

Aug. 24, 1965

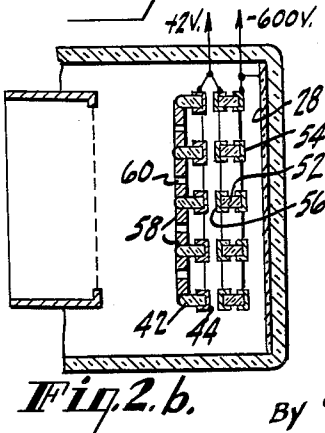
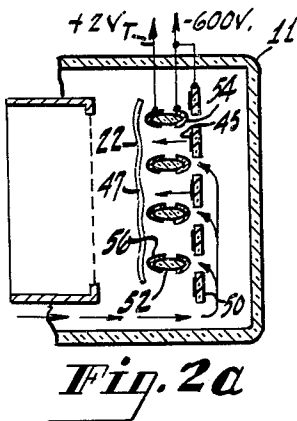
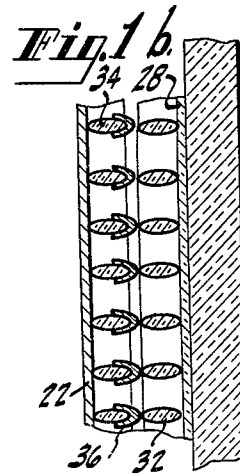
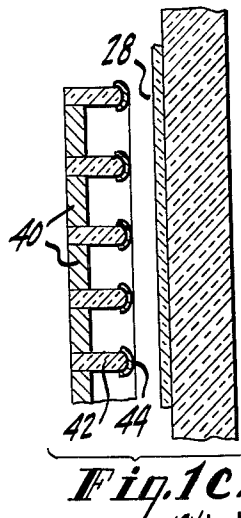
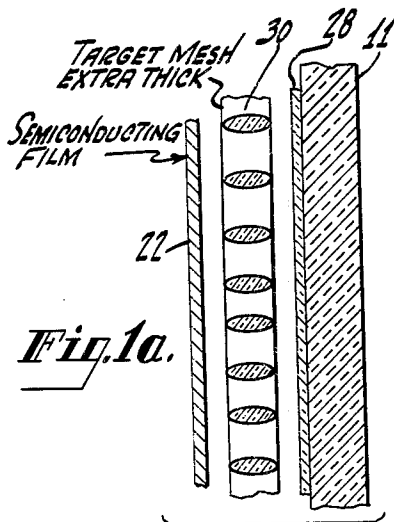
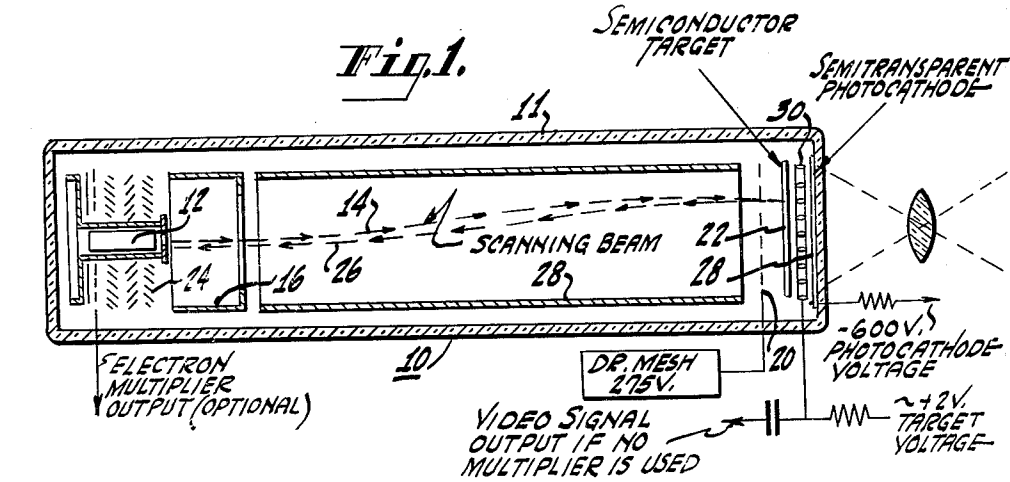
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3,202,853

