THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 58, No. 3, March 1979
Printed in U.S.A.

LED Array Package for Optical Data Links

By A. ALBANESE and W. S. HOLDEN

(Manuscript received September 8, 1978)

A package with an array of six LEDs is described. The design represents a first effort at reducing the cost and the size of electro-optical interfaces for applications in low-bit-rate transmission systems and computer data links. A package containing six GaAs LEDs, electrical connections, and a new fiber ribbon connector was fabricated, mounted, and encapsulated using presently available technology. Each LED in the array, with 80 mA dc applied, can couple an average optical power of 5 μW into a graded-index fiber having 0.22 N.A. and 55-μm core diameter. Cross-modulation between adjacent LED signals is smaller than −50 dB. Fiber ribbon connectors fabricated with matching plates which align the fibers with the light output from the LEDs showed insertion losses as low as 0.4 dB.

I. INTRODUCTION

Optical fiber technology is of potential use in data links for computers and switching systems where optical fibers can replace existing copper wires.[1] In most of these applications, the space and the cost of the electro-optical interfaces can be decreased, as in the case of integrated circuits (ICs), by using a batch fabrication process and by having several components share the same package. A further reduction in cost and space would result from the integration of several optical devices and several ICs into a single package. This integration poses a new challenge for IC packaging where this package must include electronic components, heat sink, electrical connections, electro-optical interfaces, and optical connections.

In the present work, a package with an array of six LEDs is presented as an initial effort toward the integration of several electro-optical interfaces that share a single package as a way of reducing space and fabrication cost.

Figure 1 is a drawing of the experimental LED array package fabricated using standard dual-in-line packaging (DIP) techniques. The package has an array of six homojunction GaAs LEDs of the Burrus

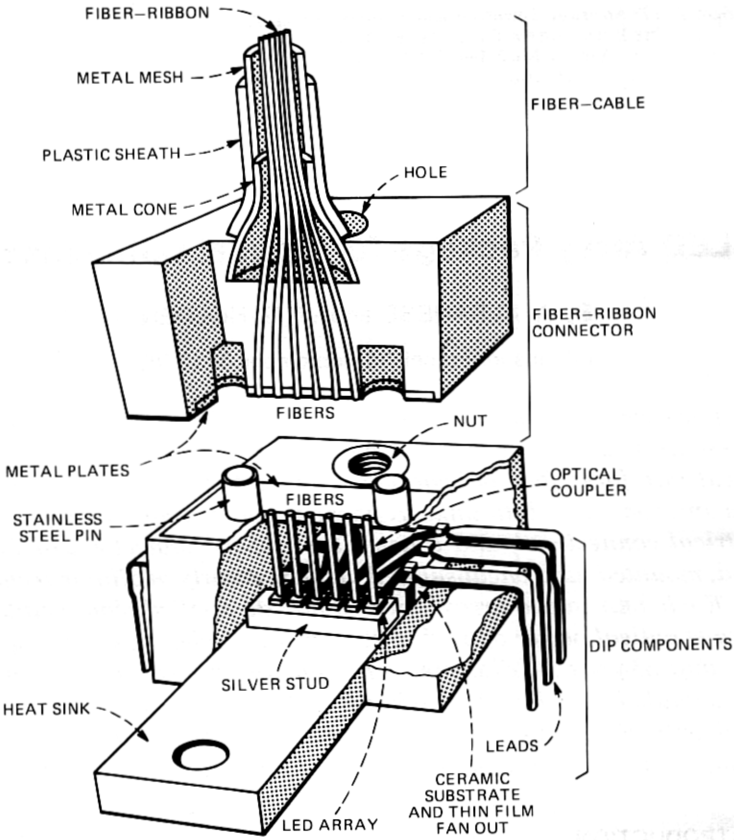

Fig. 1—LED array package.

type,[2] a thin-film fan-out to provide electrical connections, a screw-mountable copper heat-sink that supports the package and also serves as a ground terminal, and a new fiber ribbon connector that couples the light from the LEDs into an array of six fibers.

The LEDs described in this paper were fabricated on 625-μm centers with 60-μm-diameter emitting areas; however, arrays have also been made with 375-μm centers. Each diode in an array produced ≈3-mW total output power into air at 300-mA driving current. The variation in output from diode to diode in a given array is ±0.25 dB. The light output is linear in the current range of ≈25 mA to ≈250 mA. A component spacing of 625 μm was chosen for the LEDs in the transmitter array, the photodetectors in the receiver array, and the fibers in the fiber cable. Having a standard spacing will decrease the design and production costs of such a package and simplify the optical connection between the package and the fiber cable.

