

March 30, 1965

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3,176,178

FUNNELED ELECTRON MULTIPLIER

Filed Sept. 19, 1962

3 Sheets-Sheet 1

Fig. 1

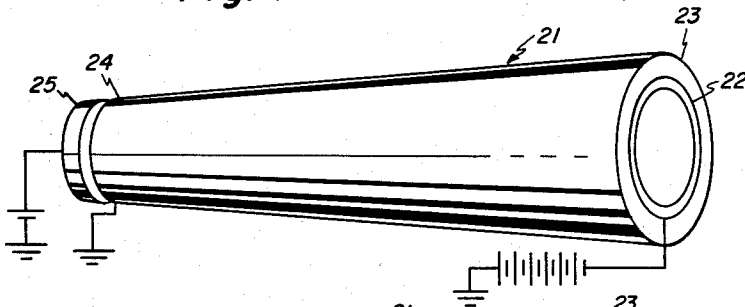


Fig. 2

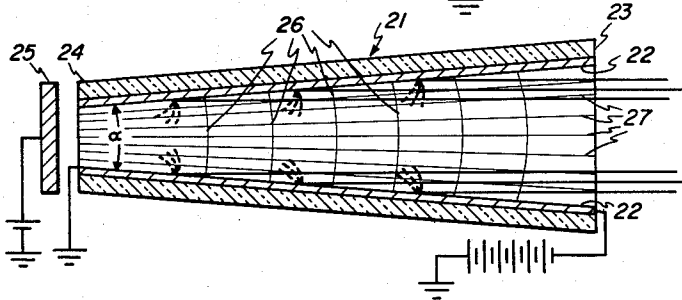
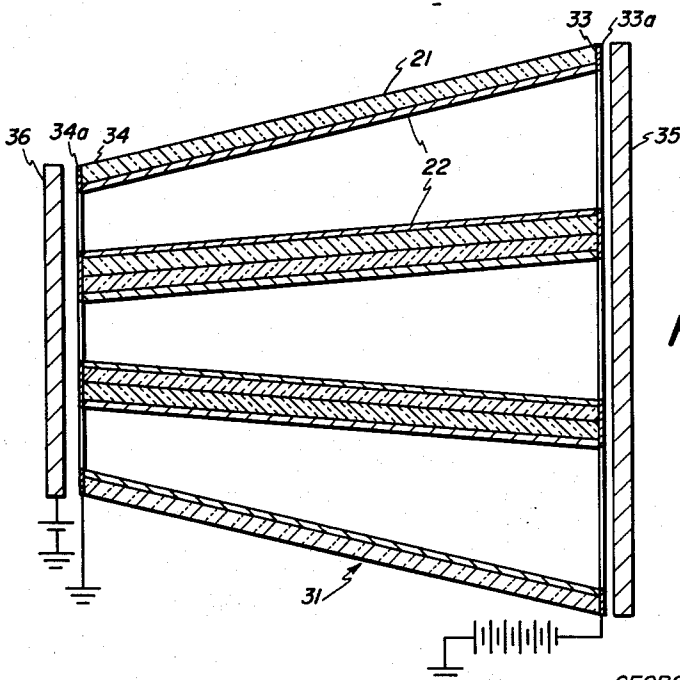


Fig. 3



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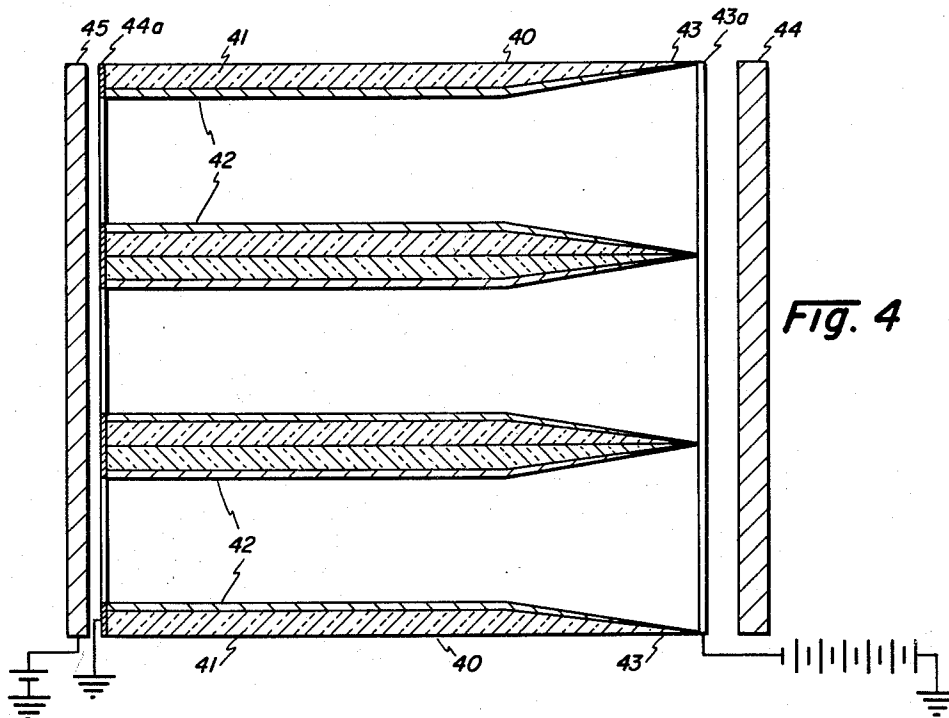


