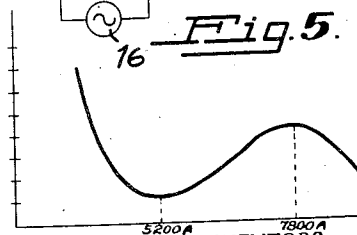
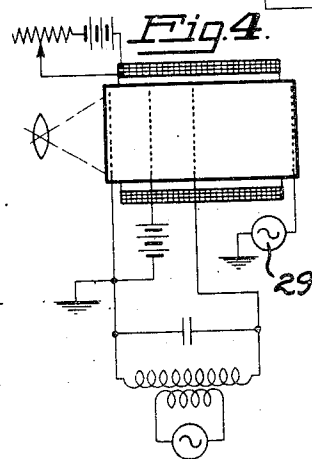
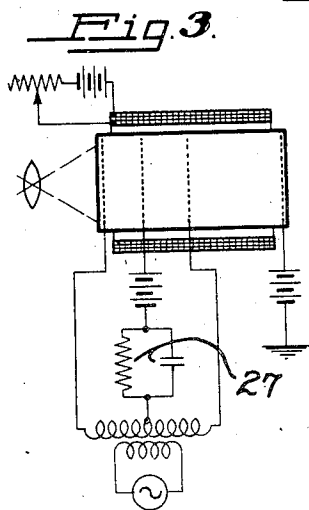
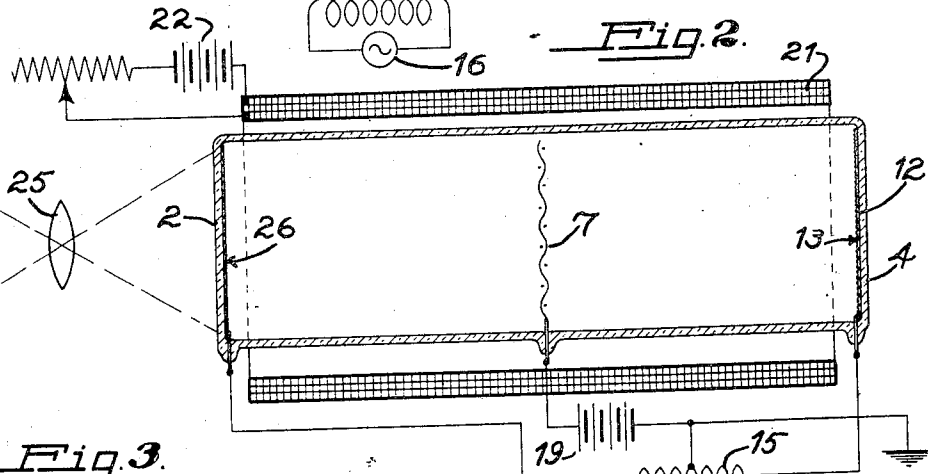
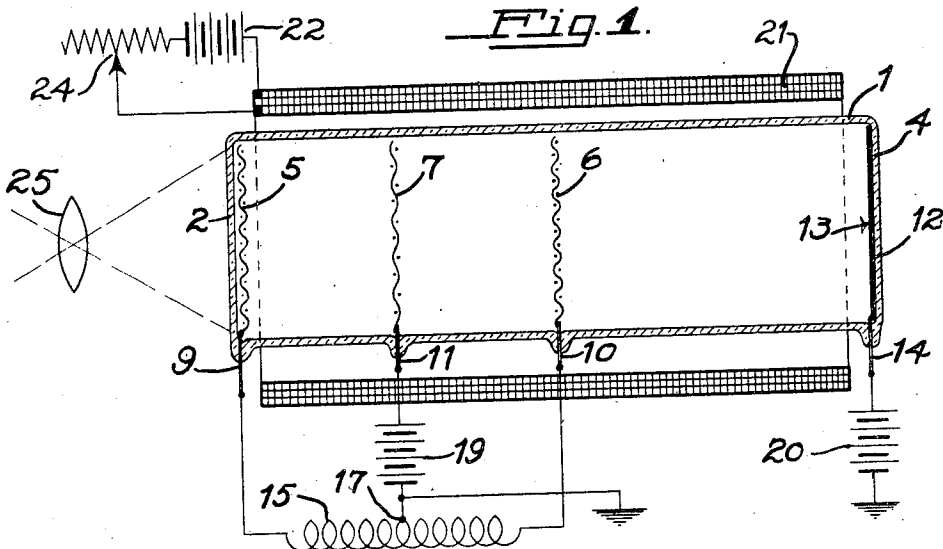


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RADIATION FREQUENCY CONVERTER

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RADIATION FREQUENCY CONVERTER

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4 Claims. (Cl. 250-1)

Our invention relates to radiation frequency converters, and more particularly to a means and method of converting radiation energy in one frequency band into radiation energy in another band.

