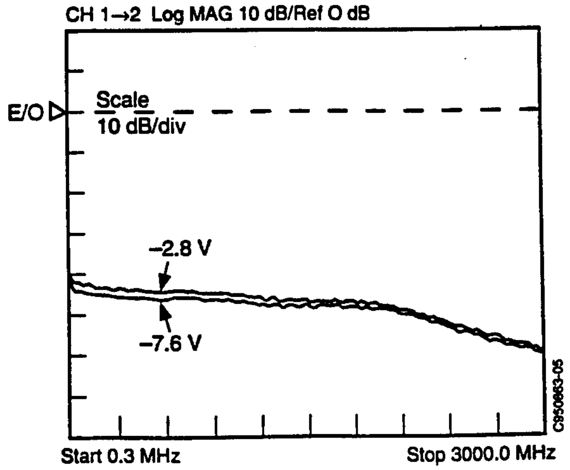


Fig. 5: Measured E/O response of the Modulator at a bias of -2.8 V and -7.6 V.

Furthermore, the output response is not constant, but rather shows a gradual decline of over 15dB from 0.3MHz-3GHz. A casual observation would indicate that this is indeed the RF frequency response of the GaAs modulator, but a careful study of the results indicates that this is not the case, and that the response is determined to a large extent by the impedance of the RF source. In order to understand this, one has to refer to Figure 6, which indicates the modulator being driven by a source of impedance Rs.

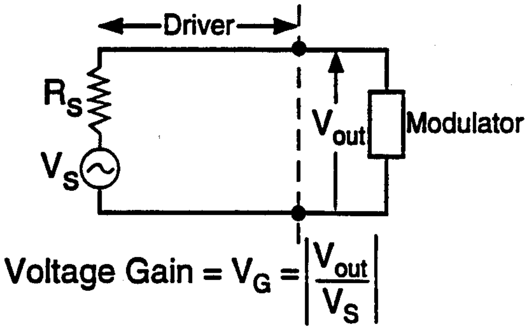


Fig. 6: Circuit Schematic of a typical RF Source Driving a Modulator

Since the RF modulation efficiency of the modulator is dependent on the RF field strength (Erf), the RF voltage developed across the modulator is an accurate indicator of its efficiency. On the basis of Figure 6 and the measured RF input impedance of the modulator, one can easily calculate the complex voltage gain (Vg) for different "Rs". These voltage gains are plotted in Figure 7 and the curve for Rs=50 is in excellent agreement with the measured response shown in Figure 5.

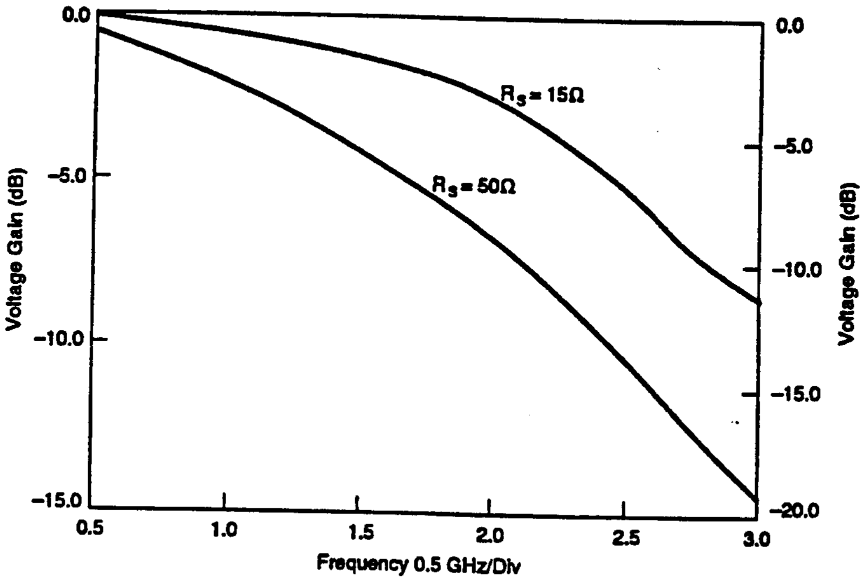


Fig. 7: Calculated Complex gain of the circuit in figure RF6 for various source impedance