ELECTRON BEAM TUBE WITH LESS THAN THREE HUNDRED MILS SPACING
BETWEEN THE TARGET ELECTRODE AND PHOTOCATHODE ELECTRODE

Filed Aug. 16, 1960

3 Sheets-Sheet 1



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ELECTRON BEAM TUBE WITH LESS THAN THREE HUNDRED MILS SPACING
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3 Sheets-Sheet 2

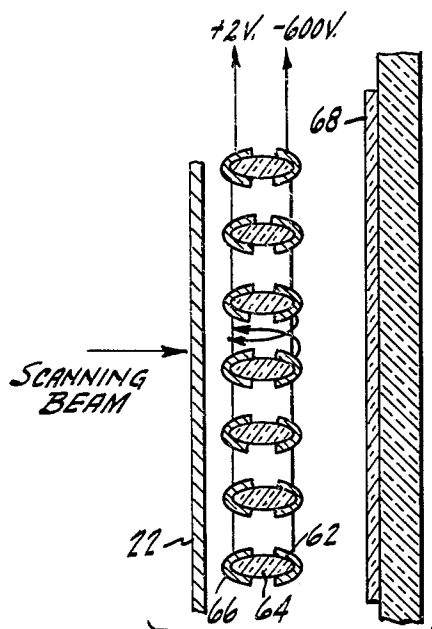


Fig. 3a.

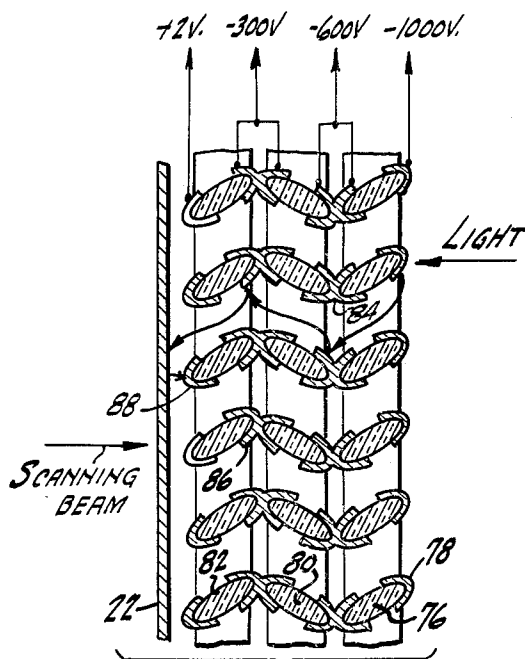


Fig. 4a

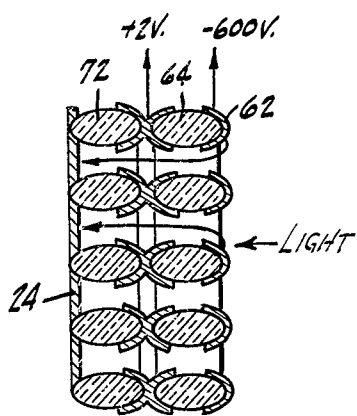


Fig. 3b.

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3 Sheets-Sheet 3

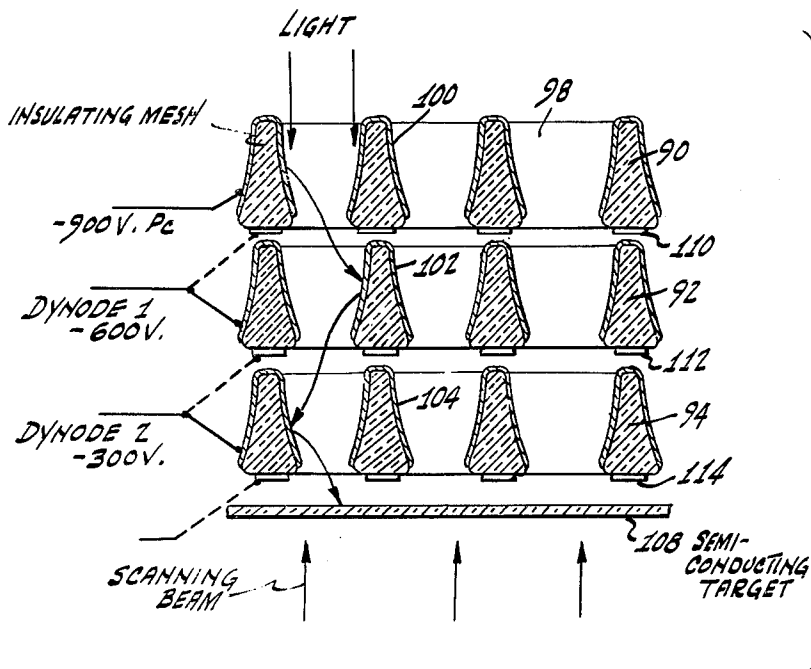


Fig. 4b.

