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ELECTROSTATIC ELECTRON LENS SYSTEM

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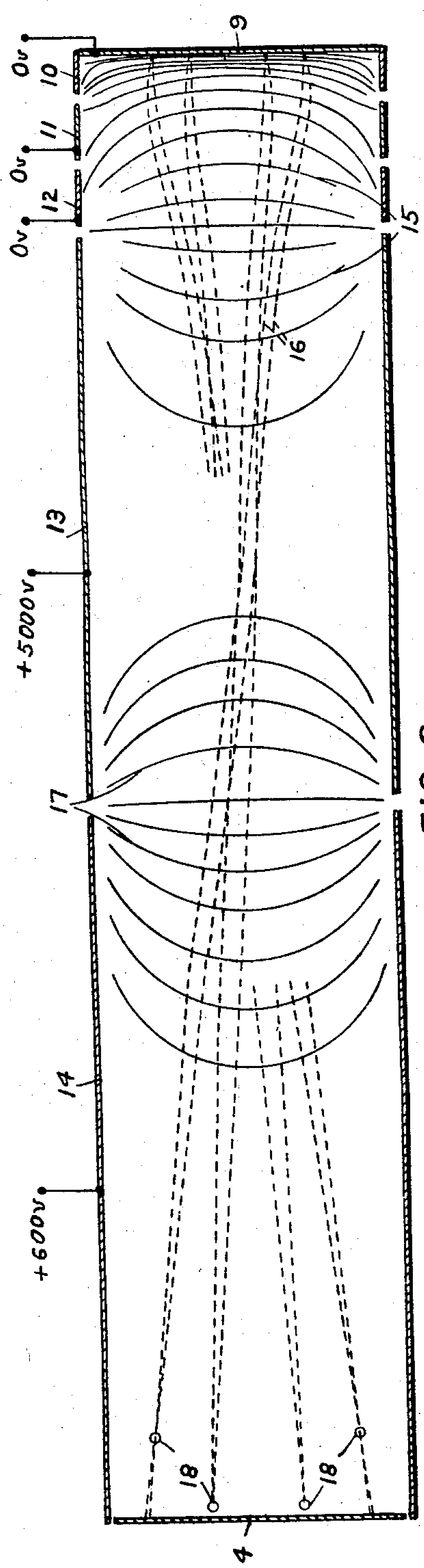

FIG. 2

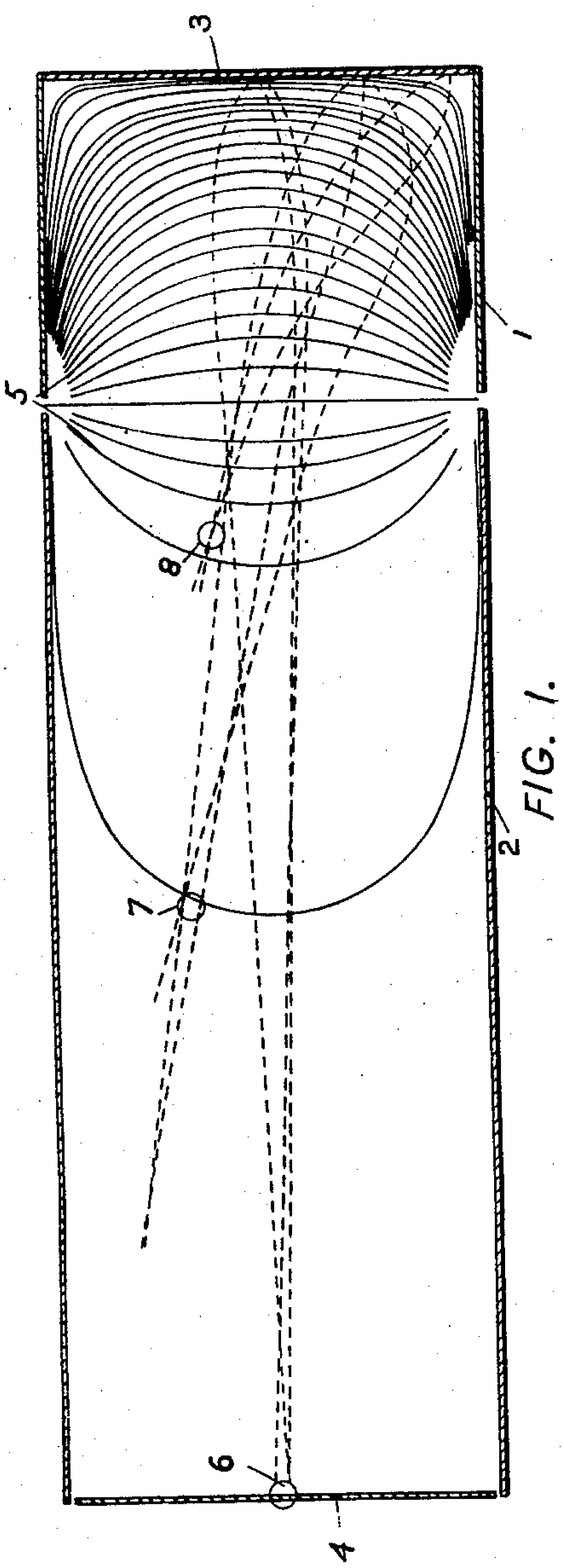

FIG. 1.

