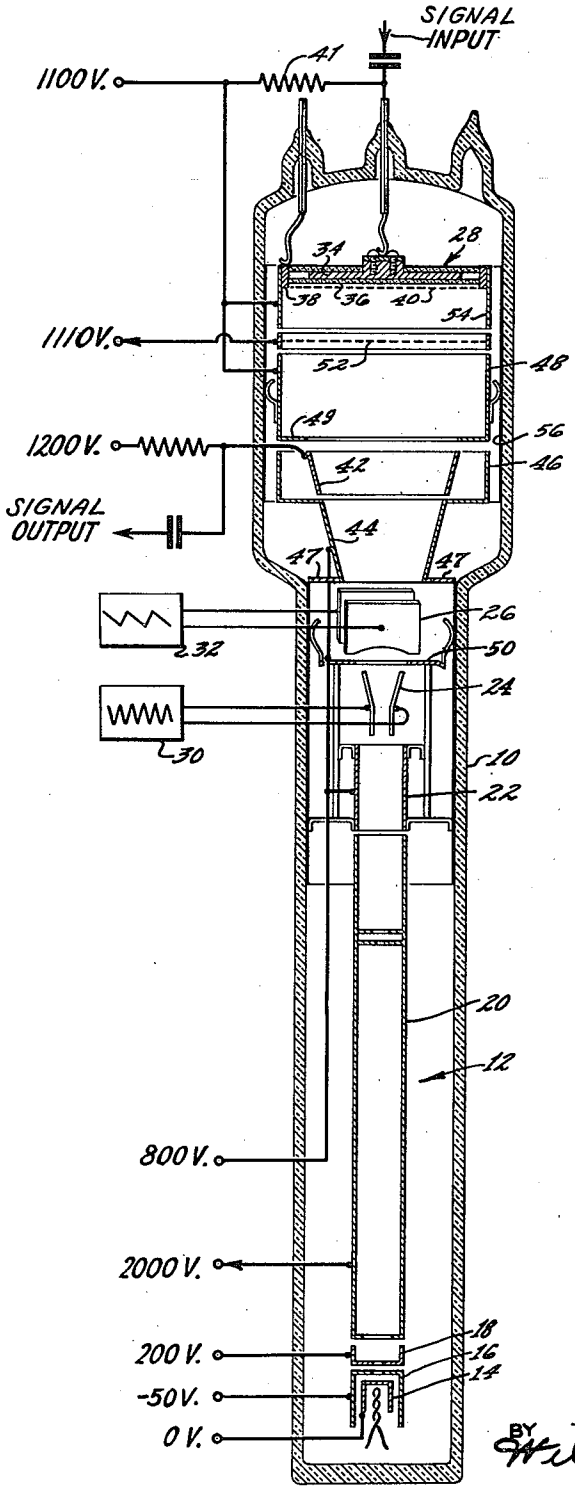
June 3, 1952 A. S. JENSEN 2,598,919

BARRIER GRID STORAGE TUBE

Filed June 30, 1950



INVENTOR
Arthur S. Jensen
BY William A. Galesak
ATTORNEY

Patented June 3, 1952

2,598,919

UNITED STATES PATENT OFFICE

2,598,919

BARRIER GRID STORAGE TUBE

Arthur S. Jensen, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application June 30, 1950, Serial No. 171,391

8 Claims. (Cl. 315—12)

1

This invention relates to electron discharge devices and in particular to improvements in storage tubes of the cathode ray type.

In such devices a charge pattern is established on an insulating surface of a target electrode by signals applied to the signal plate of the target, while an electron beam scans the insulating target surface. The output signal of the tube is that provided by a modulated secondary emission current from the insulating target surface. A tube of this type is disclosed in the U. S. Patent No. 2,548,405 of R. L. Snyder, Jr., filed July 24, 1945, Serial No. 606,812, and in U. S. Patent 2,503,949, issued to Jensen et al.

