July 5, 1938.

K. SCHLESINGER

TELEVISION TUBE

Filed June 22, 1936

2,123,161

2 Sheets-Sheet 1

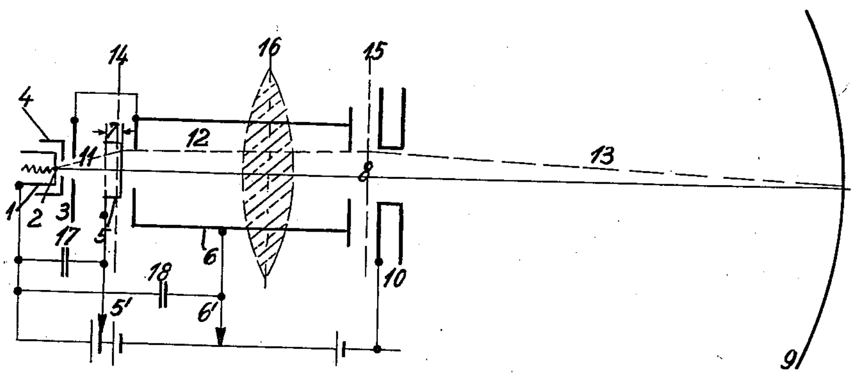

Fig. 1

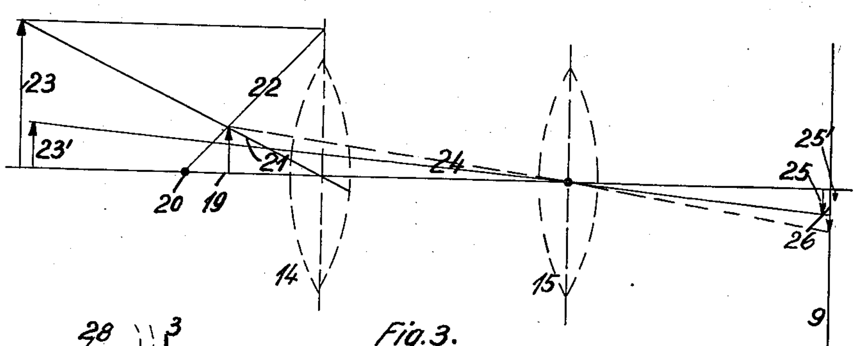

Fig. 3.

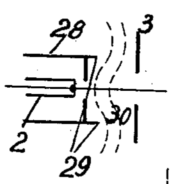

Fig. 4a

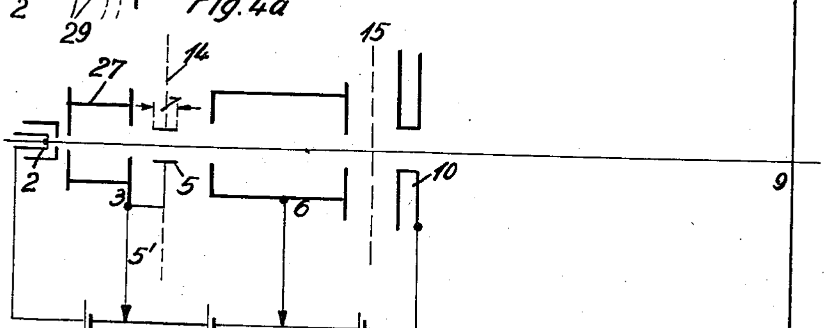

Fig. 4.

Inventor:

