Dec. 10, 1963 E. J. STERNGLASS 3,114,044

ELECTRON MULTIPLIER ISOLATING ELECTRODE STRUCTURE

Filed Sept. 30, 1959 3 Sheets-Sheet 1

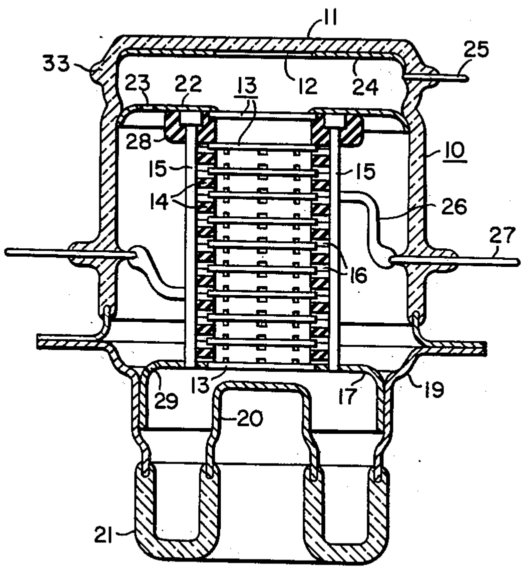

Fig. 1.

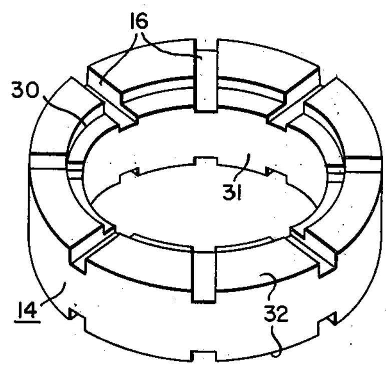

Fig. 2.

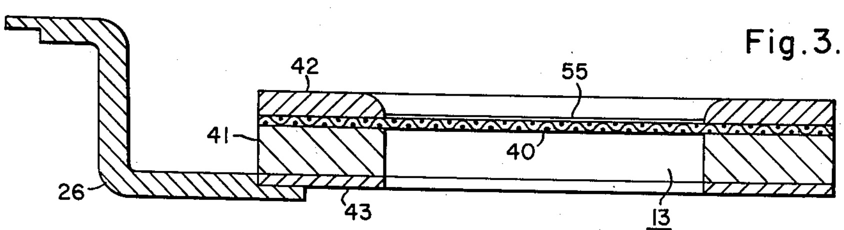

Fig. 3.

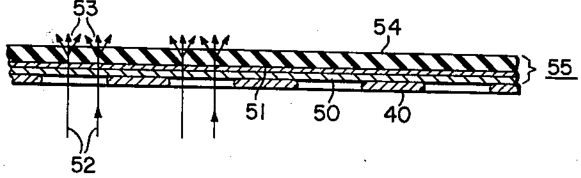

Fig. 4.

WITNESSES

Edwin E. Bassler

James F. Young

INVENTOR

Ernest J. Sternglass

BY

Charles F. Renz

ATTORNEY

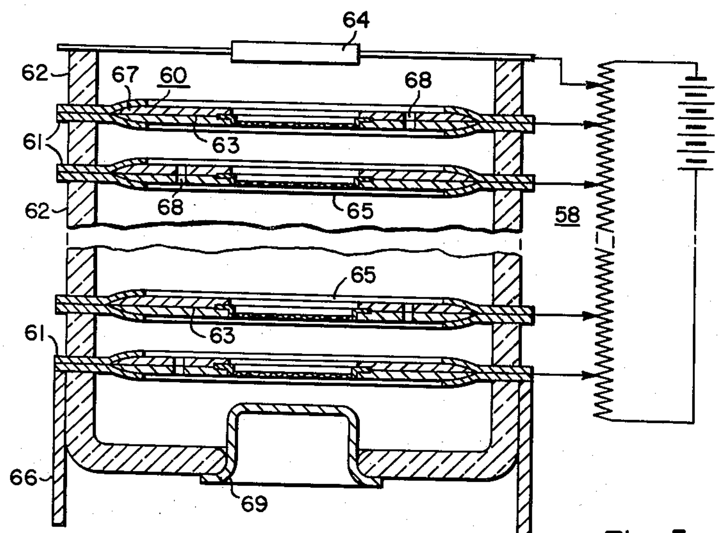
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Fig. 5.

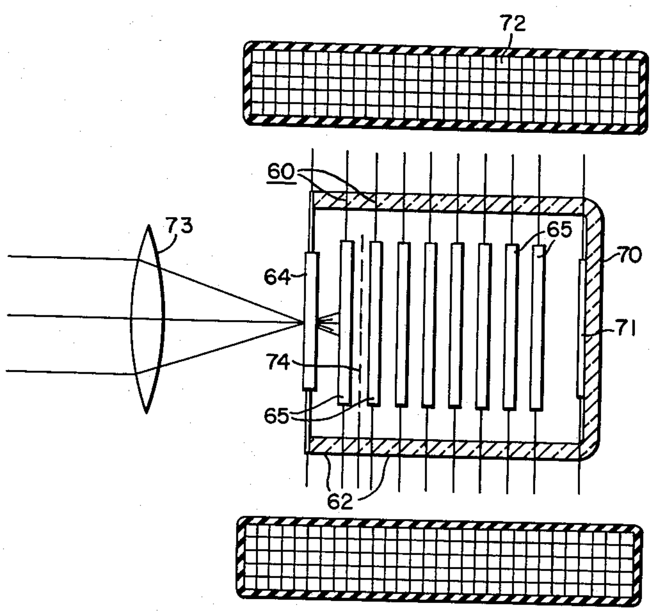
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Fig. 6.