Our invention is particularly applicable for the reproduction, within the visible range, of images, either wholly or in part, comprising radiation in the invisible portions of the spectrum.

The main object of our invention is, therefore, to make visible normally invisible objects.

Among the other objects of our invention are: To provide a radiation frequency converter wherein amplification takes place during conversion; to provide a means and method of changing an infra-red image to an image which can be seen with the human eye; to provide a radiation frequency conversion tube; to provide a means and method of simultaneously converting and amplifying energy in an invisible image; to provide a means and method of utilizing, for radiation frequency conversion, the method of electron multiplication described and claimed by Farnsworth in the following applications: Serial No. 692,585, filed October 7, 1933, Patent No. 2,071,515 granted February 23, 1937; S. N. 733,837 filed July 5, 1934, Patent No. 2,071,516 granted February 23, 1937; S. N. 706,965 filed January 17, 1934 and S. N. 10,604 filed March 12, 1935; to provide a means and method of obtaining a visual image through fog or smoke, or through other obstructions pierced by infra-red radiation; and to obtain such conversion with simplified apparatus and within a single envelope.

Our invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing our novel method. It is therefore to be understood that our method is applicable to other apparatus, and that we do not limit ourselves, in any way, to the apparatus of the present application, as we may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

As an example illustrating one conversion our invention can accomplish we will describe the conversion of infra-red energy into visible energy.

It has long been known in the television art that certain photoelectric surfaces are highly sensitive to infra-red radiation beyond the range of the human eye, and experiments have

been performed where television transmitters of the electronic type have had focused on the active surface thereof an infra-red image, this image being dissected and transmitted as a train of television signals which, when received at the receiving apparatus, may be reproduced in terms of visible light on, for instance, a cathode ray screen. In this manner images have been reproduced in the visible range through substances opaque to visible light, and Farnsworth, in prior experimentation in television transmitters of the sort described, has been able to receive excellent images on his receiver, of outdoor objects which were entirely hidden from an observer located at the dissector, by fog.

Such experiments, however, while interesting and instructive, involved far too much apparatus and complexity of circuits to be widely adopted as a practical method of fog penetration, and in this respect "fog" hereafter will be spoken of in this specification as encompassing all mists, dusts or other visual obstruction, either tenuous or solid, through which invisible radiation will pass in such form that they may later be focused either as an image on a surface, irrespective of the amplitude of radiation from the individual elements of the object being the emitter; or as a gross energy source.

We have invented a simple structure for performing the conversion required, and perform the conversion preferably within a single tube wherein energy amplification takes place.

It might be thought, that if an infra-red image were to be focused upon an emitting surface, and the electrons emitted, due to the influence of the radiation, be maintained in parallel array in the form of an electron image, and then this electron image be projected on a fluorescent screen within the same tube, that a visual image would be obtained. It is quite true that under certain circumstances of extreme brilliancy of the infra-red image a certain response would be obtained in this manner within the visible range, but when infra-red rays are passed through any of the substances, either tenuous or solid, which obstruct the visible rays, the infra-red rays are also obstructed to a greater or less extent, depending upon the size of particles and their spacing within the substance. The infra-red image then, which can be focused on a sensitized surface, must necessarily be weak, with a corresponding weakness within the electron image, sufficient to prevent a visual response on a screen.

A still further difficulty to the simple basic

structure outlined above is the fact that fluorescent materials are relatively inefficient in their reaction to electron bombardment, and for that reason it is doubtful whether a recognizable image can be obtained unless amplification of the electron image be accomplished in some manner before the electrons in that image are projected against a fluorescent screen.

Our invention provides for such amplification, and in fact provides for sufficient amplification of the electron image, that the visible image is of extreme brilliancy throughout the responsive range of the emitter surface impacted by the infra-red rays.

