June 5, 1934.

C. M. SLACK

1,961,715

LENARD RAY TUBE

Filed Nov. 16, 1928

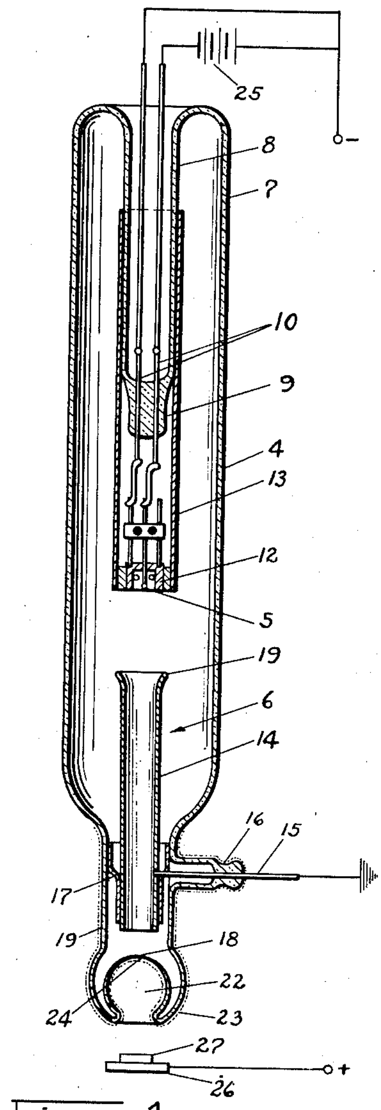

Fig. 1.

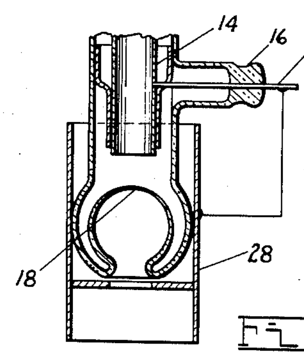

Fig. 2.

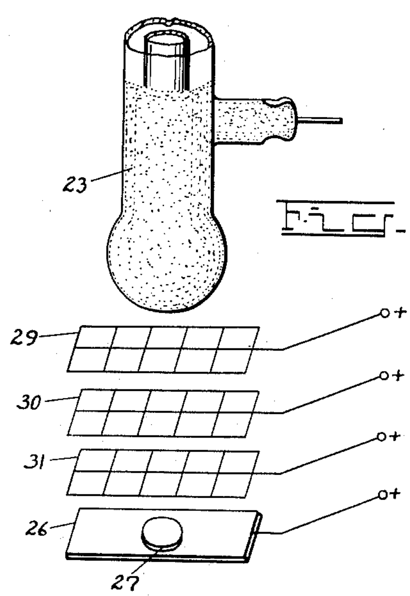

Fig. 3.

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Patented June 5, 1934

1,961,715

UNITED STATES PATENT OFFICE

1,961,715

LENARD RAY TUBE

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Application November 16, 1928, Serial No. 319,757

13 Claims. (Cl. 250—27.5)

This invention relates to a Lenard ray tube in which cathode rays are projected at high velocities through a wall of the tube into the open air so as to be available for various purposes, such as effecting chemical reactions or for germicidal and sterilizing effects.

More particularly the invention relates to a Lenard ray tube employing a glass or other vitreous window for the exit of the cathode rays, such as described in my copending application Serial No. 272,194, filed April 23, 1928, and entitled Cathode ray tube, although some of the features of the present invention are also applicable to Lenard ray tube employing metallic windows.

In accordance with the invention disclosed in the above mentioned application, a portion of the envelope of the Lenard ray tube, in direct line with the cathode beam produced within the tube is made of extreme thinness in some instances as low as .0001 inch and shaped so as to resist atmospheric pressure. Windows thinned to this extent will transmit cathode rays with only small energy losses. At a given voltage the cathode ray will penetrate about three times the thickness of glass, as of molybdenum, the metal most commonly used for cathode ray tube windows, due to the difference in density thereof.