ELECTRON MULTIPLIER ISOLATING ELECTRODE STRUCTURE

Filed Sept. 30, 1959 3 Sheets-Sheet 3

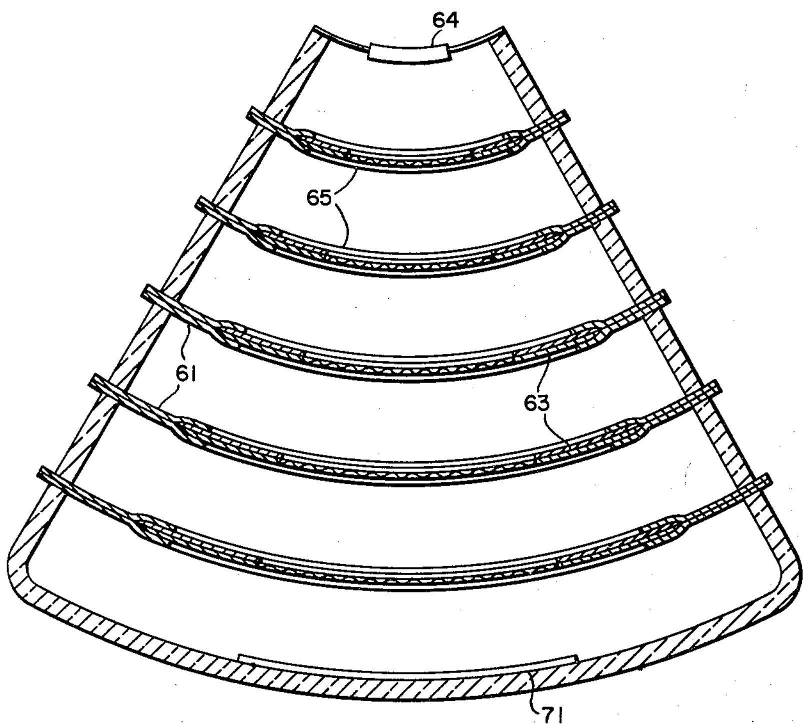

Fig. 7.

Patented Dec. 10, 1963

3,114,044

ELECTRON MULTIPLIER ISOLATING ELECTRODE STRUCTURE

Ernest J. Sternglass, Pittsburgh, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania
Filed Sept. 30, 1959, Ser. No. 843,428
13 Claims. (Cl. 250—207)

This invention relates in general to electron tubes and more particularly to photomultiplier type tubes and image intensifier tubes employing electron multiplication.

It is generally desirable for the electron multiplier structure in a phototube to amplify a pulsed signal without producing a spread in signal pulse width. The best presently known devices are able to provide this feature to the extent that a pulse rise time as small as 3×10^{-9} seconds is obtained. Pulse rise time may be defined as the time required for an output signal to pass from 10% to 90% of full amplitude for one electron leaving the cathode.

It is not practicable to further shorten the rise time in these devices. This is because of features inherent in the tube design such as the use of front-surface type dynodes which require a geometric arrangement in which electrons leaving the photoemissive cathode at the same time must travel to the first dynode by trajectories having different lengths due to the small entrance aperture. Paths between subsequent dynodes also vary in length. A more favorable geometry can be used with dynodes of the Venetian blind type but a large spread in pulse width occurs there due to low extracting fields for the secondaries.

With front-surface type dynodes it is necessary to construct photomultiplier tubes in an "open" manner to allow for the travel of electrons, but as a result it is possible for ions formed at the last multiplier stages to travel back to the cathode and cause large dark currents which counteract electron emission. An open structure also allows cesium atoms or other photoemissive materials from the cathode to diffuse throughout the tube and collect on dynodes or the tube walls where they may emit electrons due to stray radiation and thus cause additional dark current as well as deterioration of the cathode. For purposes of this discussion, dark current may be considered any output signal or portion thereof which does not directly result from the emission of photoelectrons due to the radiation sought to be amplified and secondary electrons produced therefrom in the dynode stages.

Front-surface type dynodes also are unsuitable to an arrangement from which a coaxial output can be obtained. This structural drawback results in a device having a poor high frequency response because of the impedance change to the outside of the glass envelope. Good high frequency response has been achieved in triodes by use of the well known "lighthouse" type of construction wherein electron transit times, interelectrode capacitances and lead inductances have been substantially reduced or made unimportant. This approach has hitherto been impractical in phototubes. A coaxial output can be obtained with dynodes of the Venetian blind type but there the spread in electron transit times, as mentioned above, prevents high frequency operation because of the relatively long rise time.

It is also difficult to construct a photomultiplier with front surface type dynodes which does not permit large leakage currents in the anode circuit.

The geometry used in conventional phototubes also results in non-linearity of response at high electron currents due to adverse space charge effects created by these high currents.

