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Picker

[11] **3,851,205**

[45] **Nov. 26, 1974**

[54] **JUNCTION TARGET MONOSCOPE**

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[73] Assignee: **Raytheon Company**, Lexington, Mass.

[22] Filed: **Jan. 26, 1973**

[21] Appl. No.: **327,047**

Related U.S. Application Data

[60] Division of Ser. No. 228,732, Feb. 23, 1972, abandoned, which is a continuation of Ser. No. 37,552, May 15, 1970, abandoned.

[52] **U.S. Cl.** ..... **315/11**, 315/12, 313/65 T, 313/65 AB

[51] **Int. Cl.** **H01j 31/48**

[58] **Field of Search** ..... 315/11, 12, 10; 313/65 AB, 313/65 T

[56] **References Cited**

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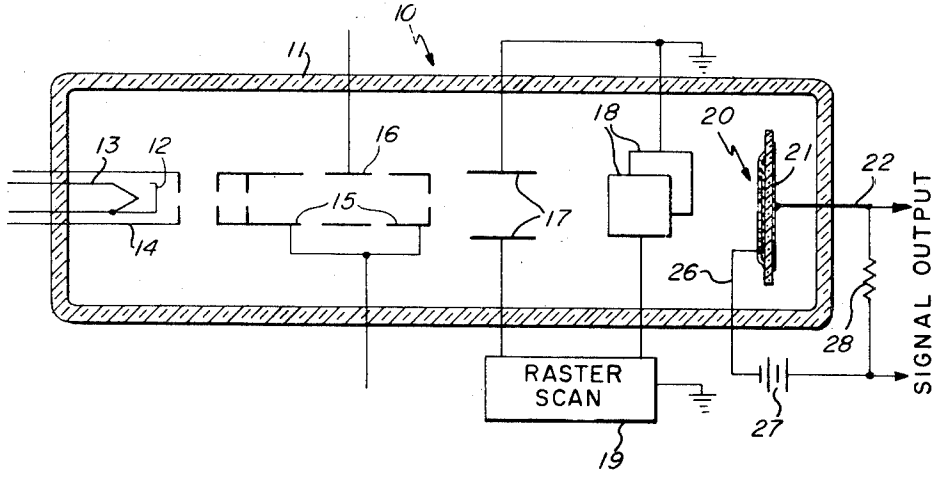
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Primary Examiner—Benjamin R. Padgett
Assistant Examiner—P. A. Nelson
Attorney, Agent, or Firm—Joseph D. Pannone; Milton D. Bartlett

[57] **ABSTRACT**

A signal display system having a visual display and a display signal generator in which a semiconductor junction target has a high conductivity P layer, a low conductivity N layer, and a surface layer of insulating material having holes in the shape of letters or other characters. The target semiconductor junction is reverse biased so that when an electron beam striking the target is scanned over the character apertures, it will produce carrier multiplication in the target and an output signal several orders of magnitude greater than a conventional monoscope. The same principle may be used for a camera pickup tube when beam electrons returning from a light sensitive target are multiplied on striking a reverse biased junction target.