Such a tube is one in which a dielectric target surface is scanned by an electron beam to provide a secondary electron emission to a collector electrode. Closely spaced from the scanned surface of the dielectric target is a fine mesh barrier screen grid, which is maintained during tube operation at a constant potential. Secondary emission from the target surface changes the target surface to the potential of the barrier grid. On an opposite surface of the dielectric target is a conductive film or signal plate electrode, to which are applied incoming sets of signals. By simultaneously applying sets of signals to the signal plate and scanning the dielectric surface, a charge pattern is established on the target. Subsequent scannings of the target surface with simultaneous applications of similar sets of signals provides no change in the secondary signal current to the collector electrode. However, changes in the sets of signals will produce a change in the secondary signal, which can be detected.

In tubes of this type, the output signal is the variation or modulation of the secondary electron current to the collector electrode. If the collection of secondary electrons is not uniform and equal from all portions of the surface of the target, as the beam scans across the target, this non-uniformity of collection will provide a spurious output signal by modulating the secondary current to the collector. This spurious signal is of a nature similar to that of "shading" in a television pickup tube. This undesired or disturbance signal is usually large compared with other disturbance signals generated by the tube, and it is essential that it be eliminated.

It has been a considerable problem to provide a uniform collection of secondaries from all portions of the target surface of a tube similar to that described above. A degree of uniformity of collection is obtained from the central portion

2

of the target, but, as the beam scans the target, toward the edges of the target surface the collection of secondary electrons or signal electrons changes due to non-uniform accelerating and collecting fields in front of the target surface. There is also a problem of directing the secondary or signal electrons toward the collector electrode and prevent their dissipation or collection by other electrode structures within the tube.

Such types of storage tubes are often used in applications where sequential signals are compared with each other. During a scansion, a charge pattern is put down on the target surface in such a manner that it will cancel the effect of the fluctuations in corresponding portions of the incoming sets of signals during subsequent scanning cycles. It is necessary, in such applications, that the charge pattern deposited during one scan on the target surface will completely cancel the effects of a repeated and identical set of signals subsequently applied to the target electrode. To obtain the optimum signal cancellation, it is necessary that the beam current be large enough to originally put down a sufficient charge on the target surface and yet that the beam spot be small enough to obtain optimum resolution.

It is therefore an object of my invention to provide a storage discharge tube of the type having a uniform collecting field over the target surface.

It is another object of this invention to provide a storage type discharge tube having an optimum collection of secondary signal electrons from the target surface.

It is another object of my invention to provide a storage type discharge tube of the type having an improved collection of secondary emission from the target surface and optimum resolution of input signals.

It is also an object of my invention to provide a storage type discharge device utilizing a cathode ray beam of large current density and minimum spot size.

The specific invention is incorporated in a storage discharge tube having a target electrode comprising an insulator surface, an input signal electrode capacitively coupled with the insulator surface, and a screen or barrier grid closely spaced to the insulator between the insulator surface and an electron beam forming means. The insulator surface of the target structure is scanned by the electron beam to provide a secondary emission. Incoming signals are applied to the input signal electrode while the in-

sulator surface is simultaneously scanned by the electron beam. This results in a charge pattern being established on the insulator target surface during one scanning cycle. If the same signal is applied to the input signal electrode, during the same phase of subsequent scans, there is no change in the effective secondary emission from the insulator surface. However, changes in the input signal will cause a variation in the effective secondary emission from the target surface, which can be detected by an appropriate circuit connected to the collector or signal output electrode. To provide uniform collection of the secondary emission from the target surface, a mesh screen electrode is positioned between the target surface and the electron beam forming means. The presence of the screen establishes a uniform off-target gradient, which provides a uniform acceleration of secondaries from all portions of the target surface. A shield electrode is used to focus the secondary emission from the target to a point adjacent the collector electrode. Screening means are used to provide optimum screening of the signal output collector electrode from the signal input plate of the target. The electron gun means is designed to provide sufficient beam current for the operating conditions specified as well as a minimum spot size to provide optimum resolution of the charge pattern by the electron beam.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims, but the invention itself will best be understood by reference to the following description taken in connection with the accompanying drawing, in which the figure discloses a sectional view of the storage discharge tube according to my invention.

