Aug. 7, 1956 W. J. DODDS 2,758,244

ELECTRON BEAM TUBES

Filed June 2, 1952

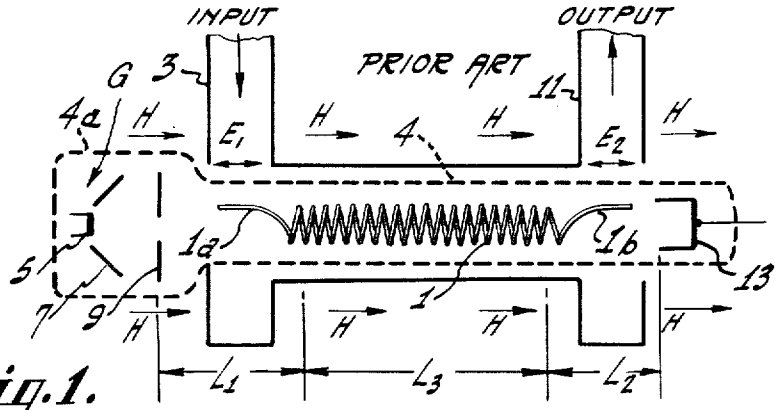


Fig. 1.

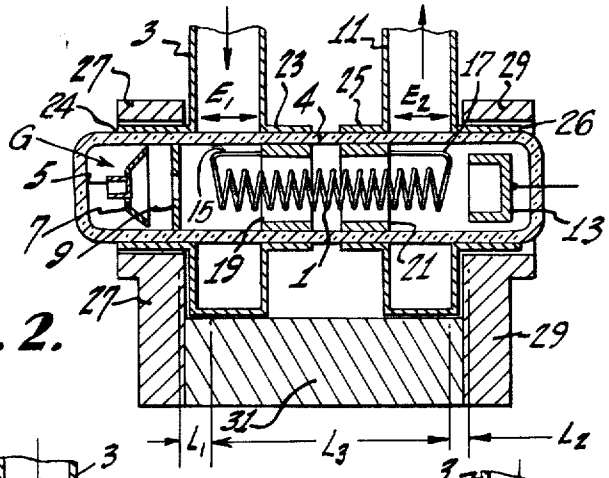


Fig. 2.

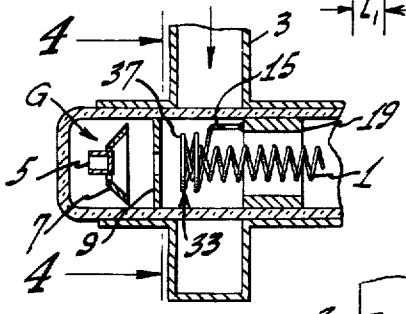


Fig. 3.

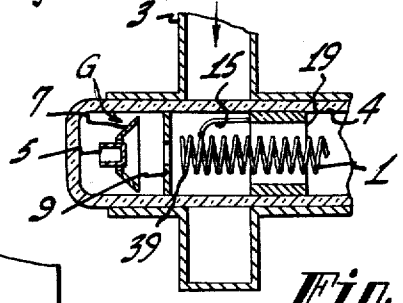


Fig. 5.

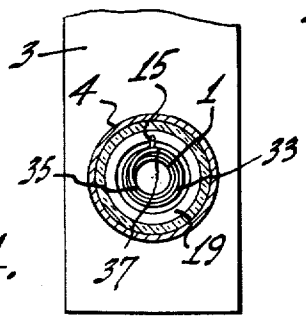


Fig. 4.

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ELECTRON BEAM TUBES

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Application June 2, 1952, Serial No. 291,189

8 Claims. (Cl. 315—3.5)

This invention relates to electron beam tubes, and particularly, to helix type traveling wave amplifier tubes.

The object of the invention is to provide improved means for coupling the circuit helix of a traveling wave tube to the input and output transmission lines.

In the drawing:

Fig. 1 is a schematic view of a conventional helix type traveling wave tube;

Fig. 2 is an axial sectional view of a helix type traveling wave tube embodying the invention.

