April 29, 1969 R. H. CLAYTON 3,441,786

CAMERA TUBE HAVING A VARIABLE RESOLVING APERTURE

Filed Nov. 29, 1966 Sheet 1 of 2

FIG. 1

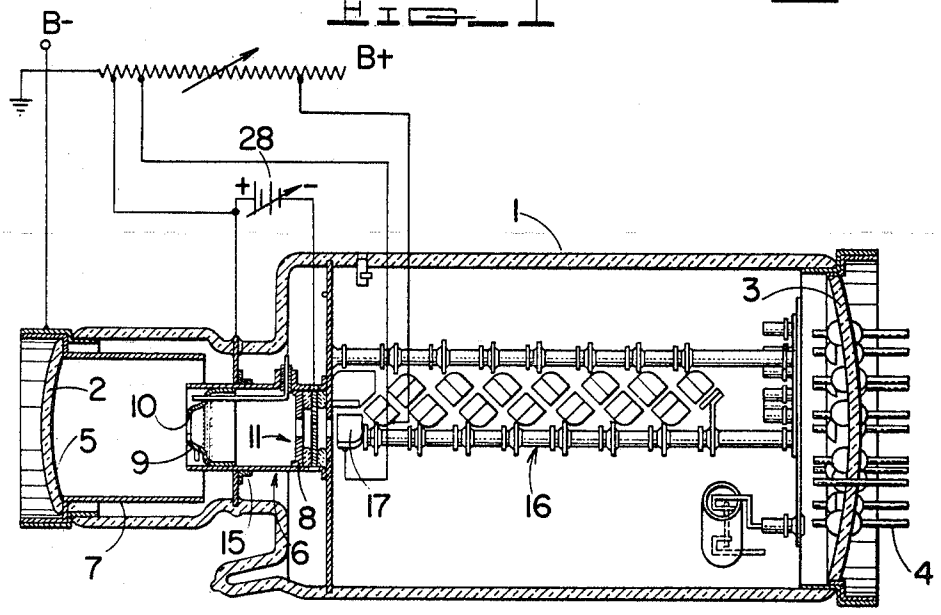
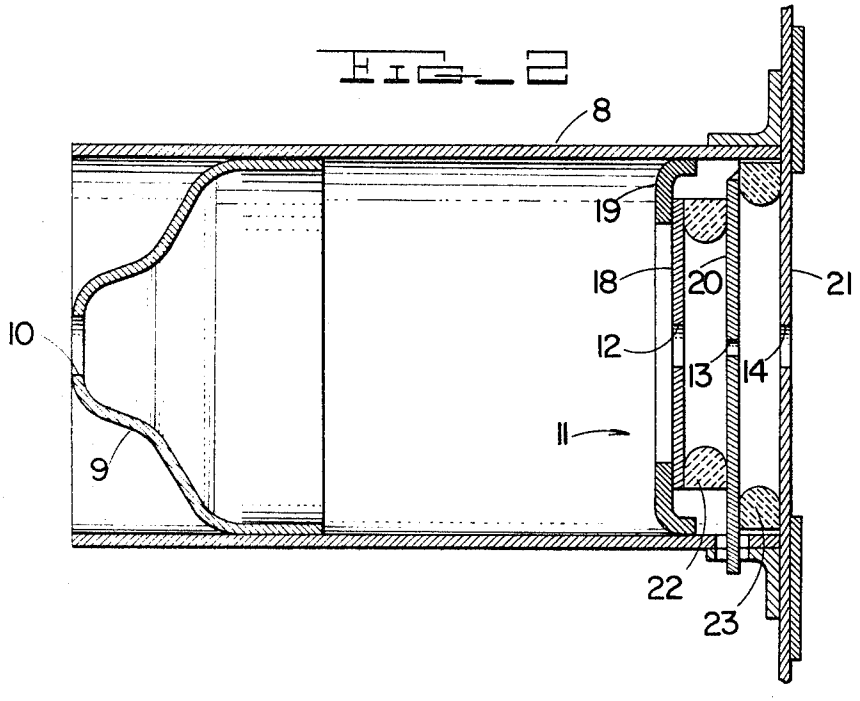



