May 24, 1966 VON C. CAMPBELL 3,253,086

LIGHT VALVE APPARATUS

Filed Dec. 23, 1963

FIG. 1

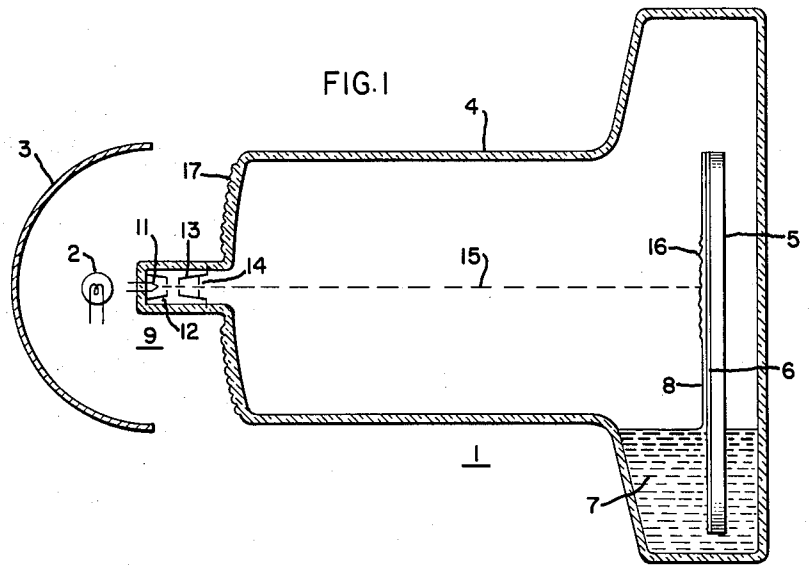


FIG. 2

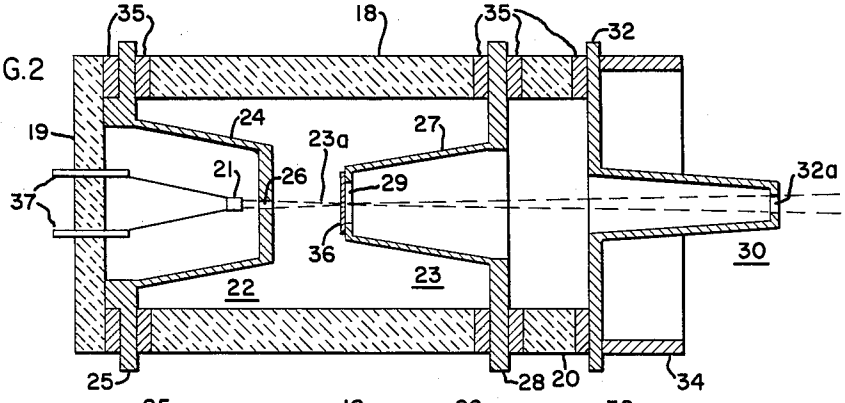
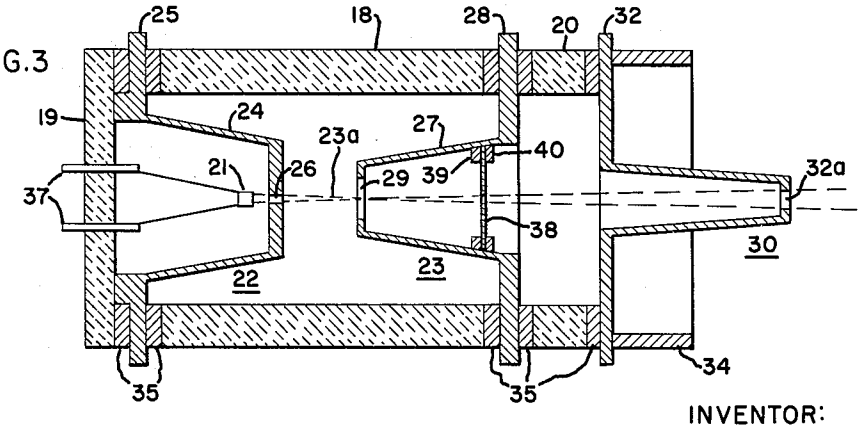


FIG. 3



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LIGHT VALVE APPARATUS

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6 Claims. (Cl. 178—7.87)

The present invention relates to a light valve apparatus and, more specifically, to a light valve tube suitable for the projection of a television image.

