May 3, 1960 R. C. KNECHTLI 2,935,636

ELECTRON GUN STRUCTURE

Filed Oct. 31, 1955 2 Sheets-Sheet 1

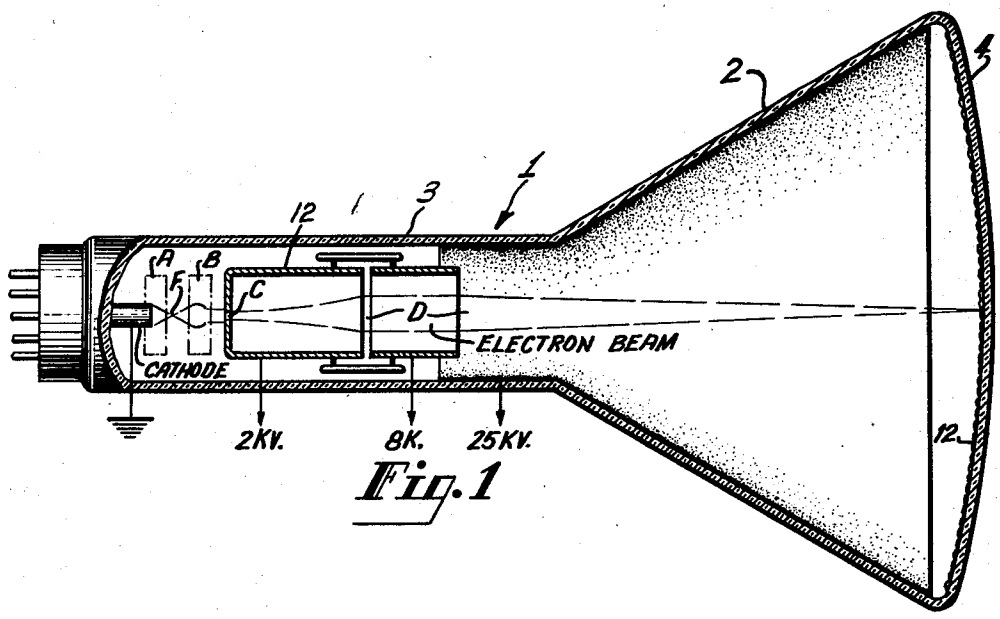


Fig. 1

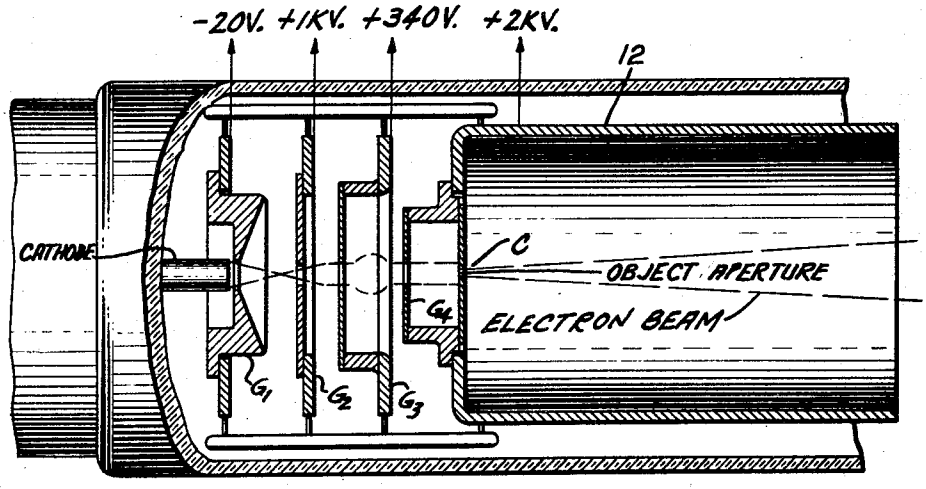


Fig. 2

INVENTOR.
RONALD C. KNECHTLI
BY
William A. Zalenak
ATTORNEY

May 3, 1960 R. C. KNECHTLI 2,935,636

ELECTRON GUN STRUCTURE

Filed Oct. 31, 1955 2 Sheets-Sheet 2

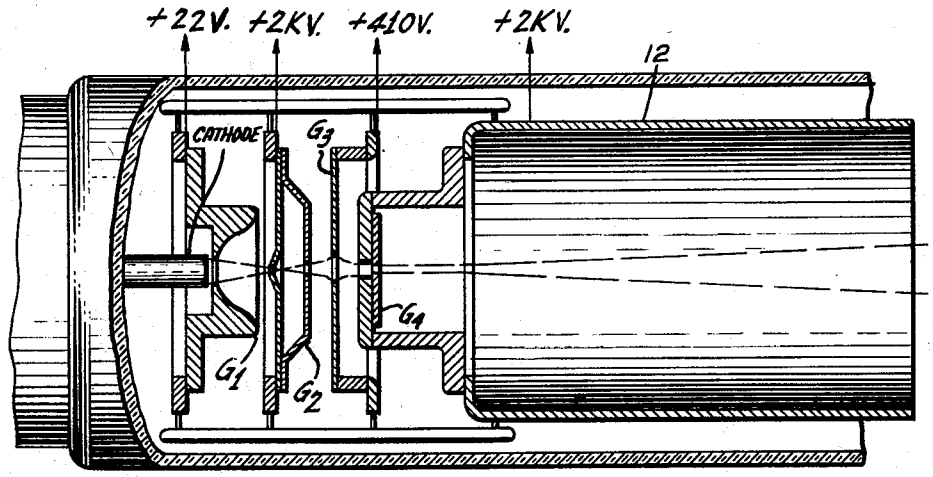


Fig. 3

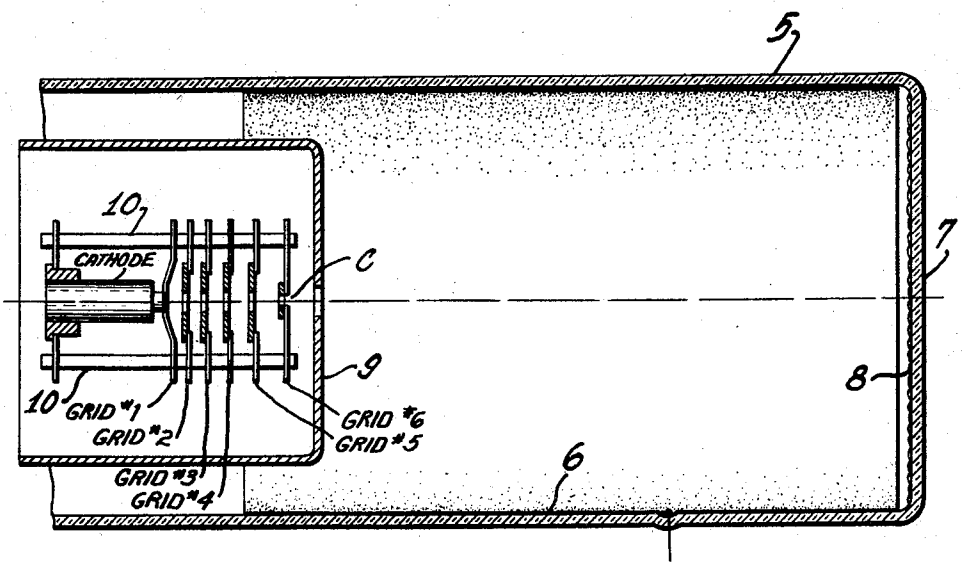


Fig. 4

INVENTOR.
RONALD C. KNECHTLI
BY
William A. Galeuak
ATTORNEY

United States Patent Office 2,935,636 Patented May 3, 1960

2,935,636

ELECTRON GUN STRUCTURE

Ronald C. Knechtli, Cranbury, N.J., assignor to Radio Corporation of America, a corporation of Delaware

Application October 31, 1955, Serial No. 543,680

5 Claims. (Cl. 313—82)

This invention relates to electron guns for cathode ray tubes, and it has for one of its objects the provision of a novel and improved high-voltage object defining aperture electron gun for cathode ray tubes.

Another object of the invention is to minimize the beam spread between object and final lens of an electron gun.

