Feb. 9, 1937. R. RÜDENBERG 2,070,319

APPARATUS FOR INFLUENCING THE CHARACTER OF ELECTRON RAYS

Filed June 3, 1932 2 Sheets-Sheet 1

Fig. 1

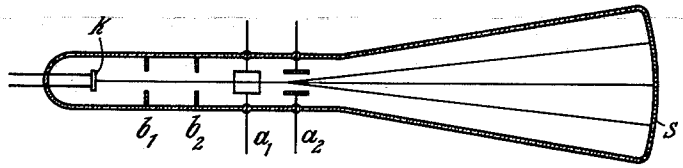


Fig. 2

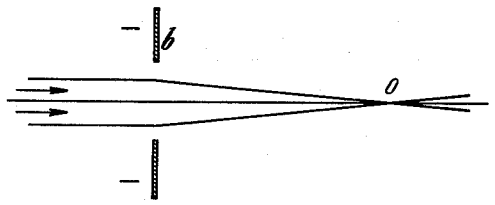


Fig. 4

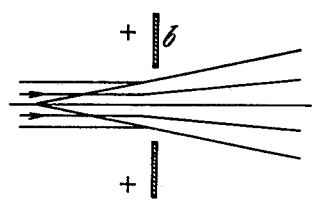


Fig. 3

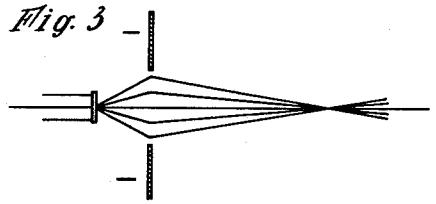
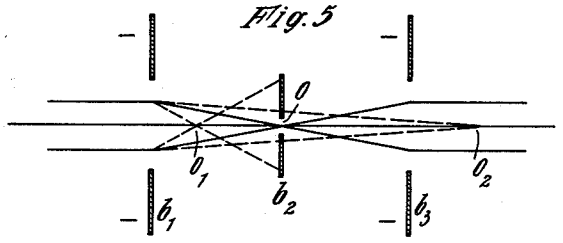


Fig. 5



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Fig. 6

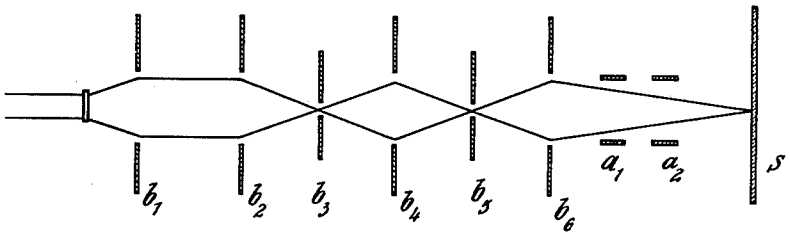
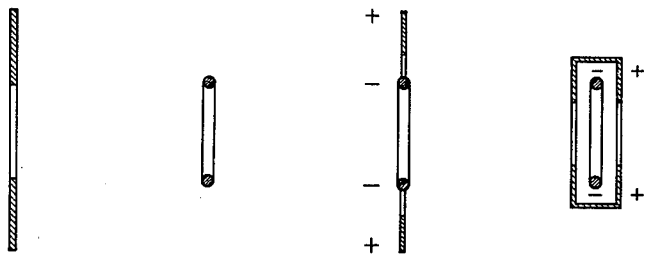


Fig. 7 Fig. 8 Fig. 9 Fig. 10



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UNITED STATES PATENT OFFICE

2,070,319

APPARATUS FOR INFLUENCING THE CHARACTER OF ELECTRON RAYS

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Application June 3, 1932, Serial No. 615,260
In Germany May 30, 1931

7 Claims. (Cl. 250—27.5)

My invention relates to improvements in apparatus for influencing the character of electron rays.