In order that this necessary amplification be obtained, we prefer to make use of the methods of electron multiplication hitherto described and claimed by Farnsworth in the applications cited above, and our invention broadly, as to method, comprises focusing radiation energy in one range on an electron emitting surface sensitized to give a response in the form of an emitted electron beam. This electron beam is then amplified by electron multiplication, and after a predetermined amplification the strengthened electron beam is projected against a luminescent screen to produce light.

In certain instances we may prefer to continuously bombard the screen with amplified electrons; in other cases we may prefer to build up an augmented electron beam and then suddenly release this augmented image against the screen. We then build up another augmented electron beam and release this new one against a screen, thus providing an interrupted bombardment of the screen. These interruptions, however, are done at such a high rate of speed that the eye is not in the least cognizant of them, and, for example, we may interrupt the bombardment at .5 to 3.0 megacycles. We prefer, in most instances, to utilize the incoming radiation as an image to create an electron image, amplifying the electron image, and finally produce therefrom a visual image.

Another feature of our invention is that the screen itself may be utilized to provide secondary electrons for multiplication purposes.

Broadly, in terms of apparatus, our invention preferably comprises a single envelope having in one end a sensitive surface responsive to infra-red radiation, means for forming a beam of electrons either gross, or comprising an electron image corresponding in all elementary details to the infra-red image, and means for oscillating the electrons within the image against two opposed surfaces to produce secondary electrons at each impact. Thus, a highly amplified beam or electron image is produced which is thereupon projected against a fluorescent screen at the opposite end of the tube. Upon impact by the augmented electron beam, a gross response, or an image is produced on the screen, the latter corresponding in intensity within the visible range to the intensity at all points within the infra-red image if used to initiate the electron beam.

Certain other broad objects of our invention, and other modifications thereof, will be better understood by direct reference to the drawing in which:

Figure 1 is a diagrammatic view, partly in section and partly circuitual, showing one embodiment of our radiation frequency converter adapted to receive and produce images.

Figure 2 is a similar view of a slightly differing embodiment.

Figure 3 is a diagrammatic circuit, reduced to lowest terms, of an embodiment wherein amplification is interrupted at regular intervals.

Figure 4 is a circuit similar to that of Figure 3, showing a different method of interruption.

Figure 5 is a graph representing the response of a caesium-silver oxide surface to radiation.

Referring directly to Figure 1 which shows one embodiment of our invention, an envelope 1 is provided with transparent end windows 2 and 4 which may be conveniently termed input and output windows, respectively.

Just inside the envelope, and closely adjacent input window 2, is positioned a sheet of metallic gauze 5, and we prefer to have the gauze of such weave which, although fine, has approximately half of the area solid and half of the area open space. This gauze 5 may be termed a cathode.

Spaced somewhat apart, along the tube, from cathode 5 is another cathode 6, this cathode being similar in all respects to cathode 5, while midway between the two is positioned an anode 7 which may be in the form of a gauze of more open mesh than either of the cathodes, or which may be of other openwork construction, in any case preferably disposed so as to distort the field between the cathodes as little as possible. Cathodes 5 and 6 are provided with leads 9 and 10 passing through the walls of the envelope and connected to the respective cathode structures. Anode 7 is also provided with a lead 11 in a similar manner.

If we assume that cathode 5 is positioned at one end of the tube adjacent the input window 2, and that cathode 6 is positioned substantially at the midpoint of the envelope, we then prefer to position a fluorescent screen assembly adjacent the opposite end of the envelope in a position where it will be visible through the output window 4. This fluorescent screen assembly preferably comprises, first, an extremely thin, transparent, yet conducting film 12, preferably deposited on the inside surface of the window 4. This film is provided with an external lead 14 passing through the envelope wall, and on top of the film 12 we prefer to deposit a thin, uniform layer of fluorescent material 13, taken from a group having substantially an instantaneous response to electron bombardment. There are many such materials known to those skilled in the art so they will not be listed here, zinc or calcium tungstate being specific examples.

The external circuit by which the tube is made operative is relatively simple. A transformer 15 is supplied with alternating current from a generator 16, cathode leads 9 and 10 being connected to opposite ends of the transformer secondary. A center tap 17 is provided on this secondary which is grounded and which also leads to anode 7 through an anode source 19. The conducting film 12 underlying the fluorescent screen is also energized to a positive potential by screen source 20.