July 5, 1938. K. SCHLESINGER 2,123,161

TELEVISION TUBE

Filed June 22, 1936 2 Sheets-Sheet 2

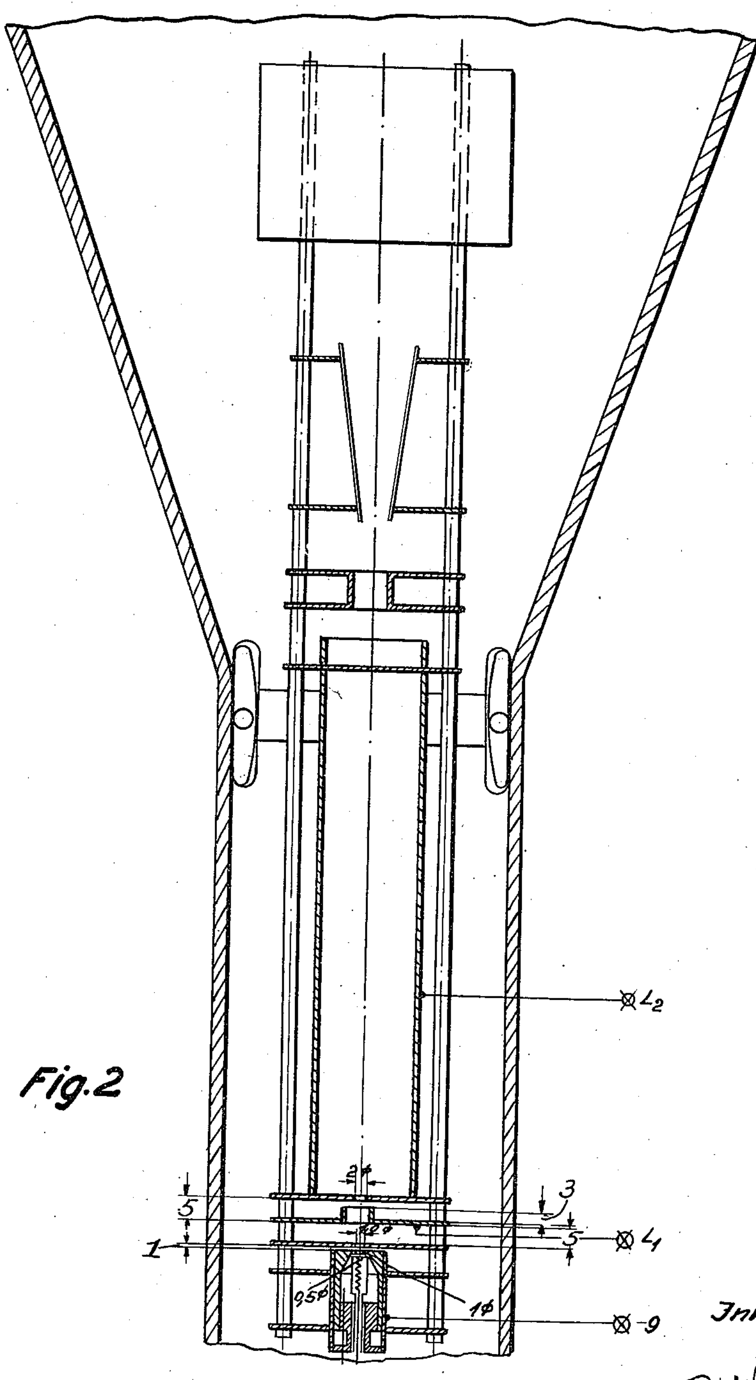

Fig. 2

Inventor:

Kurt Schlesinger

Patented July 5, 1938 2,123,161

UNITED STATES PATENT OFFICE

2,123,161

TELEVISION TUBE

Kurt Schlesinger, Berlin, Germany, assignor to Radioaktiengesellschaft D. S. Loewe, Berlin-Steglitz, Germany

Application June 22, 1936, Serial No. 86,608
In Germany June 25, 1935

10 Claims. (Cl. 250—27)

The subject matter of the invention is a high-vacuum television tube with electrostatic concentration and preferably electrostatic deflection. The essential feature of the tube according to the invention is the performance of the electrostatic concentration, operating with two collecting lenses, which are arranged in series, and which reproduce a part of the ray lying in the immediate vicinity of the surface of the cathode. Features of the invention are (1) the omission of a diaphragm, (2) the ability of the tube to produce image points of different size on the screen according to the adjustment of the refractive powers of the two lenses, (3) the fact that the lens near the cathode, the so-called first or rear lens (viewed from the screen) is unable alone to project any real image of the cathode on the luminous screen, but produces a virtual image of the cathode, and that it is only by means of the second lens (front lens) that a real, sharp image of the cathode is formed on the luminous screen.

The applicant has already described in earlier applications (application No. 730,111, filed June 11th, 1934 and No. 733,995, filed July 6th, 1934, Patent No. 2,077,272, dated April 13, 1937) television tubes which correspond to a large extent with the structural form shown in Fig. 1 according to the invention. In particular, there is already exactly described in the application No. 733,995 the use of two lenses, of which the first alone produces merely a virtual intermediate image. This application, however, operates with a diaphragm aperture as the object of reproduction, and a special condensing device is accordingly required in order to perform preliminary concentration of the ray and to prevent excessive loss at the diaphragm. The tube according to the invention no longer requires a preliminary concentration of this nature, but reproduces the emissive surface of the cathode or a cross-section of the cathode beam situated closely in front of the cathode.