One form of a light valve tube suitable for the projection of television images comprises an evacuated envelope in which is positioned an electron gun and a rotatable disc bearing a light-modulating fluid. An electron beam generated by the electron gun is scanned across a portion of the light-modulating fluid, the beam being controlled to selectively deform the surface of the fluid. An electron-beam-defining apertured plate is positioned between the electron gun and the light-modulating fluid in the path of the electron beam to provide a beam of optimum size and shape. The deformations formed in the fluid by the electron beam constitute diffraction gratings which, in conjunction with a light source and a Schlieren optical system, serve to selectively control the passage of light from the source to a screen in accordance with the image being projected.

It is found that free molecules of the light-modulating fluid dislodged by the electron beam or present because of the finite vapor pressure of the fluid will, over a period of time, pass through the beam-defining-aperture and condense on the side of the beam-defining-plate closest to the electron gun. When the deposit thus formed is irradiated by the electron beam, an insulating layer is formed on the beam-defining plate. Upon the formation of such an insulating layer, a charge will accumulate thereon which will, in time, become of sufficient magnitude to completely block the passage of the electron beam through the beam-defining aperture thereby causing failure of the tube. Thus, it is necessary to prevent the building up of a charge to insure operation of the tube over a reasonable lifetime.

The present invention prevents charge accumulation on the beam-defining plate by preventing the formation of an insulating coating thereon to thereby prolong the effective operating life of the tube.

Accordingly, an object of the present invention is to provide an improved light valve tube suitable for the projection of a television image.

Another object is to provide a light valve tube wherein charge-build-up on the beam defining plate is prevented.

Still another object is to provide a light valve tube wherein molecules of the light-modulating fliud are prevented from forming an insulating layer on the beam-defining plate.

These and other objects are achieved in one embodiment of the invention through the use of an electron-beam-defining aperture plate, such as a metal membrane, having a thickness which is directly related to the current density of the electron beam impingent thereon so as to cause the apertured plate to be heated to an elevated temperature. By maintaining the apertured plate at an elevated temperature due to the action of the electron beam, the molecules of light-modulating fluid which condense on the plate are either vaporized or carbonized to

eliminate from the plate any insulating coating formed from these molecules.

The novel and distinctive features of the invention are set forth in the appended claims. The invention itself, together with further objects and advantages thereof, may be understood by reference to the following description and accompanying drawings in which:

FIGURE 1 is a simplified cross-sectional view of a representative light valve having an electron-beam-defining apertured plate which is heated in accordance with the present invention.

FIGURE 2 is a cross sectional view of an electron gun assembly suitable for use in the light valve tube of FIGURE 1 and wherein a heated electron-beam-defining apertured plate is employed.

FIGURE 3 is a view similar to FIGURE 2 showing another embodiment of the present invention.

Referring to FIGURE 1, there is shown a light valve tube **1** located between a light source **2** and a screen (not shown) for the projection of a television image to the screen, the light source **2** being provided with a suitable reflector **3**.

The light valve tube **1** comprises an evacuated envelope **4** in which is located a rotatable disc **5** having a transparent conductive layer **6** positioned on one surface thereof. The disc **5** is rotated in its own plane about its center through a reservoir **7** of the light-modulating fluid by any suitable means. Rotation of the disc **5** through the reservoir **7** causes a continuously replenished layer of modulating fluid **8** to form on the conductive layer **6**. An electron gun **9** is positioned in a necked-down portion of the envelope opposite the layer of modulating fluid **8**. The electron gun **9** might also be a separate structure which is affixed to the envelope **4** as described and claimed in the co-pending application of V. C. Campbell and E. F. Schilling, S.N. 313,693, filed October 3, 1963, and assigned to the assignee of the present invention.