The unfavorable geometry of multipliers using front surface type dynodes produces other disadvantages, namely that any external magnetic fields seriously disturb tube operation because incident and emergent electrons to not travel in the same direction, spurious signals and dark current due to electrons striking the glass walls give rise to light flashes that travel back to the cathode; pile up of dark current pulses may be mistaken for the signal pulse; manufacturing difficulties arise due to the complex activation process necessary in the sealed-off tube; great supply voltage stability is required since yield varies exponentially with applied voltage.

The foregoing disadvantages impair the performance of electron multipliers in general. In an image intensifier, good image resolution depends on the tube being substantially free of dark current and the paths of electrons from the cathode to the first dynode and between successive dynodes being in substantially straight lines of equal length for different electrons in order to obtain good resolution. It is the principal object of this invention to provide such a device.

It is another object of this invention to provide a photomultiplier which amplifies a pulsed signal with a minimized spread in signal pulse width.

Another object is to provide a photomultiplier in which the paths of electrons from dynode to dynode are substantially equal.

Another object is to provide a photomultiplier in which the cathode and dynodes are individual isolated from one another to the extent that photomissive material from the cathode cannot readily travel throughout the tube and ions formed between dynodes cannot readily travel to the cathode.

Another object is to provide a photomultiplier in which dark current is minimized.

Another object is to provide a photomultiplier which lends itself to providing a coaxial output.

Another object is to provide a photomultiplier having a good frequency response.

Another object is to provide a photomultiplier whose response is linear at high currents.

Another object is to provide a photomultiplier in which space charge effects are minimized.

Another object is to provide a photomultiplier whose operation is not seriously impaired by external magnetic fields.

Another object is to provide a photomultiplier which can be readily manufactured.

A further object is to provide a photomultiplier readily lending itself to utilization for imaging purposes.

In my U.S. Patent 2,905,844, issued September 22, 1959, dynodes are described of the transmission secondary emission type. Such dynodes offer various advantages for photomultiplier purposes, and particularly for photomultipliers used in imaging devices, over front surface type dynodes which will become apparent hereinafter. It is therefore a further object of my invention to provide a high speed photomultiplier employing transmission secondary emission dynodes.

These and other objects are effected by my invention as will be apparent from the following description taken in accordance with the accompanying drawing, throughout which like reference characters indicate like parts, which drawing forms a part of this application and in which:

FIGURE 1 shows a sectional view of a photomultiplier tube embodying the teaching of my invention;

FIG. 2 shows a perspective view of the insulating spacer of FIG. 1;

FIG. 3 shows a sectional view of the dynode structure of FIG. 1;

FIG. 4 shows an enlarged sectional view of the metallic mesh and transmissive secondary emission material of FIG. 3;

FIG. 5 shows a sectional view of an alternate embodiment of my invention;

FIG. 6 shows a sectional view of an embodiment of my invention in an image intensifier device; and

FIG. 7 shows a sectional view of an alternate embodiment of my invention in an image intensifier device.

Referring in detail to FIG. 1, there is shown an evacuated envelope 10 having at one end an input window in the form of a polished face 11 upon the inner surface of which a layer 12 of a suitable photoemissive material such as cesium antimony has been deposited forming a photoemissive cathode. It should be noted that in the practice of this invention the source of electrons need not be a photoemitter but may be any type source including thermionic as well as cold cathodes. For many applications in which the advantages provided by this invention are particularly desirable a planar photocathode is preferred.

A plurality of disc shaped transmission secondary emission dynodes 13, like those described in my previously mentioned Patent 2,905,844, are arranged within the envelope 10 parallel to one another and to the photocathode 12. In applications where a high gain is not important, it is apparent that one dynode may be adequate.

The dynodes 13 may be constructed by suitable methods known in the art. For example, an organic film such as nitrocellulose lacquer is settled on a grid or mesh support structure by covering the grid with water and applying the organic material with a solvent on the surface of the water. As the organic solution spreads out on the surface of the water the solvent evaporates leaving the organic film. The water is then removed allowing the film to settle on the grid. The organic film is dried and an electrically conductive material such as aluminum or carbon is evaporated onto the free surface of the organic film. The organic film is then baked away. The secondary electron emissive layer of an insulating material is then evaporated onto the electrically conductive film. A thin layer of an electron scattering material, such as gold, may be evaporated before the insulator. It has been found by forming an aluminum layer thicker than the minimum thickness required for conduction that the effect is substantially the same. It is only necessary that the weight of conducting film per unit area be such as to produce appreciable scattering. The electrically conductive layer on the grid and the secondary electron layer upon the conductive layer is the resulting structure. This is only one of many methods of depositing the layers on the grid. The etched-foil type of mesh for the grid support is preferred to the woven mesh structure because of a flat surface available for supporting the thin layer of secondary electron emissive material.

Another method of construction is to deposit the secondary electron emissive layer onto a permanent film of a suitable material such as SiO or Al or Al_2O_3 of a thickness of the order of hundreds of angstroms. The permanent film may be deposited by techniques similar to that described above for the organic film. It is also possible, if the voltage between dynode structure is sufficiently high, to use a self-supporting thin metallic film instead of the supporting grid and the secondary electron emissive layer. A very thin secondary electron emissive layer may be employed, particularly if an electron scattering layer of a high atomic number metal is deposited previous to the secondary electron emissive layer so that an incident electron has a relatively long path through the secondary electron emissive material thereby forming many secondaries.