FIG. 2




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FIG. 3

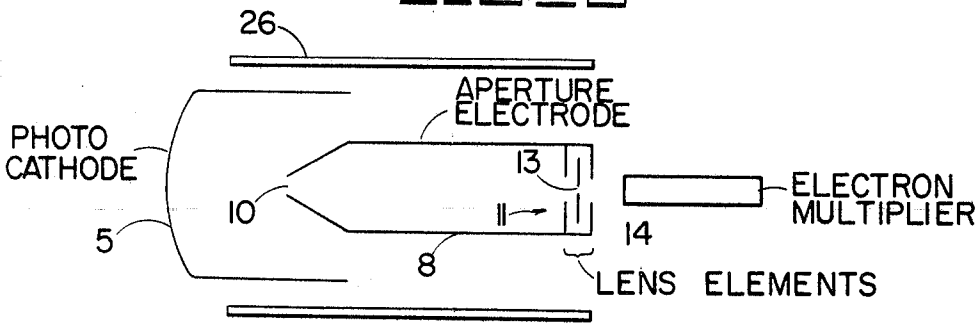



FIG. 4

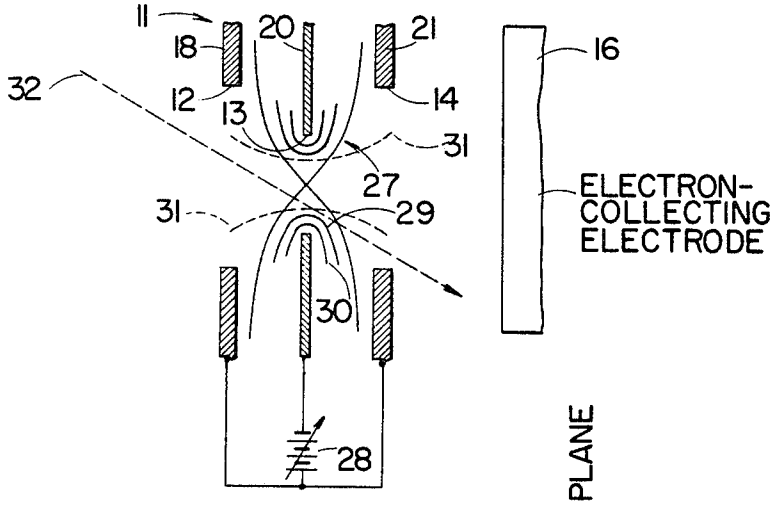
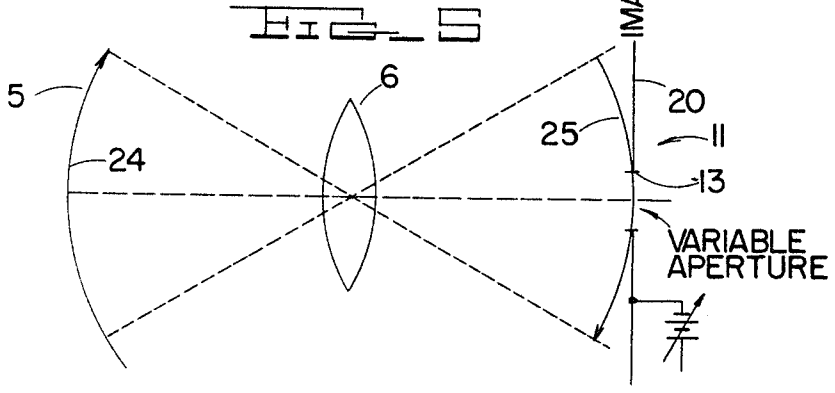



FIG. 5




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3,441,786

# CAMERA TUBE HAVING A VARIABLE RESOLVING APERTURE

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U.S. Cl. 315—11 10 Claims

## ABSTRACT OF THE DISCLOSURE

An image tube is provided with a variable apertured electrode wherein the image is focused onto the electrode and an adjustable electric field is applied thereto which varies the effective aperture size. The focusing of electrons of an increment of the image is not changed by variation of the aperture size.

The present invention relates to a camera tube having a variable resolving aperture, and more particularly to a camera tube corresponding to the image dissector in which the resolving aperture has an electronically variable size.

A conventional image dissector tube comprises a photocathode for emitting an electron image in response to and corresponding to incident radiation. In the usual instances, the electron image is formed and focused into an image plane. A defining or resolving aperture is located within this image plane, and means are provided for deflecting the beam in a raster pattern over the aperture in generating a time-based video output signal. The electrons which pass through the aperture are received by target electrode means, typically an electron multiplier, from which the video signal may be taken.