The loss of energy of the cathode rays in passing through any material of a definite thickness is proportional to the square root of the density of the material and can be determined mathematically for any specific material. However, in the case of glass windows or window composed of other insulating material it was found that the voltage necessary to penetrate the window was also a function of the size of the window and greater than that given by the calculations.

I have discovered that this disparity between the actual energy loss and the theoretical loss of energy in the passage of the cathode rays through the window and into the external atmosphere is due to a negative electric charge accumulating on the glass and in the air in the immediate neighborhood of the window, which is very similar to space charge in its effect and retards the passage of the cathode rays. This necessitates the use of higher voltages to project the electrons through the window.

One of the objects of the present invention is to overcome this retarding effect on the electron stream and to provide a construction by which the negative charge on the window and in the air adjacent the window may be dissipated.

Another object is to increase the range of the Lenard rays externally of the tube.

A still further object is to increase the velocity of the cathode rays in air after they emerge from the window of the tube.

Other objects and advantages of the invention will hereinafter appear.

In accordance with one phase of my invention I provide a conducting body in contact with the window or in the neighborhood of the window and maintain the same at the potential of the anode. This conducting body serves to dissipate the negative space charge adjacent the window and prevents the accumulation of a negative charge on the glass.

The elimination of the negative charge on and adjacent the glass reduces the critical voltage required for the electrons to penetrate the window, and renders this critical voltage independent of the area of the window, thus bringing it into conformity with the theoretical penetrating voltage for the glass at the thickness employed. The ultimate result of this dissipation of the negative space charge, is an increased emergent velocity of the electrons and greater range or penetrability in the air.

The range of the cathode rays may be still further increased by producing a positive field externally of the tube in the direction of motion of the electrons. If precautions are taken to prevent the accumulation of a negative space charge in the air between the window and the source of positive potential the velocity of the electrons after they emerge into the air can be increased and the range and available energy of the cathode stream increased indefinitely.

Lenard ray tubes employing glass windows have been constructed by me in which the cathode rays emerge from the window with a kinetic energy corresponding to from 14,000 volts or less to 300,000 volts or more. The rate of loss of energy of an electron in air when the kinetic energy of the electron corresponds to about 20,000 volts, is about 10,000 per cm. so that a field of 10,000 volts per cm. applied in the direction of motion of the electron, is sufficient to counterbalance the average losses. If the field is increased above 10,000 volts per cm. the velocity of the electron will continuously be accelerated until it collides with an electron or a nucleus with such directness as to have its direction of motion materially changed. If the direction of motion is maintained anywhere within 60 degrees of the direction of the accelerating field, an electron having an energy corresponding to about 20,000 volts will be accelerated by a field of about 20,000 volts per cm. Still faster traveling electrons may be accelerated even if their divergence is nearly 90 degrees from the direction of the field. The chance of an electron in traveling 1 cm. of making such a direct contact in air as to be deflected more than 90 degrees, is only about 1 in 15, if the energy of the electron corresponds to about 25,000 volts so that the average distance an electron will travel without a deflection of more than 90 degrees is about 15 cm. In traveling this distance under the influence of a field of 20,000 volts per cm. the electron gains energy at the rate of more than 10,000 volts per cm. and before it has traveled 15 cm. its kinetic energy will exceed 170,000 volts and its probable length of path before an encounter sufficient to deflect it 90 degrees will have increased to more than 300 cm.

The mean rate of loss of energy of an electron in traversing a centimeter of air is an inverse function of the velocity and with an initial or emergent kinetic energy corresponding to about 150,000 volts, the loss of energy is only about 2,000 to 3,000 volts per cm. A field of this strength is, therefore, sufficient to maintain the initial velocity of the electron. Since it is practical to project in air, cathode rays having an initial velocity corresponding to a fall through 150,000 volts, it will be appreciated that the initial velocity may be readily maintained or even accelerated without the employment of potential gradients in the air of more than a few thousand volts per cm. Potential gradients very much less than that required to accelerate the electron stream, will be effective to increase very greatly the range of the cathode rays.