In the terms of this invention, a cross-sectional portion of the cathode beam situated adjacent the cathode means a cross-sectional portion of the beam situated either immediately at the surface of the cathode or in close vicinity of this surface. The illustration of the passage of the ray is essential for comprehension of the invention.

In the following detailed description of the invention reference will be had to the accompanying drawings,

Fig. 1 whereof shows the essential parts of a cathode ray tube designed according to the invention in a schematic longitudinal section together with certain circuit elements and symbols illustrating the electron-optical conditions, whereas

Fig. 2 is a dimensional longitudinal section through a cathode ray tube designed on the lines illustrated in Fig. 1, the base and the screen portion of the tube being broken away, as these may be of any conventional or other type.

Fig. 3 is a diagram illustrating in more detail the electron-optical conditions set forth in connection with Fig. 1.

Fig. 4 again is a schematic view similar to Fig. 1, showing a modification, and

Fig. 4*a* in a similar manner shows a modified form of a certain detail.

In Fig. 1 the hot cathode 1 consists of a nickel cylinder, in which there is embedded a defined spot of oxide **2**, having a diameter of say ½ mm. There is obtained a considerable emission from this cathode by means of a preferably plate shaped screening grid **3**, and this emission is controlled by a perforated plate grid **4**. The diameters of the apertures of **4** and **3** amount to 1 mm. and the ray current passes therethrough entirely unstopped. The bias of **3** amounts to several hundred volts and may also be directly connected with the tubular member **6**. Between **3** and **6** there is mounted a cylinder **5**. The cylinder is situated nearer to **6** than to **3**, and is negative in relation to the last mentioned electrodes. The longer the cylinder **5**, the greater is the refractive power thereof, and all the more positive does its bias **5'** require to be adjusted in order to obtain a refractive power of a given kind. In particular it is possible to adjust the refractive power described in the following, in the case of zero bias of the cylinder **5**, i. e., in the case of its connection with the cathode, by making its length, the distance **7**, of suitable extent. In this way a special leading-in at **5** might be dispensed with. This measure is unimportant for the comprehension of the lens system according to the invention.

If the bias of **5** is varied, commencing with positive values, say, the value **6'**, which represents the bias of the screening grid **3** and the tubular member **6**, and the bias is made always less positive, it will be observed, preferably with the aid of plates coated with luminous salt introduced into the tubular member **6**, that the narrowest point of the bundle of rays gradually approaches from the screen more and more towards the cathode. In the case of extremely positive adjustment the ray greatly diverges, and with the bias decreased more and more the cathode image, i. e., the narrowest point of the cathode bundle, approaches all the more towards the cathode. The television tube with condensing lens system described by the applicant under application No. 733,995 was so biased that the cathode image coincided with the main lens **8**. The ray in the tube according to the present invention is preliminarily concentrated to a much smaller extent. The preliminary concentration is so weak that the image of the cathode, which can be made visible on the luminous screen **9** when the anode **10** is joined up with the tubular member 6 and the refractive force **8** is not present, just disappears again in the direction away from the screen. The wiper of the potentiometer **5'** is adjusted somewhat more on the positive side than would correspond in the case of the grid **4** being maintained positive with a sharp reproduction of the cathode surface on the luminous screen. In this case there is no longer a constricted point of the ray between the screen and the cathode, and the passage of the ray is approximately such as indicated by the lines **11**, **12**, **13**. Under this condition, therefore, that an actual cathode image, i. e., an actual constriction, does not exist along the entire path of the ray from the cathode to the screen by reason of the lens **5**, **6**, which causes the first refraction at the point **14**, i. e., that there is a thick cross-section of the ray at the point of the second lens **15**, a very sharp and bright image point may be adjusted by producing the second lens **8**, which is formed by the edge of the tubular member **6** and the anode **10**. All apertures in the diaphragms within the complete tube should be made so large that these diaphragms do not intercept any electrons of the ray. Further details regarding the diameters which are necessary for this purpose are disclosed by Fig. 2. The two lenses **14** and **15** co-operate according to known optical laws in such fashion as if a single collecting lens were situated at a resulting point between the two, for example in the plane **16**. The image of the cathode **2** on the luminous screen **9** varies in size dependent on whether this resulting lens **16** is situated nearer towards the cathode or nearer towards the luminous screen. The image is smaller if the lens **16** is situated more towards the screen. This is the case if the refractive force of the rear lens 5/6 is adjusted to be weaker and the refractive force of the front lens 6/10 to be correspondingly stronger. If vice versa the refractive force of the rear lens is made somewhat stronger, and the refractive force of the front lens weaker, by displacing the wiper **5'** towards the cathode and the wiper **6'** towards the anode, there may be again obtained a sharp cathode image which then has an enlarged diameter. If this process is continued more and more, there will ultimately be obtained a wholly blurred and large spot-like image lacking in sharpness, viz., when the refractive force of **14** alone already produces an actual image on the screen. The potential 6' of the tubular member has then reached anode potential and an electronic microscope results. The opposite extreme occurs if, upon the attempt to obtain an image point as small as possible, the refractive force of the rear lens **14** is made smaller and smaller by shifting the bias **5'** more towards the anode and accordingly increasing more and more the refractive force of the front lens **15**. In this case a limit is ultimately reached due to the fact that owing to the increasing cross-section of the ray in the anode aperture **10** or in that of the cover of the tubular member there occurs a greatly increasing loss of light intensity.