In applications where a small beam spot of constant size and of shape, possibly different from the round one, is required on the phosphor screen of a cathode ray tube or kinescope, the normal type of electron gun is not suitable. The beam spot obtained therefrom is round, of variable size, depending on the current. Furthermore, the spot edges are not sharp. In high-voltage object defining aperture guns, the spot is practically of constant size because the object is not a variable crossover but a mechanically defined aperture. With the limiting aperture operated at high voltage (500 v. or more) the effects of space-charge and chromatic aberrations can be made negligible and the sharpness of definition of the spot is determined by the spherical aberration of the lens only.

Studies in connection with high-voltage object defining aperture guns show that in order to obtain, at the screen, a spot of minimum size for a given cathode current density, and a given size of object defining aperture, it is necessary to pass this current through the object defining aperture with the lowest possible value of the product $P=\sqrt{V_{ap}}\cdot\sin\theta_{ap}$, where V_{ap}=aperture voltage and θ_{ap}=angle of the outermost electron trajectory with the axis of the gun at the object defining aperture. Hence, the product $\sqrt{V_{ap}}\cdot\sin\theta_{ap}$ for a given current can be considered as a quality factor of the gun, which has to be minimized.

In one of the most efficient types of high-voltage object defining aperture electron guns heretofore proposed, the above mentioned product P equals 2.1 for a 1 ma. beam current passing through an object defining aperture of 4 x 15 mils. For currents of the order of 1 ma. or more, angular spread of the beam after passing the aperture is of the order of 3.5°, at an aperture voltage of 1.5 kv.

The present invention provides an improved high-voltage object defining aperture gun in which the product P referred to above is reduced to P=1.6 to 1.3 or better at the same current of 1 ma., and in which the angle of beam spread is decreased to a minimum. This gun, hereinafter described in detail, comprises a crossover-forming system producing a true crossover in which the cross-section of the beam is decreased to the minimum possible dimensions; an electron optical lens system whose focus coincides or nearly coincides with said crossover; an object defining aperture flooded by the beam of electrons emerging from said lens system; and an electron optical system imaging said object defining aperture onto the target surface of the screen.

The invention is described more in detail in connection with the accompanying drawings, in which:

Fig. 1 is a longitudinal sectional view through a portion of a kinescope, illustrating diagrammatically the general structure and principles of operation of a high-voltage object defining aperture electron gun embodying the invention;

Fig. 2 is a diagrammatic view in longitudinal section, illustrating an electron gun of the above type with an immersion lens crossover forming system;

Fig. 3 is a similar view of a modified electron gun with a laminar flow crossover system; and

Fig. 4 is a longitudinal sectional view of a test tube, illustrating another embodiment of the invention.

The cathode ray tube or kinescope illustrated by way of example in Fig. 1 comprises an evacuated envelope 1 having a main chamber 2 in the form of a frustum which terminates at its large end in a window 4 which may constitute the transparent foundation plate of the conventional target or screen 12 of the kinescope containing a multiplicity of phosphor dots or other areas arranged in a manner well understood in the art.

The small end of the frustum 2 terminates in a tubular neck 3 which contains the electron gun forming the subject matter of the present invention and comprising: a crossover-forming system A producing a true crossover F in which the cross-section of the electron beam is decreased to the minimum possible dimensions; and electron optical lens system B whose focus coincides or nearly coincides with F; an object defining aperture C flooded by the beam of electrons emerging from the lens system B; and an electron optical system D imaging said object defining aperture onto the screen.

The crossover F formed by the crossover-forming system A is considered in first approximations as a point source of electrons for the lens system B. In setting the focus of the lens system B on this point source, the electrons emerging from this lens system will flow in first approximation in a parallel flow, as a consequence of the fundamental properties of lenses.

