May 14, 1963 F. L. WASHBURN, JR 3,089,975

ELECTRON DISCHARGE DEVICE

Filed Nov. 21, 1961

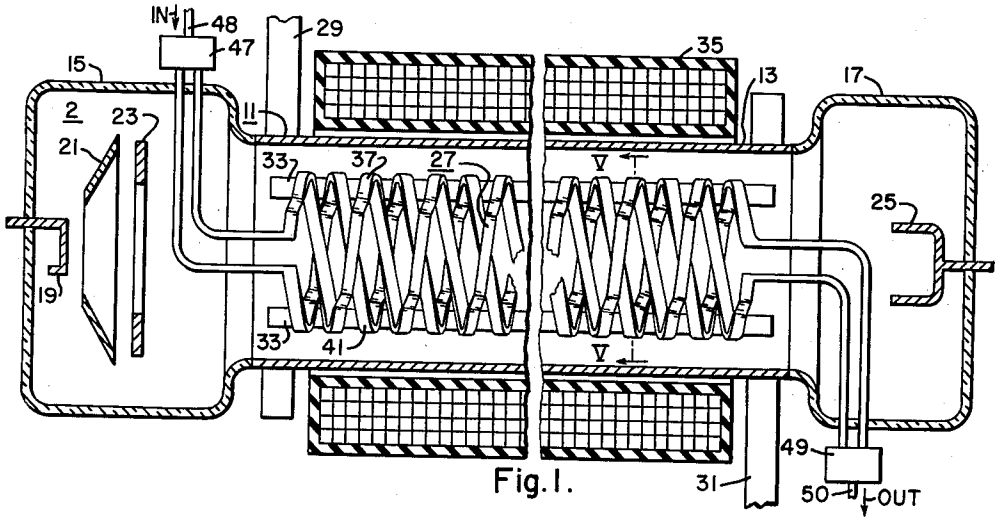


Fig. 1.

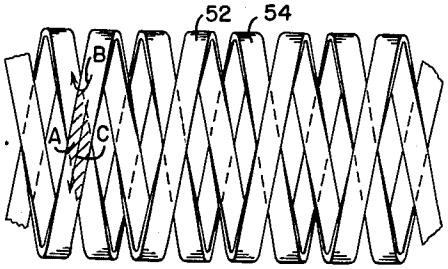


Fig. 2.

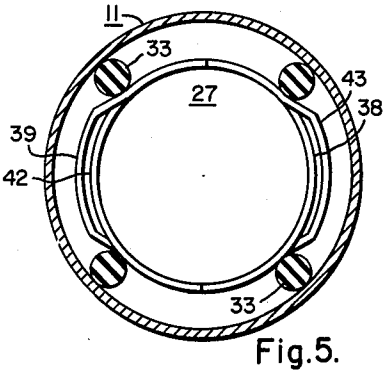


Fig. 5.

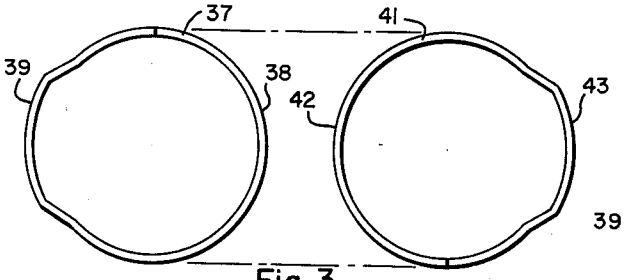


Fig. 3.

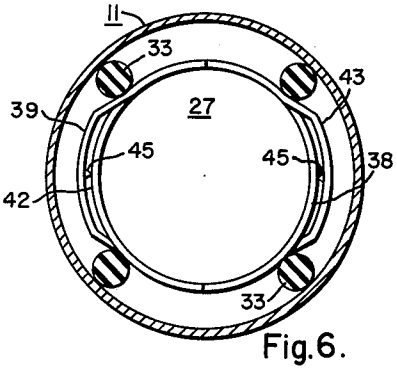


Fig. 6.

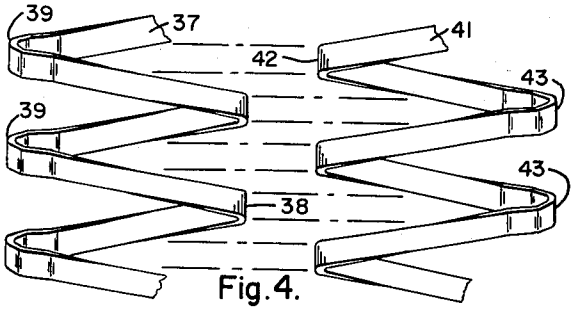


Fig. 4.