Fig. 4

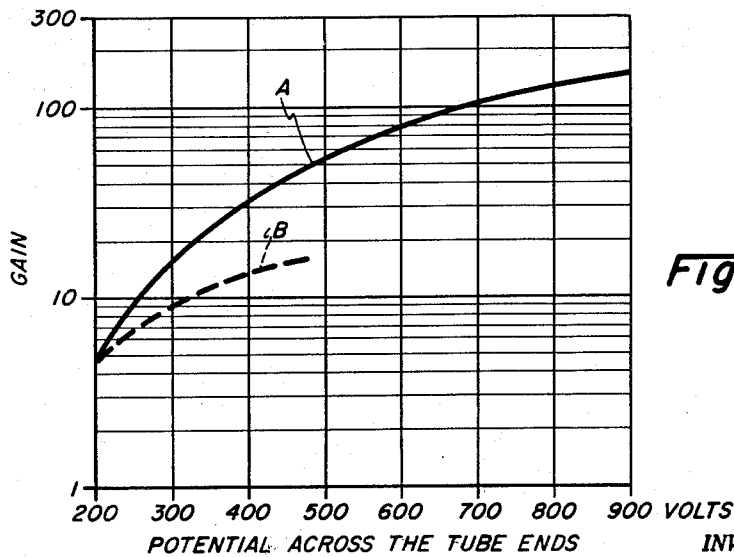


Fig. 5

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3 Sheets-Sheet 3

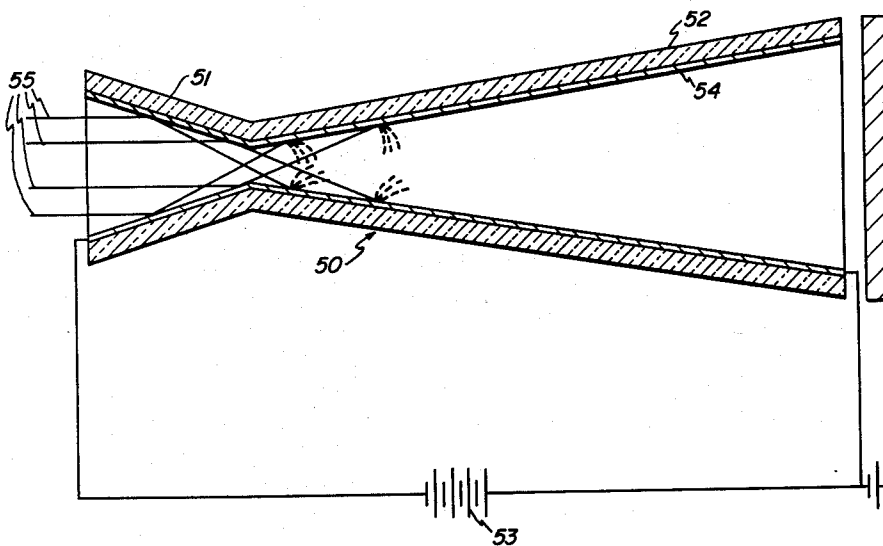


Fig. 6

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FUNNELED ELECTRON MULTIPLIER

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8 Claims. (Cl. 313-104)

This invention pertains to a funneled electron multiplier having a continuous resistive or semi-conductive coating along the walls thereof with a voltage source connected to the ends of the multiplier to provide a continuous potential drop along the walls of the multiplier.