Another modified dynode structure is described in U.S. Patent 2,898,499, issued August 4, 1959, by E. J. Sternglass and W. A. Feibelman. The dynode described in this patent utilizes a coherent oxide such as aluminum or magnesium oxide on a support layer which in turn supports a conductive layer and the secondary electron emissive layer.

The foregoing have been mere examples of dynodes suitable for use in accordance with the present invention. In addition to transmissive dynodes having a continuous surface, the open mesh type dynode, well known as the Weiss multiplier, is also suitable, for some purposes, for use in the present invention. This latter type dynode does not, however, provide the degree of compartmentalization attainable with transmissive dynodes and is therefore not as desirable for use in some applications, such as in image intensifiers.

The dynodes 13 are separated from each other and supported by ring-shaped insulating spacers 14 which are held together by insulating rods 15 at their periphery and a top plate 28. Holes 16 are provided in the insulating spacers 14, as shown in FIG. 2, for pumping out the spaces between dynodes 13 and also for making electrical connection between the dynodes 13 and an external voltage source (not shown) by means of lead 26 and pin 27 in the glass envelope 10, for example. A base plate 17 is conductively connected to the last dynode 13 and rests on a flange 19. The flange 19 forms the outer part of a coaxial output electrode system, the inner member of which is an anode 20 insulated from the flange by a glass seal 21. The base plate 17 is provided with one or more pumping holes 29. A cathode shield 22, whose purpose is to seal off the cathode region from the dynode structure proper, is also provided with a pumping hole 23.

The cathode shield 22 is desirable in order to prevent large amounts of photoemissive material such as cesium in the cathode space from reaching the remaining parts of the tube where it could lead to excessive field emission and dark-current. A further purpose of the cathode shield 22 is to prevent gaseous products from the dynode 13 from reaching the cathode 12. The opening 23 may be closed by means of a suitable ball manipulated through a side-arm 33 during cathode activation, the side-arm 33 being subsequently sealed off. If complete separation of the dynode structure is desired, the cathode shield 22 and the first dynode 13 may be tightly connected without any pump hole communicating with the remainder of the tube, a separate pump-connection being used to evacuate the space below the first dynode. A conductive coating 24 makes electrical connection between the cathode 12 and a pin 25 in the glass envelope.

In FIG. 2 the insulating spacer 14 is seen to have pumping holes 16, as has been previously discussed, and a groove 30 to receive the dynode assembly. The interior wall of the spacer, which may be of a suitable ceramic material, is coated with a resistive paint 31 such as chromic oxide in order to minimize charging of the wall. To further aid in this, the faces of the spacer are coated with a conductive material 32 such as platinum or silver which may be applied by evaporation in vacuum, sputtering, painting or other suitable means.

FIG. 3 shows an enlarged cross-section of a dynode structure 13 comprising a metallic mesh 40 of a suitable material such as nickel, on which the layers 55 have been deposited, supported between two metallic rings 41 and 42, which also may be of nickel. A third ring 43 provides a means of making electrical contact to a conductive lead 26.

FIG. 4 shows a greatly enlarged cross-section of the metallic mesh 40 of FIG. 3 and the layers 55 deposited thereon. The structure shown in FIG. 4 is one of the suitable dynode structures which have been previously discussed. The mesh 40 carries a support layer 50, of about 100 angstroms thickness composed of a stable material such as SiO on which is a very thin layer 51 weighing about 0.01 mg./cm.^{2} of a metallic element that acts to scatter the incident electrons 52 coming from below and to provide conductivity over the dynode surface. Aluminum may be used for the conductive and scattering layer. The incident electrons finally form secondary electrons 53 in a layer of insulating material 54, as described in my beforementioned Patent 2,905,844, which is of the order of 200–2000 angstroms thick. Potassium chloride is a suitable material for this purpose.

As has been previously discussed, other dynode structures are suitable for use in the practice of my invention. The support layer 50 is not always necessary since techniques have been mentioned which make it possible to form a conductive layer directly on the metallic mesh. Also, the conductive layer could be self-supporting. Many additional modifications are possible.

The device shown in FIG. 1, is a photomultiplier which may be operated in a conventional manner. For example, light incident upon the cathode 12 causes electrons to be emitted therefrom in numbers proportional to the intensity of impinging radiation to which the photosurface is sensitive. By providing successively higher positive potentials between the electrodes 12, 13 and 20 the photo electrons are accelerated to the first dynode where transmission secondary electrons are emitted in numbers larger than the number of incident photoelectrons, but proportional thereto; the secondary electrons are further accelerated to the second dynode where further multiplication takes place. The process is repeated until the electrons reach the anode 20 from which a signal may be obtained of much greater intensity than could be provided by the original photoelectrons.

The embodiment of my invention just described greatly reduces the spread in pulse width between dynode stage 13 by their plane-parallel structure. The effect of the initial velocity distribution of the secondaries is greatly minimized by the higher voltages between stages required by the transmissive type of dynode, viz., about 2 to 4 kv. instead of 100 volts per stage. With this structure pulse rise times of about 3×10^{-11} seconds are attainable, which is about two orders of magnitude less than that which previous tubes could attain.