In order that the invention may be more fully understood reference will be had to the accompanying drawing in which,

Fig. 1 is a sectional view of a Lenard ray tube embodying my invention.

Fig. 2 is a fragmentary view of a modified embodiment of the invention, and

Fig. 3 is a fragmentary view of a Lenard ray tube in conjunction with means for increasing the velocity of the electron stream in air.

The tube shown in Fig. 1 comprises a glass envelope 4 having a relatively heavy wall and containing a filamentary electron emitting cathode 5 and an anode 6. The cathode end 7 of the tube has a reentrant glass stem 8 terminating in a press 9 through which the leading-in conductors 10 for the cathode, are sealed.

The envelope may be composed of any suitable glass, such as Pyrex or lime glass, but I prefer to use a glass more opaque to X rays which may be generated in the tube, such as lead glass or a boro-silicate glass, known in the trade as 702-P. The lead wires, in case 702-P glass is used, may be of either tungsten or molybdenum.

The cathode 5 may be of any suitable electron emitting material but preferably I form it of tungsten or tantalum in the form of a coil or spiral mounted within a focusing cup 12.

An electrostatic shield 13 surrounds the cathode and protects the seal from puncturing. It also prevents sharp point sparking from the cathode. This shield may take the form of a split metal tube of nickel, Monel metal, chrome-iron or other metal, held in place on the reentrant stem 8 by friction. Obviously, other convenient methods of support may be readily devised.

The anode consists of a tube 14, preferably of copper, provided with a leading-in conductor 15 sealed through the wall of the device, as at 16. The tubular anode is supported in the envelope by a split collar 17 of chrome-iron or other suitable metal which fits snugly into the glass envelope and is secured to the anode in any suitable manner as by pins, screws, friction, etc. The tubular anode is arranged with its axis aligned with the axis of the electron stream from the cathode so that the electrons drawn over by the anode pass therethrough and are projected against the window 18. The tubular anode also serves as a shield to prevent electrons from striking undesired portions of the envelope. For this purpose, the end 19 adjacent the cathode may be enlarged.

The end of the envelope adjacent the anode may be reduced in diameter where the window 18 is formed therein. Preferably the window 18 is formed in the closed end of a short length of Pyrex glass tubing which is subsequently joined to the envelope by an intermediate section of uranium glass. In forming the window, it is only necessary to heat the closed end of a piece of tubing, as in a blow pipe frame, and to create a suction on the interior thereof so that the plastic glass is drawn in, the suction and heating being continued until the requisite size and thickness of the bulbous portion is produced.

Glass windows produced in this manner, as thin as .0002 inch will withstand atmospheric tension but with such extremely thin windows difficulty is sometimes experienced due to collapsing of the window when it is sealed into the envelope. This difficulty may be overcome by putting an air pressure in the opposite direction during the sealing operation. This procedure is not necessary with windows having a thickness of about .0005 inch.

While Pyrex glass has been specified as the preferred window material, any strong heat resisting glass, or quartz, or non-porous porcelain may be used and by the term "vitreous material," it is intended to include all material of this nature.

In order to prevent the accumulation of a negative charge on the glass adjacent the window and in the air within the cavity 22 formed by the window I coat the glass on the exterior with a conducting material 23 which is electrically connected with the anode lead 15. This coating may consist of a very thin metallic deposit such as silver, deposited from solution, or may consist of aluminum paint. A conducting coating which I have found to be very satisfactory is ordinary carbon ink, such as India ink.

