

June 22, 1943.

H. A. IAMS
ELECTRONIC DEVICE
Filed Dec. 14, 1937

2,322,361

2 Sheets-Sheet 1

Fig. 1

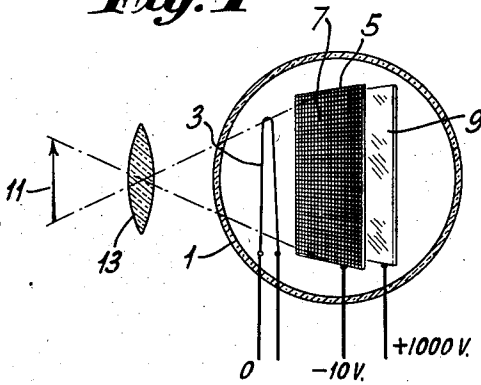


Fig. 2

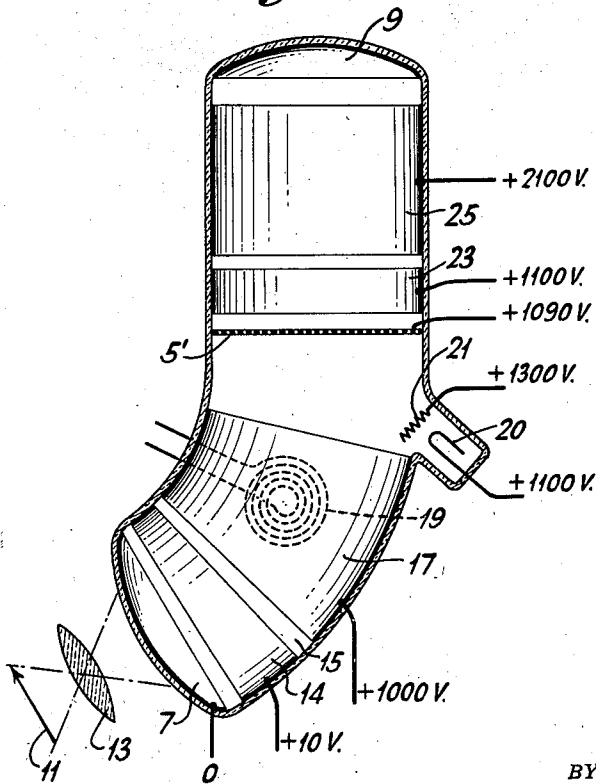


Fig. 3

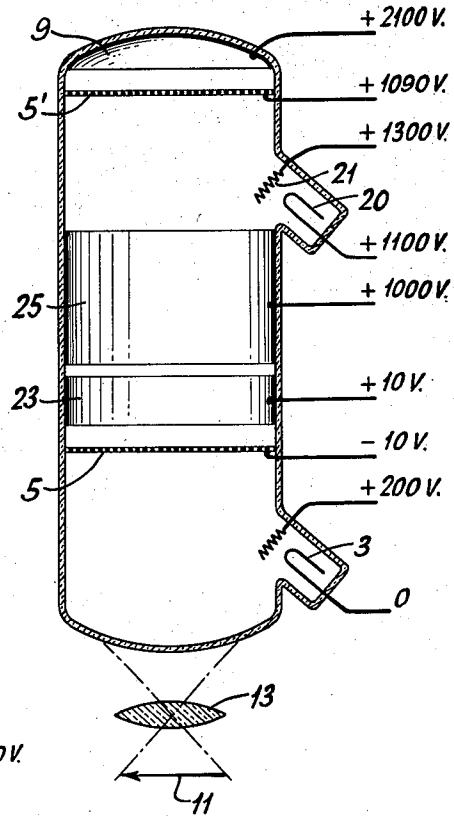
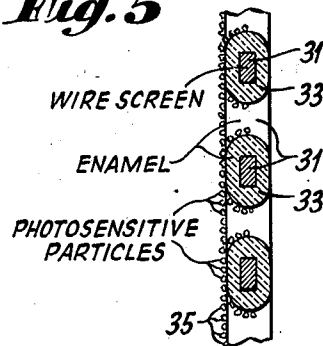


