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LASER ENERGIZED HOT CATHODE TYPE OF ELECTRON DISCHARGE DEVICE

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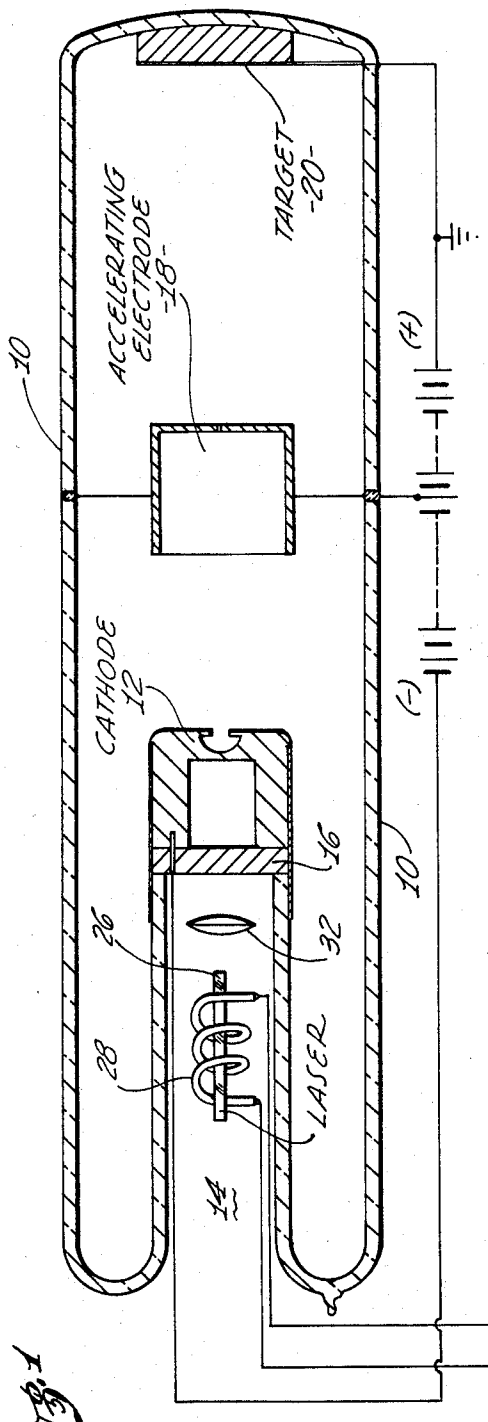


Fig. 1

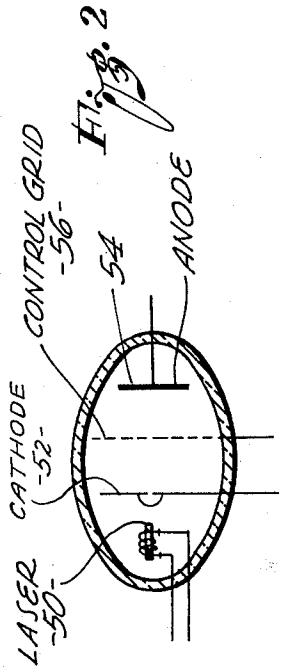


Fig. 2

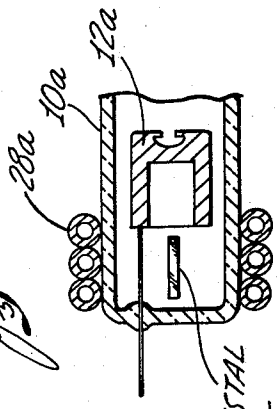


Fig. 3

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LASER ENERGIZED HOT CATHODE TYPE OF ELECTRON DISCHARGE DEVICE

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ABSTRACT OF THE DISCLOSURE

An electron discharge device of the hot cathode type is provided. In accordance with the concepts of the present invention, a laser-type beam including infra-red heat rays is directed to the cathode to bring it up to its operating electron emissive temperature. This technique precludes any need for the usual electric heating of the cathode, and inherent insulation problems.

The present invention relates to electron discharge devices of the hot cathode type, and it relates more particularly to an improved cathode-heater combination for producing electron emission in such a device.

Hot cathode electron discharge devices are presently in widespread use in the electronic art. These devices take the form, for example, of radio and television vacuum tubes, cathode-ray devices, X-ray tubes and the like.

