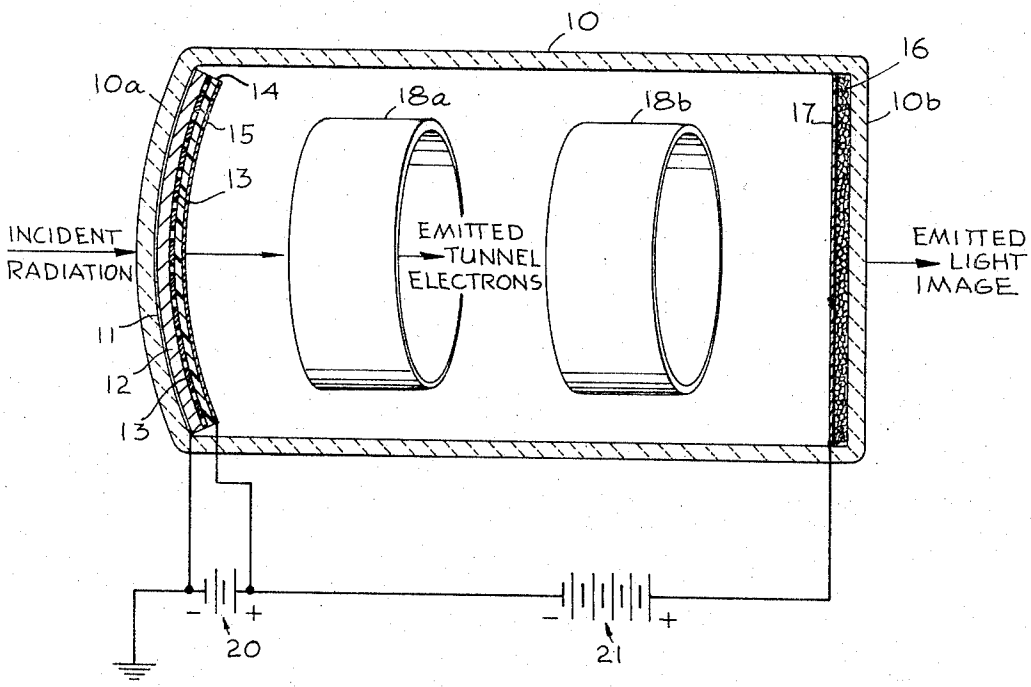
Feb. 6, 1968 B. KAZAN 3,368,077

INFRA-RED IMAGE INTENSIFIER HAVING A TUNNEL-EMISSION CATHODE HAVING A CONDUCTIVE MOSAIC

Filed March 8, 1963



BENJAMIN KAZAN
INVENTOR.

BY Allen E. Bottney

ATTORNEY

United States Patent Office 3,368,077 Patented Feb. 6, 1968

3,368,077

INFRA-RED IMAGE INTENSIFIER HAVING A TUNNEL-EMISSION CATHODE HAVING A CONDUCTIVE MOSAIC

Benjamin Kazan, Los Angeles, Calif., assignor to Electro-Optical Systems, Inc., Pasadena, Calif.

Filed Mar. 8, 1963, Ser. No. 263,861
3 Claims. (Cl. 250—213)

The present invention relates in general to the image intensifier tube art and more particularly relates to a new and improved image intensifier tube based on what are known as cold emission techniques.

With respect to the conventional image intensifier, an image of visible light falling on the photoemissive surface causes the emission of a pattern of electrons. These are accelerated and imaged on a phosphor screen to provide an intensified image corresponding to the input image. However, to a large extent, the operation is limited by the qualities of the photoemissive screen. More specifically, because its maximum quantum yield (number of photoelectrons emitted per absorbed quantum) is usually considerably less than thirty percent, the overall gain of the device is limited. Moreover, due to the physical nature of the photoemissive process, satisfactory operation in the far infra-red region, for example, at wavelengths greater than one micron has heretofore not been possible. In addition, because the screen is very thin, the absorption of X-ray energy is very small, thus making direct excitation with images of such radiation impractical.

The shortcomings of these earlier image intensifier tubes are overcome by means of the present invention which permits the design of a new type of image intensifier tube capable of much higher gains than the conventional tube. Furthermore, image intensifier tubes constructed in accordance with the present invention are also capable of operation with input images in the far infra-red and in the X-ray regions whereas, as was previously mentioned, the conventional intensifier tube is restricted to visible and near infra-red radiation. These improvements in the operation of image intensifier tubes are made possible by applying the concept of either tunnel emission or internal avalanching to them which, in turn, involves the use of a new combination of materials and elements.

It is, therefore, an object of the present invention to provide an image intensifier tube that is capable not only of operating in the visible light region but also in the far infra-red and X-ray regions as well.

It is another object of the present invention to provide a sensitive image intensifier tube that will operate effectively where the detection of low-level images of visible light is involved.

It is a further object of the present invention to employ either tunnel-emission or internal avalanching principles to expand the efficiency and range of operation of image intensifier tubes.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only and is not intended as a definition of the limits of the invention.

The drawing itself schematically illustrates a new type of image intensifier tube based on the concept of the present invention.