Fig. 5



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Fig. 4

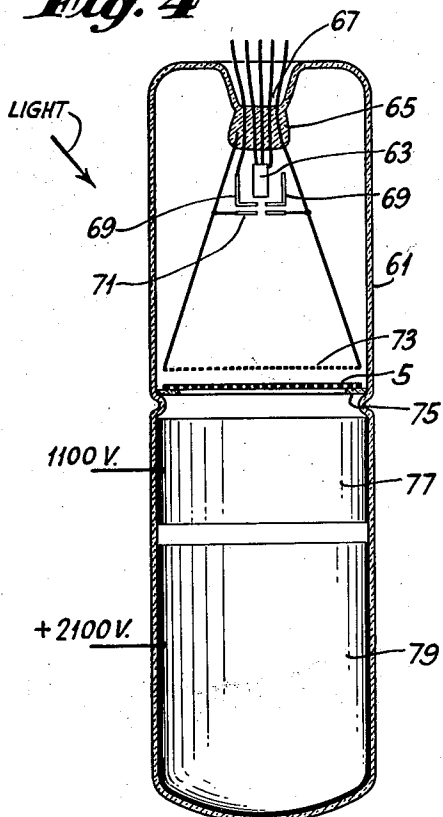


Fig. 6

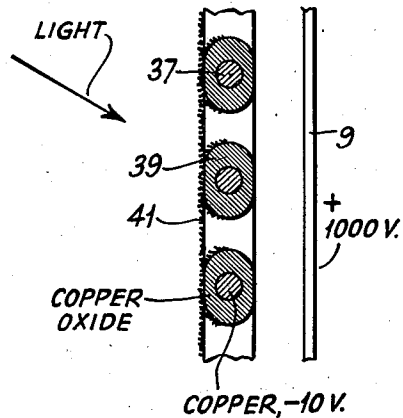


Fig. 7

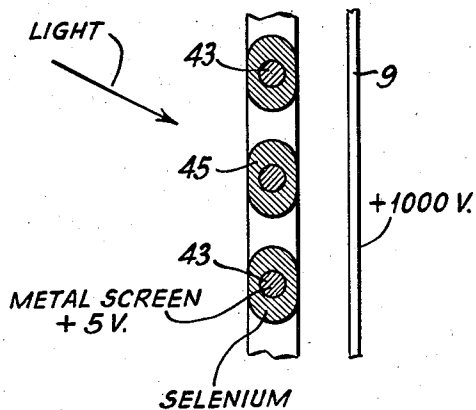
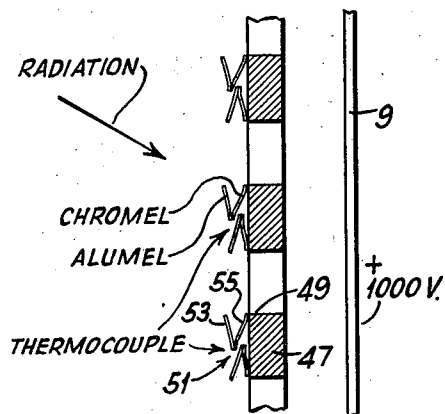


Fig. 8



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2,322,361

ELECTRONIC DEVICE

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Application December 14, 1937, Serial No. 179,678

8 Claims. (Cl. 250—41.5)

The present invention relates to image amplifiers and is concerned primarily with devices used to simultaneously amplify the intensity of every part of an object, scene, or pictorial representation focussed upon the device and then to render visible radiations to which the eye is either normally sensitive or insensitive. It is, of course, obvious that the proposed form of devices may readily be applied to television pick-up devices of either the storage or non-storage type as well as for use as image tubes for making astronomical observations, for use as electron microscopes or for use in aircraft or ship navigation, such as through darkness or fog.

As a fundamental proposition the image amplifiers herein disclosed have as their principal aims and objects those of providing ways and means to amplify an electron picture or representation by means of secondary emission. While in the past it has been known that secondary emission effects may be used to some extent to amplify current representative of images of which a replica is to be produced, such methods, as a general proposition, have been limited to amplifications of approximately 10 times per stage, which is of course the attainable ratio of secondary emission to primary emission.

