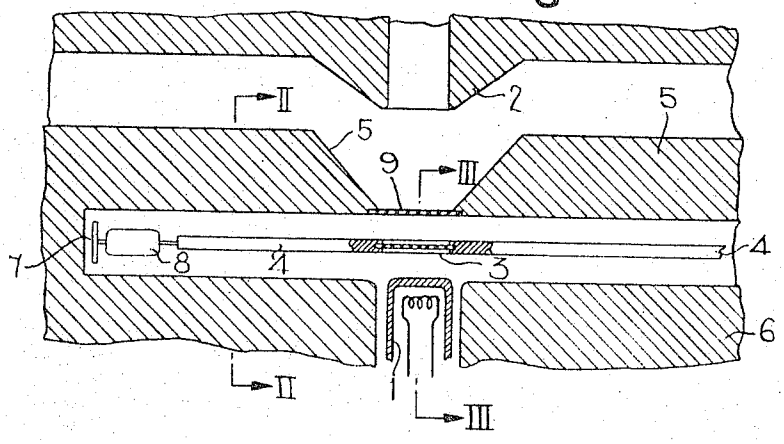
March 14, 1967 M. C. CROWLEY-MILLING 3,309,557

ELECTRON GUN UTILIZING A STRIP TRANSMISSION LINE TO EXTRACT ELECTRONS FROM A CATHODE

Filed July 8, 1963 2 Sheets-Sheet 1

Fig.1.



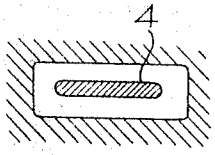


Fig 2.

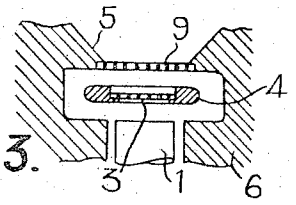


Fig.3.

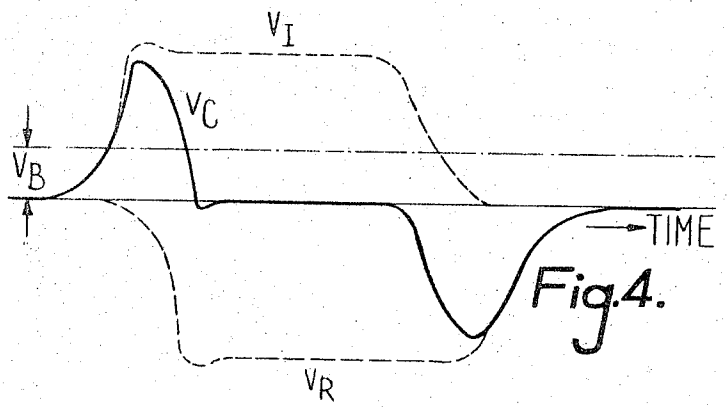


Fig.4.

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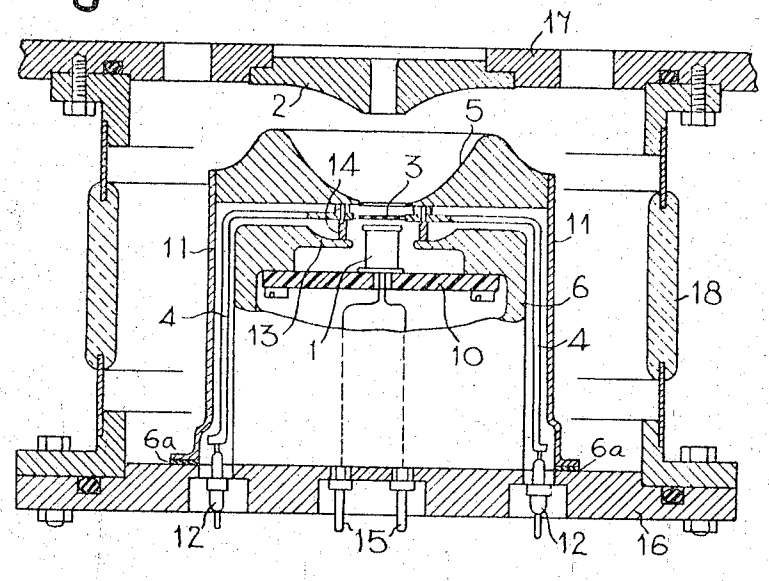
By: Morris + Bateman
Attys

March 14, 1967 M. C. CROWLEY-MILLING 3,309,557

ELECTRON GUN UTILIZING A STRIP TRANSMISSION LINE TO EXTRACT ELECTRONS FROM A CATHODE

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Fig. 5.