It is known to be possible to control by means of electrical and magnetic fields the course in space of electron rays, as produced and employed, for example, in cathode ray tubes by using lateral deflecting plates placed in different positions relatively to one another, and which deflect the rays in two different directions and through the control of which, therefore, any kind of figure can be traced on a screen.

The present invention relates to an arrangement by the means of which not so much the path of the electron ray beam as its character with respect to its concentration or density can be influenced. For this purpose according to the invention electrostatically controlled diaphragms, disposed substantially in symmetrical arrangement by way of surrounding the beam, by which diaphragms according to their position and electric charge the beam of electron rays is made convergent, divergent or parallel.

My invention is illustrated in the accompanying drawings in which—

Fig. 1 shows the general arrangement of a cathode ray tube with means for deflecting the ray and for influencing its character.

Figs. 2 to 6 show diagrammatically several ways for differently converging and diverging a cathode ray beam by means of differently arranged and charged diaphragms, and

Figs. 7 to 10 show in transverse section several modifications of the diaphragm shape to attain special effects.

Referring to Fig. 1, k represents the complete source of cathode rays, including the cathode and anode, not shown here in detail since the construction of such sources is well known in the art. The two pairs of deflecting plates a_1, a_2 set at 90° to one another are arranged in the customary manner in the tube so that the cathode ray beam passes between them on its way to the screen S. When varying charges are applied to these two pairs of plates the direction of the beam can be controlled and it can trace in well known manner any kind of configuration on the screen.

The locations of the aforementioned diaphragms constituting the subject matter of the present invention are indicated by b_1 and b_2.

The charged diaphragms have, contrary to the known magnetic influence through stricture fields, the advantage of having very much smaller time constants for their action and are therefore capable of responding correctly as to quantity to exceedingly rapidly occurring influences. Through the variable convergence or divergence of the individual paths of the electron beam brought about by the diaphragms, the width of the beam can be altered. It can be made narrower or broader and, therefore, its radial extension be diminished or increased. The homogeneity of the velocity of the electrons in the beam can also be increased. By such means, on the one hand, much more clearly defined light spots than hitherto obtainable can be produced on the screen s, and, on the other hand, the light spots can be blurred to a certain degree. It is furthermore possible to regulate the intensity of the beam and the light within wide limits and one is able to control all these operations with practically any desired speed from the outside through the application of variable voltages.

In Fig. 2, the electrostatic field of such a charged diaphragm is represented by its lines of force. The charge is, for example, assumed to be negative. When the electrons of a cathode ray stream through the diaphragm, they are repelled by it and have the tendency to move toward the axis. They are, therefore, deflected from their original paths, which were assumed to be parallel, toward the axis and caused to form a convergent beam terminating in a focal point o, beyond which the beam becomes divergent. As the radial component of the field strength of the diaphragm is zero in its axis and at first increases outwardly linearly, the individual electrons will be all the more deflected from their paths the greater their distance from the axis of the beam and of the diaphragm. Hereby all the rays are caused to meet in the same focal point o. To obtain with sufficient accuracy this proportionality of the radial field strength to the distance from the axis, it is advisable to make the diaphragm opening considerably larger than the diameter of the original beam.

This arrangement may be used to define more sharply the spot of light on the screen of Fig. 1. It is thus also possible to increase the brightness of the spot of light, for the pencil point of electron rays can now be obtained not only by carving out, by means of a diaphragm, the parallel center part of a bundle of rays diverging from the cathode k in all directions, but also, by employing a diaphragm of the said kind with a suitably wide opening and a correctly chosen voltage and placing it relatively close to the cathode, the outwardly straying rays can be collected and made either parallel or convergent, as shown

in Fig. 3. By this means an exceedingly greater brightness of light is obtained on the screen and the cathode beam is much more efficiently utilized.

If the potential of the diaphragm is made positive instead of negative, the individual electrons of the beam will be drawn toward the diaphragm. The parallel beam then becomes a diverging beam as shown in Fig. 4. Whilst the negative diaphragm has the effect of a convex lens in optics, the positive diaphragm has the effect of a diverging concave lens. By combining such diaphragms, all the instruments known in optics and involving converging and diverging light beams can be imitated for electron rays and thereby a series of interesting and useful results be obtained. It is in this manner possible, for example, to build a microscope for use with direct or reflected electron rays, and with which a much greater magnification can be obtained than with our optical microscopes, limited in this respect by the wave length of light.