To aid in further shortening the pulse rise time of the multiplier, the last dynode 13 may be replaced by an open mesh grid. Use of the grid serves to accelerate the electrons from the preceding dynode to a high velocity and to electrostatically shield the anode 20 so that the electron cloud traveling through the tube from the preceding dynode will not induce charge in the anode circuit prior to the actual impingement of the electrons on the anode. The grid should be located close to the anode 20 but should be separated sufficiently so that the space between the anode and grid is substantially field free.

The cathode 12 can be of large size so that its effective size need not be less than the photosurface area. This avoids the problem of achieving a uniform travel time from different areas of the photocathode into a small multiplier entrance aperture.

High collecting fields at the emitting surface of the photocathode 12 and at each dynode 13 help reduce the transit time spread. The continuous nature of the dynodes 13, as opposed to the Venetian-blind type, for example, insures the presence of these high fields and avoids the variation in multiplication efficiency from point to point.

Ion feedback is essentially eliminated by the complete isolation of the stages from each other achieved in the present structure. Because, at a given voltage, ions have less penetrating power than electrons, ions formed in the last few stages are unable to pass through the dynode layers by virtue of the continuous nature of the dynodes 13 and the insulating spacer construction. This construction also prevents the ions from escaping sideways so that they are unable to reach the photocathode 12.

The structure is suited for coaxial output since the last dynode 13, conductively attached to the flange 19, and the collecting anode 20 form part of a coaxial transmission line that can be continued without change of impedance to the outside of the glass envelope. In this way, electrical reflections that lead to poor rise-time characteristics are avoided and full advantage can be taken of the rapid pulse rise time characteristics of the structure.

Nonlinearity at high currents is greatly reduced by virtue of the close spacings and high voltages between stages. Conventional multipliers begin to show saturation due to space-charge limitations at about 10 to 100 ma. peak current while the present structure may be built to allow peak currents on the order of 1–10 amperes without non-linearity.

A long leakage path between the anode 20 and the last dynode 13 is automatically provided by the coaxial output structure. The base plate 17 also helps raise the leakage resistance by reducing the amount of photoemissive material from the cathode 12 from reaching the tube seal 21.

The cathode shield 22 and the base plate 17 both aid in confining the photoemissive material to the cathode space. In addition, the insulating spacers 14 prevent photoemissive material from reaching the dynode surfaces and therefore minimize dark current due to electron emission from the dynodes 13. As pointed out earlier, the cathode space, as enclosed by the tube face 11, the cathode shield 22 and the first dynode 13, may be completely sealed off and separately evacuated to further reduce the dark current which might result due to photoemissive material reaching the dynode structure.

Since both incident and emergent electrons move along the axial direction of the structure, it is possible to eliminate effects of even very strong magnetic fields simply by orienting the tube axis parallel to the lines of flux. Where it is desired to use scintillation counter in or near strong magnetic fields produced by particle accelerators, this is a very important advantage not realizable in any other type of electron-multiplier now available.

There is little chance for electrons to reach the glass walls of the envelope 10 since they are confined by the insulating spacers 14 or in the anode space. Thus, spurious scintillations in the glass walls which can give rise to electron emission from the photo-cathode are rare.

Since the resolving time of the structure is of the order of 5×10^{-11} seconds, there is small probability that more than a single dark-current electron will be emitted from the cathode 12 in an interval equal to the resolving time. As a result there is almost no "pile-up" of dark current pulses to form a large pulse that could be mistaken for a signal pulse.

The tube can be operated at voltages high enough so as to achieve maximum secondary emission yield. In this region variations in voltage will not produce any appreciable variation in yield, in contrast with the rapid variation of gain elsewhere along the yield-curve. Conventional multipliers experience destructive dark-currents long before the maximum in the yield-curve can be reached, so that their overall gain is very sensitive to variations in the supply voltage.

Manufacture of the device just described is facilitated by the fact that dynodes of the transmissive type require no processing in the sealed-off tube, as do most conventional types of dynodes.

It will be apparent to those skilled in the art of tube fabrication that the structure of FIG. 1 may be modified so that the leads 27 are brought out through the base of the tube.

Another embodiment of my invention may be seen in FIG. 5. In this embodiment the dynodes 65, which may be similar to those previously discussed, are supported in a disc-seal type of structure in which each dynode is supported by conductive supports 60 which are sealed to insulating members 62. The conductive supports 60 include rings 61 of a material such as Kovar, an alloy of about 20% Ni, 17% Co, 0.2% Mn and the balance Fe, which can be sealed to glass or ceramic. Rings 61 of this type are shown sealed to insulating rings 62 of a suitable material such as glass or ceramic that provide insulation between electrodes and that at the same time form a vacuum envelope. A ceramic material of the aluminum oxide type is suitable for the insulating rings 62. Since the Kovar metal is magnetic, the rings 61 must be kept a small distance from the dynodes 65 by means of non-magnetic spacers 63 in order to avoid affecting the electron trajectories. The non-magnetic spacers 63 may be of any suitable metal such as Inconel, a nickel-chromium iron alloy, or of an insulating material coated with a metallic film. The non-magnetic spacers 63 and the metal rings 61 may be combined in a single member of a nonmagnetic material which may be sealed to insulators of materials such as glass or ceramic. These spacers 63 are provided with staggered pumping holes 68 which allow evacuation of the envelope while not allowing photoemissive vapor from the cathode 64 to travel throughout the tube. Alternatively, where extremely low dark currents are desired, the first dynode supports 61 and 63 may be made continuous so as to seal off the space between the cathode 64 and the first dynode 65 completely, a separate pumping outlet being provided for each portion of the tube.