This invention is an improvement over the electron multiplier disclosed in copending application, U.S. Patent No. 3,128,408, entitled "Electron Multiplier," issued April 7, 1964, to G. W. Goodrich and W. C. Wiley. The electron multiplier in the aforementioned copending application comprises a tube or channel having a large length to diameter ratio, in the order of ten to one for every power of ten of multiplication desired, which has a coating on the inside thereof of a resistive nature. A potential is then applied to the resistive coating across opposite ends of the tube or channel to provide a voltage drop therein which accelerates electrons introduced into the low voltage end of the tube. Since the tube has a large length to diameter ratio, the random velocities of the electrons entering the tube are sufficient to cause the electrons to impact on the walls of the tube.

This invention improves over the previous construction by introducing a funneling or convergence to the walls of the tube so that the incoming electrons are more likely to strike the wall of the tube near the incoming end of the tube to improve electron multiplication.

Also, since the input area is larger than the output area, larger images may be reduced to smaller areas. Also, the input area may be smaller than the output area, resulting in magnification.

By connecting a plurality of funneled channels into adjoining rows, an array is formed; and by placing a photocathode at the large end of the array and a phosphorous screen at the small end, an image intensifier is provided which can reduce an image focussed on the photocathode. Conversely, reversing the direction of the array provides an image intensifier which magnifies the image focussed on the photocathode. In this latter case, however, there is not as great a possibility that the electrons will strike a wall of the tube since the walls are flared in the direction of the electron travel. For this reason, a funnel-flare may be used with the funnel being shorter than the flare.

These and other objects and advantages of this invention will become more apparent when preferred embodiments are considered in connection with the drawings, in which:

FIGURE 1 is a perspective view of a first embodiment of this invention;

FIGURE 2 is a longitudinal cross section of FIGURE 1 shown with a source of particles to be multiplied and a collector;

FIGURE 3 is an array of tubes like that shown in FIGURE 1 which are fused together;

FIGURE 4 is an array of channels which are funneled at one end only and fused together with the funneled ends all at one end of the array;

FIGURE 5 is a graph showing the gain characteristics of a funneled channel versus a parallel wall channel; and

FIGURE 6 is a longitudinal cross section of a tube having a funnel-flare.

The embodiment in FIGURES 1 and 2 will first be considered. Funneled channel 21 has a resistance coating 22 formed interiorly thereof. Coating 22 has 10^9 ohms per square in this embodiment. A potential of minus 1,000 volts is connected to coating 22 at end 23 of channel 21. The other end of resistance coating 22 at end 24 of channel 21 is connected to ground and a circular collector 25 at a potential of 100 volts is placed adjacent end 24 to collect the multiplied electrons.

Application of potential to the ends of resistive coating 22 causes a potential drop thereacross, thereby forming equipotential lines 26 and electric field lines 27 which are perpendicular thereto within the enclosed volume.

The equipotential lines 26 are slightly curved due to end effects and the increasing potential gradient towards the small end of the channel. The particles to be multiplied, which in this embodiment are electrons from a photocathode in an image intensifier, are directed into the enlarged end 23 of tube 21 where they are accelerated along electric field lines 27 until they strike secondary emissive resistive surface 22 at which point they are multiplied due to the secondary electrons which are released by the energy of impact.

With the construction shown in FIGURES 1 and 2 it is seen that the probability of incoming electrons striking the walls or coating 22 is increased over a tube having parallel sides.

The secondary electrons are then accelerated by field 27 into another portion of surface 22 to cause additional multiplication. A collector 25 receives the multiplied particles and directs them to a meter or recorder or in the case of an image intensifier, the collector 25 is a phosphorus screen and changes the energy of the multiplied particles into light energy.

The conical tube 21 is formed by taking a longitudinal tube, heating, and then forcing over a conical mandrel until the desired shape is obtained. The glass used in tube 21 has a high lead content such as 25 percent or more of lead oxide so that when hydrogen gas is passed through at a temperature of between 345 to 375 degrees centigrade for several hours, the resistance coating 22 is formed. In the embodiment of FIGURES 1 and 2 the angle alpha of the flared sides is about 16 degrees; the diameter at end 24 is about .040 inch, and the diameter at end 23 is about .4 inch while the length of the tube is about 1.3 inches.

The multiplying characteristics of the tube shown in FIGURES 1 and 2 is indicated in FIGURE 5 where Gain, or Input over Output, is plotted along the ordinate on a logarithmic scale and Potential Across the Tube Ends (23 and 24) is shown on the abscissa. Curve A shows the characteristics for the conical channel 21 having a funnel angle of about 16 degrees while Curve B shows the characteristics of a comparable parallel wall channel.

The voltage gradient of the cone 21 gradually becomes steeper as the smaller end 24 is approached since the resistance per longitudinal inch along tube or channel 21 increases as the cone becomes smaller.