A hot cathode electron discharge device includes a cathode electrode which is composed, at least partially, of an electron-emissive material. The cathode electrode is caused to emit electrons in the evacuated envelope of the discharge device when it is heated to an elevated operating temperature. It is usual to heat the cathode of the prior art electron discharge device of this type by means of a filament, or similar heater electrode, which is disposed in intimate contact with the cathode. This filament, or heater electrode, responds to an electrical current to become heated, and the resulting heat is transferred to the cathode to raise it to its elevated electron-emissive operating temperature.

The prior art use of the electrically conductive filament, or heater electrode, to heat the cathode to its electron-emissive temperature is practical for most purposes. However, in some applications problems arise due to the voltage differential which must be maintained between the cathode and the anode of the device in order for the electrons emitted by the cathode to be drawn with high velocity to the anode.

In X-ray tubes, for example, this potential differential is of the order of many thousands of volts. Also, in many X-ray tubes, for example, it is desirable for safety reasons to maintain the anode, or target electrode, at ground potential. The cathode of such a tube, therefore, must be maintained at a high negative potential. This requirement, as is well known, creates major insulation problems either in the cathode-filament structure itself, or in the construction of the transformer supplying the electric current to the filament.

The present invention is particularly applicable to structures of the type mentioned in the preceding paragraph, in which the cathode electrode must be maintained at an extremely high negative potential. The invention provides an improved heater-cathode structure and combination in which the cathode is heated by a radiant beam. This beam may be generated, for example, by a laser, and it has the advantage of being completely isolated electrically from the cathode. In fact, if so desired, the source of the heating beam may be situated a long distance away from the cathode itself.

The structural combination of the present invention, therefore, permits the cathode to be operated at high negative voltages, without creating any insulation problems in the heater circuit.

It is, accordingly, an object of the invention to provide an improved cathode-heater combination in a hot cathode electron discharge device, by which the cathode is heated by a source of heat energy, the source being electrically isolated from the cathode so as to obviate any electrical insulating problems.

Another object of the invention is to provide such an improved heater-cathode structural combination which is capable of elevating the cathode to its operating temperature without the creation of electrical insulating problems, even though the cathode is to be operated at extremely high negative voltages.

A still further object of the invention is to provide such an improved structural combination in which the heating of the cathode electrode is achieved efficiently and conveniently; and in which such heating is achieved without the need for current conducting filaments, or the like.

Yet another object of the invention is to provide such an improved structural combination by which the cathode electrode is heated in an improved and simplified manner to provide a sharp electron beam of relatively small cross-sectional area for improved operation in such application, for example, as cathode-ray and X-ray discharge tubes.

Lasers have been in successful operation since 1960. The laser constitutes a light source which includes infrared energy, so that it is ideally suited for the generation of a radiant heat beam. The laser source amplifies radiant energy in the light and infrared portion of the spectrum and it radiates the amplified energy in the form of a fine coherent beam. A description of laser action, or optical maser action as it is sometimes called, may be found in the Physical Review Letters, volume 7, No. 12, Dec. 15, 1961, in an article by E. Snitzer entitled, "Optical Maser Action in Nd^{+3} in Barium Crown Glass," this being a publication of the American Physical Society.

Other articles on laser action have also been published, such as the following: A. L. Schawlow and C. H. Townes, Physical Review, 112, 1940 (1958); T. H. Maiman, Nature, 187, 493 (1960); P. O. Sorokin and M. J. Stevenson, Physical Review Letters, 5, 557 (1960); and I. Wieder and L. R. Sarles, Physical Review Letters, 695 (1961).

In the practice of the invention, the resulting coherent beam from the excited laser crystal is directed, as will be described, to the cathode electrode of an electron discharge device with which the laser crystal is associated. The laser beam is caused to impinge on the cathode surface, and it thereby heats the cathode to its emission temperature. The optical pulsing rate of the laser crystal can be controlled by the usual laser control system, so as to provide a convenient control of the cathode temperature.

Other objects and advantages of the invention will become apparent from a consideration of the following specification when taken in conjunction with the accompanying drawing, in which:

FIGURE 1 is a schematic, side sectional representation of the structural combination of the invention incorporated into an X-ray tube;

FIGURE 2 is a schematic representation of the structural combination of the invention incorporated into a vacuum tube of the control grid type; and

FIGURE 3 is a schematic side sectional representation of a modification of the invention.