Referring to the drawing, the tube of my invention includes an evacuated envelope 10 having therein means for forming an electron beam comprising an electron gun 12. The electron gun is provided with a conventional type cathode electrode 14 surrounded by a control electrode or grid 16 closed at one end by an apertured plate as shown. Closely spaced from the apertured end of control grid 16 and spaced axially along the tube envelope 10 are successively, a short thimble-like screen grid 18, a tubular first anode electrode 20 and a short tubular second anode electrode 22. These electrodes are used to form and accelerate an electron beam along the tube 10.

Two pairs of deflection plates respectively 24 and 26 are mounted along the beam path between the second anode electrode 22 and a target electrode 28. As is well known in the art, the two pairs of deflection plates 24 and 26 each produce electrostatic fields at right angles to each other and to the path of the electron beam. It is understood that these pairs of plates respectively will have varying voltages applied, by saw-tooth or other type of deflection voltage generators 30 and 32 respectively for providing line and frame scansion of the beam over the surface of the target electrode 28. The scans of the electron beam may be of any other type desired such as spiral scansion or radial scansion. The means for producing different types of scansion are well known in the art and need not be further described.

The target electrode 28 comprises essentially a signal input electrode or plate 34 mounted in contact with a thin mica or other insulating sheet 36, both of which are mounted within a

support ring 38. Ring 38 also conductively supports a fine mesh screen 40. The target electrode has been made in one form as fully described in my U. S. Patent No. 2,538,836 filed January 23, 1950. As disclosed in this application, screen 40 can be a fine mesh of substantially 230 mesh per inch formed of woven stainless steel to provide an optimum spacing of the screen from the insulator surface of the mica 36. Mounted between the deflecting plates 26 and target 28 is provided a collector, or signal output electrode 42. To shield the output or collector electrode 42 from the fields of the deflecting plates 26, there is provided an electrode 44 having a conical portion as shown, a portion 47 separating the deflection plates from the collector lead, and an additional portion 46 enclosing the collector electrode. An additional shield electrode 48 is provided between the output signal electrode 42 and the target electrode 28. Shield electrode 48 is provided with a flanged portion 49 to further shield the collector from incoming signals applied to the input plate 34.

In operation, appropriate voltages are applied to the several electrodes of the tube. Examples of the voltages respectively applied to the several electrodes are disclosed in the drawing. However, these values need not be limiting, but only indicate those voltages applied during successful operation of a tube similar to that disclosed in the figure. The voltage shown on the control grid 16 is approximately the most negative required for cut-off.

During tube operation, the electron emission from cathode 14 is formed into an electron beam by the fields established between the control and screen electrodes 16 and 18. The electron beam is electrostatically focused upon the insulator surface 36 of the target by the provision of a strong converging lens field between the anode electrodes 20 and 22. This lens field is the main focusing field for the electron beam and provides substantially 70% to 80% of beam focus. Between the two pairs of plates 30 and 32, there may be mounted a shield disc electrode 50. This electrode, together with the conical shield 44 is connected to a common potential source with the second anode electrode 22 and provides a substantially anastigmatic field-free space for the beam during its passage through the deflecting system of the tube.

The main function of the electrodes between the deflecting system of plates 30 and 32 and the target 28 is that of collecting the secondary emission from the target surface and of shielding the signal output collector electrode 42 from the input electrode 34 of the target. As indicated in the figure, the barrier grid 40 is maintained substantially at 1100 volts positive relative to the cathode potential of the electron gun. The input signal plate 34 is connected to the same potential source through an input resistor 41, as shown. The signal ouput collector electrode 42 is held at substantially 100 volts more positive than grid 40 and plate 34 of target electrode 28, in order to provide a positive collecting field, for urging the secondary electrons away from the target surface.