The device which is to be described in this specification, however, is one wherein the amplification may not only be of several hundred times that of known devices, as a practical matter, but capable as well of amplification up to several thousand times that obtainable with existing known apparatus. The arrangement herein to be described primarily comprises the positioning within an electronic tube of a photosensitive insulated grid member which is used to control the electron emission directed from a cathode to a target surface which is capable of producing light upon electronic impact thereupon.

In the novel combination of elements which is to be set forth in this disclosure provision is made also for the use of a flooding stream of electrons by which it is possible to subject either or both of the photosensitive insulated grid or the insulated secondary emissive grid to the action of a stream of flooding electrons issuing from an electron source capable of producing a diffused bundle of electrons of high density to impinge upon and to cover the complete surface of these electrode elements.

One of the primary objects of this invention is, therefore, to provide an electronic image device wherein it is possible to increase substantially

the brilliance of the resultant produced electro-optical effect.

A still further object of the invention is to provide ways and means by which an electro-optical image of substantially greater brilliance than has heretofore been attained can be produced within a tube of a greatly simplified electrode structure and arrangement of parts.

A still further object of the invention is to provide various forms of photosensitive or secondary emissive insulated grid electrode structures for use within an image amplifier tube or the like, which structures shall have greatly increased operating efficiencies and which at the same time when used in multiple within such tubes function with respect to succeeding electrodes for controlling the operation thereof.

Other and further objects of the invention will be apparent and suggest themselves at once to those skilled in the art to which the invention is directed by reading the following specification and claims in connection with the accompanying drawings wherein

Figure 1 represents an image amplifying tube of simplified form wherein light of an image strikes or impinges upon a photosensitive insulating grid member to control a flooding stream of electrons.

Figure 2 illustrates a modified form of the invention wherein the arrangement of Fig. 1 is so constituted and arranged that the impinging light image has no direct effect upon the insulated secondary emissive grid;

Figure 3 represents a still further modification of Fig. 1;

Figure 4 represents a further modification applied to a complete tube; and,

Figures 5, 6, 7 and 8 represent suitable constructions for either the secondary emissive insulated grid structures or the photosensitive insulated grid structures for use with the structures of Figs. 1 through 4.

In this group of figures, Fig. 5 is a photosensitive grid; Fig. 6 is a photo-voltaic grid; Fig. 7 is a photo-conductive grid and Fig. 8 represents a thermo-couple type grid structure.

Referring now to the drawings for a further understanding of the invention, it will be seen that Fig. 1 illustrates an image amplifier tube of greatly simplified form. Essentially, the tube comprises within an enclosing envelope 1, a thermionic cathode 3, together with an insulated grid structure 5 of fine mesh enameled wire screen covered with a mosaic of photosensitive particles 7 and a fluorescent anode 9. Light of an image

11 is directed by any suitable optical means 13 upon the side of the enameled photosensitive grid structure 5 toward the thermionic cathode 3, as indicated, and causes the emission of photoelectrons from the surface of the photosensitive grid member which are drawn toward the fluorescent anode 9 by virtue of the potential gradient existing within the tube. The enameled coating upon the photosensitive grid member 5 is shown more particularly by Fig. 5 as a slight conductivity (say 10^{12} ohms/cm.³) to enable charges to leak away. The grid structure 5 is biased approximately to cut-off in darkness and when the optical image is focussed upon the photosensitive grid by means of any suitable optical system (not shown) electrons are emitted from the surfaces thereof. Each elemental section of the insulated grid structure under such conditions assumes a potential corresponding to the illumination and this acquired potential serves, in turn, to control a relatively large current flowing from the thermionic cathode. The electrons passing beyond the insulated grid structure 5 strike the fluorescent anode 9 which, for example, is maintained at a voltage of approximately 1000 volts positive relative to the thermionic cathode 3 and reproduces the amplified picture.

In general, the anode 9 is a conducting element and, as a general proposition, it is desirable that the coating on the anode which is to become luminescent upon impact of the electrons thereupon shall be of some material such as willemite or other activated zinc-ortho salt.