The structural combination of the invention, as incorporated into an X-ray tube, by way of example, is shown in FIGURE 1. The X-rays are produced by the tube of FIGURE 1 by accelerating electrons emitted by the cathode to a high velocity and by causing the high velocity electrons to collide with a target electrode. The target electrode emits X-rays in all directions from the spot

thereon where the collision by the electrons take place.

The X-ray tube of FIGURE 1 is of the hot cathode, high vacuum, high voltage type. As mentioned above, this is the type of electron discharge device to which the improved structural combination of the invention is particularly applicable and useful.

It is to be understood, of course, that although the structural combination of the invention is illustrated as incorporated into an X-ray tube in the assembly of FIGURE 1, this is merely by way of example. As the description proceeds, it will become apparent that the invention finds utility in a wide variety of electron discharge tubes using a hot cathode electrode as an electron emissive element.

The X-ray tube of FIGURE 1 includes an envelope **10** which forms an evacuated chamber for the device. The envelope **10** is composed of a suitable vitreous material, for example, such as quartz. The envelope **10** has a re-entrant configuration at one end, and a cathode **12** is mounted inside the envelope **10** at one end of the re-entrant portion.

The re-entrant portion defines a passageway **14**, and the end of the passageway is sealed by a disc-shaped member **16**. The disc-shaped member **16** is composed of a material which is capable of passing infra-red energy. A suitable material for this purpose, for example, is silicon or germanium, these being well known types of semiconductor materials.

The cathode **12** has a usual composition, and it is mounted on the inner end of the re-entrant passageway **14**. The cathode **12** is composed of a suitable electron-emissive material, and the cathode emits a stream of electrons when it is heated to an elevated temperature.

An accelerating electrode **18** is also mounted in the envelope **10**. The accelerating electrode **18** is aligned with the cathode **12**, and it is spaced from the cathode along the tube. A target, or anode, electrode **20** is mounted at the end of the tube remote from the cathode, as illustrated.

A source of unidirectional potential, indicated schematically as a battery **22**, has its positive terminal connected to a point of reference potential, such as ground; and the target electrode **20** is also connected to ground. An intermediate negative terminal of the source **22** is connected to the accelerating electrode **18**, and a further negative terminal of the source is connected to the cathode **12**.

It is evident, therefore, that when the cathode **12** is caused to emit electrons, these electrons are accelerated into a high velocity stream by the accelerating electrode **18**. The accelerating electrode **18** functions in known manner to form the stream of electrons into a sharp beam, and this beam is attracted with high velocity to the target electrode **20**. When the high velocity electrons in the beam collide with the surface of the target electrode **20**, the target electrode produces X-rays in all directions, as is well understood in the X-ray art.

It will be appreciated that if the target electrode **20** is to be operated at ground potential, which is most desirable for safety reasons, the accelerating electrode **18** must be operated at an intermediate negative potential, and the cathode **12** must be operated at a still more negative potential, as shown. In many present-day X-ray tubes, this means that the cathode **12** must be operated at a negative potential of many thousand volts. This requirement, as mentioned above, creates insulating problems in the heating of the cathode, especially when the prior art filament-type heater is used.

In accordance with the embodiment of the present invention, as shown in FIGURE 1, a laser crystal **26** is mounted in the re-entrant passageway **14** in a position to direct a laser beam through the wall **16** to the inner surface of the cathode **12**.

The laser crystal **26** is excited by a usual optical exciting tube **28**, the tube **28** being forced into a helix surrounding the crystal. The tube **28** is connected to a usual laser exciting circuit **30** and the exciting circuit provides pulses of energy to the tube **28** to cause the tube to become periodically illuminated. The periodic illumination of the tube **28** causes the laser crystal **26**, in accordance with known laser action, to emit a fine coherent beam from one end of the crystal.

This beam, as noted above, contains infra-red energy, and it is directed through the member **16** to the surface of the cathode **12**. The beam provides the desired heat for the cathode **12**, so that it may be elevated to its operating electron-emissive temperature. The temperature of the cathode can be conveniently controlled, merely by controlling the pulsing rate at which the optical tube **28** is energized by the laster exciting circuit **30**.

When so desired, a lens **32** may be mounted in the passageway **14** in the optical path between the laser crystal **26**, and the cathode **12**. This crystal serves to focus the laser beam to a fine spot on the inner surface of the cathode **12**, so that the resulting electron beam from the cathode **12** may have an extremely small cross-sectional area. This is desirable for X-ray purposes, and also in cathode-ray tubes, as mentioned above.

