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X-RAY APPARATUS

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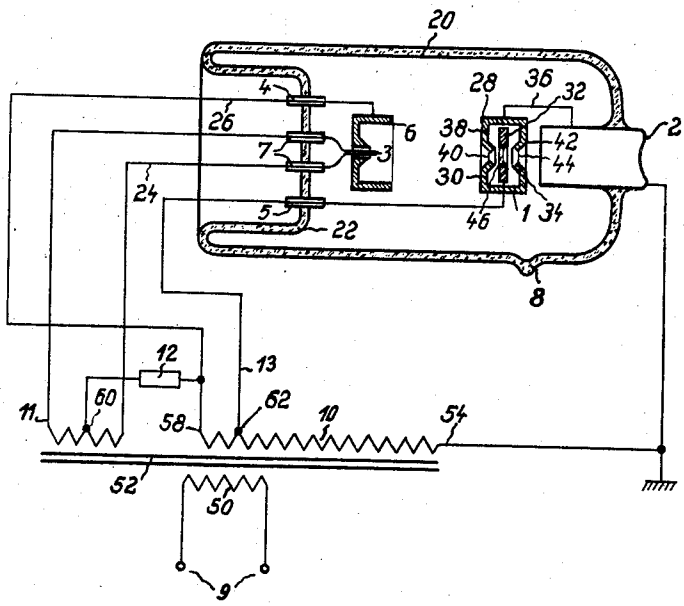

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X-RAY APPARATUS

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9 Claims. (Cl. 313—57)

The present invention relates to an X-ray apparatus and particularly to an X-ray apparatus having an X-ray tube having an electrostatic lens.

The present application is a continuation-in-part of the copending application Serial No. 300,587, filed July 24, 1952, for "X-Ray Tube," now Patent No. 2,683,223.

It is an object of the present invention to provide an X-ray apparatus having a focal spot which is as small as possible.

It is another object of the present invention to provide an X-ray apparatus which is suitable for microscopic investigations.

An X-ray apparatus according to the present invention comprises an X-ray tube including a cathode emitting electrons and an anode struck by the electrons emitted by the cathode and thus emitting X-rays, an electrostatic lens having a high refractive power and being arranged between the cathode and the anode, the electrostatic lens having a first portion, a third portion and a second portion arranged consecutively in the path of the electrons from the cathode to the anode and provided, respectively, with aligned openings, means for maintaining the first and second portions of the electrostatic lens substantially at the same potential as the anode, and means for maintaining the third portion of the electrostatic lens substantially at or near the potential of the cathode, whereby the electrons are strongly accelerated between the cathode and the first portion of the electrostatic lens, are subsequently brought substantially to a standstill while they approach the opening of the third portion of the electrostatic lens, and are finally accelerated again when they have passed the opening of the third portion of the electrostatic lens and are under the influence of the potential of the anode so that a punctiform focal spot is generated on the anode.

Preferably the portions of the electrostatic lens are arranged closely to one another so as to obtain an electrostatic lens having a high refractive power.

In a preferred embodiment of the present invention the electrostatic lens is arranged at a distance from the anode being a minor fraction of the distance between the cathode and the anode.

A preferred embodiment of the present invention comprises a Wehnelt cylinder surrounding the cathode and having a potential being preferably slightly lower than the potential of the cathode.

Preferably the cathode is formed as a flat spiral or a hairpin.

In a preferred embodiment of the present invention the electrostatic lens has a first and a second portion each formed by a disc having a central hollow projection provided with a first and second opening, respectively, said projections facing each other at a spacing distance, and a third portion formed as a disc located in the space between said first and second portions and provided with a third opening, said first, third and second openings being aligned with each other so as to be arranged consecutively in the path of the electrons from the cathode to the anode.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

The single figure is a diagrammatic sectional elevation of an X-ray tube showing the wiring diagram of the connections of the electrodes of the tube.

