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EXPERIMENTS ON THE USE OF CCDs TO DETECT PHOTOELECTRON IMAGES

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This paper will discuss the image tube design and processing requirements for building an ICCD. Work is under way at EVC for building an ICCD using the Fairchild CCD 201 (100 × 100) array, and progress will be reported. Demountable tests have been made, exposing parts of a CCD 201 to 15-kilovolt electrons over five radiation levels from approximately 10 to 10^6 rads. Other tubes built by EVC over the last few years which successfully use semiconductors to detect photoelectrons will be described briefly.

I. DIGICON AND PHOTOSIL

Two basic configurations of tubes we have built with semiconductor anodes are shown in Figure 1. The Digicon, which is on the right, is a magnetically focused tube, and the Photosil, on the left, is electrostatically focused. The tubes are, respectively, approximately 2 inches in diameter by 6 inches long and 1 inch in diameter by 2 inches long. Both types of tubes are built using externally processed molecular-beam-formed photocathodes, a process we believe to be important in avoiding poisoning of the semiconductors by alkali metals.

The design, fabrication, and use of Digicons have been described previously (Refs. 1-7). Both parallel output and self-scanned diode arrays have been used. Because one important facet of ICCD design concerns means for mounting CCDs, some Digicon headers will be shown as examples.

Figure 2 shows a header built for a 212-channel Digicon for Beaver at USCD. The ceramic (alumina) header is of multi-layer construction, so that the geometry of the diode leads can be different on the vacuum side and the air side. The basically circular contact configuration shown here is transformed into a rectilinear array of pins on 0.100-inch centers on the backside. The lateral travel of the lead paths between ceramic layers also permits an excellent hermetic seal, since the layers are metallized before the ceramic is pressed and fired. The diode manufacturer, in this case United Detector Technology, brazes the silicon chip to the header and attaches the lead wires from the substrate to the diodes. Figure 3 shows a similar header for Serkowski at the University of Arizona using a different array of 200 diodes. Figure 4 shows encapsulated and unencapsulated 200-channel Digicons.

The Photosils have been developed primarily for four-quadrant photon-counting for guiding on faint objects (Refs. 8 and 9). This is the basic tube configuration that will be used for the CCD 201. When encapsulated, the Quadrant Photosil is 2 inches in diameter and 5 inches long, including space in the rear for preamplifiers (Figure 5). One- and two-channel Photosils are planned for use in general photometry.

All of the previously described tubes have parallel outputs, and it is natural to consider the use of self-scanned arrays to permit the use of increased numbers of pixels. This has been done in the case of the Digicon, and Figure 6 shows a header for tubes using the Reticon 1024 B array. The first of these tubes was built 1 year ago for Tull of the University of Texas, and has been used successfully at the coudé spectrograph of the 107-inch telescope at McDonald Observatory.

To prevent damage to the circuitry on the chip, a mechanical mask is mounted over the chip to permit photoelectron bombardment only of the diodes. Radiation damage to the diodes in the Reticon array causing increased dark currents up to a maximum of a factor of about 15 has been measured, and is reported by Tull, Choisser, and Snow in Reference 6. Similar damage to CCDs which may increase leakage currents and adversely affect charge transfer efficiency is an important consideration in designing, building, and using ICCDs.

II. DEMOUNTABLE TESTS

In cooperation with Currie at the University of Maryland, EVC irradiated a Fairchild CCD 201 with 15-kilovolt electrons in an ultrahigh vacuum system. A mask was fabricated with five 0.020-inch-diameter holes, spaced so that they would have no rows or columns of the array in common. A second mask, with a single larger hole, was used to select the irradiation site for a particular run. The leads from the array were shorted together and grounded through a picoammeter. Photoelectrons were provided by a palladium photocathode, which was illuminated by a low-pressure mercury lamp.

Four exposures were made, representing approximately 10^3, 10^4, 10^5, and 10^6 rads. A fifth exposure was made with the mercury lamp on and the high voltage off. The array was then sent to Currie for tests.

Observation of the operating array showed no visible effect on dark current except for the spot which had received the highest irradiation. The increase in dark signal at this point was of the same order as the variations in dark current which occur normally over the area of the array.