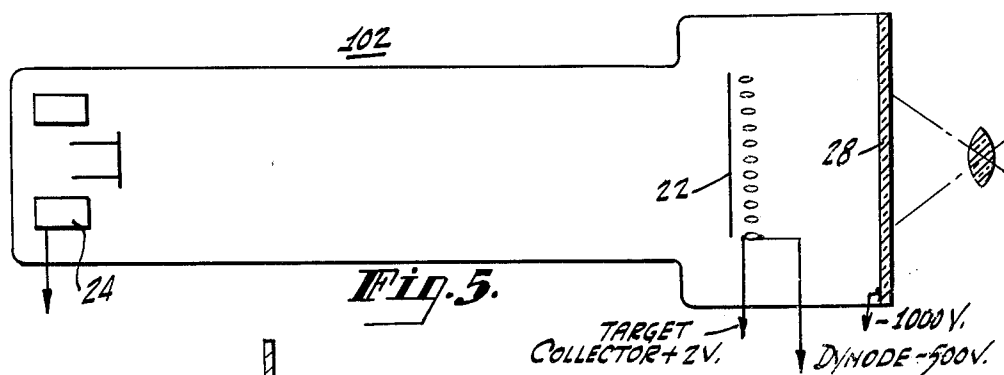


Fig. 5.

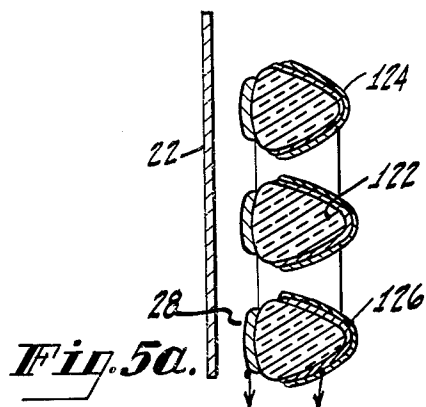


Fig. 5a.

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3,202,853

ELECTRON BEAM TUBE WITH LESS THAN THREE HUNDRED MILS SPACING BETWEEN THE TARGET ELECTRODE AND PHOTOCATHODE ELECTRODE

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3 Claims. (Cl. 313—65)

This invention relates to photosensitive tubes. In particular, this invention relates to photoemissive type photosensitive tubes and will be explained with reference to photoemissive type pickup or camera tubes.

Of the photoemissive type camera tubes that are known in the prior art, a common example is that of the image orthicon. In the conventional image orthicons, an electron image from a photocathode passes through an image section of the tube and is focused onto one side of a thin semi-conducting target. When the electron image lands on the target, an electrical charge pattern is developed on the opposite side of the target that corresponds to the original electron image. An electron beam scans the opposite side of the target and removes the charge pattern. While removing the charge pattern, the electron beam is modulated by an amount corresponding to the charge image existing at the particular spot being scanned. The modulated electron beam is then returned toward the electron gun, amplified by an electron multiplier, and the amplified return beam is used as the output signal for the tube.

Tubes that utilize one or more separate image sections, i.e. wherein the complete photoelectron image is transferred through a substantial space, are limited in resolution by the emission velocities of the photoelectron image. The reason for this is that the focal point of the electron image will vary slightly as the emission velocity of the photoelectron image varies. Also, the picture resolution is limited by failure to maintain the precise voltages in the image section that are necessary to keep the electron images in focus. Still further, stray magnetic fields from the scanning yoke may leak into the image section and may degrade picture resolution.

Although tubes of this type have worked extremely well for most applications, it has been desirable in other applications to improve the sensitivity of the pickup tube or to provide a more compact structure that is more simple to operate, or both.