The optimum number of LEDs in an array will depend on particular system requirements, fabrication yield of the array package, and the reliability of the LEDs that form the array. A design consisting of six LEDs per package was selected to prove the feasibility of packaging an array of LEDs, to explore its performance, and to determine some fabrication problems that may limit the density of devices in a package.

To facilitate the description, the following discussion of the package design deals separately with the LED array, the DIP part, the optical coupler, and the fiber ribbon connector (see Fig. 1).

II. LED ARRAY

Figure 2 shows an array of six GaAs LEDs of the Burrus type fabricated using a batch process technique. A plasma-deposited silicon nitride film, 750 Å thick, is employed as the Zn-diffusion mask in

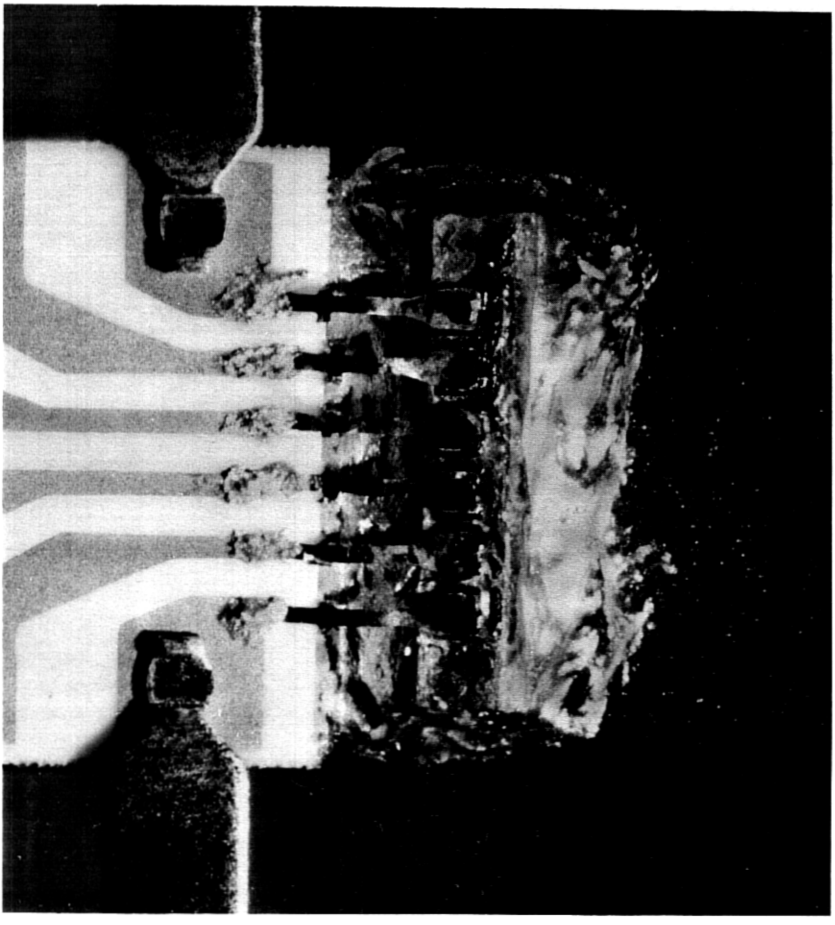

Fig. 2—LED array.

forming the planar p–n junctions.[3] The planar-diffused junction approach is ideal for lateral current confinement in the light-emitting area and thus minimizes the cross modulation between adjacent LEDs.

Burrus LEDs were selected because they were available in the laboratory, but arrays with other types of LEDs or lasers may be implemented.[4,5] However, the chemically etched "well" in the Burrus LEDs may facilitate the alignment of the fibers provided the emitting areas of the LEDs are centered within the "wells."

The LEDs have a 40-MHz bandwidth (3-dB point), and the intermodulation between the light intensity of two fibers placed in front of two adjacent LEDs is lower than −50 dB.