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ELECTROSTATIC ELECTRON LENS SYSTEM

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The invention relates to electrostatic electron lens systems for focussing composite beams of electrons as distinct from lenses for focussing fasciculated beams.

Electrostatic electron lenses for focussing composite beams, such as an electron image of an optical object, onto a mosaic target electrode or fluorescent screen are known and have comprised two cylindrical electrodes to which different potentials are applied for setting up an electrostatic focussing field. The focussing field may serve to focus an electron image emitted from a photo-electric cathode, which is disposed adjacent to the electrode maintained at the lower potential, but it is found with these lenses that considerable curvature of the focussed electron image occurs. Thus, assuming that the photoelectric cathode is plane, it is of course desirable that a plane image be formed on the target electrode or fluorescent screen. However, with the known form of lens referred to above, the electron image, instead of being focussed in a plane, is in focus on an acutely curved surface which is concave facing the cathode with the result that, if it is desired to employ a plane target electrode or fluorescent screen, the image, whilst being in focus on the axis of the system, is nevertheless widely out of focus at positions remote from the axis. In this known type of lens the radius of curvature of the image with a magnification factor of 1.7 is found to be as much as 0.13 of the radius of the second cylindrical electrode of the lens.

The object of the present invention is to provide an improved electrostatic electron lens system which does not introduce as much image curvature as in the known type of lens referred to above.

According to the present invention an electrostatic electron lens system is provided for focussing a composite beam of electrons, comprising a source of electrons from which a composite beam can be produced, a plurality of electrodes to which potentials are applied so as to form first and second electron lenses, the first lens being arranged to cause pencils of electrons from said source to converge towards the axis of the system whilst said second lens is arranged to cause said convergent pencils to be focussed, the electrode of said second lens which is more remote from said source being maintained at a potential which is less than (and preferably less than 0.4 of) the potential applied to an electrode of said second lens which is nearer to said source.

Lens systems in accordance with the present invention can be designed to produce unity magnification or magnification greater than unity or demagnification.

In order that the said invention may be clearly understood and readily carried into effect it will now be more fully described with reference to the accompanying drawings, in which:

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Figure 1 represents diagrammatically the known form of lens referred to above, and,

Figure 2 is a similar view illustrating a lens according to one embodiment of the present invention.

As shown in Figure 1 of the drawings, the lens comprises a pair of tubular electrodes 1 and 2 which are of circular form in cross-section, the electrode 1 being connected to a photoelectric cathode 3 which emits electrons when an optical image is projected thereon, the lens formed by the electrodes 1 and 2 being intended to focus the electron image on to a plane surface 4 which may be a target electrode or a fluorescent screen. In operating the lens, the electrode 1 may be maintained at the potential of the cathode 3, which may be zero potential, and the electrode 2 is maintained at a positive potential. The maintenance of the two electrodes 1 and 2 at the different potentials mentioned serves to set up an electrostatic focussing field, the equi-potential surfaces of which are indicated by the full lines 5. The dotted lines indicated in Figure 1 illustrate pencils of electrons emitted from the photo-electric cathode, and it will be observed from this figure that the electron pencils are rather wide and, furthermore the image points of the axial, zonal and marginal electron pencils indicated at 6, 7 and 8 respectively show that the curvature in the image is considerable, so that, whilst the axial electron pencils will be in focus at the surface 4, the marginal electron pencils will be widely out of focus. In this form of lens the curvature of the image formed on the surface 4 is as high as 0.13 of the radius of the electrode 2.

Figure 2 of the drawings illustrates a lens in accordance with the present invention and in this figure the photoelectric cathode is indicated by the reference numeral 9 and the plane surface such as the target electrode or fluorescent screen on which the image is to be focussed is indicated at 4. Adjacent to the cathode 9 is a series of tubular or ring-shaped electrodes 10, 11 and 12 followed by a longer tubular electrode 13 which together with the electrodes 10, 11 and 12 form a first electron lens. The electrode 13 is followed by a further tubular electrode 14 the electrodes 13 and 14 forming a second electron lens. In one specific example of a lens system according to the invention, the photo-electric cathode 9 may have a diameter of 5 centimetres, the electrode 10 which is connected to the cathode 9 a diameter of 5 centimetres and a length of 0.4 centimetre, the electrodes 11 and 12 a diameter of 5 centimetres and each a length of 0.5 centimetre, the electrode 13 a diameter of

