# United States Patent

**Sackinger et al.**

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[54] **HIGH GAIN STORAGE TARGET**

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[52] **U.S. Cl.** ..................................**315/12,** 315/11, 313/103, 250/213

[51] **Int. Cl.** ..........................................................**H01j 29/41**

[58] **Field of Search** ................315/11, 10, 12; 313/103, 104, 313/105; 250/213

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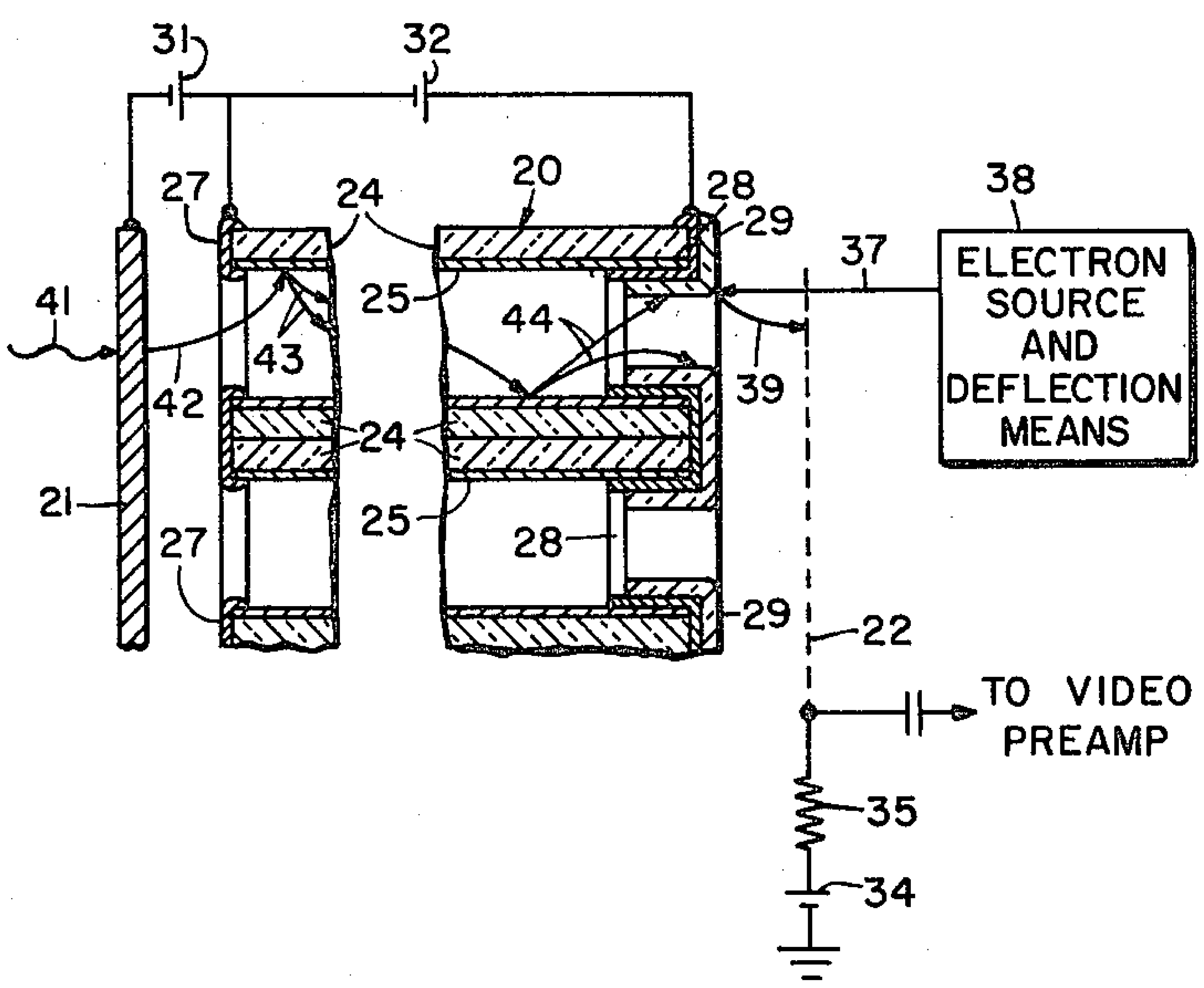
[57] **ABSTRACT**

An image conversion device of the type wherein an input photon image is converted to a photoelectron image which creates on a storage target a charge pattern corresponding to the input optical image. According to this invention a multichannel plate is disposed in intercepting relationship with the photoelectrons to provide electron multiplication of the photoelectron image.