10 Claims, 7 Drawing Figures



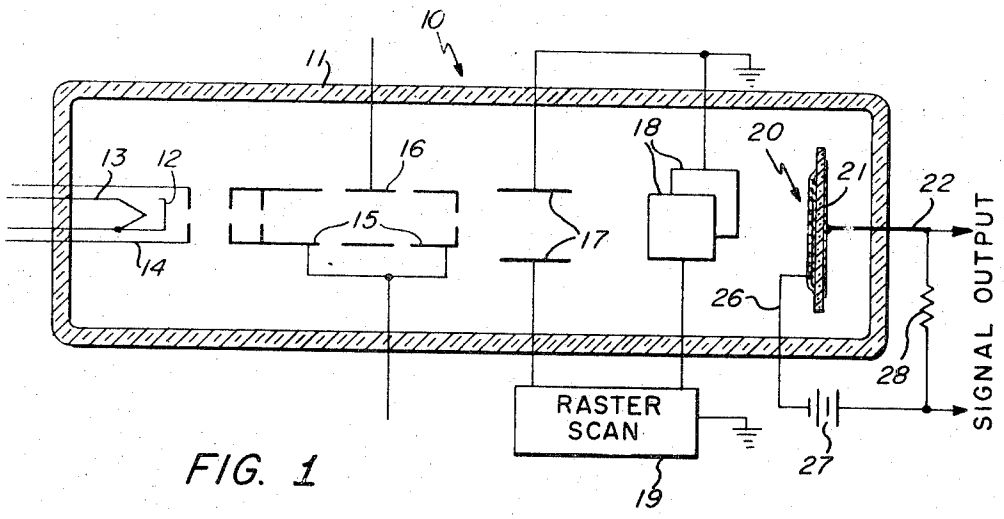


FIG. 1

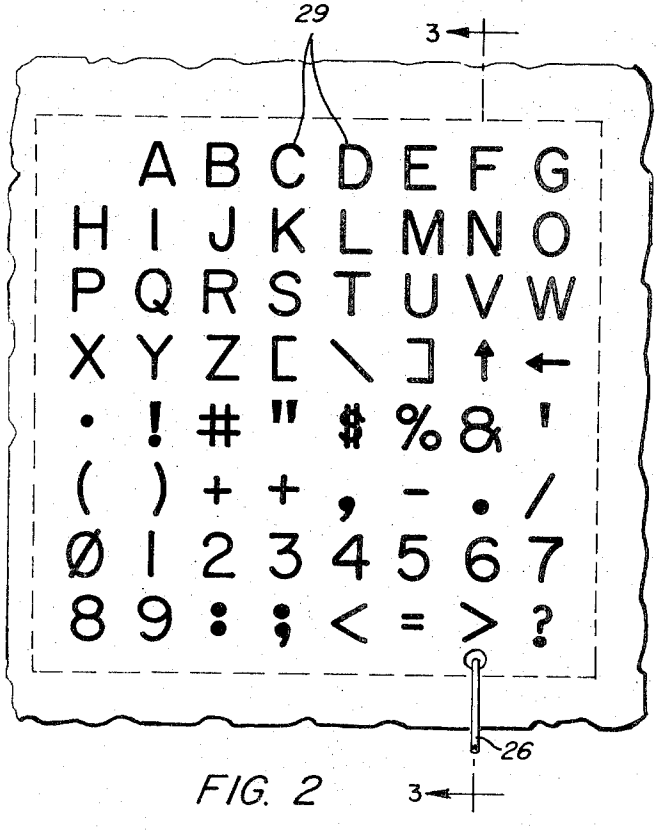


FIG. 2

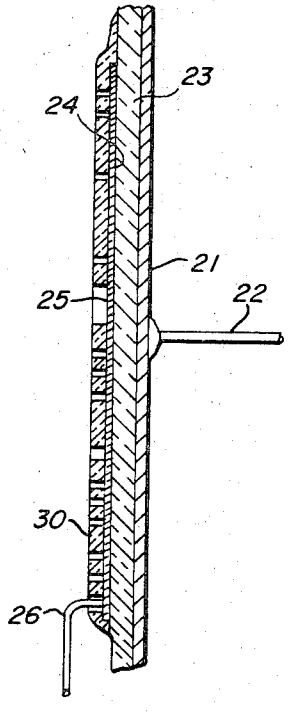


FIG. 3

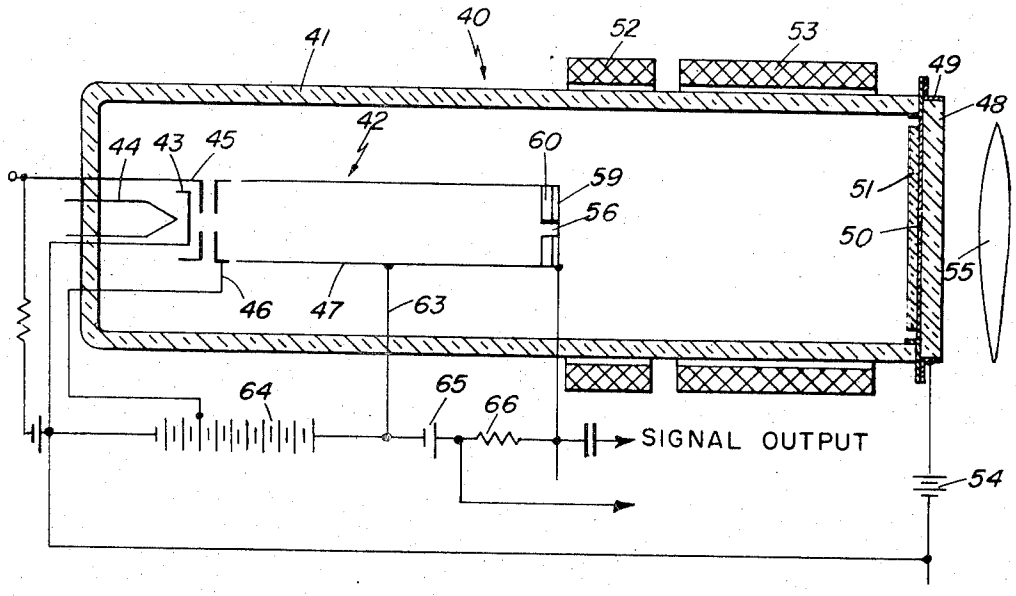


FIG. 4

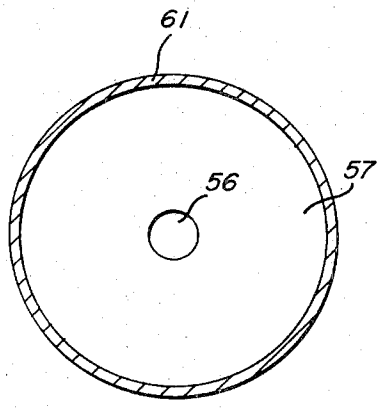


FIG. 5

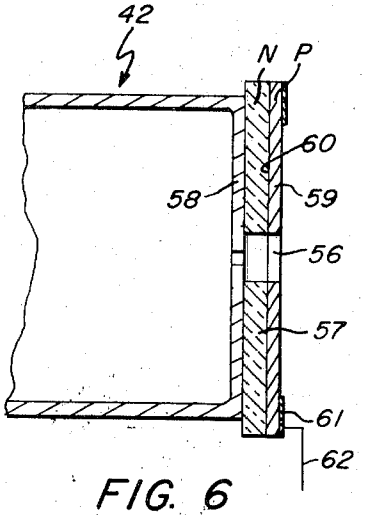


FIG. 6

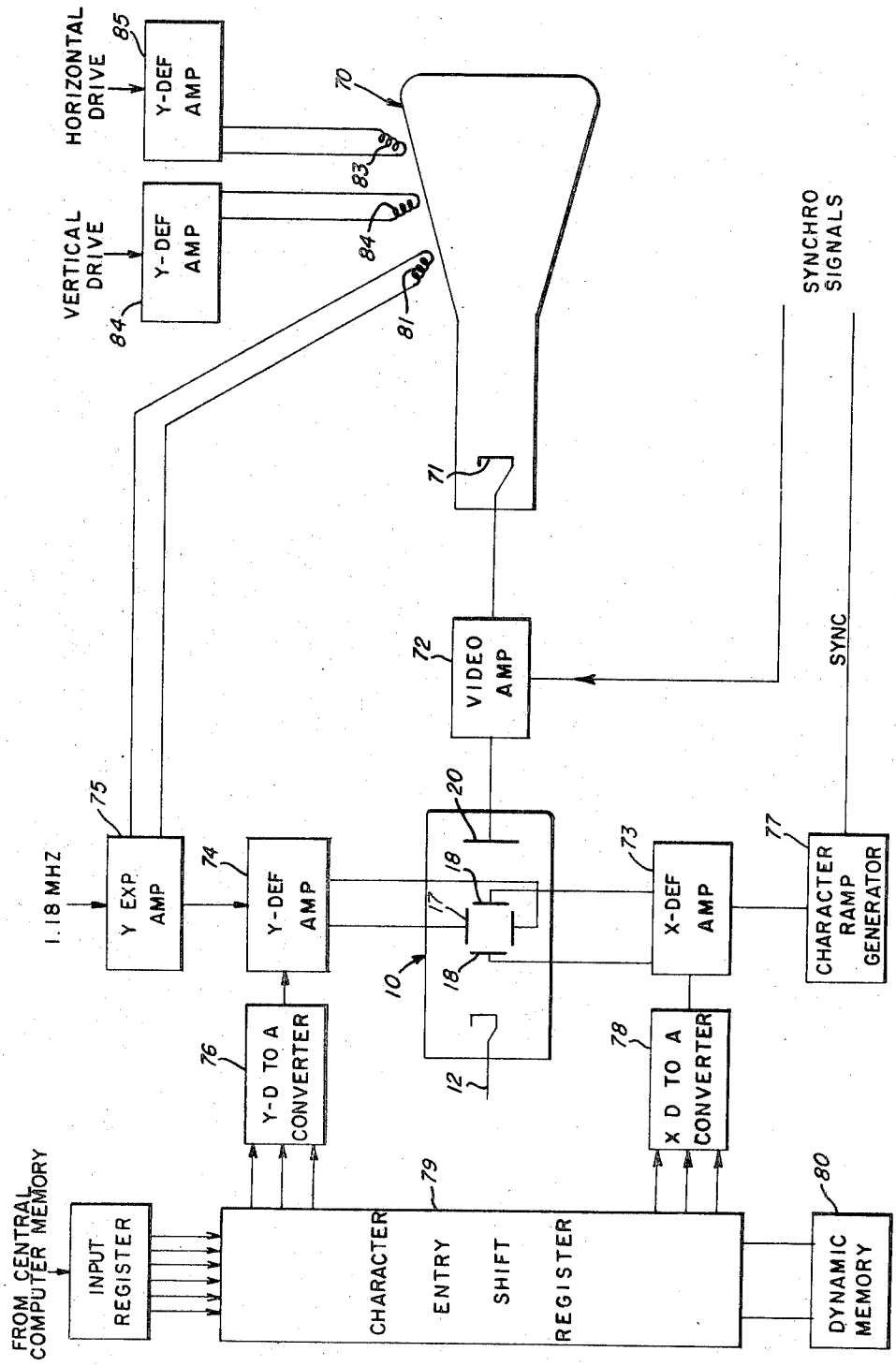

HORIZONTAL DRIVE
85
Y-DEF AMP
VERTICAL DRIVE
84
Y-DEF AMP
84
70
83
84
81
71
SYNCHRO SIGNALS
SYNC
72
VIDEO AMP
20
75
1.18 MHZ
Y EXP AMP
74
Y-DEF AMP
18
17
18
10
12
73
X-DEF AMP
77
CHARACTER RAMP GENERATOR
76
Y-D TO A CONVERTER
78
X D TO A CONVERTER
FROM CENTRAL COMPUTER MEMORY
INPUT REGISTER
79
CHARACTER ENTRY SHIFT REGISTER
80
DYNAMIC MEMORY

FIG. 7

JUNCTION TARGET MONOSCOPE

This is a division of application Ser. No. 228,732 filed Feb. 23, 1972, now abandoned which is a continuation of application Ser. No. 37,552 filed May 15, 1970, now abandoned.

REFERENCE TO RELATED APPLICATIONS