Examples of tubes which have been designed to provide the ultra high sensitivity desirable in certain pickup tube applications are tubes of the image intensifier image orthicon type and also tubes that are based on the bombardment induced conductivity phenomena. These tubes do provide the ultra-high sensitivity that is desired for certain uses. However, these tube types require excessively high voltages for operation.

It is therefore an object of this invention to provide a new and improved tube.

It is another object of this invention to provide a novel camera tube characterized in its improved sensitivity, or compact geometry, or both.

These and other objects are provided in accordance with this invention by providing a novel photoemissive type tube wherein one or more of the following are present: (1) close spacing between the target and the photocathode so that problems of electron imaging the photoelectron image are substantially eliminated; (2) means is provided for guiding the electrons from the photocathode to the target within the tube so that the problems of electron focusing are eliminated; and (3) electron intensification of the complete electron image between the photoemissive cathode and the target is provided, by means of multiply-

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ing the photoelectron image as it passes from the photoemissive cathode to the target electrode, resulting in a more sensitive pickup tube.

The invention will be more clearly understood by reference to the accompanying three sheets of drawings, wherein:

FIG. 1 is a schematic sectional view of an improved pickup tube made in accordance with this invention;

FIG. 1a is an enlarged fragmentary sectional view of the photocathode-target structure shown in FIG. 1;

FIG. 1b is an enlarged fragmentary sectional view of another embodiment of a photocathode-target structure made in accordance with this invention;

FIG. 1c is an enlarged fragmentary sectional view of another embodiment of a photocathode-target structure in accordance with this invention and utilizing a plug type target;

FIG. 2a is an enlarged fragmentary sectional view of an embodiment of this invention illustrating a method of manufacturing a photocathode-target structure;

FIG. 2b is an embodiment of this invention similar to FIG. 2a and utilizing a plug type target;

FIG. 3a is an enlarged fragmentary sectional view of a photocathode-target structure of an embodiment of this invention wherein the photocathode is spaced from the face plate;

FIG. 3b is an enlarged fragmentary sectional view of a modification of the target shown in FIG. 3a;

FIG. 4a is an enlarged fragmentary sectional view of an embodiment of this invention utilizing electron multiplication between the photocathode and target of this invention;

FIG. 4b is an embodiment of this invention functionally similar to that shown in FIG. 4a;

FIG. 5 is a schematic view of an image orthicon type pickup tube shaped in known manner but having an image section including an electron multiplier in accordance with this invention; and

FIG. 5a is an enlarged fragmentary sectional view of the electron multiplier structure shown in FIG. 5.

Referring specifically now to FIG. 1, there is shown a pickup or camera tube 10 made in accordance with this invention. The tube 10 comprises an evacuated envelope 11 having an electron gun 12, which may be any conventional structure, positioned in one end thereof. The electron gun 12 is used for the purpose of providing an electron beam 14 which is directed, by means of accelerating electrodes 16, 18 and 20, toward a semi-conductor target electrode 22. Surrounding the electron gun 12 is a plurality of electron multipliers 24 which serve the purpose of collecting and multiplying a return electron beam 26.

Within the opposite end of the envelope 11, and shown more clearly in FIG. 1a, there is provided a semi-transparent photocathode 28. The photocathode 28 is deposited, in this embodiment, upon the closed end or transparent faceplate portion of the envelope 11. The photocathode 28 may comprise any suitable photoemissive material, for example, a cesiated antimony or a multi-alkali photoemissive surface. Spaced closely adjacent to the photoemissive cathode 28 is a target mesh electrode 30. The target mesh electrode 30 comprises a wire mesh screen having a large plurality of apertures extending therethrough. The number of apertures in the mesh screen 30 will, in part, determine the picture definition obtainable from the tube and, for highest definition, should be as large as possible. Mesh screens having approximately 500 apertures per inch or greater have been found suitable for most applications. The mesh screen electrode 30 may be an electroformed mesh screen made of a material such as copper or nickel.

The mesh screen electrode 30 should be sufficiently thick to provide adequate electrical shielding between the

target electrode 22 and the photocathode 28. Also, with the conventional potentials such as those illustrated in FIG. 1, there is a strong electrostatic, attractive field existing between the photocathode 28 and the mesh screen 30. Therefore, the mesh screen electrode 30 should be sufficiently thick to withstand a strong electrostatic force that exists, due to the appropriate electrical fields, between the photocathode 28 and the mesh screen 30 during tube operation. An example of a suitable thickness of the mesh screen 30 is 0.010 inch. The spacing between the mesh screen 30 and the photocathode 28 should be approximately 0.010 inch, when a picture resolution of more than 700 lines per inch is desired. Too large a spacing between the photocathode 28 and the mesh screen electrode 30 will permit objectionable spreading of the electron image due to the lateral component of the emission velocities of the photoelectrons.

