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LB-1049

A MINIATURE VIDICON OF HIGH SENSITIVITY

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A MINIATURE VIDICON OF HIGH SENSITIVITY

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Approved

Stuart Wm Seeley

Experimental models of a sensitive miniature Vidicon pickup tube ½ inch in diameter and 3 inches long have been built and operated in prototype equipment. With such a small photolayer area, the use of a photoconductor having the sensitivity of conventional one inch by six inch Vidicons would require an excessively fast lens or an increase in scene illumination. A new photoconductor has been developed which has sufficient operating sensitivity to more than offset the reduction in light collecting area.

The spectral response of the new tube covers the approximate range from 400 to 800 millimicrons with a maximum in the neighborhood of 600 millimicrons. Resolution and picture lag are adequate for many applications where the small size is particularly attractive. The ½ inch tube requires only one-fourth the heater power and one-third the deflection power of the conventional one-inch Vidicon.

Introduction

In 1950 a new class of television pickup tubes was described for which the name Vidicon was adopted.[1] The Vidicon type tube, first produced commercially as the RCA 6198 and 6326, differs from earlier camera tubes in that the light sensitive surface is photoconductive rather than photoemissive. Such photoconductive materials have the inherent promise, now only partially realized, of more efficient use of the incident light energy to generate a video signal.

The present commercially available Vidicons produce pictures of 600 television lines at light levels of from 3 to 10 foot-candles incident upon the tube. They have proven to be useful in a variety of closed-circuit applications where the simplicity and compactness of the associated equipment has been of value.[2] In the broadcast field the major use so far has been in film pickup apparatus.[3] Indicative of the current trend, this past summer at the political conventions considerable use was made of portable vidicon equipment for live pickup.

The trend toward miniaturization of television pickup equipment has been given added impetus by the rapid progress in transistorized video circuits.[4] Further size and weight reduction of Vidicon cameras was severely limited both by the size of the one inch by six inch commercial tube with its associated deflection and focus field assemblies, and by the operating power requirements of the gun heater and the deflection yoke.

Because the scene to be transmitted must be focussed on the light sensitive element of the pickup tube, the area of the photolayer is chosen to be suitable for use with readily available camera optics. The one inch tube was designed to make use of the variety of lenses available for 16 mm motion picture cameras. When considering a reduction in the size of the pickup tube a photolayer area matched to 8 mm motion picture lenses is a natural choice. Recently a small Vidicon tube has been available from Germany* which employs this area target.

There are a number of effects associated with the reduction by a factor of four in the area of the photolayer of the pickup tube. An 8 mm lens operating at the same f/number as its 16 mm equivalent has one-fourth the light gathering power and twice the depth of field. If a photoconductor of the same sensitivity is used both in the larger and smaller target area tubes and the associated lenses are set at the same f/number, an increase in scene illumination of four times would be required to produce an equal output signal in the small tube. This is strictly true only if the signal generated is proportional to the amount of incident light. If the gamma of the surface, that is the slope of the log signal vs log illumination plot, is less than unity, then an even greater increase in scene brightness is required. A gamma of less than unity is a desirable characteristic in the pickup tube since it increases the dynamic range of the device. The photoconductor used in the present Vidicon has a gamma of about 0.7.

An increase of scene illumination can be avoided by using a faster lens for the small camera and sacrific-

*Physcialish — Technische Werkstatten, Wiesbaden, Germany.

ing depth of field. Consider the case where the depth of field of the two lenses is made equal. This is done by making the actual aperture diameters identical, that is by employing a smaller f/number with the 8 mm lens. This brings the total light flux back to the same level for each tube though once again the signal of the small tube is reduced by the gamma factor. The practical limits to this approach are the availability and cost of 8 mm lenses of speeds greater than f/1.9. It is apparent, therefore, that a small Vidicon should have a photoconductor of greater sensitivity to compete successfully with the one inch tube.

It is the purpose of this bulletin to describe the characteristics of an experimental minature Vidicon tube which employs a new photoconductor layer of higher operating sensitivity than has previously been available. Adequate signal is generated with a scene illumination of 10 footcandles and an f/1.9 lens to give a noise free display.

Description of the New Tube

General

Fig. 1 shows the experimental small Vidicon, the standard one inch Vidicon, and the Image Orthicon pickup tubes. The diameter of this new tube is ½ inch, the length three inches. As with the standard Vidicon, the ½ inch tube operates in a linear magnetic field of 80 gausses (Fig. 2). This can be either an electromagnetic or a permanent magnet field. The power required to deflect the tube electromagnetically is about 20 ampere turns or approximately 1/3 that of the larger Vidicon. This modest power requirement falls within the capabilities of low power transistors of the audio amplifier variety.