**7 Claims, 2 Drawing Figures**



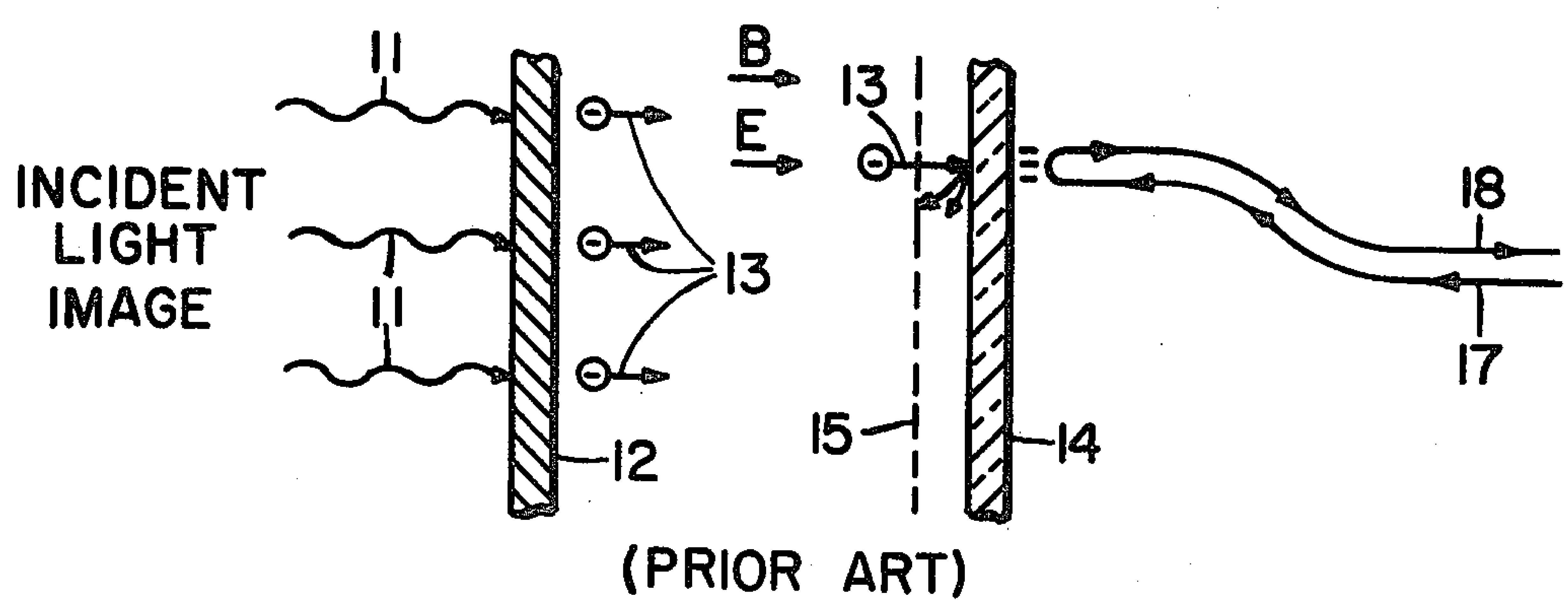



Fig. 1

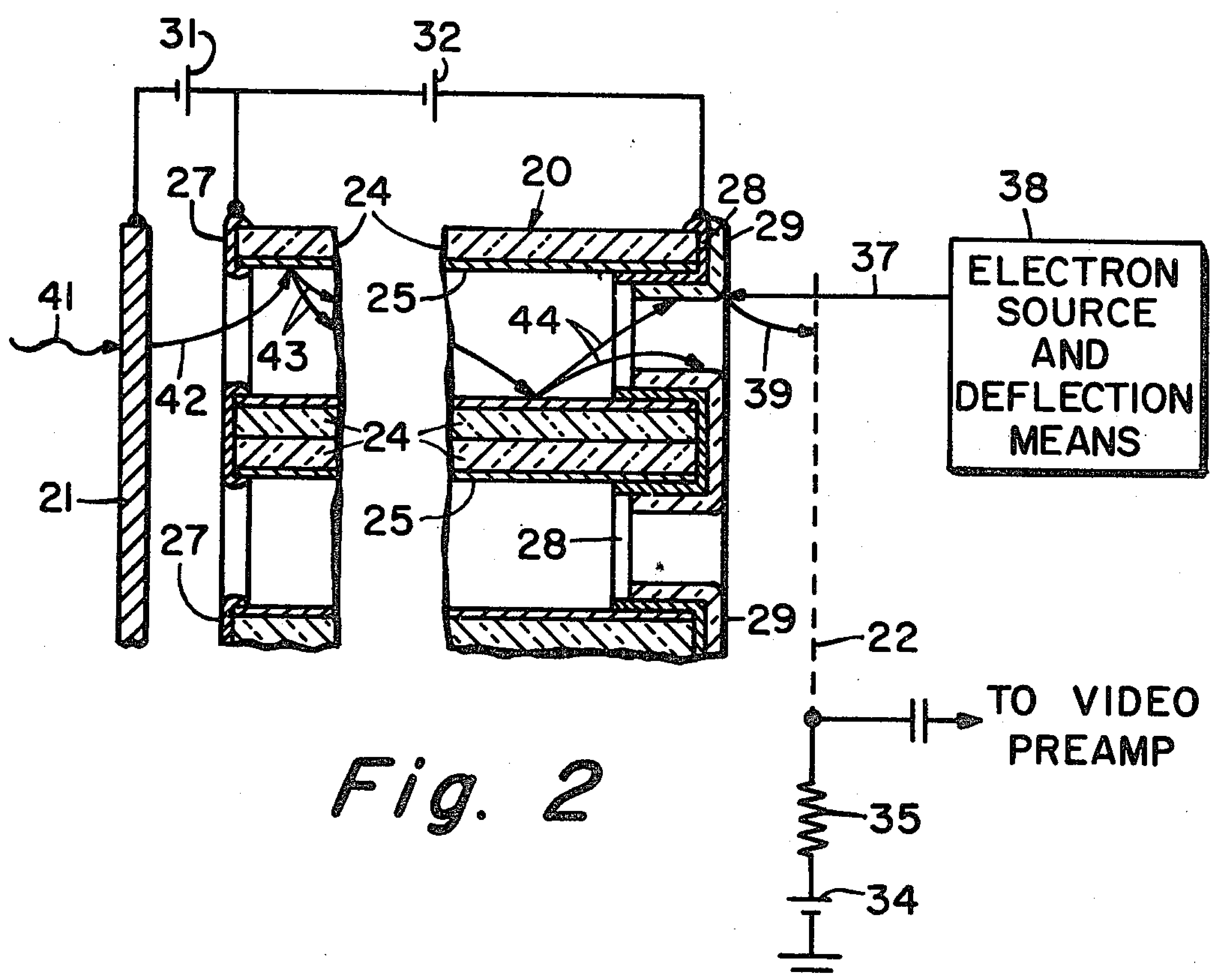



Fig. 2

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## HIGH GAIN STORAGE TARGET

### BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to improved charge storage targets and to photon and electron image devices utilizing the same. More particularly, this invention relates to a high gain storage target which both intensifies and stores an incident photon or electron image which can be subsequently read out by either destructive or non-destructive modes. Storage times of the order of days are possible along with gains of at least $10^4$. This invention finds utility in such applications as storage targets in television camera tubes, storage media for computers, and the like.

2. Description of the Prior Art

The conventional image orthicon camera tube converts an optical image into a video signal. In such a tube the incident light image is converted by a photoemissive layer into an electron image. The photoelectrons which constitute the electron image are accelerated by an applied electric field towards a storage target. In order to preserve the resolution of the electron image, the paths of the photoelectrons are confined by an applied magnetic field during this acceleration process. Photoelectrons striking the storage target create secondary electrons which are collected on a fine mesh screen adjacent the front of the storage target. Since the secondary emission ratio is greater than **1**, a positive charge pattern representative of the input optical image is stored on the front side of the target, and a negative charge accumulation is induced on the opposite side of the target.