In order that electrons maintain themselves in parallel paths throughout the extent of the tube, we prefer to position around the tube a focusing coil 21 supplied from a focusing source 22 under the control of a variable resistor 24, and we prefer to generate a relatively heavy field in the focusing assembly. We wish it to be distinctly understood, however, that the use of magnetic focusing is not essential to the proper operation of our device, as Farnsworth has pointed out, in the applications cited above, that the electrodes themselves may be so shaped as to provide a proper electrostatic guiding field for his

multipliers, and the same observation holds true for the present device.

The device, connected as shown, is ready for operation, the sequence of which is as follows:

5 An infra-red image, irrespective of its origin, is focused by means of a suitable lens system 25, or other equivalent device on the cathode 5. During the evacuation of the envelope I we prefer to form the cathodes 5 and 6 either of a material which, in itself, will emit secondary electrons at a ratio greater than unity, when impacted by electrons traveling at a proper velocity, or to so sensitize these electrodes that they will respond in the same manner. It is possible to
10 obtain secondaries with a ratio as high as 1 to 6, provided the two cathodes are sensitized, for example, by the caesium on silver oxide procedure heretofore mainly used for producing photoelectric surfaces, and as extreme amplification is desired in a tube of this sort, we prefer to utilize the higher emission ratios, although this is purely a matter of degree.

Inasmuch, however, as the caesium-silver oxide combination is not only a good emitter of
25 secondaries but is also a good photoelectric material, when the infra-red image is focused on the cathode 5 electrons will be emitted therefrom photoelectrically. For example, in the graph shown in Figure 5 we have reproduced, in terms
30 of relative response, the action of the caesium-oxide-silver photocell, and it will be seen that there is a response peak occurring between 7,000 and 8,000 angstroms which is below the visible range and well into the infra-red.

35 Electrons, then, will be emitted from cathode 5 over its extent in proportion to the intensity of the elemental areas of the infra-red image, and these electrons will be pulled through the apertures in cathode 5 and will enter the multiplier chamber defined by cathodes 5 and 6, and will thereafter be accelerated because of the positive potential on anode 7 toward anode 7 and
40 cathode 6. Inasmuch, however, as anode 7 is of relatively large mesh, most of the electrons will go through and drive toward cathode 6. At the same time oscillator 16, through the medium of the transformer 15, is cyclically energizing cathodes 5 and 6, and if cathode 6 is made positive as the electron cloud approaches it, electrons in this
45 cloud will impact cathode 6 with a velocity sufficient to release secondaries therefrom.

Immediately thereafter, due to the action of oscillator 16, the potentials on cathodes 5 and 6 will reverse and the augmented cloud will travel
55 again toward anode 7 to impact cathode 5 and create a still further increase in the number of electrons, and this condition will continue, especially if the potential on anode 7 is so adjusted that the time of flight across the tube coincides with the frequency supplied by alternator 16,
60 and in this regard we prefer to utilize for this multiplication process an oscillator giving a frequency of from 60 to 80 megacycles, but other frequencies may readily be utilized.

65 The impressed R. F. on cathodes 5 and 6 initiates, by the multiplication process, a cloud of electrons of the proper phase to absorb energy from the oscillator. This cloud of electrons would oscillate by itself at approximately the same frequency as that of the circuit except for
70 the fact that the R. F. itself accelerates the cloud, and the electrons make the trip across the tube in less than a half period of the tuned circuit. The mere fact that the electrons are thus speeded
75 up ensures that they strike the cathodes. The

returning group of electrons also make the trip in slightly less than a one-half cycle. The result is that the fastest electrons very rapidly get out of phase with the applied R. F. potential.

The process results in electrons being fed from 5 the multiplication phase into the opposite phase wherein an electron is decelerated rather than accelerated by the R. F. Electrons in this phase do not strike the cathodes at all but continue to oscillate between them, delivering energy to the
10 external circuit as they are slowed down by the R. F. If the probability of an electron striking the anode is sufficiently small, an equilibrium current results wherein the total multiplication is, linearly, a function of the number of electrons
15 delivered into the chamber by the action of the infra-red radiation on cathode 5.

While the electrons are oscillating back and forth within the chamber, however, the strong focusing field is in action and the electron cloud, 20 considered in cross section, at all times constitutes an electrical image, changing only as the infra-red image changes on cathode 5. The only change that takes place within the cloud is that the elemental electron count in the cross section in-
25 creases with each trip.