The small heater-cathode assembly has been designed to minimize the heat conducted away through its support structure. The gun dissipates approximately 0.8 watt, a fourth that of the larger tube. The beam spot has been made smaller by reduction of the limiting gun aperture, so that the resolution is not greatly sacrificed over larger tubes, even though the scanning raster is only 0.24 by 0.18 inch.

In order that the optical scene can be imaged on the light sensitive material, the uniform layer of photoconductor which is only a few microns thick is deposited on a transparent, conducting signal plate. Contact to the other surface of the layer is made by the electron beam which scans over the entire raster once each 1/30 second if the normal television scanning rate is used.

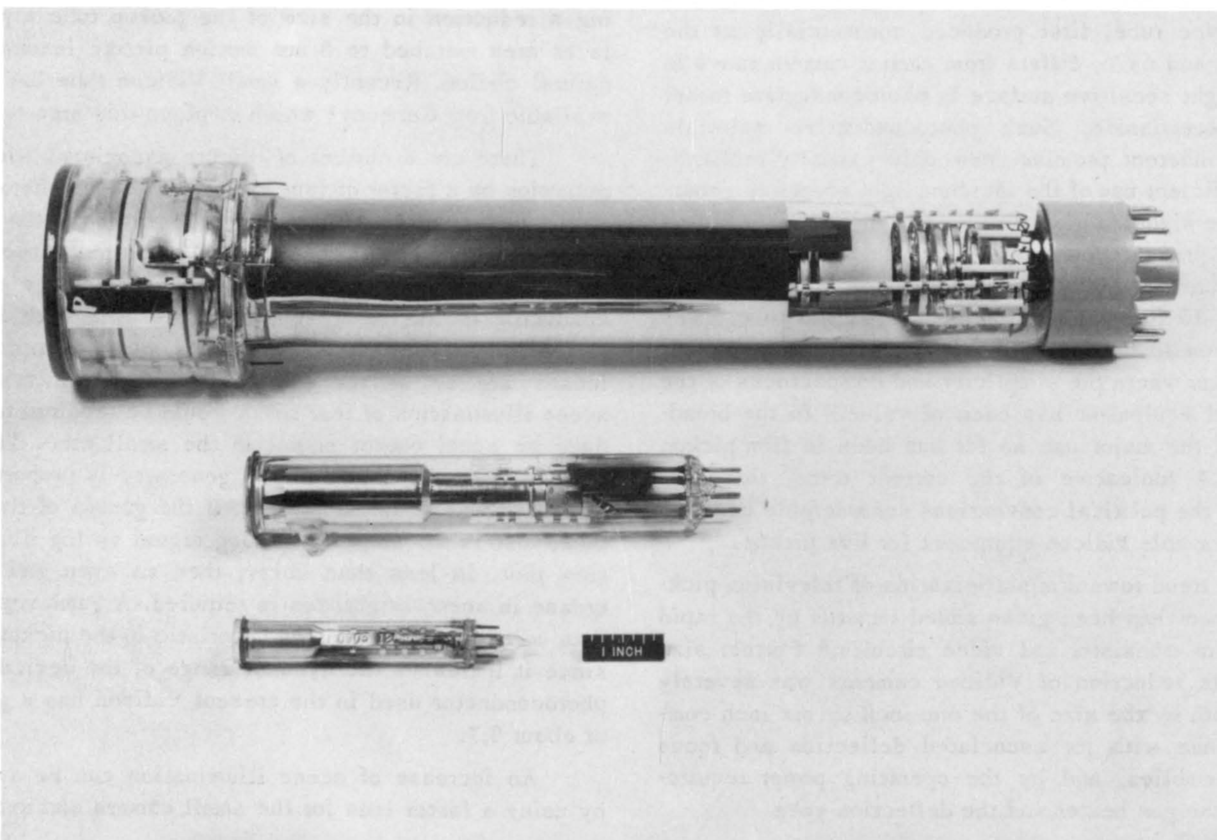

Fig. 1 – Photograph of three pickup tubes; Image Orthicon, one-inch Vidicon and experimental miniature Vidicon.

