Nov. 21, 1933. W. D. COOLIDGE 1,936,424

ELECTRICAL DISCHARGE DEVICE AND METHOD OF OPERATION

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Fig. 1.

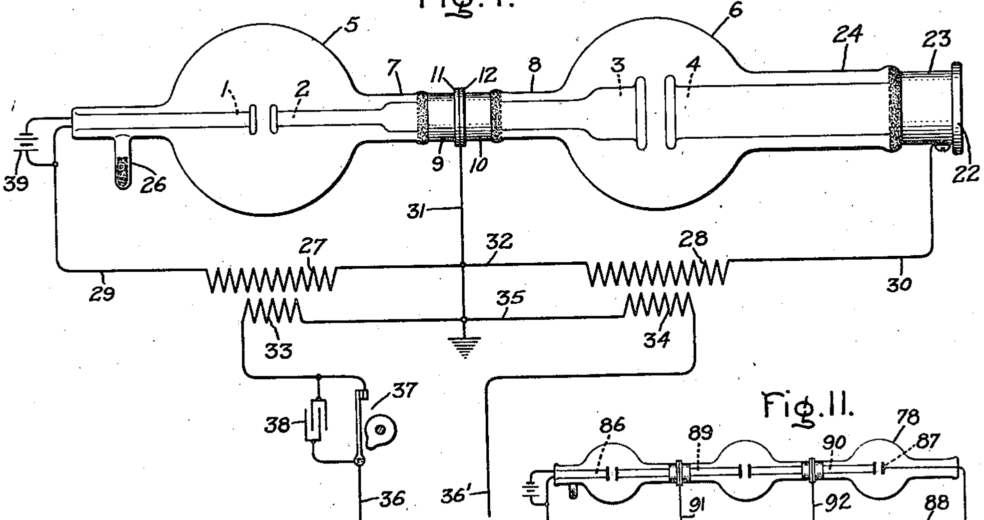


Fig. 11.

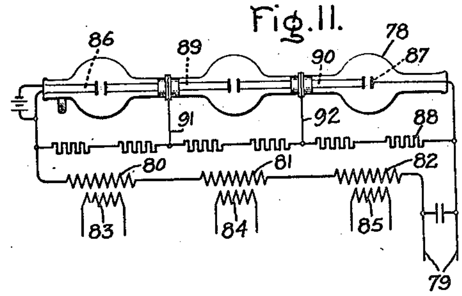


Fig. 2.

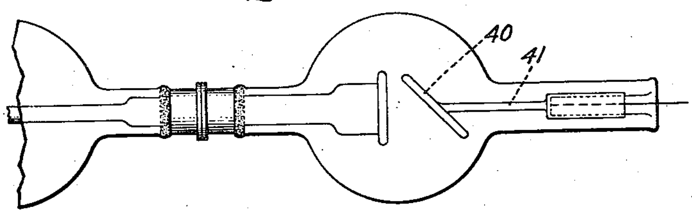


Fig. 10.

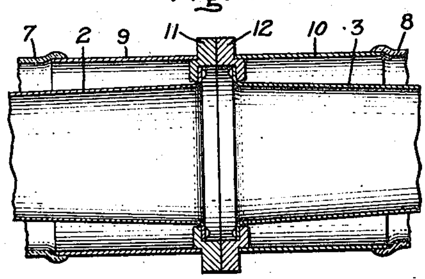
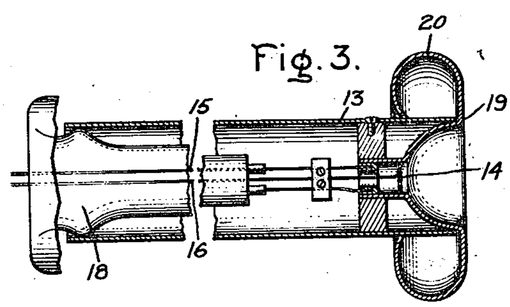


Fig. 3.



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ELECTRICAL DISCHARGE DEVICE AND METHOD OF OPERATION

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Fig. 4.