According to the invention, said possibilities of influencing a bundle or beam of electron rays similarly to the way light rays are acted upon by optical lenses, are made use of in the following manner to influence the bundle of rays in accordance with the phenomenon to be reproduced.

For instance close to a focal point, an aperture diaphragm is placed which only permits rays of a certain velocity to pass. An arrangement of that kind is illustrated in Fig. 5. As the deflection of each individual electron depends upon its velocity, only rays of the same velocity meet in the focal point *o*. For each velocity occurring in a non-homogeneous beam of electrons, a different focal point is obtained. For example, for a beam having a range of velocities from v_1 to v_2, focal points are obtained which according to Fig. 5 are located between O_1 and O_2. If at a spot *o* within the said focal range, an aperture diaphragm b_2, without a charge or with the potential zero, is placed, only rays having the definite velocity *v* will focus at the point *o* and be able to pass through the aperture, whereas the others will strike against this aperture diaphragm and be excluded by it, either before or after they have focused as shown in dash lines. The charge thereby imparted to the aperture diaphragm can easily be led away. Behind the diaphragm, a homogeneous beam of substantially uniform velocity is obtained. If this beam is now deflected from its direction in space by deflecting plates a_1 and a_2 such as are shown in Fig. 1 or by magnetic fields, the spot of light will in its movements always retain the same sharpness owing to the deflecting fields being able to deflect all parts of the beam at the same angle of deflection, depending upon their field strength and upon the uniform velocity of the rays.

By varying the negative strength of the controllable diaphragm b_1, the velocity of the beam passing through the aperture diaphragm b_2 can be varied at will. It can, therefore, easily be adjusted to a value, at which the velocities occurring in the beam can be utilized to best advantage. Should it be desired to make the beam leaving the diaphragm b_2 in a diverging form parallel again, all that is required is to place a second negatively charged convergence diaphragm b_3 at the same distance as b_1 from the focal point *o*, and to impart to it the same potential, as b_1. The charge on diaphragm b_3 must therefore be adjustable and controllable simultaneously with that on diaphragm b_1.

In a similar manner the intensity of the beam may be varied. Let us assume that, in Fig. 5, the beam coming from the left has an approximately homogeneous velocity, then it will only be able to pass through the opening of the aperture diaphragm b_2 when the controlling diaphragm b_1 has a quite definite voltage. At every other voltage of the diaphragm b_1, large portions of the beam will strike against the aperture diaphragm itself and cannot pass through its opening. It is, therefore, possible by controlling the voltage, to vary to a great extent the intensity of the beam passing through the diaphragm. By choosing the proper kind of opening for diaphragm b_2, both with respect to size and shape, the change in intensity of the beam passing through it can be made completely or approximately proportional to the variation of the voltage of the diaphragm b_1. The intensity of the beam can, therefore, be controlled in a simple manner and for any desired velocity. As the intensity of the impression of the light on the luminous screen is not exactly proportional to the intensity of the beam, and as the effect on the eye or on the photographic plate or on any other receiver is not proportional to the light intensity of the luminous screen, all these relations can be taken into account in choosing the shape of the diaphragm *o*, in order to obtain a proportional or other functional relation between the last impression and the controlling voltage of the diaphragm b_1.