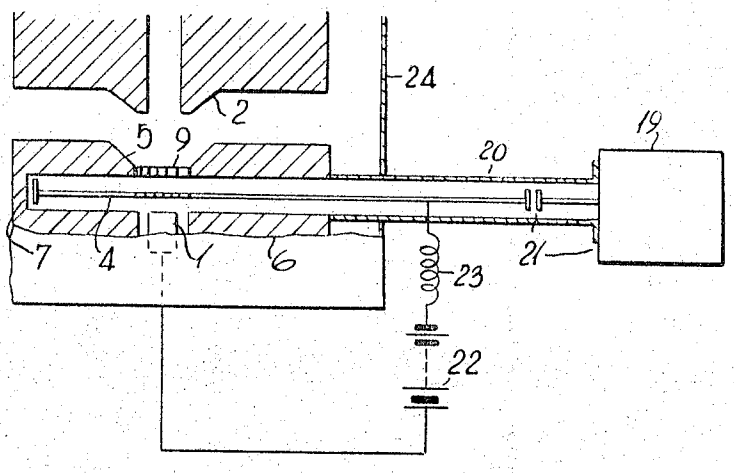


Fig. 6.

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3,309,557

ELECTRON GUN UTILIZING A STRIP TRANSMISSION LINE TO EXTRACT ELECTRONS FROM A CATHODE

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Claims priority, application Great Britain, July 12, 1962, 26,882/62
9 Claims. (Cl. 315—5)

This invention relates to electron guns and more particularly to electron guns for producing high energy electron pulses of short duration.

The invention has an important application in high energy electron accelerators.

For many experiments in neuclear physics it is desirable to have very short pulses of electrons accelerated to high energies. The means of production of short pulses of electrons down to a duration of about 1.0 μsec. are well known. Typically, an electron gun for producing such short pulses has a cathode which may be a tungsten spiral direct emitter or an indirect emitter such as an oxide coated cathode or one of the well known impregnated sintered metal cathodes. Immediately in front of and closely spaced from the cathode is a grid normally held negative with respect to the cathode. In front of the grid are beam forming electrodes and beyond this the anode of the gun. When positive pulses sufficient to overcome the negative bias are applied to the grid, electrons can flow from the cathode through the grid and the beam forming electrodes and through an aperture in the anode into the accelerator. The main difficulty with the use of this type of gun for very short pulses of electrons is that the capacitance between the grid and the cathode and between grid and beam forming electrodes and of the connecting leads tends to distort the applied pulse. This limitation need not be serious for pulses down to about 0.05 μsec., but it is now desirable to produce pulses as short as 10^{-3} μsec. Methods of overcoming this limitation by making the gun of co-axial construction have been proposed, but this leads to difficulty with the connections to the cathode heater system etc.

It is therefore an object of the present invention to provide an electron gun in which distortion of the control pulses is sufficiently reduced to allow electron bursts in the 0.001 μsec. duration range to be produced.

According to the present invention, an electron gun comprises a cathode, an aperture anode and a strip transmission line disposed transversely between said anode and said cathode, the inner conductor of said line having an aperture in alignment with said anode aperture and said cathode and carrying a control grid extending across the said aperture, and the outer conductor of said line being apertured in alignment with said anode aperture and said cathode to allow the passage of electrons between cathode and anode.

In a preferred embodiment of the invention that portion of the said outer conductor defining the aperture remote from the cathode forms a beam electrode for focusing electrons passing through said aperture and may conveniently carry a screen grid extending across the said aperture.

Preferably, the cathode is suitably insulated from and mechanically supported by the apertured portion of the outer conductor adjacent said cathode.

Advantageously, an electrical resistor of the same impedance as the transmission line may be connected in a circuit extending between the inner and outer conductors of said line.

Alternatively one end of the transmission line may be short circuited with respect to current pulses.

The components of the gun may be said to be "aligned" when, in operation of the gun, electrons emitted from the cathode pass through the inner conductor aperture, the control grid located across this aperture, the outer conductor aperture whose walls form a beam electrode to focus the electrons, the screen grid located across said outer conductor aperture, and through the anode aperture to provide an electron source for apparatus located beyond said anode.

In the specific embodiments described, the cathode is shown to be projected through a first aperture in said outer conductor so as to be adjacent the grid electrode. Alternatively, the cathode may be located outside said first aperture which then extends across the electron path.