It is evident that the disclosed heater-cathode combination, by which the cathode is heated by a radiant energy beam, obviates any insulation problems. This is because the laser assembly is electrically isolated from the actual electrical circuit of the cathode. In fact, if so desired, the laser assembly can be moved back and away from the cathode any desired distance.

As mentioned above, the heater-cathode structural combination of the invention is not limited to X-ray tubes. In the schematic representation of FIGURE 2, a laser **50** is shown mounted in a triode-type radio vacuum tube in a position to direct the laser beam to the cathode electrode **52** of the tube. The laser beam may be controlled in the manner described above, so that the cathode **52** may be elevated to its electron-emissive operating temperature. When the cathode is so elevated, it emits electrons in the vacuum tube, and these electrons are attracted to the anode electrode **54**, in accordance with the usual operating characteristics of vacuum tubes. The electron flow between the cathode **52** and the anode **54** in the tube may be controlled by a usual control grid **56**.

It will be appreciated that the laser **50**, which is illustrated in FIGURE 2, as being disposed within the envelope of the vacuum tube, could be removed entirely from the tube to be external of the envelope. The envelope itself may be composed at least partially of the vitreous material, such as quartz, or of semiconductor material, so that the laser beam may be directed through the envelope and onto the cathode so as to produce the desired heating of the cathode.

The embodiment of FIGURE 3 shows the structural combination of the invention applied to a tube, which may be similar to the X-ray tube of FIGURE 1. The latter tube includes a cathode **12*a*** which is supported within the vacuum envelope **10*a***, and it also includes a laser crystal **26*a*** supported within the envelope. The laser crystal is aligned with the cathode, so that when the crystal is excited, the resulting laser beam is directed to the cathode to bring it up to its operating electron-emissive temperature.

In the embodiment of FIGURE 3, the optical exciting tube **28*a*** for the laser crystal **26*a*** is illustrated as being mounted externally of the envelope **10*a***, and around the envelope. Upon the subsequent periodic energization of the exciting tube **28*a***, the light pulses from the tube pass through the quartz envelope **10*a*** and excite the laser crystal **26*a*** in usual laser manner.

The invention provides, therefore, an improved cathode-heater structural combination for use in electron discharge devices. As described above, the invention is particularly useful in devices in which the cathode must be operated at a high negative potential.

While particular embodiments of the invention have been shown and described, modifications may be made, and it is intended in the following claims to cover all such modifications as fall within the scope of the invention.

What is claimed is:

1. In an electron discharge device of the hot cathode type, the combination of: an evacuated envelope; a cathode electrode positioned in said envelope and composed of electron-emissive material having the property of emitting electrons in said evacuated envelope when said cathode is heated to an elevated electron-emissive operating temperature; a laser crystal capable of generating a radiant beam including infra-red heat rays isolated electrically from said cathode and positioned to direct such a beam in a direction to cause said heat rays to be incident on said cathode; and optical exciting means positioned in operative relationship with said laser crystal to excite said crystal and cause it to generate said radiant beam and thereby heat said cathode to said elevated electron-emissive operating temperature.

2. The combination defined in claim 1 in which said optical exciting means excites said laser crystal at a controlled pulsed rate so as to establish the temperature of said cathode at a predetermined level.

3. The combination defined in claim 1 and which includes beam focusing means interposed between said laser crystal and said cathode to focus said radiant beam to a fine spot on the surface of said cathode.

4. The combination defined in claim 1 in which said envelope has an end wall capable of passing said infra-red heat rays, and in which said laser crystal is positioned externally of said envelope in axial alignment with said end wall to direct said heat rays through said end wall to said cathode.

5. The combination defined in claim 4 in which said end wall is composed of a semi-conductor material selected from the group comprising silicon and germanium.

6. The combination defined in claim 1 in which at least a portion of said envelope is composed of transparent vitreous material, in which said laser crystal is positioned in said envelope, and in which said optical exciting means is disposed externally of said transparent vitreous portion of said envelope.

7. The combination defined in claim 1 and which includes a target electrode capable of producing X-rays upon impingement thereon by an electron beam; and means for directing electrons emitted by said cathode as a beam to said target electrode.

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