In accordance with my invention, and in order to provide a uniform collection of secondary electrons over all of the target surface, a second screen electrode 52 is mounted parallel to the target surface of sheet 36 and to the barrier grid or screen 40. As indicated in the figure, screen 52 is maintained substantially 10 volts,

positive relative to the barrier grid 40. This potential difference is sufficient to provide an accelerating field between the two screens so that the low velocity secondary electrons penetrating the barrier grid 40 are quickly caught up and urged toward the second screen 52. Without screen 52, the collecting field of electrode 42 would tend to extend to the barrier grid 40, and in a manner such that the equipotential surfaces of the field would be parallel at the center of the target, but considerably curved and distorted at the target edges. Without screen 52, the collection of secondaries from the target surface would in no way be uniform over all portions of the target. However, the second screen 52 flattens out the electrostatic field in front of the target surface, so that there is a parallel, uniform accelerating field over substantially all of the target surface. Screen 52 thus provides a uniform off target voltage gradient for providing equal electron collection over all of the target surface. Screen 52 is made of relatively large mesh, such as woven or knitted stainless steel wire approximately 1 mil in thickness, and 10 mesh per inch. As is done to the barrier grid 40, the screen 52 may be sprayed or sputtered with gold or carbon to reduce the secondary emission from the screen to that having a ratio of substantially unity. The form of the screen is not critical, as it may be made by spacing parallel wires up to ½'' apart. However, its transparency should be at least 97%. With such transparency, only approximately 6% of the primary beam going through to the target and of the secondary signal beam from the target is lost.

When the electron beam of the gun strikes the insulator surface of plate 36 of the target electrode, secondary electrons are emitted in a greater number than there were primary electrons. The energies of most of the secondaries average between 10 and 20 volts, and escape through the barrier grid 40 of the target and in various directions. As shown in the figure, support ring 38 of the target is extended or has mounted thereon an open tubular portion 54, maintained at essentially the same potential as the barrier grid 40 so that secondaries heading in a direction to strike the sides of the tube envelope 10 being in the field between this tubular portion 54 and screen 52 may be accelerated and redirected back toward the tube axis. The electrons passing through the barrier grid 40 are accelerated by the second screen 52 and will pass therethrough to enter the collecting field of the electrode 42. Shield 48 is also maintained at the potential of the barrier grid 40 so as to present a negative or repelling field to the secondaries passing through screen 52. Another function of the shield electrode 48 is to provide between it and the signal output electrode 42 a lens field for focusing the secondary emission toward the tube axis and into the region of the collector electrode 42. As shown in the figure, there is approximately a difference of 100 volts between electrodes 42 and 48. Also, due to the wide opening of electrode 48, the collecting field of electrode 42 will extend substantially to the screen electrode 52. The secondary electrons passing through the center portion of screen 52 will continue in their passage along the axis of the tube. However, those secondaries coming through the edge portions of screen 52 will encounter a field having a converging action on their paths and will be directed toward the tube axis and into the opening of the collector electrode 42.

The potential of screen 52 is one which is substantially of optimum value for the conditions of operation described. If the potential of screen 52 is made too positive, then the screen itself tends to become a collector of the secondary emission from the target 28. Again if the screen is maintained at too negative a potential, it will tend to emit more secondary electrons than unity and hence provide a spurious signal. Accordingly, then, the potential of screen 52 is adjusted until the disturbance caused by screen 52 is at a minimum.