It is also contemplated, however, by this invention to provide any suitable form of so-called thermal-screen as the impact surface. Under such conditions, the thermal-screen is usually heated in a suitable manner by means of a source of current so as to maintain it substantially at all times just slightly below the temperature required for white incandescence.

By the arrangement of Fig. 2 a modified form of the arrangement of the invention has been disclosed. In this figure provision has been made for the prevention of the so-called re-generation due to light from the fluorescent screen or target element 9 falling back upon the photosensitive surface 7 upon which the original light image 11 is focussed. With the arrangement of Fig. 2 the light of a suitable image 11 which is to be magnified is focussed in suitable manner by the optical system 13 upon the translucent or semi-transparent photosensitive cathode 5 and by means of a suitable electron lens 14, 15 preferably comprising conducting bands coated upon the inner surface of the tube wall 17, or by virtue of conducting rings positioned and supported within the tube. These elements 14 and 15 are maintained at suitable potentials relative to each other and relative to the cathode 7 of which one suitable set of voltage values has been indicated. These elements are positioned between the translucent photocathode 7 and an insulated grid structure 5 of the general nature disclosed by Fig. 1.

It will be noted with the arrangement of Fig. 2, that the tube wall 17 is curved between the photosensitive cathode member 7 and the fluorescent or luminescent target or screen 9 upon which the magnified optical image is ultimately to be reproduced. The electron flow due to the emission of photoelectrons from the photocathode, is carried through the tube and accelerated and focussed by the electron lens system comprising the electrodes 14 and 15 so as to fall or impinge

upon the insulated grid structure 5' located intermediate the photosensitive cathode 7 and the luminescent screen 9. In view of the curvature of the tube wall in the area between the photosensitive cathode and the insulated grid structure, provision is made for curving in a corresponding manner the electron flow through this portion of the tube. This curvature is provided by the interpositioning of a magnetic field produced either from a fixed magnet of suitable form, so as to produce the desired flux density, or by virtue of an electromagnet 19 having a field strength which is determined in accordance with the desired curvature to be given to the electron flow.

As was suggested by the arrangement of Fig. 1, the insulated grid member 5 is not only subjected to the initially produced stream of electrons due to photo-emission, but is also subjected to a flooding stream of electrons which are copious in number and which are emitted preferably from a source of thermionic emission 20 and accelerated toward the insulated grid structure 5 by way of the control electrode 21. As was explained in my copending application, Serial No. 116,689, filed December 19, 1936, the insulated grid member 5' may be one which acquires charges in accordance with the electrons reaching it from some controlled source. In connection with the arrangement shown by Fig. 2 the controlled source of electrons is the translucent photo-cathode 7 from which the electron emission is variable in accordance with the intensity of light and shadow on elemental areas of the object focussed thereupon. In this way charges are acquired by elemental sections of the insulated grid structure 5' and in accordance with the acquired charges which are positive in nature due to the fact that the photoelectrons leaving the translucent photocathode impact the insulated grid at high velocity to emit secondary electrons, controls the number of flooding electrons which pass through the insulated grid toward the fluorescent target. In this instance, the insulated grid structure 5' being interposed in the path of the flooding electrons from source 3 causes a virtual cathode to be formed near the insulated grid 5 and on the side thereof toward the flooding source.

The electron flow in the portion of the tube intermediate the insulated grid 5' and the fluorescent target 9 is governed in accordance with the charges acquired by the insulated grid member.

Whatever electrons flow between the insulated grid and the fluorescent target and which represent the photoelectric current increased in magnitude are suitably focussed by the electron lens system comprising the electrode members 23 and 25. These electrode members like those positioned intermediate the photosensitive cathode and the insulated grid may also be formed as conducting films upon the inner surface of the tube wall. Suitable potentials may be applied to these elements 23 and 25 or the electron lens may be constituted by virtue of suitable conducting rings positioned within the tube.

In Fig. 3 a still further modification of the invention has been shown wherein the light image which is to be amplified and reproduced upon the fluorescent target is projected directly upon a photosensitive insulated grid member which is initially subjected also to a flooding stream of electrons as was disclosed by the arrangement of Fig. 1.