This clearly indicates that in fact the intrinsic RF response of the modulator is constant over the 0.3MHz-3GHz range, whereas the overall RF response is very much dependent on "Rs" and dramatically improves as "Rs" approaches zero, or a true voltage source. Thus if higher frequency performance were desired, it would be important to develop an RF driver having as low an impedance as possible.

2.2 AlGaAs Modulator Array Packaging. Task leader: Mr. John Lehman

No activity during the current reporting period.

2.3. Polymer Backplane Development. Task leader: Dr. Julian Bristow

No activity during the current reporting period.

2.4 Vertical Cavity Surface Emitting Laser Development. Task leader: Dr. Mary Hibbs-Brenner

At the point in time when this task was initiated, Honeywell had demonstrated VCSELs under another program where the goal was to integrate VCSELs with photodetectors and Field Effect Transistors (FETs). The structure was therefore slightly different than what is optimum for OETC. Integration necessitated the use of a semi-insulating substrate and so in order to make contact to the n-side of the junction a special thick n-doped contact layer was included in the cavity such that the cavity becomes three wavelengths thick. In order to make contact to this layer we etch down to it, thus creating a mesa structure. Since integration with dissimilar devices is not required as part of OETC, we can migrate our structure toward one which is planar. The device can be grown on a conducting substrate and a common contact can be made by depositing metal on the back side of the wafer. The mesa etch is not required.

We have therefore chosen to use a process similar to AT&T's VCSEL process. This involves using proton implantation to provide current confinement, a broad area ohmic contact on the back side of the wafer, and a circular ohmic contact on the top side. During the current reporting period we implemented some of the steps required to migrate to this structure. We removed the contact layer from the cavity so that the total cavity thickness was the equivalent of one wavelength, and put a broad area contact on the back side of the wafer. We temporarily continued to use the mesa etch to provide current confinement. VCSELs were successfully fabricated with this structure.

We also investigated the origin of the high resistance of our devices, and believe it to lie in the top p-ohmic contact. Experiments were carried out to increase the doping of the top contact layer. It was discovered that increased Zn doping seemed to have a negative effect on contact resistance. Subsequent investigation revealed that Zn doping in high Al containing layers led to those layers becoming relatively resistive and resulted in higher resistance ohmic contacts. The optimum doping profile in the contact region will be investigated

3.0. Fourth quarter plans.

3.1. AlGaAs Modulator Array Development.

The modulator array development task is essentially complete.

3.2. AlGaAs Modulator Array Packaging.

Once the packages are assembled and upon receipt of the modulator drivers we will be able to assemble the first packaged 4 channel modulator arrays.

3.3. Polymer Backplane Development.

A laboratory benchtop demonstration of a board to board polymer waveguide based interconnect will be carried out. Boards will be mounted on micropositioner stages so that measurements of the connector's tolerance to alignment can be made.

3.4. Vertical Cavity Surface Emitting Laser Development.

This effort will be continued under the OETC-2 program. No further development will take place under the current program.

4.0. Summary.

During the current reporting period effort was concentrated on verifying the high speed characteristics of the waveguide modulators, and preparing to produce VCSEL arrays.

The waveguide modulators were found to exceed the speed requirements for the link. The speed of the transmitter will therefore be limited by the speed of the driver circuit and the impedance matching between the driver and the modulator.

Progress in the area of VCSELs included the elimination of the special contact layer, and an improved understanding of the factors limiting the ohmic contact resistance.

During the remainder of the program we will package the waveguide modulators into a transmitter module with the driver chips and measure DC performance over temperature. We will also evaluate the board level interconnect demonstration. In particular we will examine the connector tolerance to misalignment.