The distance between the first principal plane of the lens system B and the crossover (equal to or nearly equal to the first focal length of the lens system B) is chosen such that the diameter of the beam emerging from this lens system is not appreciably larger than the largest dimension of the object defining aperture C following it. Thus, the object defining aperture C is flooded by a parallel-flowing (essentially non-divergent) electron beam, as illustrated in Fig. 1. For a round object defining aperture, the transmission efficiency η_r (ratio of total beam current to transmitted current) will be close to 1; for a rectangular object defining aperture, where aperture C would have a width a and a length b, and with $b>a$, one has in first approximation:

$$\eta_r\cong\frac{ab}{\frac{\pi}{4}b^2}=\frac{4}{\pi}\cdot\frac{a}{b}$$

The spread of the beam leaving the object defining aperture C will be ideally only due to space-charge. This will be the minimum possible beam spread, corresponding to all electrons emerging parallel to the axis from the object defining aperture C. The actual beam spread, however, will be larger than this ideal value because of the following effects: (1) finite size of the crossover formed by the system A, which size cannot be reduced below a definite limit because of initial thermal electron-velocities; and (2) aberrations in the lens system B.

As the crossover voltage can be raised without difficulty up to several kv. (this crossover can well be at a higher potential than the object defining aperture C) the first of the above-mentioned limitations is not too important. As for the second limitation, by proper design (e.g. several weak lenses in series) the aberrations in the lens system B can be reduced to a tolerable value. As a practical order of magnitude, it is possible for an

optimized design and with a rectangular object aperture of 4 x 15 mils at a voltage of 1.5 kv. (which may be lower than the crossover voltage) to obtain a current of 2 ma. through the object defining aperture C with an angle of beam spread $\theta_{ap}<3°$. This corresponds to a product $P=\sqrt{V_{ap}}.\sin\theta_{ap}<2$. Reduced to 1 ma. effective beam current, this becomes $P<1.3$. This takes into account thermal limitations (finite size of crossover), beam spread due to space-charge, and lens aberrations. No secondary electron emission occurs in such electron gun to disturb the electron optical imaging of the aperture C onto the screen of the tube.

The crossover-forming system A producing the crossover F may be of the immersion lens type illustrated in Fig. 2. This immersion lens crossover-forming system is designed according to standard practice; a typical design procedure for said system may be found in a paper by M. Polke, entitled "Elementary Theory of Production of Electron Beams with Triode Systems," in Zeitschrift für Angewandte Physik, December 1951 and January 1952 (vols. 3 and 4). As the crossover voltage in the system of Fig. 2 normally does not exceed a few hundred volts, the electron optical system B can consist of one or a combination of bipotential lenses. Because of the short axial distances involved, aperture lenses are usually preferred. The cross-over point forming system of Fig. 2 comprises the cathode, a negative control grid G_1 adjacent the gun cathode, and a high voltage screen grid G_2. The lens system corresponding to B of Fig. 1 consists of the same high voltage screen G_2, a low voltage electrode G_3 and a high voltage electrode G_4. In the embodiment illustrated, the crossover-forming system A is designed to work with the electrode G_2 at a voltage equal to or of the order of magnitude of the voltage of the object defining aperture C. The system shown in Fig. 2 employs a screen grid G_2 at the same high voltage as the object aperture C ($V_{ap}\cong 1-3$ kv.).

Fig. 3 illustrates another embodiment of the invention employing an electron gun with a laminar flow crossover-forming system. The said crossover-forming system A is a structure of the type generally known as a "Pierce gun" (see Spangenberg, "Vacuum Tubes," pp. 449–465). This type of structure gives a good approximation to laminar spherical convergent flow, and it is particularly suited where high current, high current density and good cutoff characteristics are required. Because of the high voltage of the screen grid G_2 and of the crossover on which the beam is made to converge, the lens system B of Fig. 3 is preferably of the unipotential type. However, the potential of the electrode G_3 through which the beam leaves the lens system B may be lower than the potential of the electrode G_2 through which the beam enters the lens system.