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ELECTRON DISCHARGE DEVICE

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The present invention relates generally to electron discharge devices, and more particularly to slow-wave propagating structures for use in devices such as traveling-wave tubes.

Traveling-wave tubes comprise generally an elongated envelope with an electron beam producing means disposed at one end thereof for the production and projection of an electron beam through the envelope. A slow-wave propagating means coaxially mounted within the envelope functions to propagate electromagnetic energy along the length of the envelope in an interacting relationship with the electron beam. An electron collector assembly is disposed at the opposite end of the envelope for collecting the electron beam.

It has been shown that a non-contacting cross-wound structure having two helices which are oppositely wound and interposed has a mode which possesses higher impedance in the fundamental and lower impedance in the spatial harmonic than a single helix (Chodorow and Chu, "Cross-Wound Twin Helices for Traveling-Wave Tubes," Journal of Applied Physics, volume 26, pages 33–43; January 1955). It has also been shown that such a cross-wound structure has less velocity dispersion than the usual ring-and-bar structure which is in general present-day use. However, such a non-contacting structure in which the two helices have the same radius and longitudinal axis and which is suitable for high frequency operation has not lent itself to being readily manufactured. Those that have been made have had large areas of contact between the helices with a resulting degradation in the slowing effect of the structure. It is for this reason that the prior devices have generally utilized structures of the ring-and-bar type.

It is, therefore, an object of this invention to provide an improved electron discharge device.

A further object of this invention is to provide an improved slow-wave propagating means for use in electron discharge devices.

Another object is to provide a slow-wave propagating structure of the cross-wound helices which are non-contacting in the usual sense.

A further object of this invention is to provide a slow-wave propagating structure comprising two cross-wound helices having only a small contact area.

A still further object is the provision of a slow-wave propagating structure which consists of two helices formed in opposite senses and which are non-circular in cross-sectional configuration.

Stated briefly, this invention is directed to a traveling-wave tube which utilizes two helical members of slightly non-circular configuration which, when fitted together, form a substantially circular tunnel through which the electron beam passes. The slightly non-circular configuration permits the two helices to be fitted together in an interposed manner and yet does not allow the helices to contact one another in the normal sense of the term.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the accompanying drawings in which:

FIGURE 1 is an elevational view partially in section, of a traveling-wave tube embodying the present invention;

FIG. 2 is a schematic representation of two helices wound in opposite senses or in a cross-wound configuration which do not embody the present invention;

FIG. 3 is an end view of the two helices of FIG. 1 showing the non-circular configuration;

FIG. 4 is an exploded view of the two helices of FIG. 1 which are wound in opposite senses in accordance with the present invention;

FIG. 5 is a cross-sectional view taken along line V—V of FIG. 1 and showing two non-circular helices assembled in accordance with the present invention; and

FIG. 6 is a modification of FIG. 5 showing the preferred embodiment of the present invention.

With specific reference to FIG. 1, there is shown an electron discharge device of the traveling-wave tube type comprising an envelope **11** comprising a central tubular portion **13**, which may be made of a suitable material such as glass, and two enlarged end portions **15** and **17**, which are of a suitable material such as copper, and which are connected and sealed to the glass tube **13**. An electron beam source, indicated generally by the reference character **2**, is disposed at one end of the envelope **11** within the bulb portion **15**. This beam source **2** comprises an electron emissive cathode **19**, a focusing electrode **21**, and an accelerating electrode **23**. These elements are connected to suitable sources of voltage, which have not been shown, and collectively act to produce and direct a beam of electrons centrally along the axial length of the envelope **11** to the opposite end of the envelope. An electron collector **25** is positioned at the opposite end of the envelope **11** within the bulb portion **17** and serves to collect the electrons of the beam after they have passed through the tubular portion **13**.

A slow-wave propagating means **27** is positioned intermediate the electron beam source **2** and collector **25**. This propagating means **27** functions to propagate electromagnetic energy along the length of the tubular portion **13** in an interacting relationship with a major portion of the outer edge electrons of the electron beam. The propagating means in the present instance is two separate helices **37** and **41** of electrically conducting material formed into a cross-wound configuration as will be more fully explained later.