Let us, then, consider what happens at cathode 6 which, as has been pointed out above, is apertured. It will be seen at once that if the apertures in this cathode are equal to the solid portions in area, one-half of the electrons of the
30 cloud at each approach to cathode 6 will pass through the cathode, but as each electron in the cloud which does impact the cathode emits more than two secondaries, the multiplication process
35 within the chamber bounded by cathodes 5 and 6 continues, even though half of the cloud is lost, as far as the multiplication process is concerned, at each portion of the cycle when it contacts cathode 6. The chamber beyond cathode 6, there-
40 fore, between cathode 6 and screen 13, is being constantly supplied with an amplified cloud of electrons which, due to the urge of the potential on the underlying film 12, are drawn toward the output end of the tube and impact the fluorescent
45 screen material 13. During the traversal of the space between cathode 6 and fluorescent screen 13, however, the guiding or focusing field is still in operation; therefore, when these electrons im-
50 pact the screen they still have their electron image relationship, and a visible image is formed on the screen in response to the bombardment thereof. The focusing field thus keeps the image relation-
55 ship of the electrons throughout the entire length of the tube. They are traveling in both directions between cathodes 5 and 6 but only in one direction between cathode 6 and screen 13.

Because of the high amplification of the electron emission from the elementary areas of the cathode 5, when the electrons corresponding to
60 this elementary area impact the screen 13 they are tremendously augmented in number and therefore give to the screen a far greater energy than they would if they had been directed thereon straight from the cathode 5. Thus, an electron image
65 emitted from cathode 5, which would under ordinary circumstances have insufficient energy to cause a visual image to occur on screen 13, has become sufficiently strong that a visual image of relatively great brilliancy is readily formed on the
70 screen. The radiation which falls on cathode 5 is invisible but the radiation emitted from screen 13 is visible.

We have therefore converted an invisible image into a visible image, the visible image, however, 75

being of enormously greater energy content than was present in the original invisible image. In this manner we have been able to see objects, for example, through obstructions, because these objects radiate infra-red rays which are capable of passing through the obstructions while visible rays are not.

Before going on to consider alternative embodiments of our invention, there is one feature which should be pointed out in connection with all the devices herein described. It will be seen that as cathodes 5 and 6 are both photoelectric and secondarily emissive, cathode 6 is exposed, to some extent, to the light from the screen 13 during the operation of the tube, and that this light does not fall upon cathode 6 in the form of an image but falls thereon as a diffuse, gross illumination. This, however, does not affect the operation of the tube to any great extent for several reasons. If, for example, with a steady potential of 4,000 volts on the screen backing 12, and with fifty per cent of the electron emission from the cathodes constantly falling on the fluorescent screen, the illumination of the screen will be D. L. with the result that some illumination falls on the photoelectric cathodes, producing further electron emission and further illumination D. L./100. If the R. F. is applied to the plates the cathode current builds up exponentially with them, and the illumination builds up proportionally, but the amount of regenerative build-up produced by the light from the screen falling back on the photoelectric surfaces is less than unity.

The photoelectric emission produced by the screen light is always at least one hundred times less than the electron current which produced the light. There will be no trouble if the screen is sufficiently instantaneous so that no considerable quantities of light are emitted therefrom during any period when the multiplier current is low.

Furthermore, we have found that it is possible to choose a screen material which emits light to which the cathodes have a minimum sensitivity. In Figure 5 it will be seen that the maximum sensitivity of the caesium-silver oxide cell to infra-red is between 7,000 and 8,000 angstroms, and that the response curve of this type of surface shows that there is a minimum response to radiation frequencies at approximately 5,000 angstroms. We prefer, therefore, to utilize a screen material having its maximum radiation in the visible range in the neighborhood of 5,000 angstroms, thus greatly reducing the sensitivity of the cathodes to any regenerative build-up.

We have, however, developed alternative devices in which this problem does not occur, as will be explained later. In the alternative device shown in Figure 2, the two multiplier cathodes are positioned at opposite ends of the tube and are preferably applied directly to windows 2 and 4. For example, window 2 is backed, in this case, by a cathode film 26 which is photoelectric, secondarily emissive, and at least semi-transparent. Certain alkali metal films fulfill these requirements.

At the opposite end of the tube the transparent film 12 has deposited thereon the fluorescent screen 13 which may be, in itself, capable of emitting secondaries, or which may be further sensitized by the deposition thereon of a small amount of alkali metal. The external circuit is substantially the same as that shown for the multiplier portion of the device shown in Figure 1, no additional source being necessary, of course, for the fluorescent screen inasmuch as it is con-

nected directly to the oscillating potential. At each traversal of the tube, therefore, during the multiplication process which takes place between the screen assembly and the cathode 26, a portion of the energy delivered to the screen is utilized for producing light, the remaining portion causes secondaries which are utilized for the multiplication action.