Although these results appear encouraging, they should be considered somewhat inconclusive. The tests would have been more realistic, and possibly more damaging to the array, if the array were operating during irradiation. In addition, it was unfortunately not possible to make the tests at higher voltage, and there is some possibility that the 15-kilovolt electrons could not penetrate to the regions where damage would be more pronounced. In any case, additional more carefully controlled tests will be possible soon with the array in a tube, and with the protective oxide surface over the array removed.

III. ICCD DESIGN AND FABRICATION

Due primarily to the availability of the array, and because of the potential advantages of frontside bombardment if damage mechanisms permit (i.e., economics and cooling simplicity), it was decided to build an ICCD using a modified Fairchild CCD 201 and a Photosil tube design. The project is in cooperation with Currie at the University of Maryland, who will perform the test and analysis of the first devices (Ref. 10). The tubes are being built for a project sponsored by the Air Force Space and Missiles Systems Organization.

As previously stated, the tube will be made using the design of the electrostatically focused Photosil, shown in Figure 1. A 1-inch-diameter header has been built which conforms to Fairchild specifications in the die attach and wire bond region. The contact leads descend to a subsurface layer, where they are brought out to a pin circle near the perimeter of the header. This leaves the center area of the air side of the header clear for a cooling probe, and leaves most of the vacuum side available for brazing the copper sealing washer and Kovar anode cone mounting ring. The header is shown in Figure 7, along with a partially finished 2-inch header to be used in a Digicon with two parallel Reticon RL-1024 B arrays.

Later this month (March 1975), the headers will be sent to Fairchild for attachment of the arrays. The first tube is scheduled to be built in April, and tests will commence immediately.

IV. SUMMARY

Because of the number of successful image tubes built over the last few years at EVC using semiconductors of various types as anodes, we feel that the technology is at hand to build ICCDs as suitable arrays become available. In his paper (Ref. 11), for example, Collins will describe CCD arrays built at Texas Instruments specifically designed and mounted for rear illumination by photoelectrons. We are in hopes that, as future arrays are designed by the semiconductor manufacturers, the potential advantages to their use as photoelectron detectors will be kept in mind.

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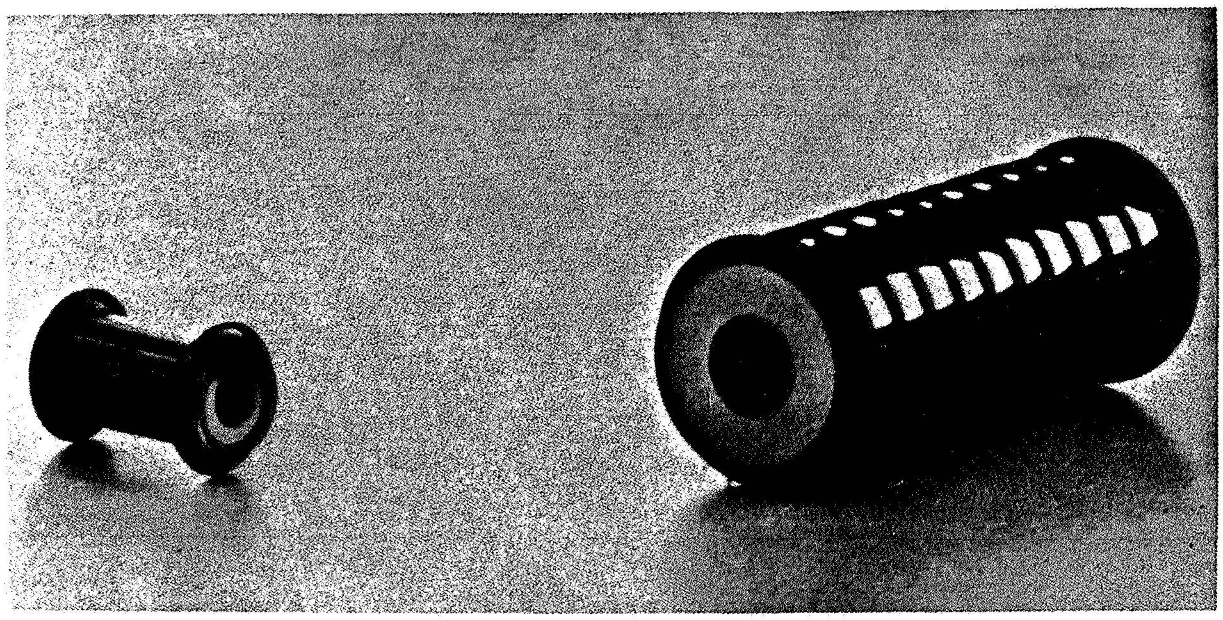