Fig. 3 is a fragmentary view similar to Fig. 2 of a modification embodying the invention; and

Fig. 4 is a transverse sectional view taken on the line 4—4 of Fig. 3;

In a conventional traveling wave amplifier tube of the helix type, an electron beam is projected along an elongated helix at a velocity approximately equal to the axial phase velocity of waves traveling along the helix. By successive processes of electron velocity modulation and inductive output, the beam is modulated by the electric fields set up along the helix by the signal wave, and the modulated beam gives up energy to the wave to increase its amplitude.

Suitable means are provided at the input and output ends of the helix for coupling the helix to input and output transmission lines. These transmission lines may be waveguides or coaxial lines. Fig. 1 shows a conventional tube in which the input end of the helix **1** is coupled through the dielectric envelope **4** to an external input waveguide **3** extending transversely of the tube axis by means of an axially-extended variable-pitch transition portion **1***a* of the helix extending parallel to the electric field component E_1 in the waveguide **3**. A conventional electron gun G, including a cathode **5**, focusing electrode **7** and accelerating electrode **9**, is mounted in an enlarged end portion **4***a* of the dielectric envelope **4**, in axial alignment with the helix **1**. The distance from the accelerating electrode **9** to the end of the variable-pitch transition portion **1***a*, where the active portion of the helix begins, is indicated by the letter L_1. The opposite end of the helix **1** is coupled through the envelope **4** to an external output waveguide **11** by means of an axially-extended variable-pitch transition portion **1***b* of the helix, similar to transition portion **1***a*, extending parallel to the electric field component E_2 in the waveguide **11**. A collector electrode **13** is mounted adjacent to the end of the transition portion **16**. The distance from the end of the variable-pitch portion **1***b* to the collector **13** is indicated by L_2. The active length of the helix is indicated by L_3.

It is of greatest importance to make a traveling wave tube as short as possible for a given gain. No axial space should be used by anything that has no importance for beam forming and beamfield interaction. In conventional designs considerable axial space is used up to provide a broad-band match between the feeding lines and the helix, as illustrated in Fig. 1.

The conventional coupling arrangement shown in Fig. 1 has several disadvantages. First, the parts of the electron beam that extend along the two transition portions **1***a* and **1***b* are not electrically shielded from the surrounding dielectric envelope wall, and hence, variable potentials are produced along the inner wall of these parts of the envelope during operation. These variable potentials cause undesirable variations in beam velocity along the tube axis in these regions. A second disadvantage of the arrangement of Fig. 1 lies in the increased cost of providing a suitable axial focusing magnetic field for preventing spreading of the beam and consequent collection of electrons by the helix. The gain of a traveling wave amplifier tube is proportional to the active length of the helix. However, the focusing magnetic field must be provided over substantially the entire beam path, as indicated by the arrows H in Fig. 1. Hence, any reduction in the overall length of the beam path, such as by reducing the distances L_1 and L_2, results in lower cost for a tube of given active length, or gain. Third, the relatively large distance L_1 may impose a series limitation on the signal-to-noise ratio of the tube. In order to obtain lowest noise figure, it may be necessary that the distance L_1 be as small as possible. The shorter the active helix, the larger the relative length of the coupling antenna and the more important to eliminate the latter.

In accordance with the present invention, the input end of the active helix is positioned close to the accelerating electrode of the electron gun and the helix is coupled to the external input transmission line by means of a conductor located entirely within the envelope and extending laterally substantially from the end of the helix and back along the helix away from the electron gun and closely coupled capacitively to the transmission line. In the case of waveguide input, the helix extends at least partly through the input waveguide to a point close to the electron gun and the coupling conductor extends back across the waveguide substantially parallel with the high frequency electric field therein and is connected to a coupling ring surrounding the helix and capacitively coupled to a coupling flange on the waveguide. Furthermore, the output end of the active helix is positioned close to the collector electrode and the helix is inductively coupled to the output transmission line by means of a similar conductor located entirely within the envelope and extending laterally from the end of the helix and back along the helix away from the collector electrode and toward the input coupling conductor and closely coupled capacitively to the output line. In waveguide output, the helix extends at least partly through the output waveguide and the coupling conductor extends back across the waveguide substantially parallel with the high frequency electric field therein and is capacitively coupled to the waveguide. The helix itself does not couple to the electric fields within the waveguides. Therefore, these fields are not disturbed by the helix running across them.