The target 22, in this embodiment, comprises a thin, e.g. about five microns, semi-conducting film, such as a glass similar to that found in known image orthicon type pickup tubes. The mesh screen 30, and the target 22, may be supported in the envelope in any suitable manner, for example on annular support rings. Therefore, specific details of the support structure are not shown.

The spacing between the target 22 and the mesh screen electrode 30 may be any selected from a few tenths of a mil up to approximately 150 mils depending upon the desired operation. When the closer spacings are used the tube is more suitable for average light levels while the wider spacings are more useful for low light level uses. However, for spacings greater than approximately 10 mils some deterioration in resolution will result. With the close photocathode-target spacing, there is no problem of directing the photoelectron image from the photoemissive cathode onto the target 22. The reason is that, due to the close spacing and the strong electrostatic field, the electrons are quickly accelerated to the target and do not have sufficient time to become defocused in the short space existing. In short, there is no problem, such as that found in presently known tubes, of maintaining the precise voltages which are necessary to keep an image in focus since, in the tube described here, the electrons travel quickly through the close spaced image section, and the mesh screen occupies at least $\frac{1}{20}$ of the space between the photocathode and the target.

In operation of the device shown in FIG. 1, a light image is directed onto the photocathode 28 which produces an electron image corresponding to the light image. The electron image is accelerated, by potentials such as those shown, onto one side of the semi-conducting target 22. When the electron image lands on the semi-conducting target 22, an electron charge image is established on the opposite surface of the target 22 due to the thinness of the target and its semi-conducting properties. Then, the electron beam 14 is scanned over the target 22, by means of a conventional deflection yoke not shown, and sufficient electrons are deposited by the beam to remove the charge image. The deposition of these electrons produces an output signal as a return electron beam 26, which is multiplied in any suitable, known electron multiplier structure 24. In the alternative, the output signal may be taken from the target mesh screen 30, by capacitive coupling of the mesh screen 30 to the beam as the beam lands on the signal areas of the target 22.

The close photocathode to target spacing is such that the photoelectron image will not deteriorate before it enters the mesh screen electrode 30, in which deterioration is prevented by the walls of the mesh screen electrode, or after the photoelectron image leaves the mesh screen electrode to strike the target. With available mesh thickness, this results in the close photocathode to target spacing being less than approximately 300 mils for optimum resolution.

Referring to FIG. 1b there is shown an embodiment of this invention wherein the physical problems of maintain-

ing the close photocathode-to-target spacing are substantially eliminated. In this embodiment, a photocathode physically bears against an apertured insulating mesh member 32. Physically touching the semi-conducting target 22 is a second apertured electrically insulating mesh member 34. Covering a surface of the insulating mesh 34 is a conductive coating 36. The apertured insulating member 32 physically touches the conductive coating 36 so that the close photocathode-to-target spacing is maintained. The conductive coating 36 functions, during operation, as the target mesh electrode similar to electrode 30 shown in FIG. 1a. The semi-conducting target 22 in FIG. 1b is maintained in spaced relation from the mesh screen electrode 36 by the presence of the apertured insulating mesh member 34. The mesh screen 36 is maintained in spaced relation with respect to the photocathode 28 by the presence of the apertured insulating member 32. Thus, in the embodiment illustrated in FIG. 1b, the photocathode 28 and the target 22 are physically spaced by solid support members throughout their entire areas. Thus, the attractive, electrostatic fields that are encountered during tube operation will not move these electrodes with respect to each other.