Figure 1. Magnetically focused Digicon (right) and electrostatically focused Photosil (left)

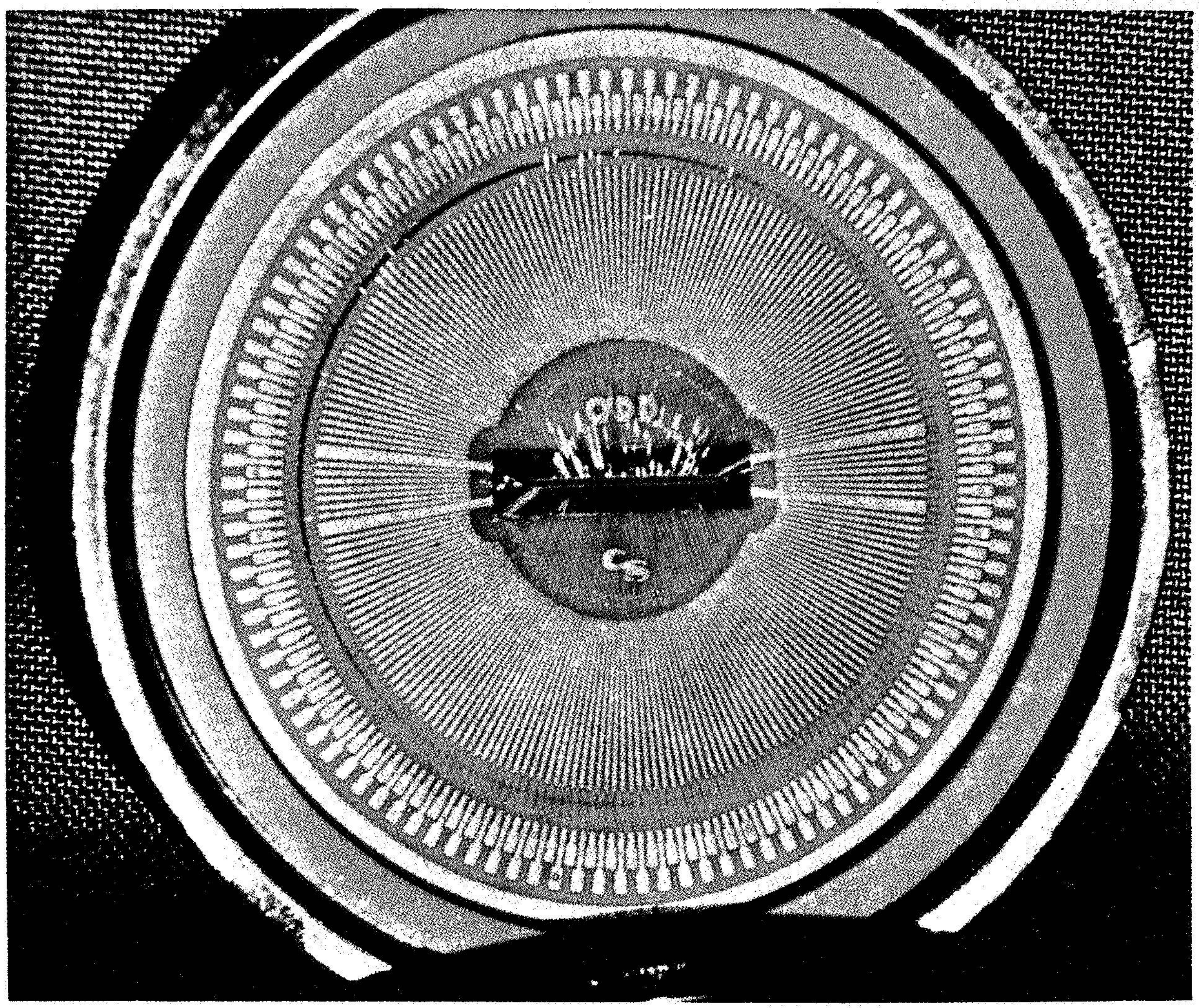

Figure 2. Multilayer ceramic header