In Fig. 6 is illustrated a manner in which the various effects of the electrostatic diaphragms may be combined. From the cathode *k*, a divergent beam is emitted, which passes through the suitably charged diaphragm b_1 by which it is made almost parallel. The properly charged diaphragm b_2 concentrates the beam and throws through the opening in the uncharged aperture diaphragm b_3 only the rays having the desired velocity. Under certain conditions b_1 and b_2 can be joined into one. Thus, a homogeneous divergent beam is projected through diaphragm b_4, which may carry a pulsating charge, and thus the beam is passed to the diaphragm b_5 through the opening of which only the rays pass which vary in intensity. The charged diaphragm b_6 concentrates on to the luminous screen *s* the divergent beam coming from b_5. The diaphragm b_6 may be controlled in dependence on b_4, in order again to concentrate on the luminous screen *s* also the rays partly screened off and having a different focal point outside of b_5. By means of the deflecting plates a_1 and a_2, the homogeneous beam varying in its intensity can now be easily and accurately moved in the direction of the various coordinates.

Regarding the shape to be given to the electrostatic diaphragm, there are various possibilities producing differing results. The simplest form is that of the disk-diaphragm according to Fig. 7 with a round opening. Another shape is represented by a circular ring, as in Fig. 8, also producing an axially symmetrical field, which is proportional to the distance from the axis. By combining the ring with the disk-diaphragm, as in Fig. 9, the two being similarly or contrarily charged or only having a difference in voltage, the course of the field can be varied in the effective deflecting zone. A similar variation is also obtained by means of a combination of a circular ring with a surrounding differently charged cas-

ing, as in Fig. 10. To obtain a sharp lens- or focus-effect, forms of electrodes or diaphragms with edges forming such curves are employed that their effect upon the electron beam passing through them only takes place within a narrowly limited zone, and that within that zone the radial field strength is as proportional as possible to the distance from the axis, whilst the axial field strength to the right and left of the diaphragm is symmetrical in its course, in order that the additional axial acceleration and retardation of the electrons cancel each other in their effect.

By means of the described arrangements, it is possible to obtain clear and sharp images on the luminous screen *s*, said images giving, when the fields of the diaphragms and the deflecting fields are suitably adjusted and controlled, the impression of a stationary moving picture frame.

I claim as my invention:

1. A tube containing a source for producing a beam of electrically charged rays of a given diameter and normally extending substantially in line with a given tube axis, an apertured diaphragm in said tube having its aperture disposed symmetrically to said tube axis, said aperture being substantially larger than the beam diameter to permit the passage of the entire beam, said diaphragm adapted to be electrically charged at a suitable negative potential with respect to said beam source and being spaced therefrom for converging some of the beam rays with respect to others, and a second apertured diaphragm, spaced entirely independent from the first diaphragm in the direction of the beam travel, and having its aperture also disposed symmetrically to the tube axis, said second diaphragm aperture being of smaller diameter than the first diaphragm aperture to permit the passage only of those beam rays deflected by the first diaphragm, which focus in the aperture of the second diaphragm, whereby only rays of similar speed are permitted to pass through the second diaphragm.

2. A tube containing a source for producing a beam of electrically charged rays of a given beam diameter, and normally extending substantially in line with a given tube axis, an apertured diaphragm in said tube having its aperture disposed symmetrically to said tube axis, said aperture being substantially larger than said beam diameter to permit the passage of the entire beam, said diaphragm adapted to be electrically charged at a suitable negative potential with respect to said source and being spaced therefrom for converging the rays of the beam, a second apertured diaphragm spaced entirely independent from the first diaphragm in the direction of the beam travel, and having its aperture also disposed symmetrically to the tube axis, said second diaphragm aperture being of smaller diameter than the first diaphragm aperture to permit the passage only of those beam rays converged by the first diaphragm, which focus in the aperture of the second diaphragm, whereby only rays of similar speed are permitted to pass through the second diaphragm, and a third apertured diaphragm having its aperture disposed in the tube axis and having a larger diameter than the beam, said third diaphragm being spaced in the beam direction from the second diaphragm to converge the diverging beam rays emanating from the aperture of said second diaphragm, when a charge negative with respect to said source is applied to said third diaphragm.