The coating should be sufficiently thin, at least over the dome portion 24 of the window so as not to materially interfere with this transmission of the cathode rays. If desired a piece of thin aluminum foil of known thickness may be secured over the dome portion of the window and joined to the anode lead by the conducting coatings. The coating being at the same potential as the anode permits any negative charge on the glass to be neutralized and also serves to dissipate any negative space charge in the interior portion 22 of the window. This enables the electron stream to pass through the glass and to be received in the air with much reduced loss of energy and greatly increases the range of the cathode or Lenard rays in the atmosphere.

The anode 6 is preferably maintained at ground potential and the cathode 5 connected to a source of high negative potential. The cathode may be heated to an electron emitting temperature by a battery 25.

The range of the cathode rays may be still further increased by producing a strong positive field in the direction of motion of the electron stream. For this purpose a metal plate 26 may be disposed in line with the cathode stream below the window 18 and maintained at a high positive potential relative to the anode. The specimen 27 being subjected to the cathode rays may be mounted on the plate 26. The positive field produced serves to attract the electron stream to the specimen and also to dissipate the space charge between the window of the tube and the specimen.

With a single plate, as shown in Fig. 1, spaced several inches from the window, it is probably not possible to actually accelerate the electron stream because of the retarding actions of the space charge which accumulates in the intervening space but I have been able by this means to greatly increase the normal range of the cathode rays, in air.

In Fig. 2 I have illustrated an alternative means for relieving the window and adjacent air of a negative electric charge. The window may be left uncoated and a metal cylinder 28 be disposed about the window and connected electrically to the anode. This cylinder may extend below the window to dissipate the space charge in the line of travel of the cathode stream, for some distance from the window.

In Fig. 3 I have shown means for dissipating the space charge between the window 18 and the specimen 27. This means consists of a series of metallic grids 29, 30 and 31 positioned below the window and sufficiently close together so that when they are charged positive they will serve to neutralize or greatly reduce the space charge in the path of the cathode rays. The grids 29, 30 and 31 and the plate 26 are charged at progressively higher positive potentials in the order of their respective distances from the window and the potentials applied to these elements may be sufficiently high so that the accelerating effect of the field produced thereby is sufficient to balance the retarding effect of the atmosphere on the electrons whereby the initial velocity of the electron will be maintained, or such potentials may be sufficiently high to produce an acceleration of the electrons in the air. Thus, if the Lenard rays emerge from the window with a kinetic energy corresponding to a potential drop of 150,000 volts, the initial velocity of the rays may be maintained by applying positive potentials to the grid elements equal to from 2,000 to 3,000 volts per cm. and the rays may be accelerated by the use of voltages above this level.

It will be noted that I have produced a Lenard ray tube with which the cathode rays may be projected into the atmosphere with high initial velocities and low energy losses. The loss in energy in the window varies with the kinetic energy of the electrons striking the window and decreases rapidly as higher voltages are employed.

With a glass window having a thickness of 0.00025 inch, there is a loss of energy in the window of only about 6,000 volts when the kinetic energy of the electron corresponds to a potential gradient of 60,000 volts. At 100,000 volts the loss of energy in the glass corresponds to a voltage drop of only about 3,000 volts.

It will be further noted that starting with high velocity electrons, the velocity thereof may be increased in the air and their range indefinitely lengthened. The exterior of the bulbous window, with the exception of the inner end or dome portion through which the cathode rays pass, may be coated with a strengthening material such as shellac, which serves to reinforce the thin glass and impart additional strength thereto. Shellac gradually breaks down under the bombardment of stray electrons, however, and should be protected by a coating of a dense material, such as the metallic coating 19, which prevents direct bombardment of the shellac. Other strengthening materials may also be used.

It is obvious that modifications may be made in the specific embodiments of the invention disclosed without departing from the invention and I do not desire to be restricted to the specific forms shown and described, except in accordance with the appended claims.

What is claimed is:

1. A Lenard ray tube for projecting cathode rays into the atmosphere comprising an envelope, a source of electrons therein, an anode having an aperture and a vitreous window transparent to cathode rays disposed opposite said aperture, said window having a conducting coating on the exterior surface thereof, electrically connected to the anode.