The size of the aperture, that is to say the electron-transmission cross-section thereof, in part determines the tube sensitivity and resolution characteristics, the larger the aperture the greater the sensitivity but the poorer the resolution. In the prior art, such defining apertures are normally determined as to size by the physical dimensions of an opening in a metal disc or plate.

In view of the foregoing, it is an object of this invention to provide a camera tube having a resolving or defining aperture which may be selectively, electronically varied in size for adjusting tube sensitivity and resolution characteristics.

It is another object of this invention to provide a camera tube in which an electron image is focused into an image plane said tube having a resolving aperture in said image plane which may be electronically varied in size without producing deleterious defocusing effects.

It is still another object of this invention to provide a camera tube having certain sensitivity and resolution characteristics which may be easily and simply controlled.

In accordance with the present invention, there is provided an electron discharge device having an element capable of emitting an electron image. This element may be in the form of the usual translucent, extended area photocathode. First means are provided for focusing the electron image into an image plane spaced a predetermined distance from the element. Second means having an electron-transmitting aperture of variable effective size for transmitting electrons of an incremental area of the focused image is so disposed as to located the aperture substantially in the aforesaid image plane. An electron multiplier or similar collecting electrode is positioned for collecting the electrons transmitted by the aperture and for generating a signal in desponse thereto. Of importance is the fact that the second means is so arranged as to maintain the electrons of said incremental area as transmitted by the aperture substantially focused in said image plane even though the electron-transmitting size of the aperture may be electrically varied.



The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is an axial section of an embodiment of this invention showing the manner of connecting operating potentials thereto;

FIG. 2 is a similar sectional view in enlarged form, of a portion of the structure shown in FIG. 1;

FIG. 3 is a diagrammatic illustration of the tube of FIG. 1 used in explaining operation;

FIG. 4 is an enlarged fragmentary cross-sectional view of that portion of the structure of the preceding figures which provides the variable resolving aperture; and

FIG. 5 is a diagram showing the focusing system of the illustrated embodiment, which is used further in explaining tube operation.

Referring to the drawings, an evacuated, cylindrical envelope **1** is provided on its left-hand end with a conventional transparent faceplate **2** and on its right-hand end with a base **3** for supporting suitable terminal pins **4**. A photoelectric material, indicated by the numeral **5**, is coated on the inner face of the end plate **2**, this material including any of the well-known photoelectric compositions such as silver-oxidecesium. This cathode arrangement is conventional and serves to emit electrons in response to radiant energy focused on the left-hand surface thereof through the transparent faceplate **2**.

An electron lens indicated generally by the reference numeral **6** is supported within the envelope **1** in cooperative relation with the cathode **5**. This lens comprises a cathode sleeve **7**, cylindrical in shape, conductively connected at its left-hand end to the cathode **2**, and an accelerating or anode sleeve **8** which is smaller and coaxially extends a short distance into the sleeve **7**. An apertured member **9** is fitted into the left-hand end of the cylindrical sleeve **8** and has a small opening **10** serving a purpose which will be explained later. A defining or resolving electrode assembly, indicated generally by reference numeral **11**, having a central coaxially arranged series of openings indicated respectively by numerals **12**, **13** and **14** is electrically connected to the right-hand end of the sleeve **8**. The sizes of the sleeves **7** and **8** and the positions thereof are somewhat critical and can be determined by conventional, experimental or mathematical techniques in order to meet given design requirements. For the purposes of this invention, it is only necessary to state that the structure of the electron lens **6** is such as will focus an electron image emitted by the cathode **5** into an image plane substantially coincident with the plane of the opening **13**. The method and structure for obtaining an electron image in this so-called "image plane" are well known and need not be further elaborated here.

The sleeve **8** and the two ends **9** and **11**, respectively, provide an essentially closed cylinder with the exception of the openings **10**, **12**, **13** and **14**. Thus, there is little, if any, electric field inside the sleeve **8**, this serving a purpose to become apparent from the later description. Additionally, the sleeve **8** is supported inside the envelope **1** by means of a solid conductive disc **15** which, in conjunction with the sleeve structure itself, substantially isolates that portion of the phototube on the left side of the disc **15** from that portion on the right side with the exception of the openings previously described.