Electromagnetic energy is supplied to the slow-wave propagating means **27** by means of a waveguide **29** which is positioned near the enlarged portion **15** in a manner well known in the art. Similarly, a second wave-guide structure **31** is provided near the enlarged portion **17** for the removal of electromagnetic energy from the slow-wave propagating means **27**.

The propagating means **27** is supported within the envelope **11** by means of a plurality of supporting rods **33** which are disposed along the axial length of the envelope for substantially the entire length of the propagating means **27**. The support rods **33** are preferably made of a suitable heat conducting, electrical insulating material such as alumina or beryllia. In the present example, four support rods are utilized.

In order to prevent the electron beam from spreading to such an extent that it would be intercepted by propagating means **27**, it is necessary to provide some form of focusing. Focusing in the present instance is provided by producing a magnetic field axially along the envelope **11** by the utilization of a long annular solenoid **35** which surrounds the envelope **11** for substantially the entire length of the propagating means **27**. To simplify the

present drawing and description, the solenoid 35 is only schematically illustrated and its source of energization is not shown.

Referring now to FIG. 2, there are shown two circular helices 52 and 54 which are wound in opposite senses and which do not embody the present invention. Cross-hatched area A indicates the amount of contact area which is present at each cross-over of the two helices 52 and 54. With this type structure, the currents of the electro-magnetic energy which is being propagated along helices 52 and 54 tend to take the shorter path to the next cross-over as is represented by line B rather than take the longer preferred path which is represented by line C. This taking of the shorter path lessens the slowing effect and hence reduces the effectiveness of the propagation structure. As is readily apparent, as the pitch of helices is lessened, the area of contact is increased and the short path represented by line 3 becomes even shorter relative to the preferred path (line C) with a resulting increase in the tendency for the currents to take the shorter path.

With reference now to FIGS. 3 through 5, there are shown enlarged views of the slow-wave propagating means of FIG. 1 in accordance with the present invention. A first helical member 37 of conducting material is formed substantially circular in cross-sectional area but is made slightly non-circular insofar as it includes an offset portion 39. The portion 39 should be offset only slightly more than the thickness of the material constituting the helical member. In a like manner, a second helical member 41 of conducting material and having the same basic radius as the first helix 37 is provided with an offset portion 43. The offset portion 39 of member 37 is shown to be on the left while the offset portion 43 of member 41 is shown to be on the right. As is best shown in FIG. 4, member 37 shown to be wound in the left-hand or counterclockwise sense while member 41 is shown to be wound in the right-hand or clockwise sense. Each of the helical members 37 and 41 are formed so as to have the same basic radius and the same pitch. After the helical members 37 and 41 have been so formed, they are interposed or positioned together in such a maner so as to be coaxial. As well as being coaxial, the helical members are arranged so that a circular portion 38 of member 37 corresponds angularly and longitudinally with the offset portion 43 of helical member 41 and in a like manner the circular portion 42 directly opposite offset portion 43 of member 41 is in direct angular and longitudinal alignment with the offset portion 39 of helical member 37. By this arrangement, as can best be seen in FIG. 5, a substantially circular tubular member or slow-wave propagating means is achieved. The two helical members which together constitute the slow-wave propagating means 27 may now be positioned within the envelope 11 and supported therein by the electrically insulating supporting members 33. In the present example, four such insulating members 33 are used to support the slow-wave propagating means 27 within the envelope 11.

Because non-contacting cross-wound helices can potentially operate in a push-pull mode giving rise to feedback and/or backward wave oscillations, some type of mode suppression is often desirable. FIG. 6 illustrates the present invention in its preferred form. The embodiment shown in FIG. 6 is the same as that shown in the earlier figures (FIGS. 2–5) with the addition of small tabs or points 45 which are formed on each of the offset portions 43 and 39 (although they may be formed on the circular portions 42 and 38 with equal advantage). These tabs 45 of such a size as to provide substantially a point contact between the two helical members 37 and 41. While it is true that there is some contact between the two members in this instance, this contact is of a very small area and does not make the helical members contacting in the usual sense of the word. The amount of actual contact between the helical members 37 and 41 is insufficient to permit the currents flowing in one helix to trnsfer to the other but yet is sufficient to suppress a push-pull mode of operation.