Referring now to the drawing, the tube envelope is designated **10**, the faceplate portion of it being designated

10*a*. On the inside surface of faceplate **10***a* is a very thin transparent conductive coating **11**, such as stannous oxide, over which a photoconductive layer **12** is coated. The photoconductive layer is about 1 mil thick or less and while a number of different photoconductive materials are available for forming such a layer, cadmium sulphide is an example of one such material that may be employed. Photoconductive layer **12** is covered with an image retaining mosaic of conducting elements **13** which, in turn, are covered with a thin insulating layer **14**, the insulating layer being very thin, in the order, for example, of 100 Angstroms. The conducting elements of the mosaic may be made of gold. Finally, a very thin metallic conducting film **15**, such as gold, is provided on the surface of the insulating layer.

At the other end of tube envelope **10**, opposite faceplate **10***a*, is the flat base **10***b* of the tube which, on its inside surface is coated over with a cathode luminescent phosphor layer **16**, the phosphor layer having an aluminized coating **17** over it as is shown in the figure.

As is customary with these types of tubes, the inside of the tube is evacuated and contains focusing electrodes **18***a* and **18***b*. Alternatively, magnetic focusing may be used. Since the construction and operation of focusing electrodes are very well known in the art, it is deemed sufficient to merely schematically represent them in the figure and to mention that they focus the electrons emitted from the faceplate portion of the tube into an image at the baseplate portion of the tube. Of course, as is well known, focusing electrodes are customarily connected to sources of potential which are not shown in the figure. However, two voltage sources, respectively designated **20** and **21**, are shown in the figure, source **20** providing approximately twenty volts between its terminals and source **21** providing approximately **10** kilovolts between its terminals.

Before considering the operation of the present invention, it should first be stated that cold emission involves the phenomena by which electrons are emitted into a vacuum when a large electric field is placed across a thin insulating layer, the reason for this phenomena being due, for example, either to a tunneling action or internal avalanching processes. The tunneling of electrons through thin insulating films and the observance of electron emission into a vacuum has been reported by C. Mead in Journal of Applied Physics, volume 32, pages 646–652, published in 1961. On the other hand, the internal avalanching process is discussed in an article by Messrs. H. Jacobs, J. Freely and F. A. Brand, in Physical Review, volume 88, page 492, published in 1952.

Considering now the operation, the effect of incident radiation at a local point on photoconductor **12** is to lower its resistance so that more voltage appears across insulating layer **14** at the corresponding point. As was previously mentioned, the insulating layer is assumed to be very thin, for example, in the order of 100 Angstroms, so that, in accordance with the principles mentioned, electric current flows through the insulator. By also making outer conducting metal film **15** very thin, it can be expected that a substantial fraction of the electrons moving through the insulator will be emitted into the vacuum.

Assuming that only about one-tenth of the total number of electrons emerge into the vacuum space, the overall quantum yield of the combined photoconductive cold-emission cathode can nevertheless be made much higher than a photoemissive surface since the quantum yield of numerous photoconductive materials is many orders of magnitude higher than that of a photoemitter. At the same time, the use of a photoconductor makes possible operation in the far infra-red region since photoconductors sensitive in this range of the spectrum are existent, such as lead oxide activated with sulphur. For other applications, em-

bodiments of the present invention can be used for operation where the detection of low-level images of visible light is involved. Also, since photoconductive layers of sufficient thickness and high sensitivity to X-rays are available, image intensifier tubes encompassing the present invention can be used to convert and to intensify low-level X-ray images.

Having thus described the invention, what is claimed is:

1. An image intensifier tube comprising: a transparent conductive layer coated on the inside surface of the tube faceplate; a photoconductive layer over said transparent conductive layer; a mosaic of separate and distinct conducting elements covering said photoconductive layer; an insulating layer deposited over said mosaic; a metallic film deposited on the surface of said insulating layer; a phosphor layer deposited on the inside surface of the tube baseplate; and an aluminized coating over said phosphor layer.

2. An image intensifier tube comprising: a transparent conductive layer coated on the inside surface of the tube faceplate; a photoconductive layer deposited over said transparent conductive layer; elements forming a plurality of tunnel-emission diodes mounted over said photoconductive layer; a luminescent screen deposited on the inside surface of the tube baseplate; and means for focusing

electrons tunneling into the vacuum of the tube onto the screen.

3. The image intensifier tube defined in claim 2 wherein said tunnel-emission diode includes a mosaic of thin metallic elements mounted over said photoconductive layer, an insulating layer over said mosaic, and a thin metallic film deposited on the surface of said insulating layer.

References Cited

UNITED STATES PATENTS

2,824,986	2/1958	Rome	250—213 X
2,889,488	8/1959	Kalfaian	313—66
2,903,596	9/1959	Reed	250—213
2,929,935	3/1960	Lempert	250—213 X
2,944,155	7/1960	Moyer	250—213
3,056,073	9/1962	Mead	317—234
3,107,303	10/1963	Berkowitz	250—213
3,148,297	9/1964	Schneeberger et al.	313—94
3,246,200	4/1966	Kanter	315—94

RALPH G. NILSON, *Primary Examiner.*

E. STRICKLAND, M. AMBRAMSON,
Assistant Examiners.