for a 212-channel Digicon

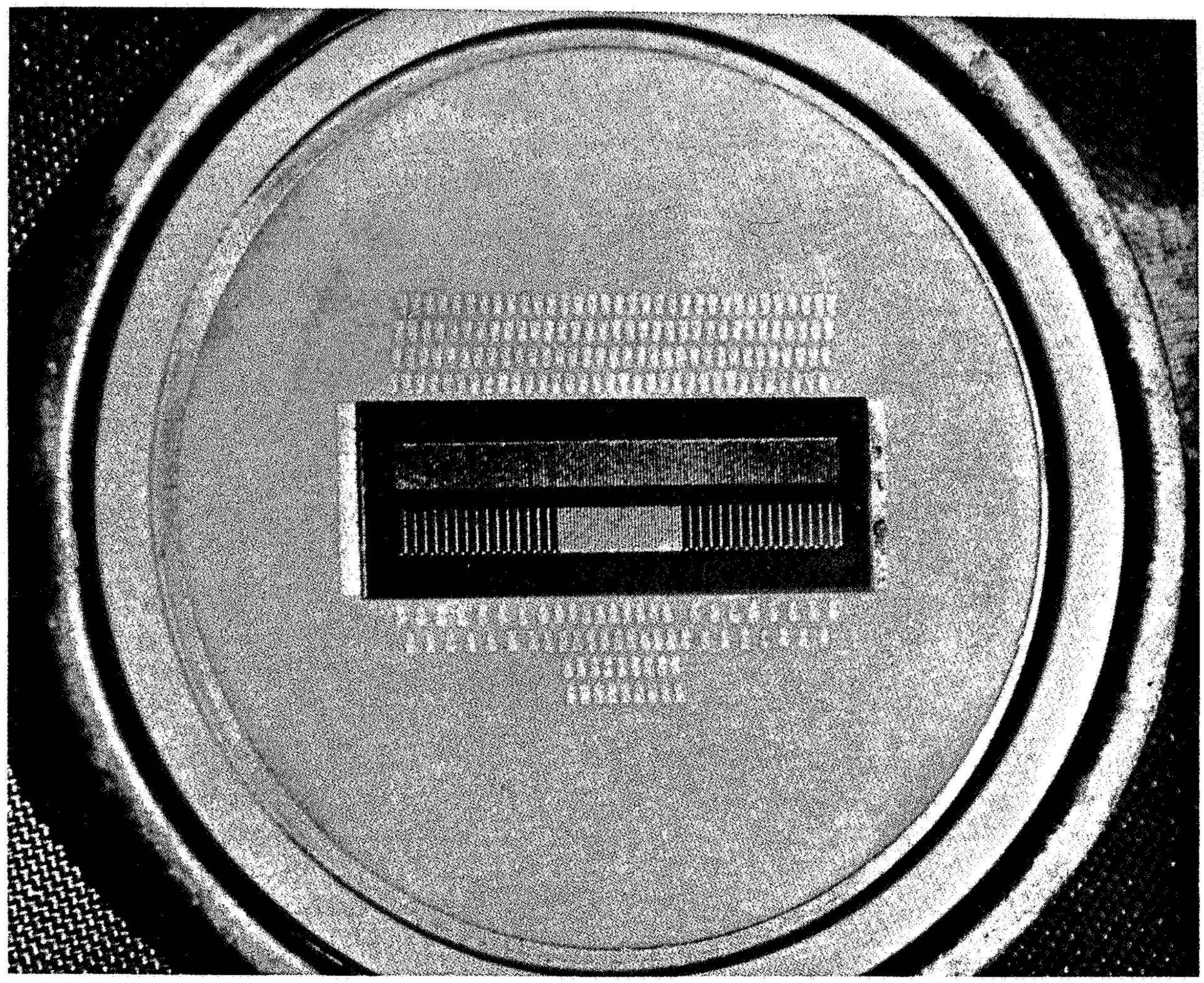

Figure 3. Multilayer ceramic header for a 200-channel Digicon

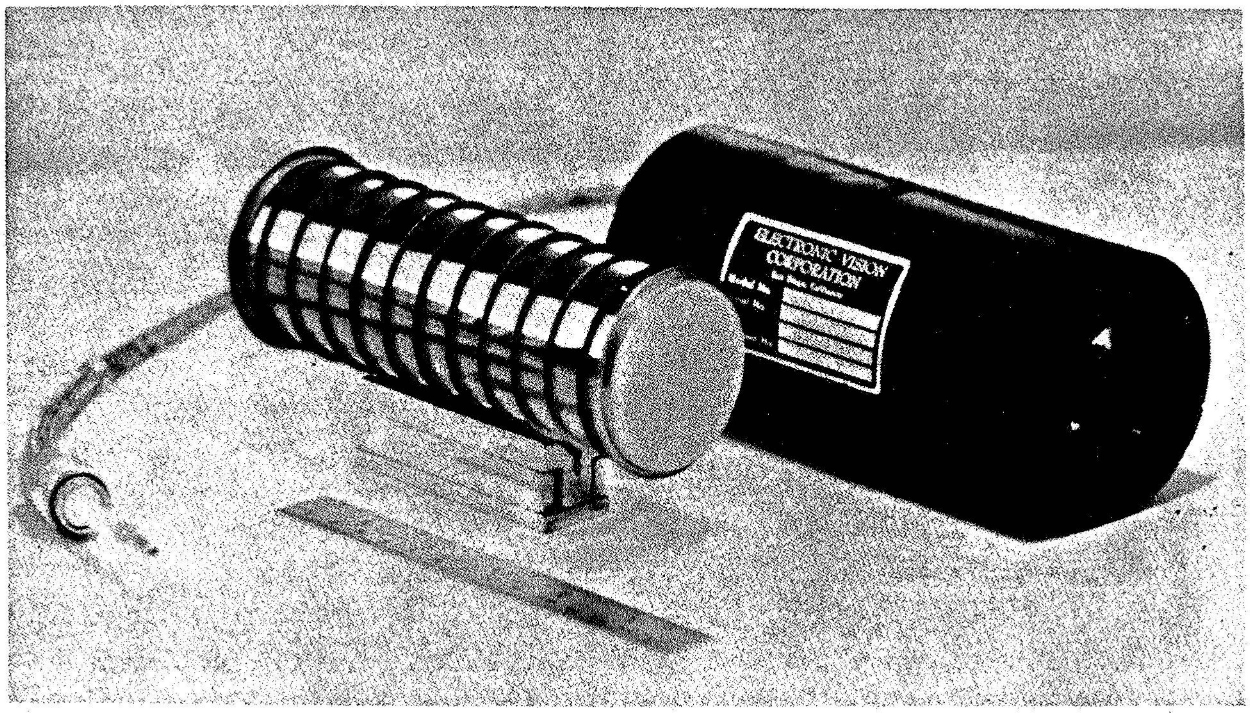