The term "strip transmission line" as used in the specification, is to be interpreted as a transmission line comprising a first electrical conductor which is a strip of which the width is appreciably greater than the thickness and a second electrical conductor which partially or completely surrounds the first conductor.

The electron gun would be located in a suitable vacuum system in accordance with well known practice.

The cathode may be an indirectly heated sintered metal-type and be a part of a turret system of the type disclosed in British patent specification No. 697,823 whereby the cathode assemblies are replaceable without disturbance of the vacuum system.

By way of example, the invention will now be described with reference to the accompanping drawings, in which:

FIG. 1 is a diagrammatic longitudinal section of an electron gun according to one embodiment of the invention;

FIG. 2 is a cross section along the line II—II of FIG. 1;

FIG. 3 is a cross section along the line III—III of FIG. 1.

FIG. 4 illustrates graphically the formation of a control pulse for the grid in another embodiment of the invention in which one end of the transmission line is short-circuited;

FIG. 5 is a longitudinal cross section of an electron gun according to the invention showing the constructional details of the gun; and

FIG. 6 shows the general arrangement of the invention in conjunction with a pulse generator.

Referring to FIGS. 1, 2 and 3, the electron gun comprises essentially an indirectly heated cathode **1**, an axially apertured anode **2** and a control grid **3** mounted on an apertured portion of the inner conductor **4** of a strip transmission line whose outer conductor is formed by an upper portion and a lower portion which together surround the inner conductor **4**. The upper wall **5** is apertured to provide a beam forming electrode whilst the lower wall **6** serves as a support structure for the cathode **1**. The inner and outer conductors are coupled together through a capacitor **7** which enables a negative bias to be applied to the grid **3** relative to cathode **1**. In operation, positive pulses are applied to grid **3** through conductor **4** which pulses overcome negative grid bias and allow corresponding bursts of electrons to be emitted from the cathode. The impedance of capacitor **7** is chosen to be negligible at the control pulse frequency. In the embodiment shown, between the capacitor **7** and the conductor **4** there is connected a resistor **8** offering the same impedance as the transmission line to the control pulses. If the grid-cathode spacing and the impedance of the line are correctly chosen a short pulse applied to one end of the line can be transmitted without distortion to be absorbed in the resistor **8** at the other end of the line. With such an arrangement, control pulses of about 10^{-3} μsec. duration can be transmitted to the grid **3** with-

out distortion and correspondingly short bursts of electrons are emitted from the cathode.

In order to reduce the size of the control pulses applied to conductor 4 (typically from several hundred volts to about fifty volts amplitude) the beam electrode 5 may be fitted with a screen grid 9 in alignment with the cathode control grid and anode. In this case the two portions 5 and 6 of the outer conductor are separated from one another by an insulating film 6*a* in the manner shown in the embodiment of FIGURE 5 to allow the screen-grid to be maintained at a suitable positive potential with respect to the cathode.

In an alternative embodiment to that shown in FIGS. 1–3, the resistance 8 may be omitted from the arrangement so that the transmission line is effectively short circuited at one end. With this arrangement, provided that the positive pulse incident on conductor 4 has a sharp fronted waveform, it will be reflected with change of polarity at the short circuited end of the line and will introduce a pulse train on grid 3 which is the resultant of the incident and reflected pulses. The positive portion of this train will exceed the grid bias to provide positive control pulses for the cathode during which correspondingly short bursts of electrons will be emitted. The formation of such a control pulse is shown in FIG. 4 which is a plot of pulse voltage against time at the grid 3. V_I represents a positive pulse transmitted by the conductor 4 to the grid and V_R the reflection of that pulse from the short circuited end of the transmission line. The resultant pulse train at the grid is represented in FIG. 4 by the full line of which the portion V_C exceeding the grid bias magnitude V_B represents the control pulse for the grid.

The duration of these control pulses are dependent only on the phase shift between the incident and reflected pulses at the grid 3 and this is in turn dependent on the length of transmission line between the grid and the short circuited end. Thus with such an arrangement the duration of the control pulse is largely independent of that of the incident pulses so that resultant control pulses and electron bursts of 10^{-3} μsec. duration or less can be easily produced using comparatively long incident pulses.