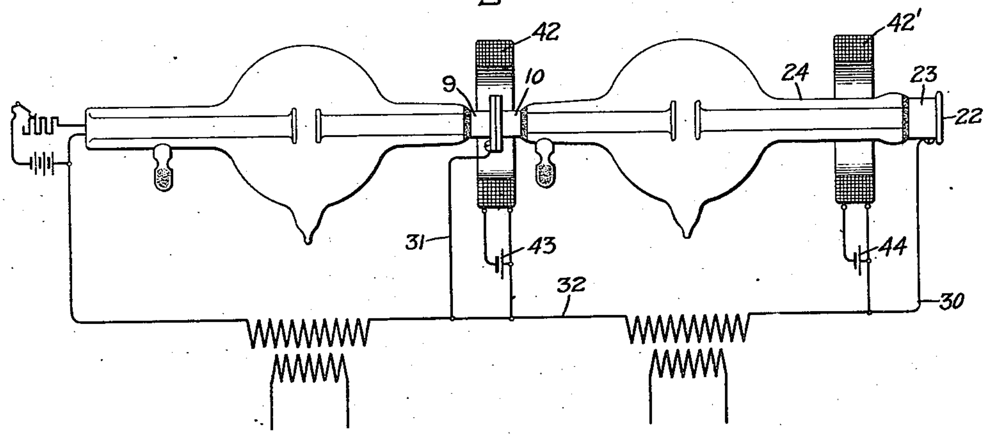


Fig. 5.

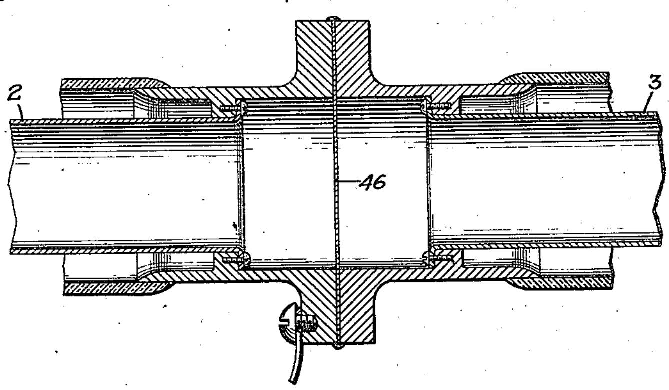


Fig. 6.

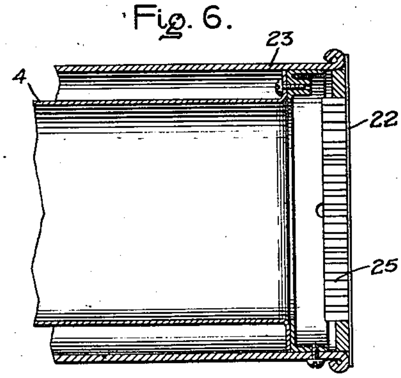
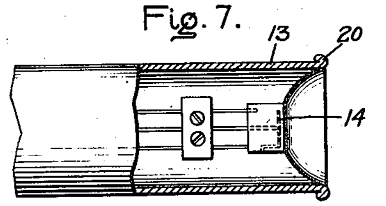


Fig. 7.



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ELECTRICAL DISCHARGE DEVICE AND METHOD OF OPERATION

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Fig. 8.