The electron gun **9** comprises an electron-emitting cathode electrode **11** in conjunction with an electron lens comprising first electrode **12** and second electrode **13**. An apertured plate **14** is positioned in the path of electron beam **15** generated by the cathode **11**, the aperture in the plate defining the size and shape of the electron beam. Generally, the aperture in the plate **14** is referred to as an object aperture if located at the cross-over point of the electron beam whereas if the aperture is located at a point where the beam has a larger cross section, it is referred to as a limiting aperture. The electron beam **15** impinges upon the layer of modulating fluid **8** and deposits charges thereon. The charges are attracted to the conductive layer **6** to cause deformations **16** in the layer of modulating fluid **8**. The electron beam **15** is swept across the layer of modulating fluid **8** by any suitable scanning means to define a raster area, the beam being controlled to selectively deform a light-modulating fluid to form a diffraction grating thereon.

Light rays from the source **2**, as reflected by the reflector **3**, are directed by a lenticular lens system **17** formed on the rear wall of the envelope **4** to the raster area as described and claimed in the copending application of W. E. Good, Mr. Graser, Jr., and L. A. Juhlin, Jr., S.N. 316,606, filed October 16, 1963, and assigned to the assignee of the present invention.

By modulating the electron beam **15** through the use

of suitable deflection elements (not shown), the diffraction grating formed by the deformations **16** in the layer of modulating fluid **8** is selectively controlled. Thus, through the use of a Schlieren optical system, an image representative of the electron-beam-modulating intelligence is projected upon the screen.

In the light valve tube, as shown in FIGURE 1, the electron beam dislodges molecules of the light-modulating fluid from the rotating disc **5**. Further, the light-modulating fluid, although necessarily chosen to exhibit an extremely low vapor pressure to maintain the desired degree of vacuum, does exhibit some finite vapor pressure. Thus, free molecules of the light-modulating fluid are present in the envelope **4**. Over a period of time some of these molecules find their way through the aperture in the beam defining plate **14** and become deposited on the side of the plate nearest the cathode **11**. When the molecules thus deposited are irradiated by the electrons from cathode **11** striking the beam-defining plate **14** an insulating layer is built up on the plate. When such a layer is formed charges become deposited thereon and, since the aperture in the plate **14** is necessarily small to provide the required beam definition, the charge over a period of time becomes of sufficient magnitude to completely block the beam and cause failure of the tube. The free molecules of modulating fluid will also be deposited on other elements of the electron gun, such as the first and second electrodes. However, since these elements do not physically block the electron beam, the molecules deposited thereon are not irradiated and an insulating film is not formed on these elements except when excessive secondary electrons are allowed to impinge thereon.

In accordance with the present invention, the electron beam **15** is utilized to heat the beam-defining plate **14** to an elevated temperature whereby molecules of the light-modulating medium are vaporized from the plate or are charged so as to become conductive.

The electron-beam-defining plate **14** is so dimensioned with respect to the current density of the electron beam impingent thereon as to be heated to an elevated temperature. The current density of the electron beam at any point along the axis of the electron beam is defined by the total beam current emitted by the cathode and the solid angle which this beam describes. Thus, the current density of the beam impingent on the plate **14** is determined for a given beam current and angle by the distance from the plate **14** to the cathode, or more correctly, by the distance of the plate **14** from the cross-over point of the beam. The aperture in the plate **14** is chosen so as to give an optimum interrelationship between the beam current impingent on the layer of light-modulating fluid **8** and the spot size of this beam. Normally, the beam current passing through the aperture in the plate **14** is chosen to be on the order of two percent of the total beam current. Thus, approxmiately 98 percent of the beam current emitted by the cathode is available for raising the temperature of the plate **14** to prevent the production of an insulative layer thereon. The thickness of the plate **14** must be so related to the current density and the percentage of the beam blocked by the plate **14** as to be raised to an elevated temperature without exceeding the melting point of the material. For a given beam current and angle, if the plate **14** were made too thick the plate would act as too great a heat sink and the required elevated temperature would not be achieved. Conversely, if the plate were too thin, the temperature of the plate would exceed the melting point and "burn through" of the plate **14** would occur. It is apparent that the optimum thickness of the plate **14** varies with its position along the axis of the electron beam. Thus, if the plate **14** is placed near the cathode where the current density is greater, the plate can be thicker than would be the case at a position further removed from the cathode where the current density is less. In addition to selecting the plate thickness is accordance with the temperaure desired, the thermal conductivity of the material employed and the heat sinking characteristics of other elements of the electron gun which the plate **14** contacts also must be considered.