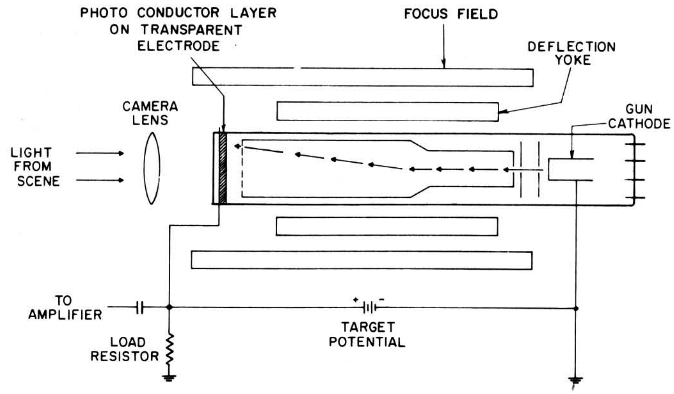

Fig. 2 – Schematic diagram of Vidicon tube and its associated components.

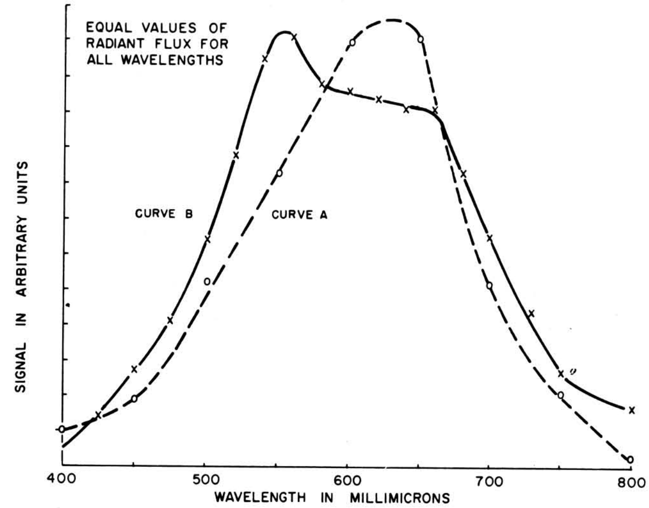

Fig. 3 – Spectral response of new photoconductor surface being used in miniature Vidicon. Relative output signal of the tube is shown as a function of wavelength for equal energy illumination.

With an electric field applied across the photoconductor layer the effect of exposure to an optical image is to produce a point by point variation in conductivity. This causes a charge pattern to be built up on the scanned surface which is related to the light image. As each point of the raster is contacted cyclically by the low velocity beam, sufficient charge is deposited to restore the surface to cathode potential, at the same time causing a video signal current to flow in the lead connected to the signal plate. In order that full use will be made of the charge generated by the absorbed light, the photoconductor must be sufficiently resistive in the dark for its dielectric time constant to be greater than the 1/30 second frame time. This requirement places the photoconductor in the insulator class, the dark resistivity being of the order of 10^{11} ohm-cm or greater.

Photolayer

The new photoconductive layer used in the miniature Vidicon has a sensitivity of the order of 1000 to 2000μa/lumen when operating at signal levels of the order of 0.02 to 0.05μa. The spectral response for the higher sensitivity layers peaks at 650 millimicrons (mμ) as shown by curve A of Fig. 3. A more panchromatic layer with a peak response at 550 mμ as shown by curve B can also be made. The gamma of the surface is dependent upon the current density. At low illumination levels the signal varies linearly with light. At higher illumination levels, such as will produce an output signal of the order of 0.05μa or greater, the gamma drops to 0.5. The abruptness of the change in gamma has varied from one sample to another. In some cases the break has been sharp, and in others there has been a gradual shift. The reduced gamma at high light levels permits the tube to operate with a broad range of light levels in a given scene.

The operating potential of the signal plate varies from 10 to 30 volts. The value chosen for the sensitivity data quoted above is that which will limit the dark current to the order of 0.01 to 0.02μa.

The photoconductor material is deposited on the signal plate of the bulb face by high vacuum evaporation. The layer appears as a dark, glassy deposit about 2.5μ thick. X-ray diffraction studies give no indication of long range order in this type layer. Since the deposit is not affected by exposure to the atmosphere at reasonably low temperatures it is possible to fabricate the film before the bulb is sealed to the gun assembly. This allows the side tip of some earlier tubes to be eliminated.

For the beam to discharge the pickup tube target in one sweep the capacitive time constant, determined by the product of the target capacity and the beam resistance, should be less than 1/30 second. The smaller target capacity resulting from a reduction in the area of the target makes it possible to use layers which are thinner or have a higher dielectric constant.