As was above suggested in referring to Fig. 1, the electron flow intermediate the photosensitive insulated grid structure and the target represents by virtue of the flooding electrons passing beyond the insulated grid, a magnified electronic replica of the light image. This magnified electronic replica is then focussed by suitable focussing elements such as the conducting rings 23, 25 or the like which are positioned between the photosensitive insulated grid and the insulated secondary emissive grid, which is located closely adjacent the fluorescent target.

In connection with the modification shown by Fig. 3 in contrast to that shown by Figs. 1 and 2, two stages of amplification are provided within the tube and by virtue of the flooding effect, produced by the electron emission from the thermionic cathode 3 and accelerated toward the insulated secondary emissive grid, all charges acquired by this secondary emissive grid due to the electron flow passed beyond the photosensitive insulated grid toward the insulated secondary emissive grid will control the portion of the flooding electron stream from the electron emitting cathode 29 which is directed toward the fluorescent anode 9. In the arrangement shown by Fig. 3 it will be noted that the fluorescent anode itself is a conducting member such as that shown more particularly by Fig. 1. The potentials applied to the various electrode elements which are indicated by Fig. 3 are, like those suggested for use with the arrangements of Figs. 1 and 2, merely typical illustrations of values of potential measured relative to a suitable reference point in the system indicated by the potential zero volts, but it is to be understood that it is possible to vary widely the range of voltages which shall eventually be used.

In general, the design of the insulating grid members depends upon how fast the amplified picture must be capable of changing. In astronomical work, for instance, in which a minute might be allowed for changing the picture, the resistance of the enamel from which the insulated grid may be formed, may be very high and this naturally would permit a tremendous amplification. For television work, however, the resistance should preferably be sufficiently low to permit dissipation of the charges acquired, whether it be directly from the light image falling upon the insulated grid structure, or whether it be due to the impact of the electrons representing a magnified current image, so that most of these charges can be dissipated within a period of the order of one-thirtieth second.

In my copending application Serial No. 116,689, above referred to, some forms of suitable insulating grid structures have been described and reference is made to that disclosure for details of the insulating grid members as well as to further details of the manner in which the insulated grid structures may be supported, for example, within the enclosing envelope which houses the tube electrode element. However, the present invention also attempts to disclose still other modifications of the insulated grid structure and particularly suitable forms of insulated grid structures which shall be sensitive to all forms of radiant energy, as a general proposition.

By the arrangement provided for the insulated grid elements disclosed by Fig. 5 there is provided a wire screen-like mesh 31 which is coated a suitable enamel covering 33. This enamelling process is usually carried forward to a predetermined degree by dipping the mesh-like grid

structure 31 into enamel to provide a coating of enamel thereon of desired thickness. In the case of an insulating enamel, after the mesh has been dipped the enamel is baked in a suitable manner prior to assembling within the tube. However, in forming a grid of this general type it is also frequently customary to grind the enamel into a powder and then to mix this with a binder and to spray it upon the entire mesh. After spraying the coating upon the mesh it is fired at a suitable temperature to bake it and then the spraying and firing process is repeated until the enamel covering is of the desired thickness. In connection with a tube of the general character hereinafter described the thickness of the enamel coating will depend upon the usage and the desired time constant of leakage, and the leakage can be determined substantially by varying the alkali content of the enamel which is used.

After the complete grid element has been enameled to the desired thickness to provide a degree of leakage which is suitable for the particular use to which the tube is to be put, photosensitive particles 35 are coated upon the enamel structure. This photosensitizing process may be carried forward in substantially the same manner as disclosed by Essig Patent No. 2,065,570 of December 29, 1936, wherein the enamel will be covered with a suitable metallic compound or a laterally conducting metallic film, and then upon baking at a suitable temperature and for a time period substantially as disclosed by Essig, the metallic film is drawn into a series of minute size particles 35 which are insulated from each other by the insulating enamel. After this has been done the metallic particles may be suitably oxidized and photosensitized to leave a surface of photosensitive coating as indicated by Fig. 5 of the drawings.