Application Ser. No. 19,190, filed Mar. 13, 1970 now U.S. Pat. No. 3,697,955, by Joseph E. Bryden, on Visual Display System and assigned to the same assignee as this application is hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

Conventional monoscopes display systems are well known and comprise a cathode ray tube driven by a monoscope wherein a target electrode of aluminum has a pattern of characters deposited thereon in the form of carbon, which has a different secondary emission characteristic from the aluminum base material.

Under constant use such a monoscope will deteriorate in quality within a few thousand hours, and, in addition, the signal level output from the monoscope is relatively low and changes as the monoscope ages.

SUMMARY OF THE INVENTION

This invention provides for an improved monoscope or light sensitive tube display system using a target comprising semiconductor material. In the monoscope, the target comprises a wafer having a first layer of, for example, silicon, germanium or any other suitable seimconductor material, coated on one side with a conducting layer of metal, such as gold and attached to a base support plate. The other side of the wafer has a layer of low resistivity semiconductor material of the opposite conductivity type from said first layer and is covered by a mask which, at the velocity of the electron beam, is substantially impervious to electron bombardment, and may be of any desired material such as a metal, semiconductor or insulator or combinations thereof. Apertures through the mask expose the semiconductor material, and the shape of the apertures is such that a beam scanning across the apertures will produce an output signal for presentation on a cathode ray tube of the desired character. A back bias is applied to the junction by an external voltage source in series with a load impedance across which the signal output is generated.