Fig. 4 illustrates a test tube containing an experimental electron gun which I have operated according to the principles of the invention described above in connection with Fig. 1. This tube comprises an evacuated envelope **5** having an internal silver coating **6**, a window **7** constituting the transparent foundation plate of the aluminized phosphor screen **8**. Within the envelope **5**, there is a housing **9** enclosing a rectangular object defining aperture C, a conventional cathode and the electrodes G_1 to G_6 mounted on suitable supporting rods **10**. Electrode G_6 supports a rectangular object defining aperture C measuring 4 x 15 mils. The potentials applied to the electrodes for maximum current transmitted through the object defining aperture C were:

Electrode	Cathode	G_1	G_2	G_3	G_4	G_5	G_6	Screen
Potential (Volt)	0	−55	1000	100	1000	1500	1500	1600
Current (ma.)	−2.0	0	+0.050	−0.050	0	0.500	1.000	0.500

The control grid swing from 10μa. to 500 μa. screen current was 55 volts. It will be noted from the potential applied to the electrodes that this gun operated in the manner described above in connection with Fig. 1. The crossover is formed between electrodes G_1 and G_2 by the fact that $V_{g1}<0$ and $V_{g2}=1$ kv. produce a strong immergent lens. Electrodes G_2—G_3—G_4 constitute a unipotential lens (the electron optical lens system B described above); G_4—G_5 is essentially an accelerating region without major significance; and G_6 is the electrode in which the object defining aperture C is located. From the currents observed it will be appreciated that the secondary emission from the low voltage electrode G_3 is negligible, being of the order of 50 μa. for 2 ma. cathode current. The transmission efficiency of 25 to 30% through the rectangular aperture C corresponds to a round beam cross-section about equal to the length of the aperture, according to the equation for a rectangular object defining aperture of 4 x 15 mils given above in the description of Fig. 1.

The maximum beam spread in the system of Fig. 4 was observed in the direction of the long dimension of the rectangular aperture C, as is expected in a beam of rectangular cross-section spread by space-charge. The cross-section of the beam at a distance of 3" from the aperture was still nearly rectangular, the long dimension being about 5 mm. This corresponds to a maximum angle of beam spread $\theta_{ap}=2°$. With $V_{ap}=1.5$ kv. this yields a product $P=\sqrt{V_{ap}}.\sin\theta_{ap}=1.28$. Extrapolating $P=1$ ma. according to the 3/2 power law, one obtains $P=1.6$. This represents an appreciable improvement over the best performing prior art high voltage limiting gun known to me, and, as stated above, values of the product P as low as 1.3 or better can be obtained by application of the principles of the invention. In the system of Fig. 4, as in all others designed in accordance with the invention, secondary emission proved to be of negligible importance.

What is claimed is:

1. An electron beam forming device comprising, in combination, cathode means providing a source of electrons, beam converging means disposed in proximity to said cathode means for directing electrons from said source through a crossover point, lens means focused adjacent to said point for redirecting said electrons into a substantially parallel flow, electrode means having an aperture formed therein, said aperture being positioned transversely in the path of said parallel flow, the maximum dimension of said aperture being smaller than the corresponding minimum transverse dimension of said parallel flow of electrons, whereby a portion of the electrons of said parallel flow will pass through said aperture and be sharply defined by the edges thereof, a screen and an electron-optical means imaging the portion of said substantially parallel flow emerging from said aperture onto said screen.

2. A device according to claim 1, wherein said parallel flow of electrons is of circular transverse cross-section and said aperture is of rectangular configuration.

3. A device according to claim 1, wherein said beam converging means comprises an immersion lens.

4. A device according to claim 1, in which said lens means comprises a combination of several bipotential lenses.

5. A high-voltage object defining aperture electron gun for cathode ray tubes, comprising an axially symmetrical electrode system including an electron-emissive cathode,

a crossover-forming means for reducing the cross-section of the electron beam from said cathode to a minimum, an electron optical lens whose focus coincides substantially with said minimum cross-section of said beam at said crossover-forming means, an electrode having an object defining aperture therein arranged to be flooded by the beam of electrons emerging from said lens, and an electron optical system for imaging said object defining aperture onto a screen.

References Cited in the file of this patent

UNITED STATES PATENTS

2,172,739 Levin ---------- Sept. 12, 1939

2,227,034 Schlesinger ---------- Dec. 31, 1940
2,248,558 Schlesinger ---------- July 8, 1941
2,484,721 Moss ---------- Oct. 11, 1949
2,761,988 McNaney ---------- Sept. 4, 1956
2,792,515 Broderick ---------- May 14, 1957
2,825,837 Dudley ---------- Mar. 4, 1958

OTHER REFERENCES

Maloff: Electron Optics in Television, McGraw-Hill, 1938.