3. A device for influencing the individual rays of a beam of electrically charged rays of a given diameter, comprising a tube containing a source for producing said beam in a direction normally extending substantially in line with a given tube axis, an apertured diaphragm in said tube having its aperture disposed symmetrically to the tube axis, said aperture being substantially larger than the beam diameter to permit the passage of the entire beam, said diaphragm adapted to be electrically charged at a suitable negative potential with respect to said source and being spaced therefrom for converging the rays of the beam, a second apertured diaphragm spaced entirely independent from the first diaphragm in the direction of the beam travel, and having its aperture also disposed symmetrically to the tube axis, said second diaphragm aperture being of smaller diameter than the first diaphragm aperture to permit the passage only of those beam rays converged by the first diaphragm, which focus in the aperture of the second diaphragm, whereby only rays of similar speed are permitted to pass through the second diaphragm, and a third apertured diaphragm having its aperture disposed in the tube axis and of a larger diameter than the beam diameter, said third diaphragm being spaced in the beam direction from the second diaphragm, and adapted to be charged at a suitable negative potential with respect to said source to converge the diverging beam rays emanating through said second diaphragm, said first and third diaphragm being equally spaced from the second diaphragm.

4. A device for influencing the individual rays of a beam of electrically charged rays of a given diameter, comprising a tube containing a source for producing said beam in a direction normally extending substantially in line with a given tube axis, an apertured diaphragm in said tube having its aperture disposed symmetrically to the tube axis, said aperture being substantially larger than the beam diameter to permit the passage of the entire beam, said diaphragm being spaced from said source and adapted to be negatively charged with respect to said source for converging the rays of the beam, a second apertured diaphragm spaced entirely independent from the first diaphragm in the direction of the beam travel, and having its aperture also disposed symmetrically to the tube axis, said second diaphragm aperture being of smaller diameter than the first diaphragm aperture to permit the passage only of those beam rays converged by the first diaphragm, which focus in the aperture of the second diaphragm, whereby only rays of similar speed are permitted to pass through the second diaphragm, and a third apertured diaphragm having its aperture disposed in the tube axis and of a larger diameter than the beam diameter, said third diaphragm being spaced in the beam direction from the second diaphragm, and adapted to be polarized similar to said first diaphragm with respect to said source to converge the diverging beam rays emanating from said second diaphragm, a screen onto which the beam is projected, and suitably charged deflecting plates arranged on opposite sides of said beam for deflecting the entire beam from its normal direction, said plates being disposed between the screen and said diaphragms.

5. A device for influencing the individual rays of a beam of electrically charged rays of a given diameter, comprising a tube containing a source for producing said beam in a direction normally extending substantially in line with a given tube axis, an apertured diaphragm in said tube hav-

ing its aperture disposed symmetrically to the tube axis, said aperture being sufficiently large to permit the passage of the entire beam, said diaphragm adapted to be suitably polarized with respect to said source and being spaced therefrom for differently deflecting some of the beam rays with respect to others, said diaphragm being composed of a plurality of concentric elements, spaced from one another to permit their charge at different potentials.

6. A device for influencing the individual rays of a beam of electrically charged rays of a given diameter, comprising a tube containing a source for producing said beam in a direction normally extending substantially in line with a given tube axis, an apertured diaphragm in said tube having its aperture disposed symmetrically to the tube axis, said aperture being sufficiently large to permit the passage of the entire beam, said diaphragm adapted to be suitably polarized with respect to said source and being spaced therefrom for differently deflecting some of the beam rays with respect to others, said diaphragm being composed of a plurality of concentric elements located in one plane and spaced from one another to permit their charge at different potentials.

7. A device for influencing the individual rays of a beam of electrically charged rays of a given diameter, comprising a tube containing a source for producing said beam in a direction normally extending substantially in line with a given tube axis, an apertured diaphragm in said tube having its aperture disposed symmetrically to the tube axis, said aperture being sufficiently large to permit the passage of the entire beam, said diaphragm adapted to be suitably polarized with respect to said source and being spaced therefrom for differently deflecting some of the beam rays with respect to others, said diaphragm being composed of two concentric elements having different size apertures, one element surrounding the other, said elements being spaced apart from one another to permit their charge at different potentials.

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