Figures 3 and 4 show a slightly different mode of operation of the device where multiplication is periodically interrupted to allow the multiplied electrons to impact the screen. In both Figures 3 and 4 the tube itself is constructed identically with that shown in Figure 1, but in this case we have provided means for interrupting the multiplying action periodically. In Figure 3 a time constant circuit 27 is inserted in the multiplier anode line, whereas in Figure 4 an oscillator 29 is utilized to supply the screen backing 12 with an alternating potential. In either case we may use, for example, an R. F. of 60 to 80 megacycles on the multiplier cathodes, and interrupt it at a frequency of, perhaps, $\frac{1}{2}$ to 3 megacycles. A reasonable assumption is that an average multiplication can be obtained of 3 per trip, so that twenty or thirty trips will provide the maximum useable gain. We prefer, however, that the interruption frequency shall be fixed at the lowest rate possible and still maintain a reasonably sharp electron image.

The interruption takes place, for example, in the circuit shown in Figure 3 because of the periodic failure of the multiplier anode supply, thus leaving the augmented electrons within the multiplier space immediately susceptible to the positive potential on the screen backing 12, and substantially all electrons are drawn out of the multiplier chamber and drawn against the screen. The time constant circuit 27 then builds up the potential on the multiplier anode; multiplication takes place and ceases again in accordance with the interrupting frequency, and this next group of electrons is thrown against the screen. If, therefore, the screen material be of the instantaneous type, it is illuminated only when the multiplier structure is not operating. Therefore, there can be no regenerative build-up due to the light of the screen just so long as the light therefrom does not persist over into the multiplying phase.

The method of interruption shown in Figure 4 attains the same end in a slightly different manner. Here, the voltage supplied to the screen backing 12 is greater than the voltage used or built up in the multiplier structure. Consequently, when the screen backing 12 is at its highest potential, most of the electrons will be abstracted from the multiplying structure and drawn to the screen. As soon as the voltage on the screen backing 12 decreases below those voltages used in the multiplying structure, multiplication will take place therein until the screen backing is again energized.

The various embodiments shown should readily teach those skilled in the art our new method of frequency conversion. In all cases the action takes place within a single tube, thus eliminating the necessity for complicated apparatus.

The electron image amplifications which can be obtained in this manner are enormous, and brilliant visual images on the receiving screen can be obtained of exceptionally weak infra-red images, and it will of course be understood that the image seen on the screen will have the elemental characteristics of the infra-red image and

not the characteristic of the visual image which might be seen could the object be seen with visible light. This of course in no way differs from the result which is obtained when an infra-red image is photographed on a red sensitive plate and viewed thereafter by transmitted light. In all cases the visual image is, as far as the eye is concerned, entirely continuous, and follows the variation and motion of the scene which is emitting the infra-red rays.

Furthermore, while we have shown the tube, in the drawing, as having cylindrical walls and having a receiving screen of the same order of size as the transmitting screen, it should be here pointed out that the receiving screen may be larger than the transmitting screen. For example, if the envelope in the neighborhood of anode 6, in Figure 1, is made divergent, and the screen 13 made several times larger than cathode 5, then the focusing field may be so arranged as to provide a divergent field so that the electron image expands equally in all portions thereof, so that when the electron image reaches the screen it will have spread in much the same manner as would an optical image, so that it will form an enlarged image on the screen. In this case, however, the energy in the electron image will also be spread and while the total light emitted by the screen 13 will be the same, the illumination per unit area will, of course, be lower.

Such relationships of input image size to that of output image size will of course be dependent, in practical operation, upon the use to which the device is to be put and upon the general strength of the incoming infra-red light, taken together with the available multiplication, and such variations are deemed to be well within the knowledge of those skilled in the art.

It should also be pointed out here that instead of utilizing a special multiplication oscillator 15, the multiplier structure may be made self-oscillatory, as has been pointed out in Farnsworth's application, Serial No. 10,604 cited above. Furthermore, such an oscillator may also be made self-interrupting at the lower frequency, if desired, as Farnsworth has pointed out in the same application. We do not deem it necessary, therefore, to show all these modifications in the present application, the specific illustrations being deemed sufficient to illustrate the broad application of our invention.