Preferably, the target is made of a layer of N type silicon on the order of 10 mils thick having a realtively high resistance such as 10^{13} charge carriers per cubic centimeter. One side is coated with a metal conductor and the other side has diffused into it a thin layer of P type impurity, in sufficient concentration to produce a high conductivity P layer, such as for example, 10^{19} carriers per cubic centimeter. The P layer is, for example, less than 1 micron thick. The high impurity concentration in the P layer causes the P layer to act substantially as a conductor so that an additional conductive coating over the P layer is not required but may be used if desired. Rather, a contact made with the P layer and the external circuitry at one point will produce good contact with the entire useful surface of the target. The mask when made, for example, of silicon dioxide is of sufficient thickness, for example, several microns, that

the electron beam will not penetrate into the semiconductor body to the region of the junction.

A substantial back bias voltage is applied across the junction in series with an external load so that when the electron beam impinges on the semiconductor, it will penetrate into the junction region where a substantial voltage gradient is produced by the back bias. Electron-hole pairs are generated in proportion to the electron velocity as determined by its accelerating voltage divided by the theoretical voltage required to generate one electron-hole pair. In the case of a silicon target, this is approximately 3.6 volts, and therefore when an electron beam accelerated, for example, by 3,600 volts strikes the target an output signal is produced which is approximately 1,000 times the beam current. Because of the high output signal possible by relatively high beam voltages, beam current may be reduced, thereby improving definition and permitting reduction of the size of the target. This in turn reduces the output capacitance produced primarily by the target junction region thereby increasing the possible frequency response. A video frequency response extending from substantially 0 to over 100 megahertz is practicable in a display system using such a monoscope.

In a further embodiment of the invention, the semiconductor junction target is positioned on or adjacent to the gun structure and the main target structure is made separate therefrom. The main target structure produces a return stream of electrons modulated with information on the main target structure. The main target structure is, for example, a photoconductive target comprising for example, a layer of antimony trisulfide which is charged by the electron beam and areas of which are discharged by the impingement of a light pattern thereon. The discharged portions of the target accept recharging electrons when scanned by the beam whereas those portions which are not discharged reflect electrons from the beam which strike the junction target. The velocity at which the electrons strike the junction is approximately that produced by cathode to anode potential, and may be, for example, 500 to 5,000 volts. The resulting current multiplication produces an output signal across an external load impedance connected in series with an external back bias voltage source across the junction.

The invention provides for an improved display system in which any tube, such as a monoscope, light sensitive tube, informational storage tube, or other tube which can be made to produce an informational signal generated by deflection of an electron beam and by charge carrier multiplication in the tube, supplies an information signal output to a display device such as a cathode ray tube intensity modulated by said informational signal.

Further details and advantages of the invention will be apparent as the description thereof progresses reference being had to the accompanying drawings wherein:

FIG. **1** illustrates a transverse cross-sectional view of a monoscope embodying the invention,

FIG. **2** illustrates a portion of the target electrode structure of the monoscope illustrated in FIG. **1**,

FIG. **3** is a transverse cross-sectional of the portion of the target structure illustrated in FIG. **2**,

FIG. **4** is a transverse cross-sectional view of a camera tube embodying a further feature of the invention,

FIG. 5 illustrates an elevation view from the end of a gun structure, such as that shown in FIG. 4, and

FIG. 6 is a transverse cross-sectional view of the gun structure shown in FIG. 5.

FIG. 7 illustrates a data information display system embodying the invention.

Referring now to FIG. 1 there is shown a monoscope tube **10** comprising an envelope **11.** A cathode **12** heated by a heater **13,** a control grid **14,** accellerating anode structure **15,** focusing electrode **16,** vertical deflection plates **17,** and horizontal deflection plates **18** are all mounted inside the envelope **11** in a gun assembly of well known construction used in conventional monoscopes. The raster scan **19** feeds deflection voltages to the plates **17** and **18** to position the electron beam on particular positions on a target structure **20.**