III. DUAL-IN-LINE PACKAGE (DIP) COMPONENTS

The LED array shown in Fig. 3 was mounted using standard IC technology. The stud of silver supporting the LED array is indium soldered to a copper plate that serves as the heat sink and as the electrical connection for all the anodes of the LEDs. Gold-plated silver

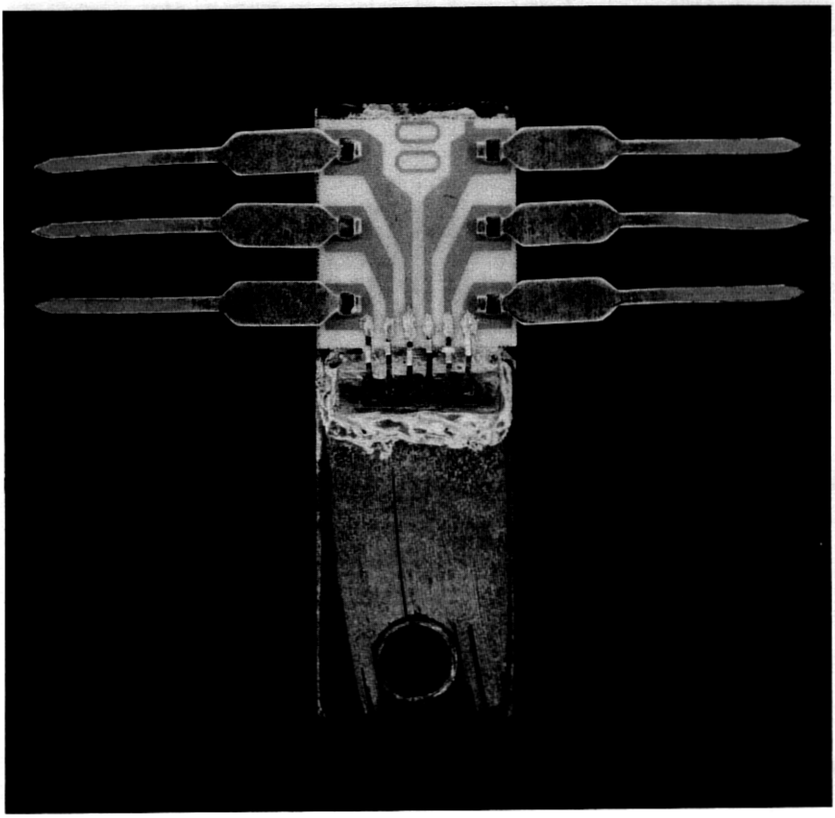

Fig. 3—LED array after being mounted on the copper plate.

tabs connect the cathode of every LED to a thin-film fan-out mounted on a ceramic board with copper leads. There is space in the package for several ICs that can serve as drive circuits for the LEDs.

IV. OPTICAL COUPLER

The optical coupler, which consists of six fiber stubs, serves the following two functions: first, it provides a protective housing for the LEDs and any associated circuitry, and second, it provides a means of light guidance from the LEDs to the fiber ribbon connector.

Several optical couplers have been implemented to improve the coupling efficiency between LEDs and fibers. Selfoc lenses,[6] glass spheres,[7] and tapers are all possible solutions. For an initial trial, short pieces (5-mm long) of graded-index fiber, similar to those in the fiber cable, were used because they were readily available. The characteristics of the fiber are: 0.22 N.A., 55-μm core diameter, and 110-μm overall fiber diameter.

Before inserting the LED array into the mold for the casting operation, the short pieces of fiber were mounted on the LEDs according to the following steps. The LED array is placed on a holder, and a current of 50 mA is applied to each LED. A 2-meter fiber with flat ends couples the light from one of the LEDs in the array to a power meter. The position of the fiber in front of the LED is adjusted until a maximum reading of the power meter is obtained. Then the fiber end is glued to the LED using a photopolymer (Norland Optical Adhesive No. 61). The fiber is subsequently fractured with a diamond scriber to yield a 5-mm length. This process is repeated for each LED in the array.

V. FIBER RIBBON CONNECTOR

A new demountable connector was designed to join a fiber ribbon to the package. The connector utilizes a metal plate with eight holes. Two large holes, 1.574 mm in diameter, serve as the guides for two stainless steel pins which align the two parts of the connector; six small holes, 114 μm in diameter, align the fibers on 625-μm centers. The position accuracy of the fiber must be better than ± 2.5 μm to achieve an insertion loss objective for the optical connection of less than 0.5 dB.[8]

The first prototypes of the connector were made of stainless steel by machining the plates in pairs. The insertion loss measured on connections made of matched plates was 0.4 dB. However, insertion losses as high as 5 dB were measured on connections with plates of different pairs.