It should be distinctly understood, however, that the converter of our invention is not limited to the reception and production of an actual image; it may be used equally as well as an indicator of the presence, absence, or difference in amount of radiation within a defined band. For example, if the lens system of any of the tubes herein described is omitted and a gross collector substituted therefor, or even if the cathode 5 simply be exposed to uniform radiation, then the entire surface of the cathode will emit electrons with equal intensities over each elementary area to form a beam of electrons of uniform cross section, disregarding, of course, whatever pattern the screen might make. This uniform beam would then be amplified exactly as above described, and when the amplified beam is projected against the fluorescent screen 13, the amount of light emitted therefrom will be proportional, within limits, to the total amount of infra-red, for example, reaching the cathode 5.

This forms a useful gross signal. For example, the collector system may be made directional and

the entire device utilized to locate an infra-red emitter positioned as a beacon. Furthermore, such a beacon could be made to flash on and off in the manner of lighthouses, and under these circumstances a visual flash corresponding to the beacon flash would be seen on the fluorescent screen. Ranging thus becomes entirely practical, the device giving the exact direction of the beacon, some indication of its distance by brilliancy of screen response, and recognition of the beacon by watching the number of flashes. Thus, the device has a wide field of use, even though no defined image is formed on the screen.

Furthermore, it is quite possible and entirely practical for the device to be used in both manners, it being practical to collect larger amounts of infra-red, for example, without forming an image, than it is to provide optical systems of large light-collecting power to give an image. We do not wish, therefore to be limited to the actual formation of an electron image within the tube.

Furthermore, it will be obvious to those skilled in the art that the particular conversion utilized for an example herein is illustrative only, and that conversion may take place between other wavelength ranges. For example, there are electron emitters known to be highly sensitive to ultra-violet and even X-rays, and under these circumstances the conversion would be from the one range into the visible range.

It might also be desirable that the conversion be reversed and that a visible image be converted to an infra-red image, for example. In such case we might prefer to utilize, in place of the fluorescent screen assembly 12 and 13, one of Farnsworth's heat screens, as is described and claimed in Farnsworth's application, Serial No. 655,784, filed February 8, 1933, wherein a screen, instead of being fluoresced by electron impact, is actually changed in temperature, thus giving rise to an infra-red image.

Again, it will be seen that the device may be used as a straight image amplifier or as a straight radiant energy amplifier wherein a relatively low intensity radiation, either unformed or as an image, may be amplified and reproduced within the same wavelength band but with a greater augmented intensity.

Our invention is therefore adapted to a wide latitude of uses and adaptations within the scope of the appended claims, whether specifically mentioned therein or not.

We claim:

1. In combination, an envelope containing a photoelectric cathode and an opposed luminescent screen, an apertured cathode capable of emitting secondary electrons at a ratio greater than unity positioned between said first mentioned cathode and said screen, means for oscillating electrons between said photoelectric cathode and said apertured cathode to create electron multiplication in the space therebetween, and means for directing electrons passing through said apertured cathode against said screen.
2. In combination, an envelope containing a photoelectric cathode and an opposed luminescent screen, an apertured cathode capable of emitting secondary electrons at a ratio greater than unity positioned between said first mentioned cathode and said screen, means for oscillating electrons between said photoelectric cathode and said apertured cathode to create electron multiplication in the space therebetween, means for directing electrons passing through

said apertured cathode against said screen, and means for maintaining substantially the same relative electron densities in the elemental cross-sectional areas of said stream at all times throughout the envelope between the photoelectric cathode and screen.

3. In combination, an envelope containing a photoelectric cathode and an opposed luminescent screen, an apertured cathode capable of emitting secondary electrons at a ratio greater than unity positioned between said first mentioned cathode and said screen, means for oscillating electrons between said photoelectric cathode and said apertured cathode to create electron multiplication in the space therebetween, means for terminating the multiplication cycle, and means for drawing the multiplied electrons

through said apertured cathode to impact said screen.

4. In combination, an envelope containing a photoelectric cathode and an opposed luminescent screen, an apertured cathode capable of emitting secondary electrons at a ratio greater than unity positioned between said first mentioned cathode and said screen, means for oscillating electrons between said photoelectric cathode and said apertured cathode to create electron multiplication in the space therebetween, and means for alternately terminating the multiplication cycle and drawing the multiplied electrons through said apertured cathode to impact said screen.

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