An electrode structure **20,** shown in greater detail in FIGS. **2** and **3,** is supported by a metal backing plate **21** on a rod **22** extending through the envelope **11.** Attached to plate **21** is a layer of silicon semiconductor material **23** preferably of N impurity type and having a relatively high resistance. For example, layer **23** may be approximately 10 mils thick and have an impurity of approximately 10^{13} atoms per cubic centimeter. A junction is formed at **24** in a well known manner by thermal diffusion of P impurity material into the layer **23** to form a relatively low resistance P type impurity layer **25.** Layer **25** may be of any desired thickness, but is sufficiently thin that electrons from the beam will readily penetrate to the junction region and for silicon is preferably between 0.1 and 1 microns in thickness. The conductivity of the P layer **25** region is made very substantially greater than the conductiviy of the N region **23** so that it will serve as a relatively low resistance conductor to all points of the layer **25.** A lead in **26** is connected to the P type semiconductor material and lead **26** extends out to the envelope **11.** A back bias is supplied across the junction formed by the portions **23** and **25** by means of a battery **27** applied between leads **26** and **22** through an output load impedance **28.**

Characters **29** illustrated in FIG. **2** are formed on the face of the target **20** in the following manner. A silicon dioxide layer **30** is formed over the complete surface of the layers **25** and **23** by heating the target structure in an oxidizing atmosphere. A photoresist is applied over the silicon dioxide, the letters and other characters **29** are put onto the photoresist and the photoresist is developed in a well known manner to remove the portions of the photoresist defining the characters. The portions of layer **30** defining characters **29** are then etched away to expose the P layer portions. The layer **30** is made sufficiently thick, for example 1 micron thick or less, that substantially no electrons from the beam will penetrate througy layer **30.** Since the layer **25** is formed by oxidizing the P layer, the P layer is first formed to a thickness somewhat greater than 1 micron and this thickness is reduced by oxidation to the final thickness.

When a suitable voltage of, for example, 500 to 5,000 volts is applied between the cathode **12** and the target electrode **20,** electrons will strike the target with sufficient velocity to penetrate the P layer **25** of the target **20** when the electron beam passes over an exposed region of P material, but when the electron beam strikes the layer **30,** electrons will not penetrate the P layer **25.** The back bias supplied across the junction **24** by the battery **27** produces a voltage gradient in layer **25** extending substantially from junction **24** to the plate **21.** As a result when beam electrons penetrate the semiconductor material to the region of junction **24,** they produce electron-hole pairs substantially in direct proportion to their electron velocity. For example, a voltage of 3,600 volts applied between the cathode **12** and the target **20** will produce approximately 1,000 electron-hole pairs in the silicon semiconductor target **20.** Because of the voltage gradient in layer **23** produced by battery **27,** 1,000 electrons would be moved to the positive side of the battery **27** and 1,000 electrons would be pulled through the load resistor **28** to neutralize the positive charge carriers moving through layer **23** to the plate **21.** Accordingly, a current gain of aproximately 1,000 times the beam currrent is produced by this target structure.

Because of this current gain the electron beam current can be much lower than present devices while still producing a sufficient output signal across the resistor **28** to drive an amplifier or even a cathode ray tube display device directly. By reducing the beam current, for example, to the order of 1 microampere or so, the spot size of the electron beam on the target **20** may be made much smaller than with previous monoscopes for the same signal output. As a result, smaller characters can be used while still maintaining the same definition. The net result of using smaller characters is that the total target size on which a given number of characters are positioned may be reduced, and this in turn results in a low interelectrode capacitance between plate **21** and the P layer **25** so that the upper frequency of the output signal in a display system using this monoscope can be much higher than in previous practical systems. For example, the target structure **20** in a practical device can have the portion thereof on which the characters are displayed approximately three-eighths inch across whereas normal monoscope targets structures are an inch or two in diameter.

Alternatively, a larger number of characters may be positioned on a given size of target.

A target area reduction of 4 or 5 to 1 produces a corresponding reduction in interelectrode capacitance, and a high signal current output permits use of a lower load resistance **28** than present systems for the same signal output power. Since the product of the output load resistance and the target interelectrode capacitance varies as an inverse function of the practical upper frequency response limit of the system, reducing this product increases the maximum frequency output. The upper frequency response of the target **20** is also limited by the transit time of a charge carrier through the semiconductor layer **23.** The resistance **28** may be reduced if the cathode to anode voltage is increased such that a higher signal current is produced through the resistor **28** due to a higher current multiplication in the target **20.** The capacitance may be reduced by making the thickness of the semiconductor wafer **23** greater. However, this increases transit time and therefore a point is reached at which, for practical values of the back-bias voltage produced by battery **27,** an upper frequency limit is defined. For example, with a bias voltage of from 100 to 300 volts and a thickness of layer **23** of 10 mils, a transit time permitting operation of frequencies in excess of 100 megacycles is possible.