5 centimetres and a length of 8 centimetres and the electrode **14** a diameter of 5 centimetres and a length of 17 centimetres. In operation the electrodes **10**, **11** and **12** may be maintained at the same potential as the photo-electric cathode **9** namely at zero potential, the electrode **13** at a positive potential of 5000 volts and the electrode **14** at a positive potential which is less than 0.4 of the potential of the electrode **13**. Preferably the potential of the electrode **14** is between 500 and 1000 volts, say at 600 volts. The equipotential surfaces set up by the first electron lens are indicated in full lines at **15** and the pencils of electrons emitted by the photo-electric cathode **9** by the dotted lines **16**. The equi-potential surfaces set up between the electrodes **13** and **14** are indicated in full lines **17**. It will be observed from a comparison of Figures 1 and 2 that in the arrangement according to the invention, the pencils of electrons **16** are narrow owing to the relatively higher field which is produced at the cathode **9** with the result that all of the rays of the pencil traverse a similar field and the depth of focus is small and the pencils are converged towards the axis of the system. The electrons in said pencils are initially slightly converged by the first electron lens and they then move in a nearly field-free region before the electrons in said pencils are converged and focussed by the second lens formed between the electrodes **13** and **14**. Hence, by the time the electron pencils reach this last-mentioned lens they are near the axis of the system, so that this latter lens introduces little aberration. The result of the lens system according to the invention is that the curvature of the image formed on the surface **4** is less compared with the lens shown in Figure 1 as is evidenced from the image points of the marginal electron pencils indicated at **18** in Figure 2. With a lens system according to the invention with the dimensions of electrodes and potentials as stated above the radius of curvature of the images was found to be 0.3 of the diameter of the electrode **14** with a magnification factor of 1.7.

Although, as stated above, the electrodes **10**, **11** and **12** may be maintained at the same potential as the photo-electric cathode **9**, it may, in some cases, be advantageous to maintain the electrodes **11** and **12** at progressively higher potentials than that of the cathode **9**. The size of the various electrodes of the system and the potentials applied thereto control the size of the image formed on the surface **4** and obviously the size of these electrodes and the potentials will be adjusted to produce a desired size of image.

In optics the well known Petzval's formula can be used to determine the curvature of an image and such formula can also be used in electron-optics. Such formula is:

$$\frac{1}{C}=N_n'\sum\left[\left\{1-\frac{N_j}{N_j'}\right\}\times\frac{1}{N_j r_j}\right] \qquad (1)$$

where C is the radius of curvature of the image surface at the axis, N_n' the refractive index of the image space, and N_j, N_j' are the indices on either side of the jth refracting surface of radius r_j. For electron optics, since the refractive index is proportional to $\sqrt{V}$, we have

$$N_j=\frac{\sqrt{V_{j-1}}+\sqrt{V_j}}{2},\; N_j'=\frac{\sqrt{V_j}+\sqrt{V_{j+1}}}{2}$$

where V_j is the potential of the equipotential j. If the surfaces are so selected that the refractive index N_j'/N_j is constant at each surface, Formula 1 is simplified to

$$\frac{1}{C}=\text{const } x.\sqrt{V_n'}\sum\frac{1}{\frac{\sqrt{V_{j-1}}+\sqrt{V_j}}{2}\cdot r_j} \qquad (2)$$

The sign convention for (1) and (2) is as follows: C and r_j have the same sign if $V_{j+1}<V_j$ and opposite signs if $V_{j+1}>V_j$.

It is thus seen that by measuring the axial radius of curvature of each equipotential the image curvature on the axis is easily found, and hence by employing said formula the design of lens according to the invention is facilitated.

I claim:

1. A circuit arrangement comprising an electron discharge device having an electrostatic electron lens system for focussing a composite beam of electrons, a source of electrons for producing a composite electron beam, a plurality of electrodes, means for applying electric potentials to a portion of said electrodes to produce an electron lens for converging pencils of electrons from said source towards the axis of the system, means for applying electric potentials to a portion of said electrodes to produce a second electron lens for focussing said convergent pencils of electrons, said latter means for applying electric potentials being proportioned to maintain an electrode of said second lens which is more remote from said source at a lower potential than that of an electrode of said second lens nearer the source.

2. A circuit arrangement according to claim 1, said source being a plane photoelectric cathode.

3. A circuit arrangement comprising an electron discharge device having an electrostatic electron lens system for focussing a composite beam of electrons, a source of electrons for producing a composite electron beam, a plurality of electrodes, means for applying electric potentials to a portion of said electrodes to produce an electron lens for converging pencils of electrons from said source towards the axis of the system, means for applying electric potentials to a portion of said electrodes to produce a second electron lens for focussing said convergent pencils of electrons, said latter means for applying electric potentials being proportioned to maintain an electrode of said second lens which is more remote from said source at a potential less than 0.4 that of an electrode of said second lens nearer to said source.

4. A circuit arrangement according to claim 3, said source being a plane photoelectric cathode.

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