Numerous disadvantages are inherent in the above-described image orthicon storage tube. Due to the limited number of photoelectrons available for establishing a charge on the storage target, the sensitivity of the conventional image orthicon is relatively low. Moreover, numerous factors contribute to the degradation of resolution in this type of device. In conventional orthicons, for example, because of the low level of stored charge and the use of return beam readout, the reading beam arrives at the target with a low velocity and cannot be focused to a fine spot size. The electron scattering effects of the fine mesh secondary electron collecting screen also degrades resolution.

Charge redistribution effects also tend to adversely effect the resolution of conventional storage targets. Both transverse redistribution of low energy secondary electrons and lateral charge leakage contribute to this effect. In the conventional image orthicon, certain areas of the target charge more positively than other areas. Those areas which have the most intense input information charge relatively quickly to a high potential. They are then capable of attracting low energy secondary electrons from the other target areas and thus act in competition with a fine mesh screen, the purpose of which is to collect secondary electrons emitted from the target. Since the storage target of a conventional image orthicon must be thick enough to be self-supporting over the entire area of the image, lateral charge leakage, which increases with target thickness, is also relatively high.

One of the techniques for improving the sensitivity of an image orthicon requires the use of an image intensifier in front of the image orthicon as a pre-amplifier. Often this image intensifier is constructed in a separate vacuum envelope with fiber optic input and output windows which couple directly to the fiber optic input window of the image orthicon itself. Such an intensifier usually consists of a photocathode, an accelerating field, and a phosphor screen. As the image passes through this additional intensifier the resolution thereof becomes degraded.

### SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide a charge storage device having improved sensitivity and resolution. Another object of this invention is to provide a television camera tube which requires no magnetic focusing, thereby resulting in a reduction in size and weight. Still another object of this invention is to provide a charge storage device having a storage target, the dimensions and geometry of which are such that charge redistribution effects are minimized.

Briefly, the camera tube of this invention comprises a multichannel plate having a plurality of parallel tubular members, the inner surfaces of which contain a resistive, secondary-electron emissive layer. The openings in the ends of the tubular members lie on first and second surfaces which constitute the input and output ends, respectively, of the multichannel plate. First and second conductive layers are disposed on the input and output ends of the multichannel plate, respectively. An electron image source is disposed adjacent the input end of the multichannel plate, and a storage target is disposed at the output end thereof. A charge image corresponding to that of the electron image source is written on the target by electrons emanating from the multichannel plate. Readout means converts the charge image stored on the target into a video signal.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of a prior art image orthicon storage tube.

FIG. **2** is a schematic illustration, partly in cross section, of an electron image storage tube incorporating the teachings of this invention.

### DETAILED DESCRIPTION

FIG. **1** is a schematic representation of a prior art image orthicon camera tube and is presented herein as being illustrative of an application of a conventional storage target. An incident light image illustrated by undulated arrows **11** is converted to an electron image by photoemissive layer **12**. The photoelectrons illustrated by arrows **13** are accelerated by an applied electric field, which is represented by the arrow E, towards a storage target **14**. During this acceleration process their paths are confined by an applied magnetic field represented by the arrow B, which is parallel to the direction of motion of the electrons. When electrons **13** strike the storage target, secondary electrons are created. The arriving energy of photoelectrons **13** is usually large enough so that the secondary emission ratio is greater than one, and therefore, the number of secondary electrons which leave the storage target is greater than the number of arriving photoelectrons. The low energy secondary electrons are collected on fine mesh screen **15** which is disposed immediately adjacent that side of the storage target facing photocathode **12**. The resulting charge pattern stored on target **14** is positive on the input side, thereby causing a corresponding negative charge accumulation on the opposite side of the target. This negative charge accumulation is representative of the input image information.

A reading electron beam illustrated by the line **17** is scanned across target **14** and wherever there are accumulations of negative charge, the reading beam, which arrives with very low velocity, is repelled back along its arrival path, as illustrated by the line **18**. The return beam is directed to an electron multiplier in the vicinity of the electron gun where the information contained in the return beam is detected.