Referring now to FIG. 4, there is shown a further embodiment of the invention wherein a light sensitive tube generally of the vidicon type is illustrated at **40.** Tube **40** comprises a glass envelope **41** and an electrode gun assembly 42 comprising a cathode **43,** a heater **44,** a control grid **45,** and a focusing and accellerating anode structure comprising tubular portions **46** and **47.** Envelope **41** has a flat glass faceplate **48** attached thereto by means of a metal ring **49.** A transparent conduction layer **50** is deposited on the inside of faceplate **48** in contact metal ring **49.** On transparent layer **50** is a layer of photoconductive materal **51** such as antimony sulfide. A focus coil **52** is provided to focus the electron beam on layer **51** and a deflection coil **53** is provided to deflect the beam across layer **51,** in any desired deflection pattern. Conductive layer **50** is maintained positive with respect to cathode **43** by a small voltage of, for example, 10 volts, by means of a battery **54** such that when the electron beam scans across the face of the target it will charge the exposed surface of the layer **51** to approximately 10 volts negative with respect to the transparent layer **50.** Light striking the target in the form of an image, for example, through a lens **55** will cause those portions of the conductive layer **51** illuminated to become photoconductive thereby discharging those portions of layer **51.** When the electron beam scans across the face of the tube it will recharge those portions of the layer **51** which have been discharged due to the local conductivity produced in layer **51** by the light pattern and this current will flow through the battery **54** to the cathode. The portion of the beam which is reflected from the target **51** by those regions where no light has impinged on the target such that the target is completely charged, is accelerated back toward the gun **42.** Because the tube has a magnetic deflection system the electrons returning from the target will return to generally the area of the end of the electron gun but will have a spot size several times the size of the aperture indicated at **56** in the end of the gun **42.** The diameter of the gun is made sufficiently large, for example, one-half inch in diameter so that substantially all the returning electrons will impinge on a current multiplying target at the end of the gun.

Referring now to FIGS. **5** and **6,** there is shown the current multiplying target comprising a semiconductor layer **57** having a hole **56** therein matching the hole in the end plate **58** of the gun **42** through which the electron beam passes. Semiconductor layer **57** is made, for example, of N type silicon approximately 10 mils thick and of relatively high resistance such as 10^{13} carriers per cubic centimeter. Diffused into exposed surface of layer **57** is a low resistance layer of P material **59** to form a junction **60** in the wafer **57.** Conductive ring **61** around the outer rim of the layer in contact therewith, is connected to a signal output lead **62** which extends out through the envelope **41.** A lead **63** applies high voltage of, for example, 500 to 5,000 volts to the anode **47** by means of a battery **64** and is connected through a battery **65** and an output load resistor **66** to lead **62** to provide a back bias across the junction **60.** Electrons returning from the target **51** and impinging on the layer **59** at high velocity will pass through junction **60** and produce a current multiplication in accordance with the principles discussed previously in connection with FIGS. **1** through **3.** For example, if battery **64** has a voltage of 1,500 volts a signal output current of approximately 400 times the beam current reflected from the target layer **51** will be produced through load resistor **66.**

From the foregoing, it may be seen that this invention discloses a structure in which information signals produced inside an evacuated envelope may be multiplied by a semiconductor target to produce a wide frequency response low noise output signal. Previous current multipliers inside tubes such as cascaded electron multipliers using a secondary emission produce substantial amounts of noise. In addition, such multipliers have phase distortion since electron transit time varies, and hence the frequency response of such devices is limited. Furthermore, such multipliers are bulky and require a large number of individual voltages to be applied to the cascade stages.

Signal generating tubes used in systems of this invention lower noise and higher output signals with higher frequency response than previous devices. Also, the power supply required for the signal output amplifiers, if indeed such amplifiers are required, need not be as closely regulated with respect to ripple, hum or other interference as is necessary when low level signals are processed resulting in a substantial reduction in cost of the overall system.