As shown, collector 42 is made as small as feasible to provide as little capacity between itself and the signal input electrode 34 of target 28 and between itself and all other nearby electrodes. The input signals applied to plate 34 average in the order of 50 volts and may go as high as 100 volts or more. If the secondary emission current to the signal output electrode 42 is approximately 2 microamperes, it can be determined that the output signal is in the order of 0.1 volt for a signal frequency band-width of one megacycle. For tubes of this type, it is desirable that the disturbance signal of the tube be in the order of $\frac{1}{100}$ of the output signal or 0.001 volt. With such a large ratio of input and output signals, it is thus necessary that there be as effective shielding as possible of collector 42 from the input signal plate 34. As described above, shield 48 is designed to provide shielding by partially closing the end of tubular member 43 adjacent to collector 42 by means of flange 49. It can be estimated that shield 48 accounts for approximately 20% of the shielding between the input and output electrodes. However, screens 40 and 52 provide substantially 70% of the total shielding effect between these electrodes. Additional shielding is obtained by providing a graphite coating 56 on the inner wall of the tube envelope 10 and extending between target 28 and shield 46. This coating is maintained at a constant potential by being connected as is shown to electrode 48. In accordance with my invention, electrode 44 has a shield portion 46 which completes the enclosure of collector 42.

The signal output electrode is provided with as small an opening as feasible for the passage of the electron beam from gun 12. The conical shape of electrode 42 allows for this minimum opening as well as for a maximum deflection of the beam by plates 24 and 26.

The secondary electrons drawn back to electrode 42 have a tendency to continue on through the collector 42 and to pass down the tube toward the gun cathode. To prevent any loss of secondary electrons in this manner, shield electrode 44 is maintained at substantially 300 volts negative relative to the potential of the barrier grid 40. Thus, electrode 44 provides a negative repelling field to the secondaries passing down the tube axis and back to the collector 42.

The electron gun structure of the tube is designed to provide a maximum beam current as well as a minimum spot size of the beam on the target electrode at the cathode to target voltage difference available. This voltage difference is limited by the secondary emission characteristics of the target insulator 36. The distance between the cathode electrode 14 and the main lens between electrodes 20 and 22 is designed to be large compared to the main lens-to-target

distance, and thus to provide a smaller spot size of the beam on the target surface in accordance with well known principles of electron optics. That is, the electron optics are somewhat analagous to normal optics, in which it can be demonstrated, that as the object-to-lens distance is increased, the lens-to-image distance decreases proportionately and also the size of the image decreases for a given lens system. A similar result is obtained in electron optics, in which the first cross-over point of the electron beam adjacent to the cathode is imaged by the lens system on the target surface, when the beam is brought into focus. In a similar manner, as the distance from the first cross-over to the effective center of the lens system is increased the lens-to-target distance may be decreased with a corresponding decrease in the size of the focused spot at the target.

The first anode electrode **20** is operated at the maximum potential and thus provides a maximum accelerating field in front of the cathode surface to draw a maximum current from the cathode surface. The second anode **22** is run at a potential negative to that of the first anode to enable this use of a maximum potential on the first anode. The main lens-to-target distance is the minimum which will allow optimum collection of the secondaries. For example, the conical portion of shield **44** is made only slightly longer than its minimum opening to provide sufficient shielding of collector **42** from the deflecting fields of plates **24** and **26**. Also, the axial dimensions of the other electrodes of the secondary electron collecting section are maintained at a minimum value.

Because of the necessity of maintaining the potential on the electrode **44** negative to that of grid **40** in order to reflect the secondaries back to the region near collector **42**, it is impossible to get away from the establishment of a lens field between electrodes **44** and **42**. This lens field also adds to the beam focusing of the main lens field between anodes **20** and **22**. Optimum focusing conditions are obtained essentially by a single field. But, in the tube shown, this is impossible. However, the focusing effect of the lens field between electrodes **42** and **44** is kept at a minimum and provides substantially 15%–20% of beam convergence.

Since target surface **36** is an insulator, during tube operation the only source of current to it is the primary beam, and the only drain of current from it is the secondary electron emission. At equilibrium, these two must be equal so that for a steady primary beam current, the secondary current is also steady. Any deposition or removal of charge on the surface **36** will appear as a modulation of this steady secondary electron emission. However, since the energy of the primary electrons, when they strike the dielectric, is such that the secondary emission ratio is greater than unity (actually about two), those secondary electrons in excess of the number arriving in the primary beam must return to the target surface to maintain the target surface **36** at an equilibrium potential which is substantially 10 volts positive with respect to the barrier grid **40**, this voltage difference being determined by the energy distribution of the secondary electrons.