It will be appreciated that, although in a preferred embodiment of applicant's invention the electron beam is utilized to raise the temperature of the plate **14** to the desired elevated temperature, other heating means might be utilized. Further, it will be appreciated that, although applicant's invention is directed toward a light valve tube employing a light modulating fluid, problems similar to that which applicant's invention overcomes might arise and be similarly overcome in devices where an electron beam impinges upon other types of mediums.

Referring to FIGURE 2 there is shown in cross section an electron gun as described and claimed in the above referred to co-pending application S.N. 313,693, suitable for use in the light valve tube of FIGURE 1 and employing a heated electron-beam-defining apertured plate.

The electron gun of FIGURE 2 comprises an annular cylindrical ceramic body member **18** in conjunction with an end closure ceramic member **19** and an annular ceramic spacer member **20**. A cathode electrode **21**, first aperture electrode **22** and a second apertured electrode **23** are coaxially arranged within the body member **18** to develop an electron beam **23***a* indicated by dotted lines in FIGURE 2. The electron **23***a* crosses over as shown. The first electrode **22** comprises a hollow truncated conical section **24** having a flat surface at the truncated end thereof and provided with a mounting flange **25**, the end surface of the conical section being provided with an aperture **26**. Similarly, the second electrode **23** comprises a hollow truncated conical section **27** having a flat surface at the truncated end thereof and provided with mounting flange **25**, the end surface of the conical section being provided with an aperture **26**. Similarly, the second electrode **23** comprises a hollow truncated conical section **27** having a flat surface at the truncated end thereof and provided with mounting flange **28**, an aperture **29** being provided in the end surface of the section **27**.

The extremity of the electron gun opposite the closure member **19** is provided with a closure member **30**, the closure member comprising a hollow truncated conical section closed at one end and provided with mounting flanges **32** at the opposite end. The gun is assembled with the closure member **30** completely closed, an aperture **32***a* being placed in the closure member after it is assembled to the tube. An annular mounting element **34** is utilized to connect the electron gun to the envelope of the light valve tube. Annular brazing rings **35** are utilized to assemble the various components of the electron gun.

An electron-beam-defining apertured plate **36** is affixed to the second electrode **23**, the aperture in the plate **36** being axially aligned with the apertures **26**, **29** and **32***a*. The plate **36** corresponds to the plate **14** of FIGURE 1 and is chosen of such a thickness that it will be heated to an elevated temperature during operation of the electron gun as outlined above.

The cathode electrode **21** is caused to emit electrons by applying a suitable potential to terminal pins **37** which extend through the closure member **19**. Suitable potentials are applied to the flanges **25** and **28** to cause the first and second electrodes to serve as an electron lens and focus the electrons emitted by the cathode into a beam. The beam **23***a* defined by the electron lens impinges upon the apertured plate **36**, only a small percentage of the beam passing through the aperture in the plate **36** and hence through the aperture **32***a* in the closure member **30** to the light modulating fluid. Since the thickness of the apertured plate **36** is selected with

relation to the energy which the electron beam imparts thereto, the apertured plate is raised to an elevated temperature. In this manner, free molecules of the light-modulating fluid which find their way through the apertures **32***a*, **29** and the aperture in the plate **36** to become coated on the plate **36** are prevented from forming an insulative coating as discussed above.

In one especially successful embodiment of applicant's invention, as shown in FIGURE 2, the following design characteristics were employed:

Critical dimensions

Axial distance of end portion of first electrode from cathode ----------inches--	.002
Axial distance of flat portion of second electrode from cathode ----------do----	.157
Axial distance of beam defining apertured plate from cathode ----------do----	.157

Operating voltages

Voltage applied to first electrode ----------	—15
Voltage applied to second electrode ----------	8000
Voltage between terminal pins **37** ----------	2.5

Electron beam characteristics

Total beam current ----------ma--	500
Beam angle, °----------	2
Current density of beam at beam defining plate amperes/sq. in.--	12
Percent of current blocked by the beam-defining plate ----------	98

It was found that a .001–.002 inch thick refractory metal (for example molybdenum) plate affixed to the second electrode **27**, as shown in FIGURE 2, and having a diameter of .024–.250 inch and an aperture of .0008–.004 inch was heated to a temperature of approximately 700° C. This temperature was found to be sufficient to prevent the formation of an insulative layer on the beam-defining plate but was low enough to prevent melting of the plate.