VI. CASTING

Figure 4 shows the mold used to cast the package of the LED array. The mold is made of brass and the movable parts are made of stainless steel. The metal plate with two stainless steel pins and six small holes aligns the fibers 625 μm apart. The post inside the mold serves to position a nut before casting. The two side plugs cover the leads of the array during casting.

The LED array with the six short pieces of glass fiber attached is placed into the mold, such that the six fibers enter into the six alignment holes of the stainless steel plate. Finally, the mold is covered and the casting material (epoxy, Bacon compound 84 plus an activator BA-63) is poured into the mold at room temperature.

After a curing time of 24 hours, the LED array package is removed from the mold. The metal plate with two stainless steel pins and the

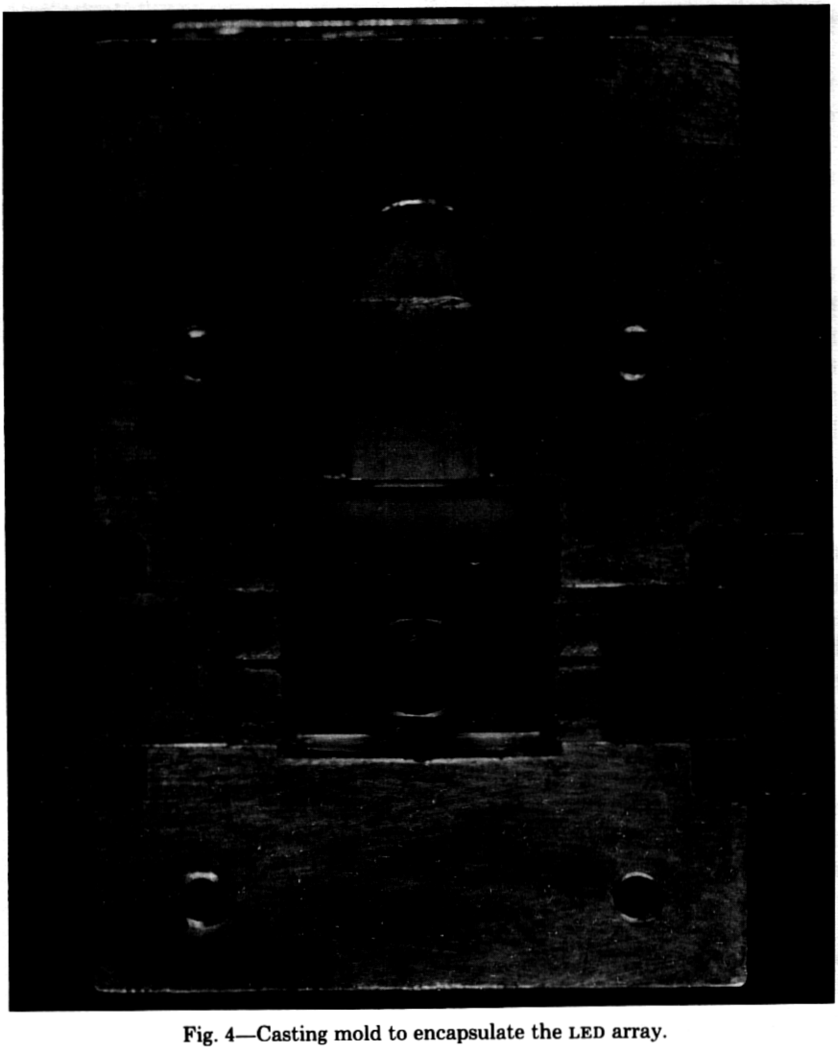

Fig. 4—Casting mold to encapsulate the LED array.