Variations in the technique of evaporation of the same material can produce a wide variation in physical properties. A case in point is antimony tri-sulfide (Sb_2S_3)[5,6] in which a variation of the effective dielectric constant of 5 times can be achieved. Table I shows the associated properties of the dense high capacitance form and the porous low capacitance form of Sb_2S_3. The operating potential of this latter form indicates that there has been a highly desirable increase in dark resistivity, but a reduced sensitivity. The slow decay of the photocurrent for the glassy form restricts its usefulness to special applications.

If the lag, that is the residual signal remaining after the illumination is removed, were due solely to the capacitive time constant a reduced area target of the

TABLE I

Antimony Tri-Sulfide Evaporated Layers

	Porous Layer	Glassy Layer
Capacitance/cm^2	1500$\mu\mu$f	12,000$\mu\mu$f
Operating potential (for 0.02μa dark current)	30-70 volts	3-5 volts
Sensitivity	100μa / ℓ	1000μa / ℓ
Peak of spectral response	450 mμ	700 mμ
Picture lag (residual signal 1/20 second after removal of illumination level of 3 foot-candles on the photolayer)	<20%	50%

dense Sb_2S_3 would have several attractive characteristics. Unfortunately the major portion of the lag signal from this layer is of the type associated with the photoconductive process itself.

Photoconductive lag can generally be reduced by increasing the current density in the material. It follows that the same amount of light concentrated on a smaller area of photoconductor will give reduced lag while preserving the same depth of field in the scene. However, the factor is not sufficient to make the normal solid form of Sb_2S_3 have sufficiently low lag to be suitable for a half inch tube of general utility.

The lag of the new photoconductive layer used in the miniature Vidicon is less than that of other material with similar photosensitivity. Fig. 4 shows the percent of signal remaining after each of the first six sweeps of the beam following the removal of illumination. This is shown for a number of levels of illumination on the tube face.

At each light level the signal current was made the same by adjusting the target potential to yield a signal of 0.2μa. Thus, the lower the illumination level the higher the dark current because of the higher operating potential. This accounts for the signal being rapidly buried in dark current for the 0.16 footcandle case and so this curve is not extended beyond 3/60 sec.

The shape of the signal decay vs time plot of the new photosurface when compared with the photosurface used in earlier Vidicons is somewhat different. The initial decay is not as rapid, but there is a smaller long term component of lag. This makes exact comparison by subjective tests somewhat difficult.

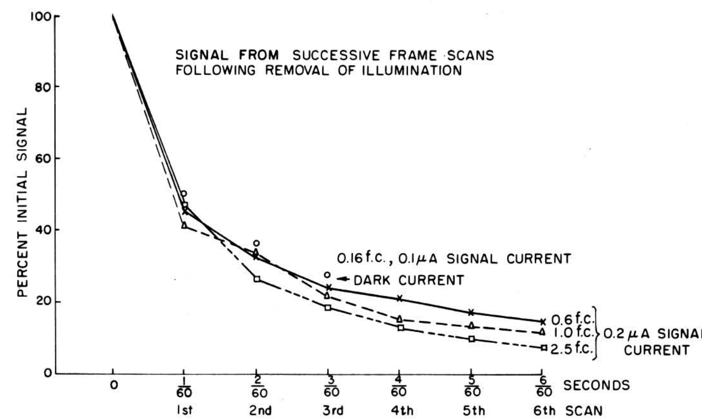

Fig. 4 – Decay of photocurrent in the miniature Vidicon after the removal of illumination. This is shown as the percent of the initial signal remaining after each successive sweep of the beam for six frames spaced 1/60 second apart. This data is given for four different levels of illumination on the target.

Comparative Performance

Tests were conducted with an experimental ½ inch Vidicon and a typical one-inch tube operating in the same type of equipment and producing comparable images of the same scene. With 10 to 20 footcandles falling on