A multi-stage electron multiplier, indicated generally by the reference numeral **16**, is mounted adjacent to the

aperture electrode assembly **11** opposite the aperture **14**. Electrons passing through the openings **12**, **13** and **14** will therefore impinge the first stage **17** of the multiplier which emits secondary electrons, these being multiplied by succeeding stages in a manner well known to the art. This multiplier may be conventional and serves the purpose of increasing the magnitude of the electron current transmitted by the openings **12**, **13** and **14**.

The electrode assembly **11**, shown in enlarged detail in FIGS. 2 and 4, will now be described. A metallic disc **18** has the opening **12** in the central portion thereof, an annular metallic support **19** welded to both the tube **8** and disc **18** securing rigidly and conductively the disc **18** in place. Another disc **20**, similar to disc **18** has centrally thereof the opening **13** and is rigidly mounted inside the tube **8** in parallel spaced relationship with respect to the disc **18**. The disc **20** is insulated from the sleeve **8** as well as the disc **18**. A larger disc **21** of metal is secured to the right-hand end of the sleeve **8** and extends radially outwardly to the wall of the envelope **1** where it is rigidly secured in place. This disc **21** has the aperture **14** centrally thereof and is conductively connected to the sleeve **8**.

In the illustrated embodiment, the three discs **18**, **20** and **21** are flat and parallel to each other and are equally spaced apart by distances determined by rings **22** and **23** of suitable insulating material such as glass or ceramic. These rings **22** and **23** are preferably suitably fused to the various discs so as to support the latter rigidly with respect to each other. It will be apparent that the two discs **18** and **21** are conductively connected to the sleeve **8** whereas the disc **20** is insulated therefrom. The arrangement of the disc **20** with respect to its mounting in size must be such that adequate insulation from the discs **18** and **21** as well as the sleeve **8** will be maintained.

The three openings **12**, **13** and **14** are coaxially arranged, with the two openings **12** and **14** being larger than the opening **13**. In the specific working embodiment illustrated, the two openings **12** and **14** are of equal size and about five times larger in diameter than the opening **13**. The three discs **18**, **20** and **21** are mounted relatively closely together as will be explained in more detail later on.

Operating potentials may be connected to the various electrodes just described in such a manner as to apply ground or zero potential to cathode **5** and sleeve **7** and a potential which is positive with respect thereto to the anode sleeve **8**. A positive potential is connected to the multiplier **16**, successively higher potentials being applied to the succeeding stages in accordance with conventional practice. Additionally, a potential negative with respect to that applied to the anode sleeve **8** is applied to the disc **20** which hereafter for purposes of convenience may be referred to as an "iris" element.

In operation, an optical image projected onto the left-hand surface of the faceplate **2** will serve to excite the cathode **5**. Electrons will be emitted from that portion of the surface of the cathode which receives the optical image, and these electrons will be accelerated through the opening **10** and focused substantially into the plane of the opening **13**. Only those electrons which fall within the areas of the openings **12**, **13** and **14** will be utilized since at least a portion of them pass through or are transmitted to the first stage **17** of the multiplier **16**. Referring more particularly to FIG. 5, the focusing of an electron image emitted by the cathode **5** into an image plane including the opening **13** is illustrated. An electron image in the form of an arrow **24** emitted by the cathode **5** is accelerated and focused by the lens **6** into an image plane, the focused image being indicated in inverted form by numeral **25**. The central portion of this image **25** coincides with the opening **13** such that the electrons of the central portion will pass therethrough.

In connection with the development of a video signal, reference may be made to FIG. 3, which illustrates diagrammatically the tube of FIG. 1 having in addition conventional deflection coils **26**. The coils **26** are used to scan in a television raster pattern the focused image **25** (FIG. 5) over the aperture provided by the openings **12**, **13** and **14** in the usual way such that at any given instant of time, only an incremental, minute area or portion of electron image is passed by the aperture. This is in accordance with conventional scanning techniques used in image dissector tubes for the purpose of developing a video signal representative of the scene or image focused onto the cathode **5**. Sensitivity and resolution characteristics of the tube are determined by the size of the composite openings **12**, **13**, **14**, and in a conventional image dissector by the counterpart, defining aperture, enlargement of the aperture resulting in greater sensitivity but poorer resolution and reduction of the aperture size having the reverse effect. However, in order to maximize resolution for a change in aperture size, it is necessary that the integrity of the focusing action, in other words focusing into the image plane, be maintained. This will receive further elaboration later on.