The barrier grid of screen **40** functions as a virtual collector, so that the equilibrium potential of the target surface **36** is established with respect to screen **40** and not to the actual collector electrode **42**. At equilibrium potential, a number of secondaries, just equal to the number of arriving primaries, are sufficiently energetic to penetrate screen **40**. These cannot return to the target, as the accelerating field of screen **52** urges them away and toward collector **42** as the secondary beam. Meanwhile, the excess electrons are not sufficiently energetic to reach screen **40** from surface **36**, and are returned to the target surface **36** by the field between screen **40** and target surface **36**. They are restricted in their motion by the close proximity of the screen to the dielectric surface **36**, so that their redistribution to portions of the target not directly under the beam is considerably reduced.

In normal operation, screen **40** over the insulating target **36** is maintained at a direct current potential and the conductor plate **34** is connected to a source of the incoming signal to be recorded. The insulating surface of target **36** is therefore capacitively coupled to the signal plate **34**. When a signal voltage is impressed on signal plate **34**, it thus appears, somewhat diminished in amplitude, on the recording surface **36** of the target.

As the beam is deflected across the surface **36**, while a signal is impressed on the signal plate **34**, it will cause each element of surface area it strikes to come to the potential of screen **40** regardless of the potential the surface would otherwise have due to the influence of the signal plate. This action, then establishes a charge between the plate **34** and the surface element of sheet **36** which will cause the element to have a potential different from that of the screen **40** when the beam moves off of the surface element and the signal plate **34** returns to its normal, quiescent potential. If the beam scans a long path over the target surface **36**, while a fluctuating voltage is impressed on the signal plate **34**, a band of charges, as wide as the beam, will remain on the path when the beam is cut off. If the signal plate **34** returns to quiescent potential, the potential along the path will vary in proportion to the signal voltage impressed during the beam transit.

The improved storage tube may be used in various ways where storage of information is desired. Signals may be so impressed on the signal plate while the beam scans a predetermined pattern over the target. The signal and beam may then be shut off, leaving the information stored in the target. At any desired later time the beam may be turned on and, with the signal plate maintained constant at its quiescent potential, scanned over the pattern so that the signal impressed during the first operation will be reproduced as the beam deposits and removes the charge returning the entire path to the equilibrium potential. The signals need not be recorded in one scansion and utilized in the next scansion. Signals can be stored at one time and reproduced at any later time merely by shutting off and turning on the beam at the desired time.

While certain specific embodiments have been illustrated and described, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

I claim:

1. An electron discharge device comprising, means for forming a beam of electrons along a path, a target electrode mounted in the path of said electron beam, said target electrode includ-

ing a surface providing secondary electron emission when struck by said electron beam and a first mesh screen overlying said target surface, means for collecting the secondary emission from said target surface, said collecting means including a collector electrode mounted between said beam forming means and said target electrode, an electron mirror electrode between said beam forming means and said collector electrode, and a second mesh screen electrode between said collector and said first mesh screen.

2. An electron discharge device comprising, means for forming a beam of electrons along a path, a target electrode mounted in the path of said electron beam, said target electrode including a surface providing secondary electron emission when struck by said electron beams and a first mesh screen overlying said target surface, means for collecting the secondary emission from said target surface, said collecting means including a collector electrode mounted between said beam forming means and said target electrode, a shield electrode between said target surface and said collector electrode, and a second mesh screen between said shield electrode and said target, lead means connected to said collector and shield electrode for respectively joining said collector and shield electrodes to potential sources of different value to establish a field for focusing said secondary electron emission near said collector electrode.