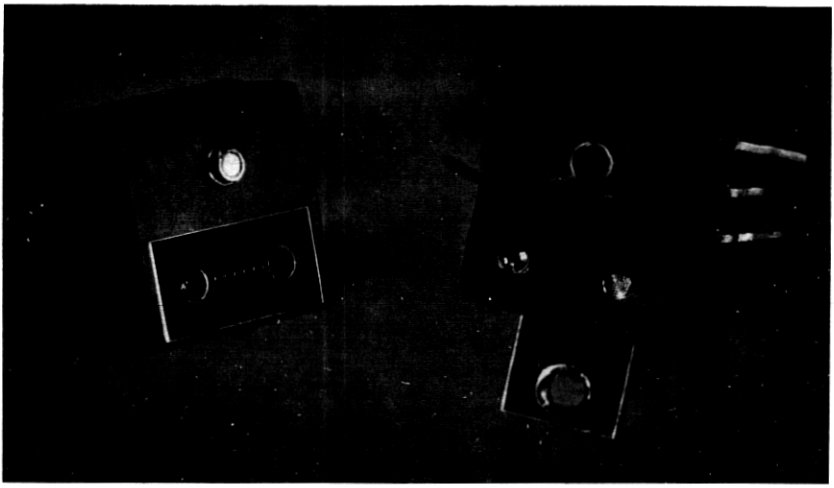

Fig. 5—LED array package and cable termination.

nut, inside the mold, becomes part of the package. The fibers sticking out of the connector surface are shortened using a diamond scriber. The two stainless steel pins are momentarily removed, and the connector surface is lapped and polished.

The cable termination of the ribbon connector was cast in a way similar to the LED array. The six fibers of the cable were threaded into the holes of a metal plate, and the connector was cast using the same mold as in the case of the LED package. Figure 5 shows the finished LED array package and the cable termination.

VII. CONCLUSIONS

A package with an array of six LEDs has been described. The design represents a first effort at reducing the cost and the size of electro-optical interfaces for applications in low-bit-rate transmission systems and computer data links. A package containing six GaAs LEDs, electrical connections, and a new fiber ribbon connector was fabricated, mounted, and encapsulated using presently available technology.

The LEDs in the array, with 80-mA dc applied, couple an average optical power of 5 μW into a graded-index fiber with 0.22 N.A. and 55-μm core diameter. Cross-modulation between adjacent LED signals is smaller than −50 dB. Fiber ribbon connectors fabricated with matching plates which align the fibers with the light output from the LEDs showed insertion losses as low as 0.4 dB.

REFERENCES

1. W. H. Hackett, Jr., C. A. Brackett, L. C. Dombrowski, L. E. Howarth, P. W. Shumate, R. G. Smith, A. W. Warner, R. S. Riggs, and J. R. Jones, "Optical Data

Links for Short-Haul High Level Performance at 16 and 32 Mb/s," Topical Meeting on Fiber Transmission II, February 22–24, 1977, Williamsburg, Virginia.
2. C. A. Burrus and R. W. Dawson, "Small-Area High-Current-Density GaAs Electroluminescent Diode and a Method of Operation for Improved Degradation Characteristics," Appl. Phys. Lett., *17,* No. 3 (August 1970).
3. W. S. Holden, T. P. Lee, C. J. Mogab, and F. B. Alexander, "High Radiance GaAs LEDs Made by Planar Diffusion of Zinc in GaAs using Low Temperature Plasma Deposited Silicon Nitride as a Diffusion Mask," unpublished work.
4. J. D. Crow, L. D. Comerford, J. S. Harper, M. J. Brady, and R. A. Laff, "AlGaAs Laser Array on Silicon Source Package," Appl. Opt., *17,* No. 3 (February 1978).
5. E. G. H. Lean, "Multimode Fiber Devices for Optical Fiber Links, Printing, and Display," IEEE Trans. Commun., *COM-26,* No. 7 (July 1978).
6. H. Yonezu, K. Kobayashi, K. Minemura, and I. Sakuma, "GaAs-Al_xGa_{1-x}As Double Heterostructure Laser for Optical Fiber Communication Systems," 1973 International Electron Device Meeting, Digest of Technical Papers, p. 324.
7. R. A. Abram, R. W. Allen, and R. C. Goodfellow, "The Coupling of Light-Emitting Diodes to Optical Fibers Using Sphere Lenses," J. Appl. Phys., *46,* No. 8 (August 1975), pp. 3468–3474.
8. T. C. Chu and A. R. McCormick, "Measurement of Loss Due to Offset, End Separation, and Angular Misalignment in Graded Index Fibers Excited by an Incoherent Source," B.S.T.J., *57,* No. 3 (March 1978), pp. 595–602.