FIGURE 3 shows array 31 of a plurality, which may number in the thousands, of channels 21 fused together. Techniques for fusing channels together are illustrated in copending applications U.S. Serial No. 116,189, "Image Intensifier Array," filed June 9, 1961, by J. R. Ignatowski and R. R. Thompson; U.S. Serial No. 117,651, "Image Intensifier Array," filed June 16, 1961, by G. W. Goodrich and J. R. Ignatowski; U.S. Serial No. 116,044, "Image Intensifier Array," filed June 9, 1961, by B. Dera-doorian, H. M. Smith, and R. R. Thompson.

Preferably the ends 33 and 34 are cut perpendicular to the longitudinal axis of the array after the individual tubes have been fused together although spherical cuts

such that each tube has an end face normal to its individual longitudinal axis is desirable in some cases. A conductive coating 33a and 34a is applied respectively to ends 33 and 34 so that all of the resistive coatings are connected together electrically. Coating 33a is connected to a negative voltage such as minus 1000 volts and coating 34a is connected to ground. When a source 35 of particles to be multiplied is placed at end 33 and a collector of multiplied particles 36 is placed at end 34 of array 31, the effect is to reduce the source size correspondingly so that if source 35 were a photocathode in an image intensifier and collector 36 were a phosphorus screen, the image on photocathode 35 would be reduced in size but much more intense on screen 36. If source 35 were reversed in position with collector 36, then the effect would be reversed and the area of incoming particles would be enlarged at the output end.

Further embodiments which employ tapered sides for only a portion of the individual tube lengths may also be used to advantage as illustrated in FIGURE 4 where a plurality of individual tubes 40, each having an outer layer 41 of insulative material and an inner layer 42 of resistive material is funneled at end 43 only. A source 44 is placed at end 43 and a collector 45 is placed at the opposite end. By so placing the individual channels 40 and so forming the funnels, the multiplying efficiency is not only increased due to the aforementioned higher probability of electron impact on the secondary emission surface, but the channel wall thickness is decreased at end 43 so that there is more open area and a higher percentage of incoming electrons or other particles are received by the channels. There is sufficient wall thickness of the glass tubes 41 towards the non-funneled end to offer adequate support to the individual channels. Conductive coatings 43a and 44a are plated on the ends of the array and the battery connections are made thereto.

For certain applications it may be desirable to form a funnel-flare channel with both ends of the channel being larger than an intermediate channel area to provide a tube that can be reversed and an input placed at either end with a collector at the other end. This is shown in FIGURE 6 where glass tube 50 has a funnel 51 and a flare 52 being longer. A battery 53 places a potential across the continuous resistive, secondary emissive coating 54 on glass tube 50. Incoming particles 55 strike the walls of funnel 51 to improve multiplication while the longer flare 52 has a larger opening to provide magnification.

This invention may also be used to provide increased signal carrying capabilities. By forming a flared portion at the output of a straight section, the area against which electrons may impact is substantially increased thereby reducing electron density near the secondary emissive surface to improve multiplication.

Although this invention has been disclosed and illustrated with reference to particular applications, the

principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

Having thus described our invention, we claim:

1. A multiplier comprising receiving means, collecting means, wall means being at least partially provided with secondary emissive material and defining at least a partially enclosed multiplying path having its longitudinal dimension between said receiving means and collecting means, said multiplying path being totally clear of field producing physical obstructions independent of said wall means, said wall means having at least a portion thereof non-parallel to said multiplier longitudinal axis, means for establishing a continuous potential gradient along said longitudinal dimension, said last means establishing a total electric field which is angularly related to the longitudinal axis corresponding to the wall means angular relation to said longitudinal axis.
2. The multiplier of claim 1 wherein, said wall means defines a cylindrical channel, said channel having at least a portion of its interior surface funneled, said electric field being funnel shaped at the funnel shaped portion of said channel.
3. The multiplier of claim 1 wherein, said wall means has portion where sides are parallel and a portion where the sides are divergent.
4. The multiplier of claim 1 wherein, said wall means having sides convergent along the entire length thereof, said electric field being convergent along the entire length thereof.
5. The multiplier of claim 4 wherein, a plurality of multipliers have the outer surfaces of their wall means fused together to form an array.
6. The multiplier of claim 3 wherein, a plurality of multipliers have the outer surfaces of their wall means fused together to form an array.
7. The multiplier of claim 1 wherein, the cross section of said wall means throughout the length thereof is substantially circular.
8. The multiplier of claim 7, where said wall means are first convergent and then divergent to provide a funnel-flare.

No references cited.

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