Referring now to FIG. **7** there is shown a digital display system embodying the invention wherein the device of FIGS. **1, 2,** and **3** or the device of FIGS. **4, 5** and **6** may be used. A cathode ray tube display device **70** has a cathode **71** driven by a video amplifier **72** whose input is driven by the output of a monoscope **10** having a target electrode **20** and a cathode **12.** Horizontal deflection plates **18** are driven by an X deflection amplifier **73** and the Y deflection plates **17** are driven by a Y deflection amplifier **74.** The Y deflection amplifier is driven by a Y expansion amplifier **75** driven by a 1.18 megahertz squarewave to vertically scan across each individual character and by a Y–D to A converter **76** which vertically positions the monoscope beam in accordance with digital input signals. The X deflection amplifier is driven by a character ramp generator **77** which generates a deflection across the individual character in response to an input synchronizing signal and is also driven by an X–D to A converter **78** which positions the electron beam in the proper position to scan a character in response to input digital signals. D to A converter **76** and **78** are driven by a character entry shift register **79** which supplies character position information to the monoscope **10** from a dynamic storage memory **80** such that the cathode ray tube **70** will continuously display a raster of information based on digital information stored in the memory **80.** Expansion amplifier **75** generates a signal which drives a small excursion deflection coil **81** on the display tube **70** in synchronism with similar excursions of the beam of the monoscope.

The position of the beam on the cathode ray tube **70** is determined by vertical deflection coils **82** and horizontal deflection coils **83** which are driven by a Y deflection amplifier **84** and an X deflection amplifier **85** respectively in accordance with synchronizing input signals to produce a normal television type raster scan of the face of the tube **70.** A synchronizing pulse supplied to the video amplifier **72** blanks the amplifier during intercharacter deflection periods such that when the beam is scanned from one character to another noise will not be amplified and appear as bright flashes on the face of the screen. The character ramp genera-

tor produces a deflection across the face of the cathode ray tube in synchronization with the monoscope horizontal deflection across the character being scanned.

As illustrated herein successive rasters of information may be displayed on the cathode ray tube **70** by being fed from a central computer memory through an input register **86** to character entry shift register **79** and stored in the dynamic memory **80.** The information which represent a raster of character positions is then continuously read by register **79** and fed to monoscope **10** to produce characters which are displayed repetitively on the face of the cathode ray tube **73.** The particular details of such a data display system are described in greater detail in the previously mentioned Bryden patent application. In such a system incorporating this invention the output from the target electrode **70** may drive the cathode **71** directly without any amplification by a video amplifier **72** if a sufficiently high voltage is supplied between the cathode **12** and the target **20.** For example, good results may be achieved with a monoscope of this invention voltage of 3,500 volts and output character signals fed directly to a cathode ray tube will have a clarity and brillance equivalent to those produced by conventional monoscopes with amplifiers including preamplifiers may be achieved.

This completes the description of the particular embodiment of the invention illustrated herein, however, many modifications thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. For example, the system may be used as a television camera and display system, a digital radar or sonar display system, or a facsimile transmission system. Accordingly, the scope of this invention is not limited except as defined by the appended claims.

What is claimed is:

1. In combination:

a visual display device;

a signal generating device; and

means for feeding signals derived from the output of said signal generating device to said visual display device;

said signal generating device comprising:

a source of electrons and a signal output structure;

means for directing electrons from said source to said output structure at velocities which will produce charge carrier multiplication in a semiconductor region of said output structure; and

control means interposed between said source and said output structure for varying the portion of said electrons directed toward said output structure which produce charge carrier multiplication in said output structure.

2. The combination in accordance with claim **1** wherein said control means comprises means for forming electrons from said source into a beam and for deflecting said beam.

3. The combination in accordance with claim **2** wherein said output structure comprises a unidirectionally conductive junction comprised of semiconductor material.

4. The combination in accordance with claim **3** wherein the output voltage signal is developed across said junction.

5. The combination in accordance with claim **4** wherein means are provided for producing a back bias across said junction.

6. The combination in accordance with claim **5** wherein said output structure comprises a mask which is impervious to penetration of electrons from said beam; and

said mask having differently shaped apertures therein through which electrons from said beam pass to produce charge carrier multiplication.

7. The combination in accordance with claim **6** wherein said mask comprises a layer of insulating material.

8. The combination in accordance with claim **7** wherein said junction comprises a first layer of relatively high resistance semiconductor material of one conductivity type and a second layer of material of substantially lower resistivity than said first layer which forms a junction with said first layer.

9. The combination in accordance with claim **8** wherein said mask is on the opposite side of said second layer from said first layer.

10. The combination in accordance with claim **9** wherein said first layer is attached to a metallic support electrode.

* * * * *