The helical members 37 and 41 constituting the slow-wave propagating means 27 are made for a suitable conducting material, for example molybdenum, and may be of wire, tape, or of tubular configuration. If the tubular configuration is used, the slow-wave propagating means 27 possesses the additional advantage that it may be liquid cooled. This cooling method is illustrated in FIG. 1 in which the two helical members are shown to be connected on one end to an input manifold 47 to which fluid is supplied by means of a conduit 48. At the other end of the slow-wave propagating means 27, the two helical members are connected to a manifold 49 which in turn is connected to a conduit 50 which removes the fluid from the slow-wave propagating structure. The conduits 48 and 50 are in turn connected to a fluid circulating means, for example, a pump, which has not been shown.

While there have been shown and described what are at present considered to be the preferred embodiments of the invention, modifications thereto will readily occur to those skilled in the art.

For example, the helices could each be of bifilar or multifilar configuration rather than the two simple helices shown. It is not desired, therefore, that the invention be limited to specific arrangements shown and described and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

I claim as my invention:

1. A traveling wave tube comprising an envelope, means disposed at one end of said envelope for the production and projection of an electron beam along the axial length of said envelope, means disposed at the other end of said envelope for the collection of said electron beams, slow-wave propagating means disposed within said envelope substantially coaxial and in an interacting relationship with said electron beam, said slow-wave propagating means comprising first and second helical members of conducting material wound in opposite directions with respect to each other and having the same basic radius and longitudinal axis, each of said helical members having a series of outwardly extending offset portions at alternate points where the two helical members cross one another.

2. An electron discharge device comprising an envelope, means disposed at one end of said envelope for the production and projection of an electron beam through said envelope, means disposed at the opposite end of said envelope for collecting said electron beams, slow-wave propagating means disposed within said envelope in an interacting relationship with said electron beam, said slow-wave propagating means comprising a first electrically conducting helix formed in a first sense and a second electrically conducting helix interposed with said first helix and formed in the opposite sense, each of said helices having the same basic radius and longitudinal axis and each having an offset portion at alternate points of cross-over to prevent contact of the two helices.

3. An electron discharge device comprising an envelope, means disposed at one end of said envelope for the production and projection of an electron beam through said envelope, means disposed at the opposite end of said envelope for collecting said electron beams, slow-wave propagating means disposed within said envelope in an interacting relationship with said electron beam, said slow-wave propagating means comprising a first helical member formed in a first sense and a second helical member formed in the second sense, each of said helical members having the same radius and longitudinal axis so as to form an essentially circular tunnel, each of said helical members having portions thereof of non-circular configu-

ration at alternate points of crossover of said members to preclude substantial contact between said helical members.

4. An electron discharge device comprising an envelope, means disposed at one end of said envelope for the production and projection of an electron beam through said envelope, means disposed at the opposite end of said envelope for collecting said electron beam, slow-wave propagating means disposed within said envelope in an interacting relationship with said electron beam, said slow-wave propagating means comprising a first helical member formed in a first sense and a second helical member formed in the opposite sense, said helical members having the same basic radius and same longitudinal axis to provide a substantially cylindrical tube in cross section, each of said helical members having an offset portion at alternate points where said helical members cross, said helical members being of tubular configuration and means for forcing a cooling fluid through said tubular members.

5. An electron discharge device comprising an envelope, means disposed at one end of said envelope for the production and projection of an electron beam through said envelope, means disposed at the opposite end of said envelope for collecting said electron beam, slow-wave propagating means disposed with said envelope in an interacting relationship with said electron beam, said slow-wave propagating means comprising first and second helical members formed in opposite senses and having the same basic radius and longitudinal axis, each of said helical members having offset portions at alternate points of crossover of said helical members, and tab members provided on one of said helical members at each crossover point to provide a point contact between said members.

6. An electron discharge device comprising an envelope, means disposed at one end of said envelope for the production and projection of an electron beam through said envelope, means disposed at the other end of said envelope for collecting said electron beam, slow-wave propagating means disposed within said envelope in an interacting relationship with said electron beam, said slow-wave propagating means comprising first and second helical members formed in opposite senses and having the same basic radius and longitudinal axis, each of said helical members having a non-circular portion at alternate points of crossover of said helical members for the prevention of substantial contact between said helical members, and means disposed on one of said helical members to provide an area of contact of insufficient area to permit substantial transfer of energy from one helical member to the other.

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