3. An electron discharge device comprising, means for forming a beam of electrons along a path, a target electrode mounted in the path of said electron beam, said target electrode including a surface providing secondary electron emission when struck by said electron beam, a signal input electrode capacitively coupled to said secondary emitting target surface and a first mesh screen overlying said target surface, means for collecting the secondary emission from said target surface, said collector means including a signal output electrode mounted between said beam forming means and said target electrode and a second mesh screen between said output electrode and said target surface, and means shielding said output electrode from said input electrode, said shielding means including a shield electrode between said target and output electrode.

4. An electron discharge device comprising, means for forming a beam of electrons along a path, a target electrode mounted in the path of said electron beam, said target electrode including an insulator surface facing said beam forming means for providing secondary electron emission when struck by said electron beam, an input signal electrode capacitively coupled to said insulator surface and a first mesh screen overlying said insulator surface, means for collecting the secondary emission from said insulator target surface, said collecting means including a tubular collector electrode mounted between said beam forming means and said target electrode and enclosing said beam path, a tubular shield electrode between said collector electrode and said target and a second mesh screen electrode between said shield electrode and said insulator target surface.

5. An electron discharge device comprising, means for forming a beam of electrons along a path, a target electrode mounted in the path of said electron beam, said target electrode including an insulator surface facing said beam forming means for providing secondary electron emission when struck by said electron beam, an input signal electrode capacitively coupled to said insulator surface and a first mesh screen overlying said insulator surface, means for collecting the secondary emission from said insulator target surface, said collecting means including a tubular collector electrode mounted between said beam forming means and said target electrode and enclosing said beam path, a tubular shield electrode between said collector electrode and said target and a second mesh screen electrode between said shield electrode and said insulator target surface, lead means connected to said collector and shield electrode for respectively joining said screen and shield electrodes to potential sources of different value to establish a field for focusing said secondary electron emission near said collector electrode.

6. An electron discharge device comprising, means for forming a beam of electrons along a path, a target electrode mounted in the path of said electron beam, said target electrode including a surface providing secondary electron emission when struck by said electron beam and a first mesh screen overlying said target surface, means for collecting the secondary emission from said target surface, said collecting means including a collector electrode mounted between said beam forming means and said target electrode, an electron mirror electrode between said beam forming means and said collector electrode, a second mesh screen electrode between said collector and said target, and lead means respectively connected to said first and second mesh screens respectively joining said mesh screens to sources of different potential for providing a uniform accelerating field between said mesh screens for the secondary emission from said target surface.

7. An electron discharge device comprising, means for forming a beam of electrons along a path, a target electrode mounted in the path of said electron beam, said target electrode including a surface providing secondary electron emission when struck by said electron beam and a first mesh screen overlying said target surface, means for collecting the secondary emission from said target surface, said collecting means including a collector electrode mounted between said beam forming means and said target electrode, a shield electrode between said target surface and said collector electrode, a second mesh screen between said shield electrode and said target, lead means respectively connected to said collector and shield electrode and to said mesh screens for respectively joining said first screen and said shield electrode to a source of common potential and for respectively joining said second mesh and said collector electrode to sources of potential different from each other and positive to said source of common potential, whereby a uniform accelerating field will be set up between said mesh screens for urging said secondary emission from said target surface and a field between said collector and shield electrodes established for focusing said secondary emission to a point near said collector electrode.

8. A signal generating device comprising, means for forming a beam of electrons along a path, a target electrode mounted in the path of said electron beam, said target electrode including an insulator surface for providing secondary emission when struck by said electron beam, an input signal electrode capacitively coupled to said insulator surface and a first

mesh screen overlying said insulator target surface, a pair of deflection plates between said beam forming means and said target electrode for scanning said electron beam over said insulator surface, means for collecting the secondary emission from said target surface, said collecting means including an output signal electrode mounted between said deflecting plates and said target electrode and a second mesh screen between said output electrode and said first mesh screen, means shielding said output electrode from said signal input electrode, said shielding means including a shield electrode between said

output electrode and said target and a second shield electrode between said output electrode and said deflecting plates.

ARTHUR S. JENSEN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,259,507	Iams	Oct. 21, 1941
2,520,244	Iams	Aug. 29, 1950