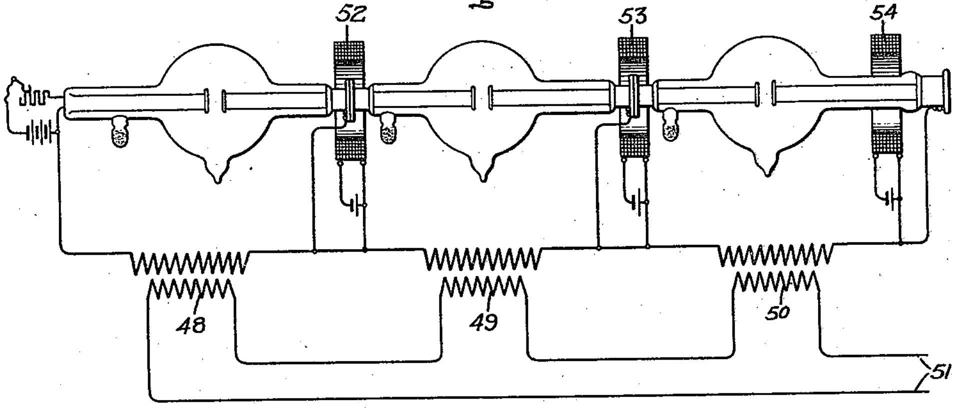
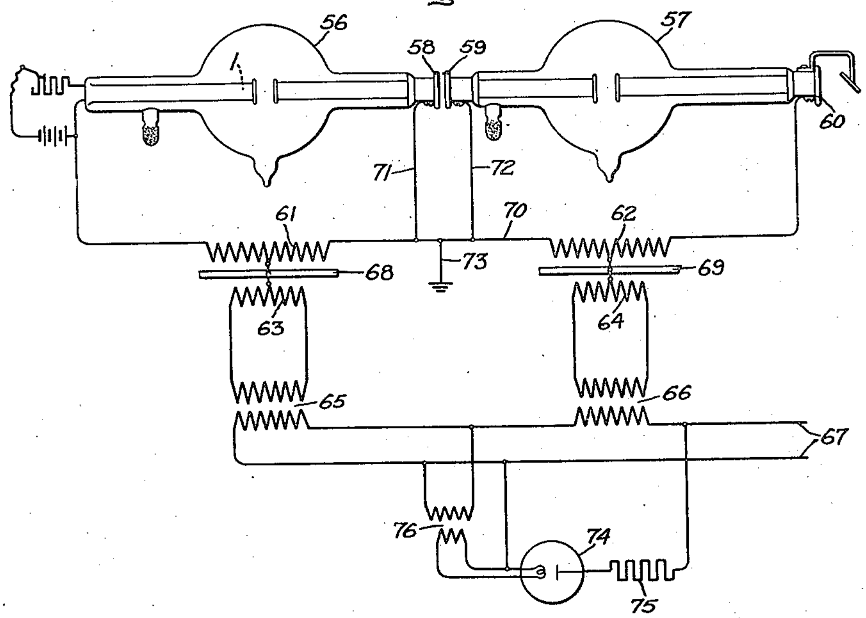


Fig. 9.



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Patented Nov. 21, 1933 1,936,424

UNITED STATES PATENT OFFICE

1,936,424

ELECTRICAL DISCHARGE DEVICE AND METHOD OF OPERATION

William D. Coolidge, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application December 31, 1927
Serial No. 244,014

16 Claims. (Cl. 250—35)

The present invention relates to electrical discharges, and its main object is to provide electronic devices which shall be capable of operation at high voltages. For example, I have constructed devices embodying my invention which are operable at impressed voltages of the order of one million volts.

In accordance with my invention, which includes both a process and a device for carrying out such process, electrical discharges are given successive cumulative accelerations of the same order of magnitude. In other words, the total impressed potential is subdivided among a plurality of electrodes placed in cascade and electrons are caused to travel successively through a discharge path in such manner as to gather acceleration in their progress.

In accordance with one modification of my invention the successive electrode stages are subdivided by walls permeable to electrons but not to positive ions, thereby intercepting the positive ions, but this construction is not a necessary part of my invention.

My invention is illustrated by the accompanying drawings in which Fig. 1 is a side elevation of a device embodying my invention; Figs. 4 and 8 are side elevations partly in section of modifications in which a permeable wall or window is provided between adjoining sets of electrodes. Figs. 3, 5, 6, 7 and 10 are sectional views illustrating various detail structural features, Figs. 2 and 9 are side elevations of modifications of my invention adapted particularly for generating X-rays, and Fig. 11 is a diagram illustrating a modified circuit connection.

Referring to the drawings, and in particular to the device embodying my invention shown in Fig. 1, two sets of electrodes 1, 2 and 3, 4 are provided, although a greater number of sets may be used as shown, for example, in the modification illustrated in Fig. 8. These sets of electrodes are respectively contained in bulbous glass tubes 5, 6 joined at their necks 7, 8. As illustrated also by Fig. 10, tubular coupling members 9, 10 consisting of thin metal, are fusion-sealed to the rims of the glass necks 7, 8 of the glass tubes and the thickened edges 11, 12 of these metal tubes 9, 10 are soldered or welded to each other to make a vacuum-tight connection.

The electrode 1, as shown in Fig. 3, comprises a metal tube 13, in which is mounted an incandescible cathode filament 14, consisting of tungsten, tantalum or other suitable refractory material. The leading-in wires 15, 16 for this filament are sealed into a stem 18. The wires 15, 16 are connected to a focussing device 19 which in turn is connected to one extremity of the filament 14. The outer edge of the focussing device 19 is connected to a rounded evolute field equalizer 20. Fig. 7 shows a slightly modified form of cathode in which the field equalizer 20 is much smaller.