FIG. 5 shows the constructional details of an electron gun according to the invention. A cathode 1 is mounted on a ceramic support plate 10 supported by a structure 6 which forms the innermost portion of the outer conductor of a transmission line. The outermost portion of this outer conductor is formed by cover plates 11 and a beam forming electrode 5. The inner conductor 4 of the line has an apertured portion which supports a control grid 3. The additional capacitance introduced by the close spacing of the cathode and grid is offset by cutting away a portion of the structure 6 at the position 13. The conductor 4 is supported near the grid by ceramic insulators 14 to maintain the correct grid to cathode spacing.

An apertured anode 2 of the gun is supported by a mounting plate 17 which may be the end plate of the accelerator vacuum chamber, and the gun base plate 16 is supported from this mounting plate by the conventional insulating means 18. The ends of the inner conductor 4 of the strip line are connected to glass-metal sealing terminals 12 where they pass through the end plate 16 of the gun. These seals are of such construction as to maintain the correct surge impedance for the strip line. Additional glass-metal seals 15 are used for the connection to the cathode 1.

It is to be understood that the invention is not limited to an electron gun including the particular constructions of strip transmission line shown in the figures but that any strip transmission line comprising an inner conductor which is a strip of which the width is appreciably greater than the thickness and an outer conductor which partially or completely surrounds the first conductor may be employed.

In FIG. 6 a pulse generator 19 is connected to the

gun by means of a transmission line 20 which may be a strip line of the same characteristics as that in the gun, or of different type of characteristics if suitable matching arrangements are included. The transmission line may be interrupted, as far as direct current is concerned, by capacitive elements 21 to prevent the grid-bias from being applied to the pulse generator. This grid-bias is applied to the conductor 4 carrying the grid 3 by means of a battery or other source 22 through the inductor 23 or other form of high impedance to the pulse voltage, connected to the central conductor of the transmission line, with suitable matching arrangements, not shown, to prevent mis-matching of said transmission line. The system would be suitably evacuated and 24 shows a part of the envelope.

What I claim is:

1. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner conductor and an outer conductor, said inner and outer conductors having apertures aligned with the said electron path to provide for the passage of electrons.

2. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner conductor and an outer conductor, said inner and outer conductors having apertures aligned with the said electron path to provide for the passage of electrons, and means for applying a control voltage to said inner conductor to control the electron flow.

3. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner conductor and an outer conductor, said inner and outer conductors having apertures aligned with the said electron path provided for the passage of electrons, and grid wires extending across the aperture in said inner conductor.

4. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner conductor and an outer conductor, said inner and outer conductors having apertures aligned with the said electron path to provide for the passage of electrons, grid wires extending across the aperture in said inner conductor, and means for applying a control potential to said grid wires to control the electron flow.

5. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner conductor and an outer conductor, said inner and outer conductors having apertures aligned with the said electron path to provide for the passage of electrons, grid wires extending across the aperture in said inner conductor, a pulse generator connected to one end of said transmission line, a resistive load connected to the further end of said transmission line, and means providing for the propagation of positive pulses from said pulse generator to said grid, said pulses being thereafter absorbed by the resistive load.

6. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner conductor and an outer conductor, said inner and outer conductors having apertures aligned with the said electron path to provide for the passage of electrons, grid wires extending across the aperture in said inner conductor, a pulse generator connected to one end of said transmission line, pulse reflecting means at the other end of said transmission line, and means for so propagating the voltage pulses along said line from said pulse generator that the pulse

train passes said grid and thereafter is returned to said generator by said pulse reflecting means to provide an electron beam that passes between the initial incidence of the pulse train on said grid and the reflected incidence thereof.

7. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner conductor and an outer conductor, said outer conductor having opposed wall portions extending transversely of said electron path with one of said wall portions extending between said cathode and said anode, said inner conductor and said wall portions having apertures aligned with the said electron path to provide for the passage of electrons, said cathode being positioned in the aperture formed in the other of said wall portions.

8. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner conductor and an outer conductor, said inner and outer conductors having apertures aligned with the said electron path to provide for the passage of electrons, means for biasing said inner conductor relatively to said cathode, and a pulse generator capacitively coupled with an end of said inner conductor.

9. An electron gun comprising a cathode and an anode, a strip transmission line extending transversely across the electron path between the cathode and anode, said strip transmission line including an inner strip conductor and an outer hollow conductor having an interior space of rectangular cross-section, with said inner strip conductor being disposed at least partially in said space, said inner and outer conductors having apertures aligned with the said electron path to provide for the passage of electrons.

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R. COHN, *Assistant Examiner.*