The apertured insulating members 32 and 34 may comprise an apertured insulating glass such as Fotoform or Fotoceram insulating glass, which are available commercially. In the alternative, the insulating members 34 and 32 may comprise a material such as, for example, aluminum oxide. The thickness of the insulating member 32 should not exceed 0.010 inch for best resolution, while the thickness of the insulating member 34 may vary from a few mils to 150 mils depending upon the desired tube operation as has been explained. The mesh electrode 36, which may be a material such as gold, may be deposited on the apertured insulating member 34 by any known means such as evaporation or sputtering. The mesh screen electrode 36 is electrically conductive so that a potential can be applied thereto for properly directing the photoelectron image onto the target 22. Also, output signals may be obtained from the mesh screen 36 as was explained in connection with FIGS. 1 and 1a. The balance of the materials, geometries and operation of the embodiment shown in FIG. 1b may be similar to those described in connection with FIG. 1a.

Referring now to FIG. 1c there is shown an embodiment of this invention wherein the target is formed of a plurality of electrically conducting plugs 40 supported in an apertured electrically insulating member 42. The apertured insulating member 42 may comprise, for example, a material such as Fotoform or Fotoceram glass, magnesium oxide or anodized aluminum oxide. The number of plugs 40 per inch is, in part, controlling of the picture definition. Thus, the largest number of plugs per inch possible is desirable for the highest picture definition, with each of the plugs electrically insulated from the other plugs by the presence of the apertured insulator 42. Targets having more than 500 plugs per inch have been found to be satisfactory for proper picture definition. On the surface of the apertured insulating plate 42 remote from the scanning beam 14 there is provided an apertured electrical conductor 44 which functions as a target mesh electrode during tube operation. Here again, the apertured conductor 44 may be formed by evaporating gold onto the insulating member 42.

During operation of this embodiment, the photoelectron image from the photocathode 28 is directed onto the closely spaced plugs 40 and produces an electrical charge pattern on these plugs. When the electron beam scans the opposite side of the conductive plugs, the charge pattern is "read out" in a manner similar to that previously described. In this embodiment, in order to prevent spreading and deterioration of the photoelectron image, the spacing between the target mesh 44 and photocathode 28 is less than 0.01 inch.

Referring now to FIG. 2a there is shown an embodi-

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ment of this invention wherein a photocathode 45 is spaced from the end of the envelope 11 to simplify the tube manufacturing process. In this embodiment, the photocathode 45 is supported on a thin transparent perforated sheet 50. The perforated sheet 50 may comprise a sheet of any transparent material, an example of which is glass. Positioned closely adjacent to e.g. less than 0.01 inch from, the perforated glass sheet 50, is an apertured insulating mesh member 52. Deposited on the insulator mesh 52 are electrically separate conductive coatings 54 and 56, the coating 54 on the side nearest the glass sheet 50 and the coating 56 on the side of mesh 52 remote from glass sheet 50. The coatings 54 and 56 may be of evaporated gold deposited in the manner previously described. Deposited on the conductive coating 56 is a thin semi-conductive target 47. The target 47 may be of a thickness similar to those previously described or may be so thin as to require the support of the conductive coating 56.

The photocathode 45 may be manufactured by evaporating antimony onto the perforated glass sheet 50 prior to the assembly of the device. Then, the insulator mesh 52 is positioned closely adjacent to the perforated glass sheet 50. In this embodiment, with the target-photocathode assembly spaced from the faceplate, cesium vapor can be passed behind the target to pass through the apertures in the glass sheet 50, as indicated by lines 53, to activate the previously deposited antimony. It should be understood that in FIG. 2a only a small number of elements are shown, for simplicity of illustration, and the actual tube would include more than 250,000 such elements.

During operation of the embodiment shown in FIG. 2a the conductive coating 54 is maintained substantially at cathode potential, to avoid capturing the photoelectrons and to provide a strong electrostatic lens between the coatings 54 and 56 to better focus the electrons onto the target. The conductive coating 56 serves as a target collector electrode similar to the screen 30 previously described.

Referring now to FIG. 2b, there is shown an embodiment of this invention wherein the target is apertured to permit the passage of cesium vapor onto the photocathode 28 from the electron gun side of the target. In this embodiment, there is provided an insulating mesh 52 having a conductive coating 54 on the side adjacent the photoemissive cathode 28 and an electrically separate conductive coating 56 on the opposite side. Spaced from the insulating mesh 52, the photocathode 28, and in registration with the insulating mesh 52, is an apertured insulating mesh 42 having a conductive coating 44 on the exposed surface thereof and on the side facing the coating 56. Within the apertured insulating member 42 are a plurality of conducting plugs 53, each of which contains a small aperture 60 extending therethrough. The apertures 60, which may be approximately 0.001 inch in diameter, are for the passage of the cesium from the gun side of the target to the photocathode.