A beam of electrons, or cathode rays, may be produced by the cathode 1 and projected into the hollow, tubular electrode 2 which with the tubular electrode 3 forms a chute or conduit extending between adjacent discharge chambers in line with one another and in non-overlapping relation. As the tubes 2, 3 are electrically connected, both being joined to the metal members 11, 12, they constitute in effect a single electrode which is intermediate in potential to the electrodes 1 and 4 and which shields the cathode from the high potential field of the main anode. The edges of the tubular electrodes 2, 3 and 4 also are provided with rounded field equalizers 20.

The outer extremity of the electrode 4 is provided with a thin metal closure 22, (Fig. 6), which functions as a window for permitting the electron beam to emerge from the tube for use in the open air.

As shown in Fig. 6, the window 22, which may consist of nickel foil about 0.0005″ in thickness is joined at its edges to a metal tube 23 which is in turn fusion joined to the glass neck 24 of the bulb 6. The window also may consist of copper, or molybdenum, or of a suitable alloy, such for example, as the alloy known as "No. 4 Resistol" and comprising 43.8% iron, 35% nickel, 18% chromium, 3% silicon and 0.2% carbon. It is supported against the pressure of the atmosphere by a grid or grating 25. This form of window electrode is described in my prior United States patent application Serial No. 26,469, filed April 28, 1925, (Italian Patent 249,225).

The bulbs 5 and 6 are deprived of occluded gases and evacuated to a vacuum sufficiently high to permit passage therethrough of a pure electron discharge, that is, an electron discharge unaccompanied by positive ionization. A suitable auxiliary exhaust means may be connected to the tube during operation. The drawing shows for illustrative purposes a side tube 26 containing charcoal or other material suitable for absorbing gases. This side tube, may be cooled in liquid air during operation of the device.

Electric energy for operating the discharge in the described device may be derived from any suitable source of direct or alternating current. The drawing shows, as an example, an induction coil, the secondary windings 27, 28 of which are connected in series by the conductors 29, 30 to the electrodes 1 and 4. The intermediate electrodes 2, 3 may be considered as a single electrode which is connected by conductor 31 to the grounded neutral connection 32 between the windings 27, 28. The primary windings 33, 34 are also grounded at the intermediate connection 35 and are connected by the conductors 36, 36' to a suitable source of low potential current, preferably direct current. A suitable interrupter 37 shunted by condenser 38 may be included in the supply circuit.

Electrons emitted by the cathode filament 14 when heated to an emission temperature by an external source such as an insulated battery 39 are caused by the electric field of the focusing electrode 19 to pass as a beam (cathode rays) through the intermediate conduit-shaped electrode constituted by the tubes 2 and 3, and to pass into the tubular electrode 4, finally emerging from the window 22 at the extremity of the device. The electrons receive in their passage from the cathode 1 into the tubular anode 4 successive accelerations by the electric fields produced by the applied electromotive forces of windings 27 and 28.

In some cases, for example, when it is desired to produce X-rays instead of causing the cathode rays to emerge through a window the cathode rays may be caused to impinge on an electrode of high atomic number, for example, tungsten. Such an electrode is shown in Fig. 2 in which the window 22 is replaced by a target 40 supported upon a stem 41, the construction of the device and its connection to a source of energy otherwise being similar to the device shown in Fig. 1.

In the device shown in Fig. 4 solenoids 42, 42' are provided around the path of the cathode rays in order to assist in confining the electrons to a circumscribed beam by the action of the electromagnetic fields generated by these solenoids. These solenoids may be energized from any suitable source of direct current as represented by the batteries 43, 44 and they may be connected as indicated to the intermediate conductor 32 and to the conductor 30.

As shown in Fig. 5 a window 46 consisting of metal foil similar to the window 22 or thinner may be provided to separate the spaces within the electrodes 2, 3, that is, to physically separate the bulbs 5 and 6 as an intermediate partition. In the operation of the device the beam of cathode rays will pass through the intermediate window while positive ions, produced by the ionization of residual gas, travelling in the reverse direction, that is, from the most positive electrode back to the incandescent filament acting as cathode, are intercepted. However, the use of such an intermediate partition which is permeable to electrons is not necessary when a sufficiently high vacuum is maintained in the device. In the outfit shown in Fig. 8, three primary windings 48, 49, 50 are provided, these windings being connected in series to supply conductors 51. The solenoids 52, 53, 54 may be omitted in some cases.