Referring now to the drawing the X-ray tube comprises an oblong envelope **20** one end of which carries an anode **2** whereas the opposite end forms a stem **22** provided with sealings **4**, **7** and **5** leading to the electrodes of the tube to be described hereinafter. The sealings **7** carry conductors **24** leading to a cathode **3** shown as a hairpin. It should be understood however that the cathode may be formed by a flat spiral of very closely wound wire having an external diameter being preferably less than 3 mm.

The cathode **3** is surrounded by a Wehnelt cylinder **6** which is connected to a conductor **26** passing through the sealing **4**.

Between the cathode **3** and the anode **2** an electrostatic lens generally denoted by **28** is arranged so that the distance thereof from the anode **2** amounts to approximately one fifth of the distance between the cathode **3** of the Wehnelt cylinder **6** and the anode **2**. The electrostatic lens comprises a first portion **30**, a third portion **32** and a second portion **34**. In the shown embodiment the first and second portions **30** and **34** form a single metallic piece connected by a conductor **36** to the anode **2**. Preferably the first portion **30** includes a disc having a central hollow projection **38** provided with a first opening **40** whereas the second portion **34** includes a similar disc having a central hollow projection **42** provided with a second opening **44**. The third portion **32** of the electrostatic lens **28** consists also of metal and is formed as a disc insulated from the first and second portions **30** and **34** and having a central opening **46** termed hereinafter the third opening. The three openings **40**, **46** and **44** are aligned with one another so as to be arranged consecutively in the path of the electrons traveling from the cathode **3** to the anode **2** where they cause an X-ray radiation leaving the envelope **20** through the X-ray window **8** preferably formed by a dome-shaped part having a very small wall thickness preferably amounting to a few thousandths of a millimeter. In the drawing the wall thickness of the window **8** is shown on a greatly enlarged scale.

The distance between the first opening **40** and the second opening **44** is very small and amounts to 8 mm. or less so that the electrostatic lens **28** has a high refractive power and a focal length of a few mm.

The electrodes of the X-ray tubes are supplied with potentials as follows: The primary **50** of a transformer **52** is connected to a voltage source **9**. The transformer **52** has two secondaries **10** and **11**. One end **54** of the secondary **10** is grounded and connected by a conductor **56** with the anode **2** of the tube. The other end **58** of the secondary **10** is connected through the conductor **26** to the Wehnelt cylinder **6** and through a resistor **12** to the midpoint **60** of the other secondary **11** which is connected through the conductors **24** with the cathode **3**. It should be understood that the secondary **10** generates a high voltage applied to the Wehnelt cylinder **6** and the cathode **3** with respect to the anode **2** whereas the secondary **11** generates only a voltage which is sufficient to produce a heating current in the hairpin cathode **3**.

A conductor **13** leads from a tap **62** of the secondary **10** being rather close to the end **58** thereof to the third

portion 32 of the electrostatic lens which is therefore maintained at a potential being substantially equal to those of the Wehnelt cylinder 6 and the cathode 3.

The operation of this device is as follows:

If the transformer 52 is switched on the cathode 3 emits electrons which cause directly in front of the cathode a potential field having the effect of a lens with slightly negative refractive power. The potential of the Wehnelt cylinder 6 is preferably chosen so as to be slightly lower than that of the cathode 3 so that the Wehnelt cylinder 6 acts as a tele-lens on the electrons. On the front surface of the Wehnelt cylinder 6 facing the anode 2 a potential field is built up having the effect of a lens of positive refractive power so that the electrons emitted by the glow cathode 3 are concentrated at a single point lying far in front of the cathode 3.

The electrons are strongly accelerated between the cathode 3 and the first portion 30 of the electrostatic lens 28. When the electrons have passed the opening 40 in the first portion 30 they are brought substantially to a standstill by the third portion 32 which is at a potential substantially equalling that of the cathode 3 and the Wehnelt cylinder 6. Finally the electrons are accelerated again when they traverse the distance between the second opening 46 and the second opening 44 so that they are concentrated so as to form a fine focal spot at the anode 2.