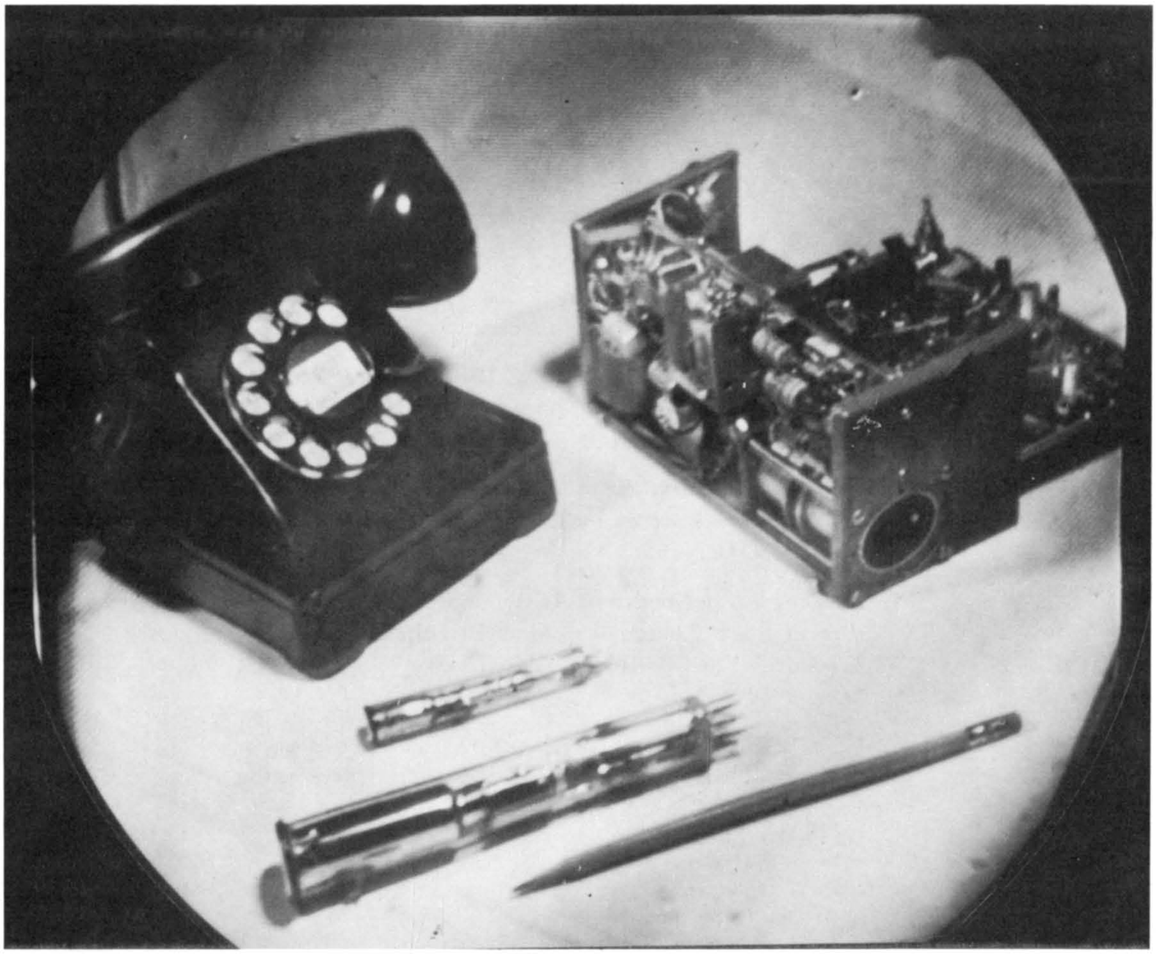

Fig. 5 – Kinescope display of scene picked up by the miniature Vidicon operating in a standard industrial television equipment. In the upper right hand corner is a developmental all transistor camera for use with the new tube. This equipment is self-contained, the video output being a modulated VHF signal which can be connected directly to the antenna terminals of a standard television receiver.

the scene, equivalent output signals with comparable lag were observed in each picture when the small camera was operating with the lens at f/4 and the lens of the large camera at f/2. The combined difference of two lens stops and the four to one area difference indicates an operating sensitivity for the small tube 16 times greater than for the larger tube. Using the same f/number with the small camera as with the large, the scene illumination could be reduced to one fourth its previous value, at the same time preserving an increased depth of field.

Fig. 5 is a photograph of the kinescope display of a standard industrial television equipment using a miniature Vidicon in the camera. The bandwidth of the amplifier was 6.5 mc and there was no aperture correction. The picture shows the large and small Vidicon tubes and two familiar objects. In the upper right hand corner is a completely transistorized camera which was developed to use the new pickup tube. The cover has been removed and the hinged panel on the right has been swung open. All circuits necessary to operate the Vidicon, including deflection and video amplification sufficient to modulate a VHF carrier are contained in this case. The output signal can be connected directly to the antenna terminals of any standard television receiver. The deflection assembly in which the Vidicon is inserted is at the lower left hand side of the case; the lens covers the large opening at the front. The camera may be powered either from the a-c line or by batteries, the total consumption being about 5 watts.

A.D. Cope

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