Referring to FIGURE 3, there is shown an electron gun similar to that of FIGURE 2 wherein the electron-beam-defining apertured plate is positioned at a greater axial distance from the cathode. For simplicity, like reference numerals are given to elements common to both FIGURES 2 and 3.

An electron-beam-defining apertured plate **38** is located within the hollow truncated conical section **27** of the second electrode **23**, the plate **38** being retained between a pair of annular mounting rings **39** and **40** which are affixed to the interior surface of the second electrode. In the embodiment of FIGURE 3, the beam-defining plate **38** must be thinner than the beam-defining plate **36** of FIGURE 2 to be heated to a corresponding elevated temperature. This is readily apparent since for a given beam current and angle, the further along the axis of the electron beam that the beam-defining plate is located, the greater the "fanning out" of the beam, and thus the less the current density of the beam impingent on the beam-defining plate.

Although the invention has been described with respect to certain specific embodiments, it will be appreciated that modifications and changes may be made by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A light valve apparatus for positioning between a light source and a screen for the projection of an image on the screen, said apparatus comprising:

(a) an evacuated envelope,

(b) a light-modulating fluid positioned in said envelope and arranged to control the passage of light from the source to the screen,

(c) cathode means positioned in said envelope and arranged to emit a beam of electrons impingent upon said light-modulating fluid to form a diffraction grating thereon for selectively controlling the passage of light from the source to the screen in accordance with the image being projected,

(d) electron-beam-defining means positioned between said cathode means and said light-modulating fluid in the path of said electron beam,

(e) said electron-beam-defining means including a plate having an electron-beam-defining aperture therein, the thickness of said plate being directly related to the current density of the electron beam impingent thereon to effect heating of said plate to an elevated temperature sufficient to eliminate from said plate any insulating coating formed from molecules of said light-modulating fluid.

2. The light valve apparatus as defined in claim **1** wherein said envelope is divided into first and second evacuated chambers by said plate,

(a) said cathode being positioned in said first chamber, and

(b) said light-modulating fluid being positioned in said second chamber.

3. The light valve apparatus as defined in claim **1** wherein said plate is a refractory metal.

4. The light valve apparatus as defined in claim **1** where said elevated temperature is in the range of 450–1000 degrees centigrade.

5. An electron gun structure for generating and projecting an electron beam upon a surface from which molecules of the material of the surface may be dislodged due to impact of said beam, said structure comprising:

(a) an electrode member having an aperture,

(b) said electrode being mounted in said structure to pass a desired portion of said beam through said aperture to said surface and to intercept a second portion of said beam,

(c) said electrode being so situated in said structure that during operation said dislodged molecules may collect thereon and cause a charge to develop thereon which may objectionably restrict the portion of the beam passed by said aperture,

(d) the dimensions of said electrode about said aperture being so related to said second portion of the beam that during operation said electrode is heated thereby sufficiently to prevent restriction of said beam due to such charge.

6. A light valve apparatus for positioning between a light source and a screen for the projection of an image on the screen, said apparatus comprising:

(a) an evacuated envelope,

(b) a light-modulating fluid positioned in said envelope and arranged to control the passage of light from the source to the screen,

(c) cathode means positioned in said envelope and arranged to emit a beam of electrons impingent upon said light-modulating fluid to form a diffraction grating thereon for selectively controlling the passage of light from the source to the screen in accordance with the image being projected,

(d) electron-beam-defining means positioned between said cathode means and said light-modulating fluid in the path of said electron beam,

(e) said electron-beam-defining means including a plate having an electron-beam-defining aperture therein,

(f) means for heating said plate to an elevated temperature sufficient to eliminate from said plate any insulating coating formed from molecules of said light-modulating fluid.

No references cited.

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