One method of fabricating the device of FIG. 5 is to seal by heliarc welding a stack of insulating members 62 and metallic members 61, alternately arranged, with the ends of the tube open. The conductive rings 61 may each comprise two rings sealed together to provide a groove 67 for the reception of the spacers 63. The members 61, which are preferably annular, may be provided with small notches on their inner edge. Dynodes 65 and spacer 63 subassemblies may be provided of such size that they may be inserted through the members 61 when there is proper alignment of the notches in the members 61 with small projections provided on the spacer 63. When the dynode is in the proper position in the tube, a small rotation will place it in permanent position. Various means of locking the dynode in place and providing good conductive contact can be used. Of course, other fabrication schemes may be used.

The photoemissive cathode may be formed by evaporating the photoemissive material onto the surface of a movable glass substrate facing away from the dynodes, and providing a wire spring mechanism to flip over the glass and thus place the cathode in operating position. In this manner cathode material does not reach any surfaces within the tube which would lead to unwanted field emission. Also, field distortion due to evaporating structures is eliminated.

The output anode 69 is also sealed to an insulating member 59 which forms a part of the vacuum envelope. The anode 69 forms part of the inner conductor of a coaxial transmission line whose outer conductor 66 is connected to the last dynode support ring 61.

The support rings 61 provide part of a low inductance connection between the dynodes 65 and an external voltage divider 58. This structure is compact and can be fabricated easily. The final assembly may be made by arc-welding the outer edges of the rings 61 so as to avoid heating the dynodes themselves. There is no need for a separate outer vacuum envelope as in FIG. 1.

It can be readily seen that the space between the cathode 64 and first dynode 65 and the spaces between successive dynodes may be completely isolated from each other. The pumping holes 68 may be very small. The cathode space need not even be provided with a pumping hole that communicates with the dynode spaces but may be separately pumped out. Complete compartmentalization may, therefore, be achieved by the insulating spacer 62 and metallic ring 61 type of construction while at the same time the need for a separate vacuum envelope is avoided.

Shielding against stray magnetic fields which are normal to the tube axis is provided automatically by the ferromagnetic Kovar rings.

FIG. 6 shows a photomultiplier constructed according to my invention embodied in an image intensifying tube. The structure is generally similar to that of FIG. 5.

The structure shown in FIG. 1 could be similarly modified for use as an image intensifier. Dynodes 65 are supported by one or more metallic members 60 which are sealed to insulating spacers 62. The image intensifier has a flat output window 70 on the inside of which is a layer of aluminized output phosphor 71. The image is focused on the cathode 64 by means of a lens 73. The image intensifier structure is disposed within a focusing coil 72 which provides a homogeneous field for magnetic focusing of the electrons.

The device may be operated with a potential of 2.5 kv. between each dynode 65 and 10 kv. between the last dynode 65 and the phosphor screen 71. The dynode spacing was 0.3 inch in a typical device which has been successfully operated, while the cathode 64 and phosphor screen 71 were separated 0.6 inch from the first and last dynodes, respectively. A gold photosurface was employed. An electron gain of 1500 was achieved with this device.

The applied potentials and spacings are not critical within narrow limits. For example, other tubes made operate successfully at potentials of about 2 kv. to 5 kv. between dynodes and from about 7 kv. to 15 kv. between the last dynode and the output. As the elements are further separated, it is desirable to employ higher voltages. A magnetic field of about 500 to 1000 gauss has been found suitable for focusing the electrons.

Between the first and second dynodes 65 is a fine mesh control grid 74 which can be used to provide a very high speed shutter action. The control grid 74 is not necessary for ordinary image intensification purposes. In order to photograph rapidly moving objects, very short exposures are needed. This need arises in studying such things as electrical discharges, shock-waves and microscopic fractures where events moving at more than 10^4 megacycles/sec. have been pictured with prior devices, but only by sacrificing light efficiency, using very high voltage pulses, or requiring a large control element capacity. Further reduction in exposure time has been limited by these factors. The fine mesh control grid 74 together with the coaxial type of lead-in made possible by the disc-seal structure provides a means of reducing the exposure time to about 5×10^{-10} seconds. Other such grids may be provided, of course, as required.

Fabrication of a device such as that shown in FIG. 5, but with one or more control grids as shown in FIG. 6, may be readily effected by employing insulating members 62 of about half the thickness of the desired dynode spacing. Rather than providing a dynode assembly between each pair of insulating members, one would be disposed after alternate insulating members with a control grid or a dummy assembly in the alternate location.

Photoelectrons are released from the cathode 64 and accelerated by a plane parallel field provided by the focusing coil 72 to the first dynode 65 where they release secondaries from the other side. If the fine mesh grid 74 is negative with respect to the first dynode by a sufficient amount, which may typically be 10–20 volts, the secondaries will be stopped and no image will appear on the output screen 71. By applying a suitable voltage pulse to the grid 74, about +20 to 50 volts, the electrons from the first dynode 65 are allowed to pass for any desired length of time and by successive multiplication produce an intensified image on the output phosphor 71. This image may then be photographed or used in any other manner, such as transmitted by a television camera or viewed directly on a long persistence screen.