In a modified form of the arrangement shown in Fig. 6 the grid structure comprises a copper mesh 37 about the wires of which is a copper oxide coating 39 of a suitable thickness. Upon this copper oxide coating 39 there is sputtered in a suitable manner, as for instance by sputtering through a mesh of suitable size a film of separated platinum particles 41. This arrangement provides what might be termed a "photo-voltaic" type of grid structure for use within the tube.

In still a further modified form of arrangement as shown by Fig. 7 for the grid structure the metallic mesh 43 of the desired size has coated upon it a coating of selenium 45 to the desired thickness and onto this coating of selenium the light image is directly projected. Such form of coating of the grid structure provides what might be termed a photo-conductive type of grid element as contrasted to the arrangement shown by Fig. 5.

In the modified form of grid structure as shown by Fig. 8 there is provided, as in the arrangements of Figs. 5, 6 and 7, a metallic screen structure 47 which is also in the form of a mesh, although in this instance it will be appreciated that the wires of the mesh need not be coated with insulation. At each intersection 49 of the wires of the mesh, which wires are woven and in which the interstices are of the desired size, there is attached in a suitable manner, as, for instance, by welding, a thermo-couple 51 formed from two different elements which slightly overlap each other. Two metals which are well

suited for this particular type of arrangement are those known as "Alumel" 53 and "Chromel" 55. These elements have the property that when heated by radiation so that the junction points are at different temperatures, a voltage will be developed.

In connection with each of the types of grid structures shown by Figs. 5, 6, 7 and 8, it will be appreciated that the common feature existing between each is that, in accordance with a light image falling thereupon voltages are developed over the surface of the grid structure which vary across the surface of the grid in accordance with the variations of light and shadow in the optical image projected thereupon. In this manner the flooding electrons which are directed toward the grid structures will pass through these grid structures to form a magnified current representative of the optical image which will be proportional to the voltages acquired at the elemental sections of the grid structure.

In Fig. 4 is disclosed a modified form of the complete assembly as above disclosed. In this arrangement it will be seen that there is provided within the tube 61 the insulated photosensitive grid member 5 preferably of the general form shown by Fig. 5, onto which the light image is projected to produce photoemission. The light image falls upon the insulated photosensitive grid 5 from the direction shown by the arrow and thus is quite closely related to the general arrangement shown by Figure 1. In the end of the tube envelope from which the light image is directed there is positioned a flooding electron source 63 which is supported in a suitable manner from the press 65 within the stem portion 67 of the tube. This flooding electron source includes a thermionic cathode heated in any suitable manner either directly or indirectly and spaced about the thermionic cathode is a space charge grid 69 and in order to draw the electrons from the cathode and to project the electrons in a flooding stream which will strike the insulated grid there is provided an anode 71, preferably in the form of a disc suitably apertured to pass the electron emission from the cathode. Closely adjacent the insulated grid element is a wire screen 73 which is primarily for the purpose of collecting secondary electrons released from the insulated grid structure. Upon the opposite side of the insulated grid structure 5 there is provided an annular mica electron barrier 75 which prevents leakage of electrons from around the edge of the grid structure 5.

At the opposite end of the tube from that at which the flooding source of electrons is located there is provided a target member 9 which is usually in the form of a luminescent coating of the inner surface of the tube end wall, although naturally where desired a so-called thermal screen may be substituted. Intermediate the insulated grid structure 5 and the target member 9 there is formed a suitable electron lens, which is constituted by the positioning of suitable conductive coatings 77 and 79 of the inner surface of the tube wall and maintaining these coatings at suitable potentials relative to the insulated grid structure and to each other to form an electrical field distribution within the tube which shall focus the electrons passing beyond the insulated grid structure upon the target member, or where desired, the electron lens may be constituted by suitable conducting ring members sep-

arated within the tube as has already been described by Morton and others.

Many and various modifications of the invention herein disclosed may be made of course without departing from the spirit and scope of this disclosure and therefore I believe myself to be entitled to make and use any and all of these modifications provided they fall fairly within the spirit and scope of the hereinafter appended claims.