The subject matter of the invention is an operative condition of this type of two-lens system, which reproduces the cathode, or a cross-section between the cathode and the first anode **3**, and which lies between the two adjustment limits aforesaid.

The practical dimensions with which a tube of this kind, as described above theoretically was successfully employed in practice are disclosed by the dimensional drawing, Fig. 2. Tubes of this nature operated with up to ½ milliampere ray current, the inner losses being practically negligible. In case appreciable ray currents should possibly impinge during the control operation on one of the intermediate electrodes **5** or **6**, it is desirable to include short-circuit condensers **17** or **18**, which ensure a constant state of the biases. The condensers should amount to approximately $1\mu F$.

In Fig. 3 there is shown an optical image construction applicable to the present case, which reveals additional aspects in accordance with the invention with regard to the dimensioning of the size of the image point. In this figure **19** is the cathode radius to be reproduced. The location of the first lens, the rear lens **14**, and the second lens, the tubular lens **15**, is entered under the same reference numeral in Fig. 3. The image screen is designated **9**. According to the invention, the focus **20** of the rear lens **14** is so adjusted that it is situated behind the object of reproduction, i. e., behind the cathode surface **19**, as shown. The virtual intermediate image **23** of the cathode **19** is found by drawing the middle-point ray **21** and the focal ray **22**. The value **23** thus found requires to be multiplied, however, in electron optics, by the factor

$$\sqrt{\frac{e_k}{e_l}}$$

e_k being the potential of the cathode which is to be reproduced, and e_l the potential in the lens space. The first-mentioned potential is comparatively small. The potential factor accordingly results in a considerably reduced size, as quite generally the reproduction of planes in the vicinity of the cathode results in practical advantages and a reduction in the size of these images to a desirable extent owing to the low speed of the electrons which prevails at that point. The intermediate image is represented by **23'**. The potential factor is entered with ⅓ corresponding with a potential ratio of 20:200 volts. From this virtual intermediate image **23** there is projected on to the luminous screen **9** by the front lens **15** the real point image, which is found by drawing the middle-point ray **24**. The screen image **25** again requires to be multiplied by a new potential factor, viz., by the factor

$$\sqrt{\frac{e_t}{e_a}}$$

wherein e_t is the potential of the electrons in the tubular member and e_a that when passing the anode **10**. In practice this factor is approximately 0.6 corresponding with a potential ratio in the main lens of 1:2.5 (for example, 800 volts potential of the tubular member with 2,000 volts anode potential). In the case of television tubes having a very short spacing of the screen, for example tubes for projection purposes in which very small and exceedingly sharp images are to be produced, this factor is more favourable for the front lens. The factor is all the more favourable the greater the refractive force of 15 requires to be, and accordingly the greater the difference in potential between the biases of anode and tubular member.

A measure for making this difference in potential as large as possible, which is a further feature of this invention, consists in selecting as large as possible the spacing between the two field-generating electrode systems 7 and 10 in Fig. 1. In this way the intensity of the field in the case of a given difference in potential will be weakened owing to the increased distance over which the field is formed, and in order nevertheless to produce the requisite refractive force the difference in potential must be increased, i. e., the bias of the tubular member 6 reduced, whereby the speed of the electrons in the space of the tubular member is slowed down and the potential factor and accordingly the size of the image point is still further diminished.