FIG. 7 shows a device constructed in accordance with my invention similar to that of FIGS. 5 and 6 with the important difference that the dynodes 65, photocathode 64 and phosphor screen 71 are curved rather than planar, but still parallel. This preserves the quality of having equal straight line electron trajectories between stages and also provides additional advantages for some applications. Since succeeding stages are larger in surface area, it can readily be seen that image magnification as well as brightness intensification may be hereby achieved. Moreover, such a device may be readily used with certain optical systems, such as a Schmidt optical system, which provide a curved image which may be imposed on the curved cathode. For use as an image intensifier, such an optical system would be employed, as would a magnetic focusing coil providing a suitable field configuration and a suitably adjusted spacing of successive dynodes to meet the focusing conditions for a non-uniform magnetic field. The latter conditions will usually necessitate a device having successively greater spacings between dynode stages, rather than the uniform spacings shown in FIG. 7, which is illustrative of the overall device. Of course, the dynodes would still be disposed parallel to each other. The optical system and focusing coil are not shown in FIG. 7.

The fact that the various components of the device are curved presents no serious difficulty in fabrication and techniques applicable to planar members are generally applicable here. To achieve the benefits of the curved dynode construction the dynodes may be supported by either flat or curved metallic members 61 and 63.

While the present invention has been described in only a few embodiments, it will be obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope thereof.

I claim as my invention:

1. An electron multiplier device comprising: a cathode and a dynode including a substantially continuous layer of transmission secondary electron emitting material capable of secondary electron emission from the side thereof remote from said cathode upon bombardment by electrons from said cathode; means to support said cathode and said dynode including an annular insulating member extending completely around the electron beam path between said cathode and said dynode substantially to isolate, in cooperation with said continuous layer, the space between said cathode and said dynode from the remainder of said device.

2. An electron multiplier device comprising: a photocathode and a plurality of dynodes substantially parallel to said photocathode of which at least the first dynode closest to said cathode has a substantially continuous layer of transmission secondary electron emitting material capable of secondary electron emission from the side thereof remote from said photocathode upon bombardment by electrons from said photocathode; means to support said photocathode and said plurality of dynodes including at least one annular insulating member extending completely around the electron beam path between said photocathode and said first dynode substantially to isolate, in cooperation with said continuous layer, the space between said photocathode and said first dynode from the remainder of said device.

3. An electron multiplier device comprising a cathode, a first transmission secondary electron emitting dynode and a second transmission secondary electron emitting dynode disposed parallel to said first dynode, said cathode and said first and second dynodes defining an electron beam path, first and second metallic support members each extending around said electron beam path and each attached essentially completely around the periphery of one of said first and second dynodes, an insulating spacer extending around said electron beam path and having said first and second support members sealed vacuum tight to opposite surfaces thereof to form a substantially isolated region bounded by said first and second dynodes, said first and second support members and said insulating spacer.

4. An electron multiplier device comprising an electron emissive cathode, a plurality of parallel dynodes and an electron collecting anode, each of said dynodes comprising a substantially continuous layer of transmission secondary electron emitting material and having a metallic support member conductively attached essentially completely around the periphery thereof, each of said metallic support members being spaced from adjacent metallic support members by insulating members to which two of said metallic support members are sealed on opposite surfaces thereof to form a substantially isolated space between each adjacent pair of said plurality of dynodes, said anode being coaxially disposed to said dynodes and having a conductive member forming the inner conductor of a coaxial output transmission line, and the one of said dynodes adjacent said anode having a conductive member attached thereto forming the outer conductor of said coaxial output transmission line.

5. An electron multiplier device comprising an electron emissive cathode, a plurality of parallel dynodes and an electron collecting anode, each of said dynodes comprising a substantially continuous layer of transmission secondary electron emitting material having a metallic support member conductively attached essentially completely around the periphery thereof, each of said metallic support members being spaced from adjacent metallic support members by insulating members to which two of said metallic support members are sealed on opposite surfaces thereof, said metallic support members and said insulating members being sealed together vacuum tight to form a portion of a vacuum envelope through which a portion of said metallic support members extend, said continuous layer of secondary electron emitting material, said insulating members and said metallic support members substantially isolating the space on opposite sides of each of said dynodes to minimize ion feedback to said cathode and transfer of electron emissive material from said cathode throughout said device, said anode being coaxially disposed to said dynodes and having a conductive member forming the inner conductor of a coaxial output transmission line, and the one of said dynodes adjacent said anode having a conductive member attached thereto forming the outer conductor of said coaxial output transmission line.

6. An electron multiplier device comprising an electron emissive cathode responsive to radiation, a plurality of parallel dynodes and an electron collecting anode, each of said dynodes comprising a substantially continuous layer of transmission secondary electron emitting material and having a metallic support member conductively attached essentially completely around the periphery thereof, each of said metallic support members being spaced from adjacent metallic support members by insulating members to which two of said metallic support members are sealed on opposite surfaces thereof to form a substantially isolated space between each adjacent pair of said plurality of dynodes, said metallic support members comprising a ring of ferromagnetic material sealed to said insulating members and separated from said dynodes by nonmagnetic conductive spacers, said anode being coaxially disposed to said dynodes and having a conductive member forming the inner conductor of a coaxial output transmission line, and the one of said dynodes adjacent said anode having a conductive member attached thereto forming the outer conductor of said coaxial output transmission line.