By adjusting the tap 62 the potential of the third portion 32 can be adjusted. By a suitable choice of the resistor 12 the proper potential of the Wehnelt cylinder 6 is obtained at a predetermined anode current.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of X-ray apparatuses differing from the types described above.

While the invention has been illustrated and described as embodied in an X-ray apparatus having an X-ray tube having an electrostatic lens, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. An X-ray apparatus, comprising, in combination, an X-ray tube including a cathode emitting electrons and an anode struck by the electrons emitted by said cathode and thus emitting X-rays; an electrostatic lens having a high refractive power and a short focal length and being arranged between said cathode and said anode, said electrostatic lens being substantially closer to said anode than to said cathode and having a first portion, a third portion and a second portion arranged consecutively in the path of the electrons from said cathode to said anode and provided, respectively, with aligned openings; means for maintaining said first and second portions of said electrostatic lens substantially at the same potential as said anode; and means for maintaining said third portion of said electrostatic lens substantially at the potential of said cathode, whereby the electrons are strongly accelerated between said cathode and said first portion of said electrostatic lens, are subsequently brought substantially to a standstill while they approach said opening of said third portion of said electrostatic lens, and are finally accelerated again when they have passed said opening of said third portion of said electrostatic lens and are under the influence of the potential of said anode so that a punctiform focal spot is generated on said anode.

2. An X-ray apparatus, comprising, in combination, an X-ray tube including a cathode emitting electrons and an anode struck by the electrons emitted by said cathode and thus emitting X-rays; a Wehnelt cylinder surrounding said cathode and having a potential slightly lower than the potential of said cathode; an electrostatic lens having a high refractive power and a short focal length and being arranged between said cathode and said anode, said electrostatic lens being substantially closer to said anode than to said cathode and having a first portion, a third portion and a second portion arranged consecutively in the path of the electrons from said cathode to said anode and provided, respectively with aligned openings; means for maintaining said first and second portions of said electrostatic lens substantially at the same potential as said anode; and means for maintaining said third portion of said electrostatic lens substantially at the potential of said cathode, whereby the electrons are strongly accelerated between said cathode and said first portion of said electrostatic lens, are subsequently brought substantially to a standstill while they approach said opening of said third portion of said electrostatic lens, and are finally accelerated again when they have passed said opening of said third portion of said electrostatic lens and are under the influence of the potential of said anode so that a punctiform focal spot is generated on said anode.

3. An X-ray apparatus, comprising, in combination, an X-ray tube including a cathode emitting electrons and an anode struck by the electrons emitted by said cathode and thus emitting X-rays; a Wehnelt cylinder surrounding said cathode and having a potential slightly lower than the potential of said cathode; an electrostatic lens having a high refractive power and a short focal length and being arranged between said cathode and said anode, said electrostatic lens having a first portion, a third portion and a second portion arranged consecutively in the path of the electrons from said cathode to said anode and provided, respectively, with aligned openings, said portions of said electrostatic lens being arranged closely to one another, said electrostatic lens being arranged at a distance from said anode being a minor fraction of the distance between said cathode and said anode; means for maintaining said first and second portions of said electrostatic lens substantially at the same potential as said anode; and means for maintaining said third portion of said electrostatic lens substantially at the potential of said cathode, whereby the electrons are strongly accelerated between said cathode and said first portion of said electrostatic lens, are subsequently brought substantially to a standstill while they approach said opening of said third portion of said electrostatic lens, and are finally accelerated again when they have passed said opening of said third portion of said electrostatic lens and are under the influence of the potential of said anode so that a punctiform focal spot is generated on said anode.