Figure 4. Encapsulated and unencapsulated 200-channel Digicons

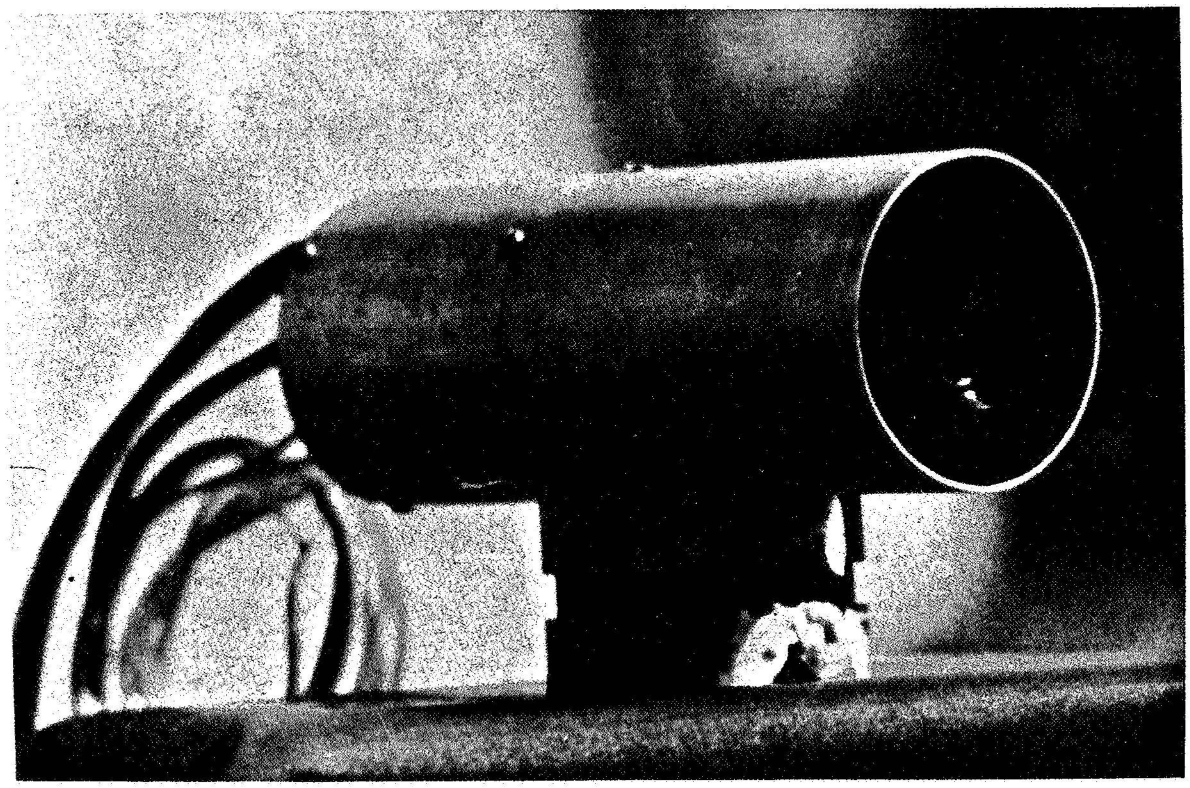

Figure 5. Quadrant Photosil for autoguiding on faint images