It is not necessary that the unit electron devices which are arranged in cascade relation should be joined physically as shown in Figs. 1, 4 and 8. Electrons may be projected from one device into another through the open air as shown in Fig. 9.

The devices 56, 57 are positioned in line with one another so that electrons passing through the window electrode 58 of the device 56 can enter the device 57 through a window electrode 59. The electrons receive a second acceleration in the vacuous space within the bulb 57 and finally emerge through the window electrode 60. The window electrodes 58, 59 and 60 may be provided with a supporting grid as described in connection with the anode of Fig. 1 and shown in Fig. 6. The cathode may be the same as the cathode of Fig. 1 and as shown in detail in Figs. 3 and 7.

In Fig. 9 the devices 56 and 57 are shown as connected to the secondaries of the transformers by the conductors 71, 72. The primaries 63, 64 of these transformers are connected respectively to insulating transformers 65, 66 which in turn are supplied in series by the mains 67. The insulating transformers 65, 66 may have a 1 to 1 ratio. The high potential, step-up transformers 61, 62 have the middle points of their primary and secondary windings connected to the magnetic cores 68, 69, as indicated. The high potential secondaries of these transformers are connected by a conductor 70 which in turn is connected to the electrodes 58, 59 by the conductors 71, 72, and also is grounded as indicated at 73; as half waves of only one polarity are utilized by the devices 56, 57 a rectifier 74 and a resistance load 75 is connected across the mains 67. The cathode of this transformer is of the thermionic type and is maintained heated by a transformer 76, as indicated to receive energy during the opposite half wave intervals, thereby avoiding the building up of undesired high potentials in the transformers during the idle half waves. Of course the illustrated energy supply system may be used in connection with other described forms of devices embodying my invention.

In some cases, especially for the operation of rectifiers embodying my invention, the potential between the various electrodes may be equalized by a potentiometer connection as shown in Fig. 11. The arrangement here shown comprises a multi-stage device 78 connected to a load circuit 79 in series with the secondary transformer windings 80, 81 and 82 having respectively primary windings 83, 84 and 85. A condenser may be connected across the load circuit. The potential difference between the cathode 86 and the anode 87 is subdivided by connecting an impedance device 88 between these electrodes and connecting the intermediate electrodes 89, 90 to intermediate points on the impedance device 88 which in the case illustrated is constituted by the ohmic resistance.

In the arrangement illustrated the conductors 91, 92 connect the intermediate electrodes 89, 90 to such points on the resistance, that the potential is divided substantially equally among the respective stages but this is not always required.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An electron discharge device comprising an envelope containing cooperating electrodes, means for producing an electron discharge between said electrodes and imperforate means intermediate said electrodes for mechanically intercepting positive ions.

2. An electron discharge apparatus comprising an envelope containing electrodes capable of supporting an electron discharge therebetween, means for focusing said discharge, tubular conductors intermediate said electrodes closely surrounding said electron discharge without obstructing the same, whereby said discharge can be given successive accelerations in passing from

one electrode to the other, and means permeable to electrons but impermeable to positive ions for preventing the passage of positive ions from one electrode to the other, said means being positioned intermediate said tubular conductors.

3. A high potential electric discharge apparatus comprising an envelope including a plurality of non-conducting sections sealed to one another by conductive material, an anode and an electron-emitting cathode in said envelope, and a common means for successively accelerating the movement of electrons toward the anode and for electrically shielding portions of said sections adjoining the seals, said means including tubular members which surround the electron stream and are adapted to be positively charged.

4. An electrical discharge apparatus comprising a plurality of containers joined with one another by an electrically conductive coupling of lesser diameter than said containers, main cooperating electrodes whereby a discharge may be projected through said coupling and an intermediate tubular member connected to said coupling and projecting into the containers joined by said coupling, and a solenoid about said coupling to assist in projecting the discharge through the coupling.