2. A Lenard ray tube for projecting cathode rays into the atmosphere comprising an envelope, a source of electrons therein, a window being a portion of said envelope and composed of non-conducting material, an anode for directing an electron stream upon said window and electrodal means disposed externally of the window for preventing the formation of a negative charge upon said window.

3. A Lenard ray tube for projecting cathode rays into the atmosphere comprising an envelope, means for creating a cathode stream therein, a vitreous window permeable to said cathode stream, and an electrically conducting coating on the exterior of said window, said coating adapted to be maintained at a positive potential with respect to said cathode stream creating means.

4. A Lenard ray tube for projecting cathode rays into the atmosphere comprising an envelope, means for creating a cathode stream therein, a non-conducting window in line with said stream transparent to said cathode rays, electrodal means disposed externally of said window for preventing an accumulation of a negative charge on said window and in the air adjacent said window.

5. A Lenard ray tube for projecting cathode rays externally of the tube comprising an envelope, a source of electrons therein, an anode and a vitreous window transparent to cathode rays, said window having a conducting body associated therewith and electrically connected to said anode, and means for producing a positive field externally of said tube in the line of motion of said cathode rays.

6. A Lenard ray tube for projecting cathode rays externally of the tube comprising an envelope, a source of electrons therein, an anode and a window being a portion of said envelope and transparent to cathode rays and means for producing a positive field externally of said tube in the line of motion of said cathode rays, said anode being spaced from said window.

7. A Lenard ray tube for projecting cathode rays externally of the tube comprising an envelope, a source of electrons therein, an anode and a window being a portion of said envelope and transparent to cathode rays emanating from said source, and an electrode externally of said tube opposite said window for producing a positive field in the line of motion of the cathode rays, said anode being spaced from said window.

8. A Lenard ray tube for projecting cathode rays externally of the tube comprising an envelope, a source of electrons therein, an anode, a window being a portion of said envelope and transparent to cathode rays emanating from said source and a plurality of electrodes externally of said tube at varying distances from said window for dissipating negative space charges in the air in the line of motion of the cathode rays.

9. A Lenard ray tube for projecting cathode rays externally of the tube comprising an envelope, an electron emitting cathode therein, an anode, a vitreous window permeable to cathode rays emanating from said cathode, an electrically conductive body adjacent the window for preventing the accumulation of a negative charge on the window and in the air adjacent thereto, and an electrode disposed externally of said tube opposite said window for producing a positive field in the air in the direction of motion of the cathode rays.

10. A Lenard ray tube for projecting cathode rays externally of the tube comprising an envelope, an electron emitting cathode and an anode in the envelope, an electrically non-conducting window being a portion of said envelope and transparent to cathode rays produced at said cathode, an electrically conductive body adjacent said window electrically connected to said anode for preventing an accumulation of a negative charge on the window and in the air adjacent thereto, and electrodal means for producing a positive electric field in the air, in the line of motion of the cathode rays.

11. A Lenard ray tube for projecting cathode rays externally of the tube comprising an envelope, means for producing an electron stream therein, a vitreous window being a portion of said envelope and transparent to said electron stream, a conductive coating on the exterior of said window and electrically connected to said anode and electrodal means for creating an electric field in the air, in the line of motion of said electron stream.

12. The method of increasing the range and velocity of electrons in air which comprises projecting said electrons from a Lenard ray tube at high velocities into the air and producing a positive field in the line of motion of the electrons, having a potential gradient per unit of distance of travel of the electrons which will produce a change of energy in the electrons of an order of magnitude comparable wtih the rate of loss of energy of the electrons in air.

13. A window for a Lenard ray tube composed of vitreous material of bulbous form having a dome permeable to high velocity electrons and a gradually thickening side wall, a coating of a strengthening material on the side wall, and a layer of dense material over said strengthening material to protect the coating from electron bombardment.

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