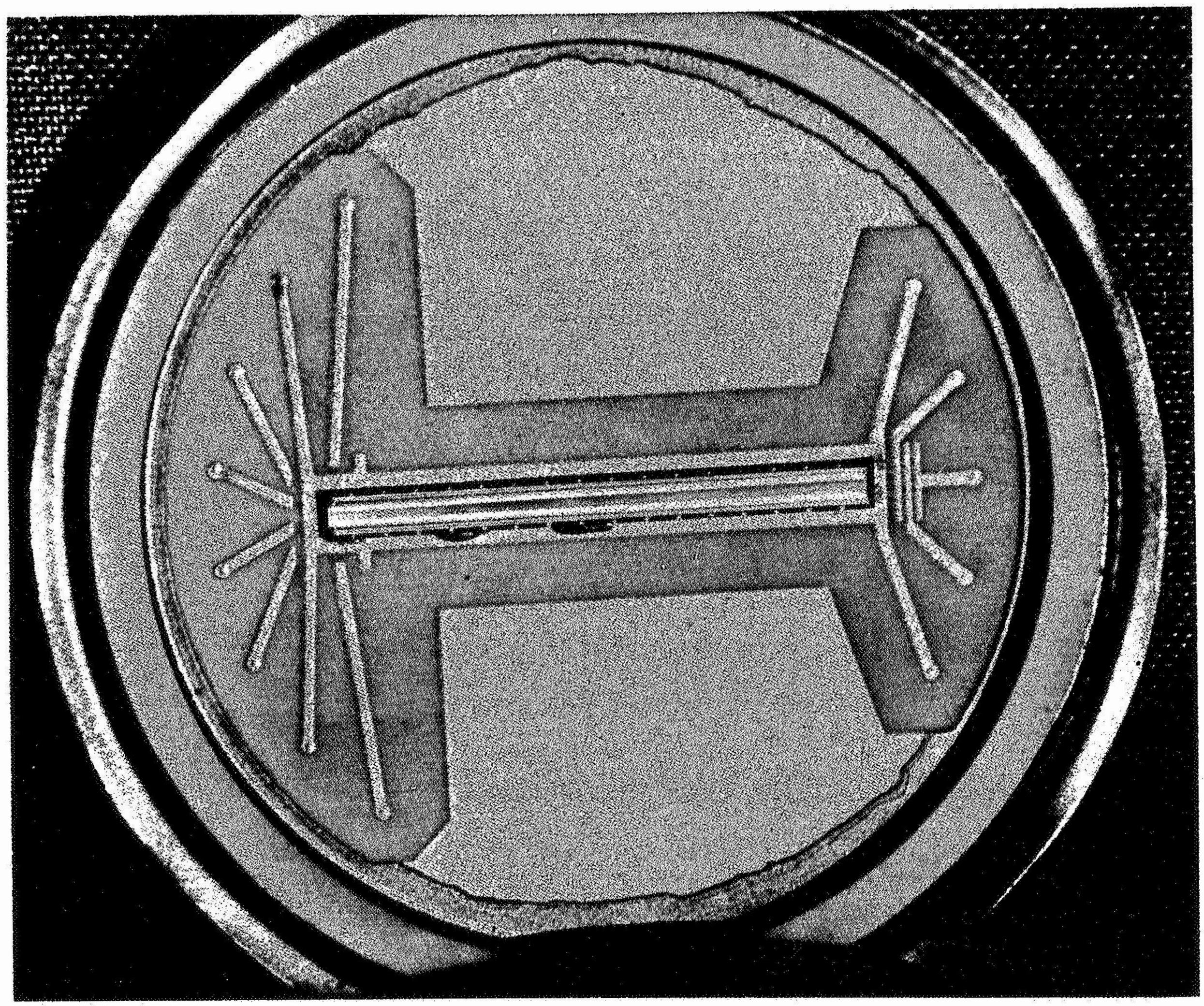

Figure 6. Multilayer ceramic header for a Digicon using the RL-1024 B Reticon array

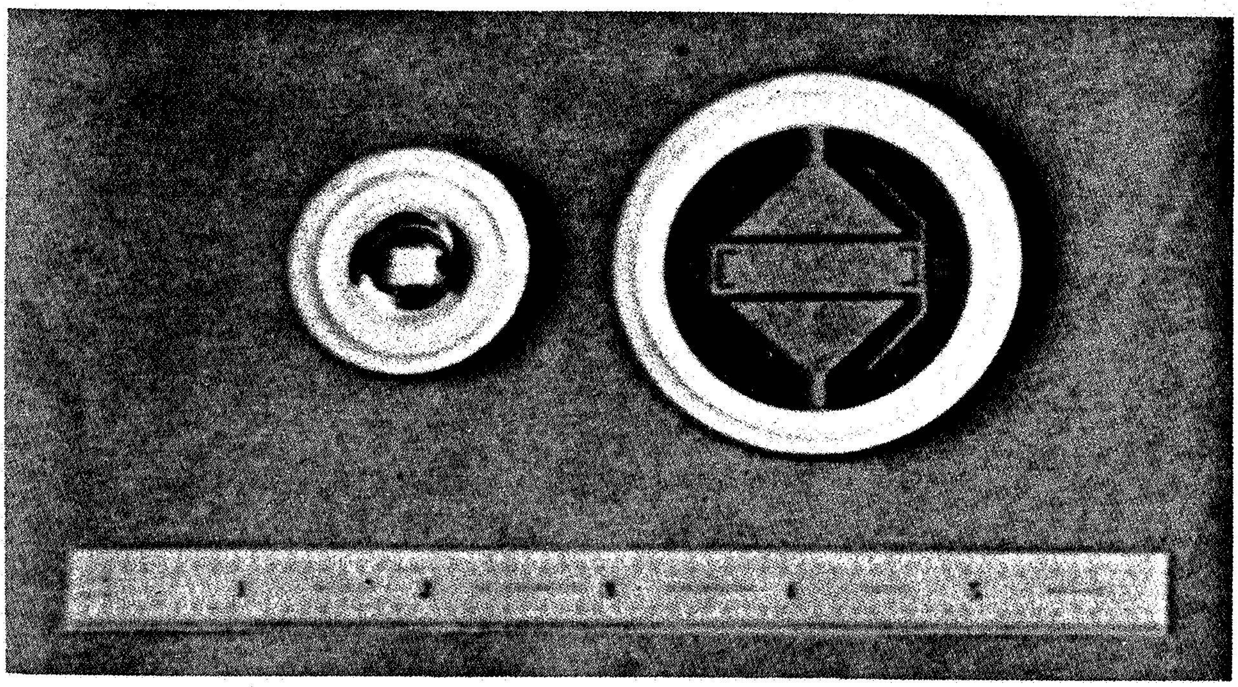

Figure 7. 1-inch-diameter Photosil header made for the Fairchild CCD-201 (left) and 2-inch-diameter Digicon header for two parallel Reticon RL-1024 B arrays (right).