5. An electrical discharge apparatus comprising a plurality of containers joined with one another by an electrically conductive coupling of lesser diameter than said containers, main cooperating electrodes whereby a discharge may be projected through said coupling and an intermediate tubular member connected to said coupling and projecting into the containers joined by said coupling, and a solenoid about said coupling to assist in projecting the discharge through the coupling, said solenoid being maintained at the same potential as the coupling.

6. An electric discharge device comprising a multi-sectional tube containing main electrodes, each of the sections being energized with progressively increased potentials whereby a high velocity cathode ray beam is produced between said electrodes, said beam being surrounded for the major portion of its length by intermediate metal tubular members arranged successively in end-to-end relation.

7. An electric discharge device comprising a multi-sectional envelope containing main and intermediate electrodes, all of said electrodes being energized with progressively increased potentials whereby a high velocity cathode ray beam is produced between the main electrodes, said beam being surrounded by metal tubular members which constitute portions of said envelope and are connected respectively to each of the intermediate electrodes.

8. An electric discharge device comprising a multi-sectional tube containing electrodes, the sections being constituted partly of metal, physically separate of one another and energized with progressively increased potentials whereby a high velocity electron stream is caused to flow between the electrodes and through the sections successively, said stream being closely surrounded for the major portion of its length by intermediate metal tubular members which form part of the respective sections.

9. An electrical discharge apparatus comprising a plurality of containers joined with one another by an electrically conductive coupling of lesser diameter than said containers, main cooperating electrodes whereby a discharge may be projected through said coupling, and an intermediate tubular member connected to said coupling and projecting into the containers joined by said coupling.

10. An electrical discharge apparatus comprising an elongated container constituted of wall members of electrically insulating and conductive material arranged in alternate relation, electrode means including an anode for producing therein a beam of electrons of restricted diameter, a plurality of tubular members of approximately the same diameter and each surrounding an appreciable part of said beam, said members being connected respectively to the conductive wall members and arranged end-to-end, with their ends spaced apart in proximity to adjacent parts of non-conductive wall members.

11. An electrical discharge apparatus comprising a plurality of bulbs, a metal tube connecting said bulbs, a pair of chutes supported in end-to-end relation by said tube and extending in opposite directions into said bulbs, means in one of said bulbs for producing a beam of electrons in line with said chutes, and means in another bulb connecting with the first bulb for receiving said electron beam.

12. An electron discharge device comprising a highly evacuated envelope containing a plurality of sets of cooperating electrodes, a metallic member positioned respectively between each pair of adjoining sets, said member being permeable to the passage of electrons from one set to another but being impermeable to the passage of positive ions from one set of electrodes to another.

13. An electrical discharge apparatus comprising an envelope including a plurality of pairs of non-conducting sections, conductive couplings respectively between each pair of said sections, conductive electron-accelerating chutes connected respectively to said couplings and being adjacent to and overlapping the major portion of said couplings in said envelope, means for producing a beam of electrons aligned to traverse said chutes in succession and an anode for receiving the successively accelerated electron beam.

14. An electrical discharge device comprising an elongated envelope made of non-conducting members, each adjoining pair of which is joined end to end respectively by a conductive coupling, main electrodes at opposite ends of said envelope for producing an electrical discharge, means for focusing said discharge in the form of a beam, tubular electron-accelerating members in said envelope respectively connected to said couplings, said tubular members having apertures sufficiently large to permit said beam to pass therethrough without intercepting any substantial part thereof, said tubular members being positioned to overlap the major portion of said couplings and extending substantially in line with one another in cascade relation.

15. An electrical discharge apparatus comprising a plurality of bulbs, a metal tube connecting said bulbs, a hollow electrode cooperating with said tube and projecting into said bulbs, means in one of said bulbs for producing a beam of electrons in line with said electrode and means in another bulb connecting with the first bulb for receiving said electron beam.

16. An electrical discharge device comprising an elongated envelope made of non-conducting members, each adjoining pair of which is joined end-to-end respectively by a conductor coupling, main electrodes at opposite ends of said envelope for producing an electrical discharge, means for

focusing said discharge in the form of a beam, tubular electron-accelerating members in said envelope respectively connected to said couplings, said tubular members having apertures sufficiently large to permit said beam to pass therethrough without intercepting any substantial part thereof, all of said tubular members being substantially in line with one another, longitudinally spaced and extending over substantially the entire length of the envelope between the main electrodes.

WILLIAM D. COOLIDGE.