What I claim is:

1. An electronic image translating device comprising an envelope wherein is housed a light sensitive light image receiving element supported in one end of the envelope for producing in accordance with the intensity of a bi-dimensional light image projected thereupon an electron flow of proportional magnitude, an electron translating target member positioned in the opposite end of said envelope, a bi-dimensional insulated grid structure positioned within the envelope intermediate the target member and the light sensitive element to receive the electron flow from the light sensitive element whereby a pattern of voltages is simultaneously developed upon the grid structure in accordance with the distribution of light intensity of the optical light image projected upon the light sensitive element, means positioned within the envelope intermediate the light sensitive element and the insulated grid structure for flooding the insulated grid structure with an uncontrolled flow of electrons and to produce in accordance therewith an intensified flow of electrons within the tube area intermediate the target member and insulated grid structure representative of the instantaneous pattern voltage produced upon the insulated grid structure, means for focussing the electron flow from the light sensitive element upon the insulated grid structure, and a second means for focussing the intensified electron flow upon the target member.

2. The apparatus claimed in the preceding claim wherein the tube envelope is of arcuate shape so that re-generation effects from electron impact upon the target member are ineffective upon the light sensitive element, and magnetic means positioned at the area of curvature of the tube for causing the electron flow to follow the path of tube curvature.

3. In an electronic light image translating system, means for producing a controlled intensity electron flow corresponding to the light densities of an optical image, an electron permeable bi-dimensional planar grid structure having insulated elemental areas positioned thereon and extending in all directions over the surface of the grid, said grid being positioned to receive the controlled intensity electron flow whereby a bi-dimensional charge image of a magnitude proportional to the intensity of the electron flow is produced over the elemental areas of the grid, means for flooding the grid structure with electrons of substantially constant magnitude to produce an intensified electronic current image in accordance with the magnitude of the produced charge image, and means for translating the intensified current image into an electro-optical representation.

4. In an electronic system for translating light values into electrical values, means for producing a controlled intensity electron flow corresponding to the light densities of an optical image, an electron permeable bi-dimensional electrode structure having insulated elemental

areas positioned on and extending in all directions over the surface of the electrode, said electrode being positioned to receive the controlled intensity electron flow to acquire a lateral non-directional distribution of potential charges on the elemental areas proportional to the intensity of the electron flow produced over the elemental areas thereof, means for flooding the electrode structure with an uncontrolled flow of electrons to produce an intensified electron flow representative of the light image, and means for converting the electron flow of intensified form developed in accordance with the acquired distribution of potential charges into an electro-optical representation.

5. The method of electrical image transmission which comprises projecting a bi-dimensional optical picture image on to an apertured and discontinuous light sensitive member to simultaneously form a contemporary bi-dimensional charge image thereon corresponding in elemental charge values and distribution to elemental light values and distribution of the optical picture image projected thereon, and controlling an instantaneous electron flow of picture image area by said charge image.

6. An electron image amplifier comprising an envelope containing means for generating a spatially uniform electron flow, a bi-dimensional planar apertured member positioned in the path of said flow, said member having a surface of insulating material, a mosaic of photoelectrically

sensitive material upon said surface, means for focusing a bi-dimensional optical image upon said mosaic to produce simultaneous electron emission therefrom, thereby contemporaneously forming a bi-dimensional charge pattern on said member, and means for directing said flow through said apertured member to form an instantaneous bi-dimensional electron current image in space.

7. In an electron tube a bi-dimensional apertured insulated grid, an electron emitting element to emit a flood of electrons, means to project the emitted flood of electrons through said apertured grid, means to simultaneously produce on said apertured grid contemporary electrostatic charges representative of a picture, a target element located on the side of said apertured grid opposite the source of said flooding electrons, and means to focus electrons passing through said grid upon said target.

8. In an electron tube a bi-dimensional apertured insulated grid, a thermionic cathode to emit a flood of electrons, means to project the thermionically emitted electrons through said apertured grid, means to simultaneously produce on said apertured grid concurrent electrostatic charges representative of a picture, a target electrode located on the side of said apertured grid opposite said thermionic cathode, and means to focus electrons passing through said grid upon said target.

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