The materials used in the embodiment shown in FIG. 2b may be similar to those previously described in connection with FIGS. 1c and 2a.

During operation of the embodiment shown in FIG. 2b, the conductive coating 54 is maintained substantially at cathode potential to avoid capturing the photoelectrons and to provide a strong electrostatic focusing lens between the conductive coatings 54, 56 between the aligned apertures. The conductive coatings 54 and 56 are electrically connected and function as the target mesh electrode as has been described.

Referring now to FIG. 3a there is shown an embodiment of this invention wherein a photocathode 62 is deposited on one surface of an apertured insulating mesh member 64. On the opposite surface of the apertured insulating mesh member 64 there is provided a conductive coating 66 which functions as a target collector electrode

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during operation of the device. The target 22 is a thin semi-conductor, such as semi-conducting glass or magnesium oxide, as has previously been described.

In this embodiment, light passing through the faceplate lands on the photocathode 62 to produce the photoelectron image. The photoelectron image is accelerated toward the target electrode 22 by the electrode 66. Thus, the spacing between the photocathode 62 and the collector electrode 66 is determined by the thickness of the apertured insulating member 64. Also, the photocathode and collector electrodes are ruggedly supported with respect to each other due to the fact that they are deposited on opposite sides of the apertured insulating member 64.

On the faceplate of the envelope, there is provided a transparent conductive coating 68 which, if used, is maintained near photocathode potential during operation of the device. The purpose of the transparent conductive coating 68 is to insure that electrons originating from the photocathode 62 are directed toward the target 22. The coating 68 is optional.

Referring now to FIG. 3b there is shown an enlarged fragmentary sectional view of an embodiment of this invention wherein the photocathode 62 is provided as a coating on the side of the apertured insulating mesh member 64 facing the faceplate of the envelope 11. The insulating member 64 in turn is coated on the opposite side with a conductive coating 70. The conductive coating 70 extends over the solid portions of an insulating mesh member 72 which in turn supports a plurality of electrically conducting plugs 74. In this embodiment, the insulating mesh supports 64 and 72 may be formed of an integral construction or may be formed by two registered meshes. The conductive coating 70 functions, during tube operation, as a target collector electrode similar to the electrode 30 shown in FIG. 1, while the conducting plugs 74 function similar to the conducting plugs 40 described in connection with FIG. 1c.

Referring now to FIG. 4a there is shown an embodiment of this invention including two electron multiplier stages. In this embodiment, an insulating member 76, having apertures therein that are arranged at an angle to the plane of the member 76, supports the photocathode 78 and is positioned in a somewhat offset position with respect to other angled apertures in an insulating member 80, which in turn is positioned in a somewhat staggered position with respect to still other angled apertures in an insulating member 82. Between the apertured insulators 76 and 80, there is provided an apertured electrical conductor 84. The conductor 84 may be of integral construction as shown or it may consist of separate coatings deposited on the insulating members 76 and 80. Also, an apertured conductor 86 is provided between apertured insulators 80 and 82. The conductor 86 may be of an integral construction or may be separately deposited coatings. The conductor 84 is made of a material that has a high secondary electron emission and may be a material such as aluminum coated with magnesium oxide. Thus, between the apertured insulators 80 and 82, there is provided the second conducting surface 86 also having a high order of secondary electron emission.

With potentials such as those shown applied to this sub-assembly, the electron image from the photocathode 78 bombards the first dynode (conductor 84) and the secondary electrons therefrom bombard the second dynode (conductor 86). The secondary electrons from the second dynode 86 land on the semi-conducting target 22. On the side of the apertured insulating mesh member 82 toward the semi-conductor 22, there is provided an electrical conductive coating 88 which functions as a target collector electrode, similar to mesh screen electrode 30, as has been explained. The insulating mesh members 76, 80 and 82 may be formed of a material such as magnesium oxide, Fotoceram glass or Fotoform glass with the apertures through the various insulating mem-

bers positioned at an angle with respect to the plane of the insulating member as shown in FIG. 4a.