In Fig. 3 with 25′ the image point on the screen which is actually produced is constructed, the factors 0.6 being taken into consideration. In comparing the size of this image, which may be derived with the two-lens tube, with the size of an image 26 which would be obtained in the presence of merely one single lens, the main lens 15, it is to be recognized that the point image obtained with the two-lens tube is smaller than that achieved with the single-lens tube. In addition it is to be stated that upon a distribution of the resulting refractive force over two lenses the passage of all ray electrons up to the screen is capable of being performed in practice without loss, whilst this in the case of merely one refractive force located at 15 is not possible at all without a condensing lens, and with a condensing lens is merely capable of being performed by the inclusion of a small diaphragm aperture in the vicinity of 14, if it is desired to obtain a small image point on the screen.

An additional measure according to the invention for obtaining an image point as small as possible consists in increasing the spacing 19/14 between the cathode and the first lens. An embodiment of this construction is shown in Fig. 4. Fig. 4 differs from Fig. 1 merely by the inclusion of a rear tubular member 27, the length of which may be comparatively small, as this tubuluar member is traversed by electrons having a low speed. By the inclusion of this tubular member the location of the object of reproduction, viz., the cathode surface 2, is removed further away from the location of the rear lens, viz., the plane 14 of the cylinder 5. 27 and 5 are linked up with a lower potential than 6. 5 may be connected with 27. By varying the length 7 of 5 it may again be accomplished that the tube operates with a virtual intermediate reproduction if the bias of 27 has value as low as possible. The smaller 7 is, and the greater the spacing between 5 and 6, the lower may be the biasing of 27 at the wiper 5′, and all the smaller, under conditions otherwise the same, is the size of the image point on the screen 9. It is obvious that an additional adjustment is possible of the size of the image point by adjustment of the cathode surface.

The effect obtained by the rear tubular member 27 may also be accomplished in similar fashion by withdrawing, as shown in Fig. 4*a*, the hot cathode 2 into the interior of the guide cylinder 28 surrounding the same. In this way there results in the known fashion by cooperation of the projecting edges 29 of the Wehnelt cylinder and the first anode 3 a field, which exerts a weak preliminary concentration, and which is indicated by the curved level 30. This field ensures that the cross-section of the ray is practically constant from the cathode 2 to the anode 3, the individual rays accordingly running practically parallel. There may then be adjusted a particularly extensive variation in the size of the image point by adjustment of the two lenses 5 and 6 at 14 and 15.

Tubes of the construction according to the invention are admirably suitable for receiving transmitters with different numbers of lines, as it is possible with the same always to adjust that size of image point at which the lines exactly follow one upon the other without intermediate spacing, in order to effect variation of the screen at the receiving end by simple electrical re-adjustment.

I claim:

1. A cathode ray tube, more particularly for television purposes, comprising means including a cathode for producing a beam of electrons, an image screen, a first electron-optical lens disposed between said cathode and said screen and adapted to produce a virtual electron optical image of a cross-sectional portion of said beam situated adjacent to said cathode, a second electron-optical lens disposed between said first lens and said screen and adapted to produce on said screen a sharp real electron-optical image of the virtual electron-optical image produced by said first lens, and electron deflecting means for causing this real image to sweep over said screen.

2. Electric apparatus more particularly for television purposes comprising a cathode ray tube comprising means including a cathode for producing a beam of electrons, an image screen, two electrodes mounted between said cathode and said image screen, means for maintaining said two electrodes at different potentials for causing said two electrodes to form an electron-optical lens adapted to produce a virtual electron-optical image of a cross-sectional portion of a beam situated adjacent to said cathode, two further electrodes mounted between said first electrodes and said screen, means for maintaining said further two electrodes at different potentials for causing said two electrodes to form a second electron-optical lens adapted to produce on said screen a sharp real electron-optical image of the virtual electron-optical image produced by said first lens, and electron deflecting means for causing this real image to sweep over said screen.

3. Electric apparatus more particularly for television purposes comprising a cathode ray tube comprising means including a cathode for producing a beam of electrons, an image screen, two electrodes mounted between said cathode and said image screen, adjustable means for maintaining said two electrodes at different potentials for causing said two electrodes to form an electron-optical lens adapted to produce a virtual electron-optical image of a cross-sectional portion of a beam situated adjacent to said cathode, two further electrodes mounted between said first electrodes and said screen, adjustable means for maintaining said further two electrodes at different potentials for causing said two electrodes to form a second electron-optical lens adapted to produce on said screen a sharp real electron-optical image of the virtual electron-optical image produced by said first lens, and

electron deflecting means for causing this real image to sweep over said screen.