One of the limitations on the sensitivity of the image orthicon is the number of photoelectrons available to write an image onto the storage target. In accordance with the present invention, this limitation is overcome and additional advantages are gained by combining a multichannel electron multiplier with the storage target and also modifying the storage target.

In the preferred embodiment shown in FIG. **2** a microchannel plate **20** is disposed between a photocathode **21** and an equilibrium mesh **22**. The microchannel plate may consist of a plurality of glass tubes or microchannels **24** each having a resistive layer **25** formed on the inner surface thereof. The glass tubes may be formed in accordance with the teachings of U. S. Pat. No. 3,331,670, issued July 18, 1967 to H. B. Cole. Resistive layer **25** must be capable of producing electron multiplication by secondary emission and may consist of such materials as tin oxide, aluminum oxide, carbon compounds or the like. Layer **25** could also be formed by reducing suitable glasses, such as lead glasses, to form a surface layer of the proper resistivity.

The input and output surfaces of the microchannel plate are provided with conductive layers **27** and **28**, respectively, an insulative target layer **29** being disposed over conductive layer **28**. The target material must be a good insulator and may consist of such materials as aluminum oxide, magnesium oxide or the like. Layer **29** of target material and conductive layers **27** and **28** can be deposited on the ends of microchannel plate **20** by such methods as sputtering or evaporation. Moreover, the surface of conductive layer **28**, which may consist of such materials as aluminum, chrome-gold alloys or the like, may be oxidized to form a layer of insulative target material.

A potential source **31** is connected between photocathode **21** and conductive layer **27** to accelerate photoelectrons generated at photocathode **21** toward the microchannel plate. In addition to increasing the number of electrons available to write an image onto the storage target, the embodiment shown in FIG. **2** has the further advantage of requiring no magnetic focusing field in the region of the microchannel plate since the parallel tubular holes therein confine the electron image. If there is only small spacing between the photocathode and the input end of the microchannel plate, magnetic focusing of the photoelectrons is unnecessary. For example, if the spacing between the two members is about 0.01 inch and a potential of 300 volts is applied between the photocathode and conductive layer **27**, the photoelectrons will travel in substantially parallel paths, and there will be little loss of resolution in this portion of the device. Potential source **32**, which is typically about 1,000 volts, provides the operating potential for the microchannel plate. Potential source **34** is connected to equilibrium mesh **22** by resistor **35** and provides the necessary field to attract secondary electrons from storage target **29** to the mesh. The potential of the source **34** is therefore slightly more positive than the potential of target layer **29**.

Because of the intimate contact between the microchannel plate and the storage target, there need be no proximity focusing stage between these two members, and therefore, resolution degradation due to such a focusing stage is eliminated. Moreover, there are no redistribution effects on the target. In a conventional image orthicon, certain areas of the target charge more positively than other areas. Those areas which have the most intense input information charge relatively quickly to a high positive potential. They are then capable of attracting low energy secondary electrons from other target areas. This transverse redistribution of low energy secondary electrons is not possible in the embodiment shown in FIG. **2**.

Since microchannel plates provide extremely high gains of the order of $10^4$ to $10^6$, it is not necessary to use return beam readout and the associated plurality of electron multipliers to intensify the returning beam as is done in the conventional image orthicon. Furthermore, the gain of the microchannel plate may be adjusted to any value appropriate to the level of the input illumination. This adjustment is accomplished by varying the voltage applied across the microchannel plate by potential source **32**. Since return beam readout is not necessary for low level image detection in this device, reading beam **37** can arrive at the target with a greater velocity and can be focused to a finer spot size on the target, thus providing higher resolution. Since the embodiment shown in FIG. **2** does not require return beam readout, other methods of readout such as capacitive coupling or equilibrium readout can be used.

One method of prime, write/storage, and readout which can be used in the embodiment shown in FIG. **2** is as follows. At zero light input intensity target layer **29** is scanned by electron beam **37** provided by source **38**. The arrival energy of electron beam **37** is sufficiently high so that the secondary emission ratio of target layer **29** is greater than one. As the potential on mesh **22** is higher than any other in the area, secondary electrons represented by arrows **39** are attracted to and collected by mesh **22**. The surface potential of the storage target thus increases positively. This continues until the surface potential of target **29** approaches that of mesh **22** at which time secondary electrons **39** are no longer collected by the mesh but can return to the target. This positively charged state of the mesh is referred to as its equilibrium condition. Thus, the potential on the mesh in effect determines the potential on the storage target. This is referred to as the storage target priming action.