4. An X-ray apparatus, comprising, in combination, an X-ray tube including a cathode emitting electrons and an anode struck by the electrons emitted by said cathode and thus emitting X-rays; an electrostatic lens having a high refractive power and a short focal length and being arranged between said cathode and said anode, said electrostatic lens being substantially closer to said anode than to said cathode and having a first and a second portion each formed by a disc having a central hollow projection provided with a first and second opening, respectively, said projections facing each other at a spacing distance, and a third portion formed as a disc located in the space between said first and second portions and provided with a third opening, said first, third and second openings being aligned with each other so as to be arranged consecu-

tively in the path of the electrons from said cathode to said anode; means for maintaining said first and second portions of said electrostatic lens substantially at the same potential as said anode; and means for maintaining said third portion of said electrostatic lens substantially at the potential of said cathode, whereby the electrons are strongly accelerated between said cathode and said first portion of said electrostatic lens, are subsequently brought substantially to a standstill while they approach said opening of said third portion of said electrostatic lens, and are finally accelerated again when they have passed said openings of such third portion of said electrostatic lens and are under the influence of the potential of said anode so that a punctiform focal spot is generated on said anode.

5. An X-ray apparatus, comprising, in combination, an X-ray tube including a cathode emitting electrons and an anode struck by the electrons emitted by said cathode and thus emitting X-rays; a Wehnelt cylinder surrounding said cathode and having a potential slightly lower than the potential of said cathode; an electrostatic lens having a high refractive power and a short focal length and being arranged between said cathode and said anode, said electrostatic lens being substantially closer to said anode than to said cathode and having a first and a second portion each formed by a disc having a central hollow projection provided with a first and second opening, respectively, said projections facing each other at a spacing distance, and a third portion formed as a disc located in the space between said first and second portions and provided with a third opening, said first, third and second openings being aligned with each other so as to be arranged consecutively in the path of the electrons from said cathode to said anode; means for maintaining said first and second portions of said electrostatic lens substantially at the same potential as said anode; and means for maintaining said third portion of said electrostatic lens substantially at the potential of said cathode, whereby the electrons are strongly accelerated between said cathode and said first portion of said electrostatic lens, are subsequently brought substantially to a standstill while they approach said opening of said third portion of said electrostatic lens, and are finally accelerated again when they have passed said opening of said third portion of said electrostatic lens and are under the influence of the potential of said anode so that a punctiform focal spot is generated on said anode.

6. An X-ray apparatus, comprising, in combination, an X-ray tube including a cathode emitting electrons and an anode struck by the electrons emitted by said cathode and thus emitting X-rays; a Wehnelt cylinder surrounding said cathode and having a potential slightly lower than the potential of said cathode; an electrostatic lens having a high refractive power and a short focal length and being arranged between said cathode and said anode, said electrostatic lens having a first and a second portion each formed by a disc having a central hollow projection provided with a first and second opening, respectively, said projections facing each other at a spacing distance, and a third portion formed as a disc located in the space between said first and second portions and provided with a third opening, said first, third and second openings being aligned with each other so as to be arranged consecutively in the path of the electrons from said cathode to said anode, said portions of said electrostatic lens being arranged closely to one another, said electrostatic lens being arranged at a distance from said anode being a minor fraction of the distance between said cathode and said anode; means for maintaining said first and second portions of said electrostatic lens substantially at the same potential as said anode; and means for maintaining said third portion of said electrostatic lens substantially at the potential of said cathode, whereby the electrons are strongly accelerated between said cathode and said first portion of said electrostatic lens, are subsequently brought substantially to a standstill while they approach said opening of said third portion of said electrostatic lens, and are finally accelerated again when they have passed said opening of said third portion of said electrostatic lens and are under the influence of the potential of said anode so that a punctiform focal spot is generated on said anode.

7. An X-ray apparatus as set forth in claim 1, wherein said cathode is formed as a hairpin.

8. An X-ray apparatus as set forth in claim 3, wherein said cathode is formed as a hairpin.

9. An X-ray apparatus as set forth in claim 6, wherein said cathode is formed as a hairpin.

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