Referring now to FIG. 4b, there is shown an enlarged fragmentary sectional view of an embodiment of this invention wherein the apertures from one dynode to the next are in alignment. However, the dynode surfaces are formed so that the proper electron trajectory will occur between adjacent stages. In this embodiment, apertured insulating members 90, 92 and 94 are similarly shaped and arranged in the order named. Member 90 is nearest the faceplate of the envelope 11 and has apertures 98 therein, as do members 92 and 94, which are bevelled or of an inverted cone-shape. On the apertured insulator member 90, there is provided a photocathode surface 100 on the surface facing the incoming light, toward which the apex of the cone is pointed. It should be understood that, in the alternative, a conventionally supported photocathode may be used with this embodiment similar to the photocathode 28 shown in FIG. 1a. Secondary electron emissive surfaces 102 and 104 are provided on the apertured insulator members 92 and 94. On the base of each apertured insulator member 94 there is provided a target collector electrode 114. Adjacent to the target collector electrode 114 is a semi-conducting target 108 which may be made of a material such as glass or magnesium oxide. On the thicker portion of each of the apertured insulator members 90, 92 and 94, there is provided a different conducting mesh screen 110, 112 and 114 respectively. The mesh screens 110 and 112 are each connected to the next adjacent dynode to help provide the desired electron trajectory. The operation and materials of this embodiment are similar to those described and include two stages of electron multiplications between the photocathode 100 and the target 108.

Referring now to FIG. 5, there is shown a schematic view of an image orthicon tube utilizing a single stage of electron multiplication between the photocathode 28 and the semi-conducting target 22. The single stage of image multiplication is shown more clearly in FIG. 5a, and comprises a perforated insulator 122 having a conducting surface 124 on the photocathode side thereof. The conducting coating 124 may comprise a material such as evaporated aluminum. On the conducting coating 124, there is provided a surface 126 which has a high secondary electron emission. The secondary electron emission surface may be of a material such as magnesium oxide. On the target side of the perforated insulator 122 there is provided a conducting coating 128 which functions as a collector electrode.

The target 22, in this embodiment, may be semi-conducting glass or in the alternative may be a conducting plug arrangement as has been described. It should be noted that the openings in the collector mesh 128 are registered with the dynode openings. Also, if a conducting plug arrangement is used, the plugs are preferably positioned behind the dynode openings. Registry of the dynode and collector mesh is readily achieved in FIG. 5a, since the opposite sides of the insulator mesh 122 are coated with the dynode material and with a coating on the insulator mesh 122 which latter coating forms the collector mesh. Alternatively, a metal mesh could

first be coated with an insulator and then the other conductor could be added. The materials used in this embodiment may be similar to those previously described. The operation of this embodiment is like that of a conventional image orthicon pickup tube with the improvement being that one stage of electron multiplication is provided between the photocathode and the target.

According to applicant's invention, there is provided an improved pickup or camera tube in which a close target-to-photocathode spacing is provided or image multiplication is provided between the photocathode and the target, or both. Thus, applicant's invention provides a more sensitive photoemissive type camera tube or one which is easier to operate since defocusing of the photo-electron image cannot occur in the short space between the photocathode and the target electrode.

What is claimed is:

1. A tube comprising an evacuated envelope, an electron gun in one end of said envelope, a photoemissive photocathode in the other end of said envelope, a target electrode spaced from said photocathode, the spacing between said target electrode and said photocathode being less than thirty mils, and a target mesh screen between said target electrode and said photocathode, said mesh screen having a thickness so as to occupy at least one-twentieth of said spacing.

2. A pickup tube comprising an evacuated envelope, an electron gun in one end of said envelope, a photocathode in the other end of said envelope, a target electrode between said gun and said photocathode, said target being spaced from said photocathode a distance of from 22 mils to less than 300 mils, a target mesh screen means positioned between said photocathode and said target electrode, the thickness of said mesh screen means being such as to occupy at least one twentieth of the space between said photocathode and said target.

3. A photoemissive tube comprising an evacuated envelope, an electron gun in one end of said envelope for producing an electron beam, a target electrode in the path of said beam, a photoemissive cathode in the other end of said envelope for directing photoelectrons toward the other side of said target electrode, and means within said envelope and between said photoemissive cathode and said target electrode for focusing said photoelectrons onto said target electrode, said means comprising a screen electrode having a thickness not less than one-twentieth the space between said cathode and target, said space being from 22 mils to less than 300 mils.

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