4. The invention as claimed in claim 3, wherein the mentioned adjustable means are separately adjustable.

5. A cathode ray tube more particularly for television purposes comprising means including a cathode for producing a beam of electrons, an image screen, an electrode system comprising electrodes for forming an electron-optical lens disposed between said cathode and said screen and adapted to produce a virtual electron-optical image of a cross-sectional portion of said beam situated adjacent to said cathode, a second electron-optical lens disposed between said first lens and said screen and adapted to produce on said screen a sharp real electron-optical image of the virtual electron-optical image produced by said first lens, and electron deflecting means for causing this real image to sweep over said screen, any such of the electrodes of which said electrode system consists which are disposed in the path of said electron beam having apertures for allowing said passage of said beam, each of said apertures being at least as large as the cross-section of said beam in the plane of said aperture so that no electrons of said beam are shuttered off.

6. In apparatus as claimed in claim 3 the method of adjusting the size of the electron-optical image point on the image screen mentioned, more particularly for adapting, in a television receiving set, the size of the image point to the number of transmitted scanning lines and a desired picture size, without impairing the sharpness of the image point, comprising the steps of adjusting the potential difference between the first mentioned two electrodes and of adjusting simultaneously with said potential difference the potential difference between the second mentioned two electrodes by an alteration opposite in sense to the alteration by which the first said potential difference is adjusted.

7. A cathode ray tube, more particularly for television purposes, comprising means including a cathode for producing a beam of electrons, an image screen, a first electron-optical collecting lens disposed between said cathode and said screen and adapted to produce a virtual electron-optical image of a cross-sectional portion of said beam situated adjacent to said cathode, a second electron-optical collecting lens disposed between said first lens and said screen and adapted to produce on said screen a sharp real electron-optical image of the virtual electron-optical image produced by said first lens, and electron deflecting means for causing this real image to sweep over said screen.

8. A cathode ray tube, more particularly for television purposes, comprising means including a cathode for producing a beam of electrons, an image screen, a first electron-optical lens disposed between said cathode and said screen and adapted to produce a virtual electron optical image of a cross-sectional portion of said beam situated adjacent to said cathode, a tubular member interposed between said cathode and said first electron-optical lens, the length of said tubular member being large in comparison with the extension of said first electron-optical lens in the direction from said cathode to said image screen, a second electron-optical lens disposed between said first lens and said screen and adapted to produce on said screen a sharp real electron-optical image of the virtual electron-optical image produced by said first lens, and electron deflecting means for causing this real image to sweep over said screen.

9. A cathode ray tube, more particularly for television purposes, comprising means including a cathode and an anode for producing a beam of electrons, a Wehnelt-cylinder surrounding said cathode, a control grid mounted inside said Wehnelt cylinder, an image screen, said anode being mounted near said Wehnelt cylinder at the side thereof facing said image screen, said cathode and said control-grid being withdrawn into the interior of said Wehnelt-cylinder so that a preliminary concentration field is formed between said anode and the surface facing said anode of said cathode, a first electron-optical lens disposed between said anode and said screen and adapted to produce a virtual electron-optical image of a cross-sectional portion of said beam situated adjacent to said cathode, a second electron-optical lens disposed between said first lens and said screen and adapted to produce on said screen a sharp real electron-optical image of the virtual electron-optical image produced by said first lens, and electron deflecting means for causing this real image to sweep over said screen.

10. Electric apparatus, more particularly for television purposes comprising a cathode ray tube comprising means including a cathode for producing a beam of electrons, an image screen, two electrodes mounted between said cathode and said image screen, means for maintaining said two electrodes at different potentials for causing said two electrodes to form an electron-optical lens adapted to produce a virtual electron-optical image of a cross-sectional portion of said beam situated adjacent to said cathode, two further electrodes mounted between said first electrodes and said screen at a large distance from each other, means for applying a large potential difference between said further two electrodes for causing said two electrodes to form a second electron-optical lens adapted to produce on said screen a sharp real electron-optical image of the virtual electron-optical image produced by said first lens, and electron deflecting means for causing this real image to sweep over said screen.

KURT SCHLESINGER.