To write, light represented by undulated arrow **41** is focused onto photocathode **21** and the resulting photoelectrons represented by arrow **42** are caused to focus and accelerate into one of the channels **24**. On impact with channel resistive layer **25**, photoelectrons **42** give rise to secondary electrons represented by arrows **43** which in turn impact further on down the channel, this process giving rise to a large electron gain. For the sake of clarity, only the secondary electrons represented by arrows **44** are shown arriving at target layer **29**. When secondary electrons **44** strike the positively charged storage target **29**, they tend to neutralize the positive charge. This effect causes the potential difference between the target and the mesh to depart from the equilibrium condition established by the scanning beam. To read this written information scanning beam **37** simply drives the surface potential of the storage target back to the more positive equilibrium state. Note that this action also automatically primes the target for further inputs.

The video signal representative of the write mode may be derived from the current due to secondary electrons **39** collected by mesh **22** during the readout mode. The voltage due to this current can be capacitively coupled from the mesh to a video pre-amplifier for further processing. Another source of video information is the displacement current in conductive coating **28** resulting from electron beam **37** landing on the target and charging it back to the equilibrium state. This current could also be capacitively coupled to a video pre-amplifier. It is noted that readout means other than that described hereinabove can be used in conjunction with the embodiment described.

Whereas the preferred embodiment described hereinabove utilizes a photocathode for generating an electron image representative of an incident light image, it is to be understood that other electron sources can be used for writing information into the storage target. For example, if the storage device of this invention is to be used as a storage medium for computers, photocathode **21** could be replaced by an addressable electron source.

We claim:

**1**. A charge storage device comprising

a multichannel plate having a plurality of parallel tubular members, the inner surfaces of which contain a resistive, secondary-electron emissive layer, the openings in the ends of said tubular members lying on first and second surfaces which constitute input and output ends, respectively, of said multichannel plate,

first and second conductive layers on said input and output ends of said multichannel plate, respectively,

an electron image source disposed adjacent said input end of said multichannel plate,

a storage target disposed at said output end of said multichannel plate, a charge image corresponding to that of said electron image source being written on said target by electrons emanating from said multichannel plate, and

readout means for converting said charge image stored on said target into a video signal.

**2**. A charge storage device in accordance with claim **1** wherein said storage target is in contact with said second conductive layer.

**3**. A charge storage device in accordance with claim **2** wherein said second conductive layer extends along a portion of the inner surfaces of said tubular members and said storage target is a layer of storage material disposed on said second conductive layer and extending into said tubular members.

4. A charge storage device in accordance with claim 3 wherein said readout means comprises

a conductive mesh spaced from and substantially parallel to said output end of said multichannel plate,

means for scanning said storage target with an electron beam, the energy of which is such that the ratio of secondary electrons to scanning electrons striking said target is greater than one,

biasing means for biasing said mesh positively with respect to said second conductive layer, and

output means for indicating the level of secondary electron current flowing from said target layer to said mesh.

5. A charge storage device in accordance with claim 4 wherein said biasing means comprises a source of potential resistively coupled to said mesh and wherein said output means comprises an output terminal capacitively coupled to said mesh.

6. A charge storage device in accordance with claim 5 wherein said electron image source comprises a photocathode closely spaced from said input end of said microchannel plate and a source of potential connected between said photocathode and said first conductive layer for accelerating photoelectrons generated at said photocathode into said tubular members, the electric field established between said photocathode and said first conductive layer by said source of potential being the sole focusing force exerted on said photoelectrons.

7. A charge storage device in accordance with claim 2 wherein said electron image source comprises a photocathode closely spaced from said input end of said microchannel plate and a source of potential connected between said photocathode and said first conductive layer for accelerating photoelectrons generated at said photocathode into said tubular member, the electric field established between said photocathode and said first conductive layer by said source of potential being the sole focusing force exerted on said photoelectrons.

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