The electrode assembly **11** is constructed and operated such that it corresponds to a conventional Einzel lens. Substantially the same positive potential is applied to the two outer discs **18** and **21** and a negative potential is applied to the central disc **20**. A so-called "saddle" electric field is developed between the three discs and within the opening **13**, this saddle in the present instance being represented by the equi-potential surfaces indicated generally by the solid line curves **27** in FIG. 4. As will be understood, these equi-potential surfaces are annular in shape and are coaxially positioned inside the opening **13**. Moving from the perimeter of the opening **13** radially inwardly toward the center thereof, the equi-potentials progressively increase in a positive-potential direction, or in other words, the equi-potentials near the center have more positive potentials than those nearer the perimeter of the opening **13**. By means of the battery or potential source **28**, it is possible to vary the potential on the disc **20** with respect to the cathode **5** such that the disc **20** may be biased either positively or negatively with respect to the cathode. For the purpose of this explanation, it may be assumed that the battery **28** is adjusted to a potential that the equi-potential surface (which is annular in shape) **29** is at zero (0) volts, or in other words, at the same potential as the cathode. This being true, the equi-potential **30** situated next adjacent to the perimeter of the opening **13** may be regarded as being at a more negative potential such as −1 or −2 volts, or in other words at a more negative potential than that of the cathode **5**. Quite obviously, this more negative potential will exert a repelling force on any electrons that may be approaching.

In imaging the electrons emitted by the cathode **5** into the image plane as already described, the electrons initially are accelerated and cross over through the opening **10** following which they enter the field-free space inside the anode sleeve **8**. Within this space, they travel at substantially constant velocity. Upon entering opening **12**, the electrons encounter the negative field of the disc **20** by the time they reach the plane of this disc **20**. Inasmuch as this disc **20** substantially coincides with the image plane, focusing of the electron image thereby occurs at a location in space at which the electrons are decelerated substantially to the same voltage as the cathode **5**, or in other words zero velocity. Those electrons approaching the more negative equi-potential **30** will of course be repelled. However, those electrons approaching the zero (0) volt equi-potential **29**, or just inside thereof, will pass on through and thereafter be accelerated onwardly through the opening **14** toward the electron multiplier **16**. It will thereby be seen that the effective electron-transmitting size of the aperture in the assembly **11** is that defined by the annular equi-potential **29**. It will now appear that the size of this aperture may be controlled by varying the voltage applied to the iris or disc **20**, which in effect shifts

or changes the voltage of the equi-potentials illustrated. The size of the transmission area may therefore be adjusted by merely adjusting the battery **28**.

If it is desired to obtain maximum sensitivity, it is only necessary to increase the voltage on the disc **20** in a positive direction thereby enlarging the diameter of the equi-potential that transmits the electrons. On the other hand, if it is desired to close or cut off electron transmission, the voltage applied to the disc **20** is made sufficiently negative, e.g., −18 to −20 volts.

Of importance in obtaining satisfactory operation is the relative positioning of the three discs **18, 20** and **21**. These are positioned as closely as possible consistent with the requirements for electrical insulation. In doing this, the radius of curvature of the equi-potentials **27**, as observed in radial cross-section, is made smaller than would be true if the discs **18, 20** and **21** were more widely separated. Equi-potentials resulting from having the discs more widely separated are indicated by the dashed line **31**. It will be noted that this dashed line has a curvature which is much larger than that of the full-line equi-potentials **27**. As a consequence of this close spacing, uniform transmission of electrons through the aperture is achieved irrespective of the approaching angle at which the electron enters the aperture from the cathode. This results in producing less vignetting in the reproduction of an image which, of course, is a desirable end result. A typical angle of electron approach is indicated by the dashed line arrow **32** in FIG. 4, which will be noted as definitely clearing the equi-potential surface **29** (which may be assumed to be at zero (0) volts), but on the other hand as intersecting the dashed line equi-potential **31**. Upon intersetcing this latter equi-potential (which is also assumed to be at zero volts), the electron will either be repelled in a reverse direction or deflected such that it will not penetrate properly the aperture. The angle of acceptance of the aperture is therefore increased by maintaining the close spacing of the three discs **18, 20** and **21**.