7. An electron multiplier device comprising a photocathode, a first transmission secondary electron emitting dynode and a second transmission secondary electron emitting dynode disposed parallel to said first dynode and to said photocathode, a first annular metallic support member and a second annular metallic support member, and first and second annular insulating spacers, said first support member conductively attached essentially completely around the periphery of said first dynode and said second support member conductively attached essentially completely around the periphery of said second dynode, said support members sealed to opposite surfaces of said first insulating spacer such that said first and second dynodes, said first and second support members and said insulating spacer enclose a space substantially isolated from said

photocathode, said first support member and said photocathode sealed to opposite surfaces of said second insulating spacer to enclose a space between said photocathode and said first dynode which is substantially isolated.

8. An image intensifier device comprising a photocathode, a plurality of dynodes, and a phosphor output screen, said photocathode, said dynodes and said phosphor output screen being substantially mutually parallel, each of said dynodes supported by a metallic support member conductively attached essentially completely around the periphery thereof and having a substantially continuous layer of transmission secondary electron emitting material, each of said metallic members spaced from adjacent metallic members by insulating members to which two of said metallic members are sealed on opposite surfaces thereof to form a substantially isolated space between each adjacent pair of said plurality of dynodes, said photocathode being affixed to an insulating member to which said support member of the first of said plurality of dynodes is affixed substantially to isolate the space between said photocathode and the first of said dynodes.

9. An image intensifier device comprising a photocathode, a plurality of dynodes, and a phosphor output screen, said photocathode, said dynodes and said phosphor output screen being substantially mutually parallel, each of said dynodes comprising a substantially continuous layer of secondary electron emitting material, each of said dynodes supported by a metallic support member conductively attached essentially completely around the periphery thereof, each of said metallic members spaced from adjacent metallic members by insulating members to which two of said metallic members are sealed on opposite surfaces thereof to form a substantially isolated space between each adjacent pair of said plurality of dynodes, said metallic support members and said insulating members being sealed together vacuum tight to form a portion of a vacuum envelope through which a portion of said metallic members extends, said photocathode being affixed to an insulating member to which said support member of the first of said plurality of dynodes is affixed substantially to isolate the space between said photocathode and the first of said dynodes.

10. An image intensifier device comprising a photocathode, a plurality of dynodes, and a phosphor output screen, said photocathode, said dynodes and said phosphor output screen being substantially mutually parallel and curved, each of said dynodes comprising a substantially continuous layer of transmission secondary electron emitting material, each of said dynodes supported by a metallic support member conductively attached essentially completely around the periphery thereof, each of said metallic support members spaced from adjacent metallic support members by insulating members to each of which two of said metallic support members are sealed on opposite surfaces thereof to form a substantially isolated space between each adjacent pair of said plurality of dynodes, said photocathode being affixed to an insulating member to which said support member of the first of said plurality of dynodes is affixed substantially to isolate the space between said photocathode and the first of said dynodes.

11. An image intensifier device comprising a photocathode, a plurality of dynodes, and a phosphor output screen, said photocathode, said dynodes and said phosphor output screen being substantially mutually parallel and curved, each of said dynodes comprising a substantially continuous layer of transmission secondary electron emitting material, each of said dynodes supported by a metallic support member conductively attached essentially completely around the periphery thereof, each of said metallic support members spaced from adjacent metallic support members by insulating members to which two of said metallic support members are sealed on opposite surfaces thereof to form a substantially isolated space between each adjacent pair of said plurality of dynodes, said metallic support members and said insulating members being sealed together vacuum tight to form a portion of a vacuum envelope through which a portion of said metallic members extends, said photocathode being affixed to an insulating member to which said support member of the first of said plurality of dynodes is affixed substantially to isolate the space between said photocathode and the first of said dynodes.

12. An image intensifier device comprising a photocathode, a plurality of dynodes, and a phosphor output screen, said photocathode, said dynodes and said phosphor output screen being substantially mutually parallel, each of said dynodes comprising a substantially continuous layer of transmission secondary electron emitting material, each of said dynodes supported by a metallic support member conductively attached essentially completely around the periphery thereof, each of said metallic members spaced from adjacent metallic members by insulating members to which two of said metallic members are sealed on opposite surfaces thereof to form a substantially isolated space between each adjacent pair of said plurality of dynodes, and a conductive mesh control grid disposed between two of said dynodes, said photocathode being affixed to an insulating member to which said support member of the first of said plurality of dynodes is affixed substantially to isolate the space between said photocathode and the first of said dynodes.

13. An image intensifier device comprising a photocathode, a plurality of dynodes, and a phosphor output screen, said photocathode, said dynodes and said phosphor output screen being substantially mutually parallel, each of said dynodes comprising a substantially continuous layer of transmission secondary electron emitting material, each of said dynodes supported by a metallic support member conductively attached essentially completely around the periphery thereof, each of said metallic members spaced from adjacent metallic members by insulating members to which two of said metallic members are sealed on opposite surfaces thereof to form a substantially isolated space between each adjacent pair of said plurality of dynodes, and a conductive mesh control grid parallel to said dynodes at a position between said photocathode and said phosphor screen, said metallic support members and said insulating members being sealed vacuum tight to form a portion of a vacuum envelope through which a portion of said metallic support members extends, said photocathode being affixed to an insulating member to which said support member of the first of said plurality of dynodes is affixed substantially to isolate the space between said photocathode and the first of said dynodes.

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