In a working embodiment of this invention, and referring more particularly to FIG. 2, the folowing dimensions of the parts in the electrode assembly **11** may be used. It should be understood, however, that these dimensions are given by way of example only and are not intended as limitations:

| | |
|---|---|
| Inner diameter of sleeve **8** | .387 inch. |
| Spacing between discs **18, 20** and **21** | .050 inch. |
| Size of the openings **12** and **14** | .050 inch. |
| Size of opening **13** | .010 inch. |
| Thickness of disc **20** | .005 inch. |
| Voltage applied to the disc **20** with respect to cathode **5** | Variable between 0 and −25 volts. |

Of importance in this invention is the unique operational feature that once the electron image emitted by the cathode is properly focused by the lens mechanism **6**, alteration of the potential on the disc does not disturb this focusing, therefore it has not affect in changing the tube resolution. This is a desirable end result inasmuch as alteration of the tube sensitivity or resolution does not entail any refocusing requirement within the tube itself.

In the use of the camera tube of this invention, it will now be obvious to a person skilled in the art that maximum resolution consistent with the usable, detected signal is always possible by merely adjusting the voltage applied to the disc **13**. Thus, for any given level of scene brightness observed by the cathode **5**, the Einsel lens may be adjusted to provide for maximum resolution. A scene having low-level brightness will, of course, produce emission of a correspondingly few electrons from the cathode **5** such that the defining aperture will necessarily have to be opened wider in order to obtain a usable signal. In opening the aperture, resolution becomes poorer. For higher-level scene brightness, greater electron emission permits the defining aperture to be reduced in size, which results in better resolution characteristics. Defocusing is avoided in both of these cases.

While the apertures **12, 13** and **14** as shown are circular, it will be obvious to persons skilled in the art that other shapes may be used without departing from the spirit and scope of this invention. For example, elongated narrow slots for the apertures may be used, these being parallel and in axial registry in the various discs **18, 20** and **21**, respectively.

While there have been described above the principles of this invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

**1.** For use in generating a video signal in response to a radiation image, an electron discharge device comprising an element capable of emitting an electron image, first means for focusing the electron image into an image plane spaced a predetermined distance from said element, second means having an electron-transmitting aperture of variable effective size for transmitting electrons of an increment of said focused image, said aperture being located substantially in said image plane, means connected to said second means to provide an adjustable electric field to vary said effective aperture size, and means for collecting the electrons transmitted by said aperture and generating a signal in response thereto, the focusing of the electrons of said increment in said image plane as transmitted by said aperture being unchanged by the variation of the electron-transmitting size of said aperture.

**2.** The device of claim **1** in which said second means includes an electrode device containing said aperture and which is otherwise impervious to electrons.

**3.** The device of claim **2** in which said electrode device is an Einzel lens having an iris element and said means connected to said second means includes a source of potential coupled to said iris element.

**4.** The device of claim **1** in which said element is a photoelectric cathode of extended area, said second means including an Einzel lens having three substantially parallel and spaced-apart conductive members provided with coaxially aligned openings, respectively, and means for applying a source of potential to said conductive members to provide annular equi-potential surfaces within the opening of the middle one of said members, said equi-potential surfaces defining said electron-transmitting aperture.

**5.** The device of claim **4** in which said middle member is insulated from the other two members, and a source of potential coupled to said members which biases said middle member negatively with respect to the other two members.

**6.** The device of claim **5** in which the opening in said middle member is smaller than the openings in said other two members, the size of the openings in said other two members being substantially equal, the spacing between said members being no greater than the size of the openings in said other two members.

**7.** The device of claim **5** in which the spacing between said members shapes said equi-potential surfaces such as to reduce vignetting of the electron image transmitted by said aperture.

**8.** The device of claim **5** in which said members are flat metal discs and said other two members are conductively connected together, said focusing means including a conductive sleeve closed at one end by said Einzel lens, said openings being coaxially positioned with respect to said sleeve, and said source of potential being variable.

**9.** The device of claim **8** in which said source of potential is variable between values which at one limit closes said aperture to the transmission of electrons and at the opposite limit opens said aperture to the transmission of electrons to about the size of the surrounding opening.

10. The device of claim 9 in which the openings of said other two members are approximately 0.05 inch in diameter, the openings in the middle member is about 0.01 inch and the spacing between said members is about 0.05 inch.


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