As shown in Fig. 2, the active helix **1** extends across the input and output waveguides **3** and **11** to points close to the accelerating electrode **9** and collector electrode **13**, respectively. The ends of the helix **1** are inductively coupled to the input and output waveguides by conductors **15** and **17** which extend laterally from the ends of the helix and then back along the helix toward each other in directions substantially parallel with the electric fields E_1 and E_2, respectively, within the two waveguides. In the arrangement shown in Fig. 2, the electric fields E_1 and E_2 and coupling conductors **15** and **17** are parallel with axis of the helix **1**. The coupling conductors **15** and **17** may be either integral extensions of the helix wire, as shown in Fig. 2, or separate conductors connected to the helix ends. The structure of Fig. 2 described thus far is disclosed and

claimed in a copending application of Rolf W. Peter, Serial No. 291,225, filed June 2, 1952, assigned to the same assignee.

In accordance with the present invention, the ends of the coupling conductors **15** and **17** remote from the ends of the helix **1** are connected, respectively, to coupling rings or sleeves **19** and **21** which surround the helix in space relation within the envelope **4**. The coupling rings **19** and **21** are capacitively coupled through the dielectric envelope wall **4** to axially extending flanges **23** and **25** on the input and output waveguides **3** and **11**, as shown in the drawing. The coupling conductors **15** and **17** and the coupling rings **19** and **21** are all located entirely within the tube envelope **4**. The waveguides **3** and **11** may also be provided with flanges **24** and **26** for electrostatically shielding the electron gun G and collector **13**, respectively, as shown in Figs. 2–4. The side walls of the waveguides **3** and **11** adjacent to the flanges **23**, **24**, **25** and **26** constitute conductors forming axial gaps across which high frequency electric fields are established during operation of the tube. The flanges **23** and **25** may be extended along the length of the helix and connected to serve as a shield therefor, as indicated in Figs. 3 and 5.

The arrangement shown does not involve any mechanical connection between the traveling wave tube and the surrounding waveguides or magnet structure. Therefore, the tube is readily insertable and removable from various waveguides and magnet structures.

Because of the close coupling between the capacitively coupling rings **19** and **21** and the flanges **23** and **25** of the two waveguides, the coupling conductors **15** and **17** are effectively shorted for high frequency currents at their ends to the waveguides **3** and **11**. As a result, the wide-band impedance match between each coupling conductor and the waveguide, and hence, between the helix and the waveguide, is far better than can be obtained without this coupling. Hence, because of the good match that can be obtained over a much wider frequency band with the low impedance coupling of the present invention, the useful band width of the tube as an amplifier, for example, is much wider than a tube without this coupling. For best results, the electrical width of the coupling rings **19** and **23** should be a quarter wavelength of the mid-frequency of the desired operating band of the tube. However, the impedance of the coupling will be relatively low for all frequencies except that for which the electrical width of the coupling rings is a half wavelength, or a multiple thereof.

In Fig. 2 is shown a magnet structure suitable for use with waveguide type input and output lines for focusing the electron beam. This structure comprises two pole pieces **27** and **29** connected by one or more permanent magnet rods or bars **31**. The various electrodes of the tube are provided with suitable supporting means and external leads for applying suitable direct-current potentials. These have not been shown since they are not part of the present invention.

Since some helices may be somewhat difficult to match to in one step, it will be useful to incorporate an intermediate impedance transformer section between each end of the helix and the axial portion of the coupling conductor connected thereto. The transformer may be a conductor **33** including a radial spiral portion **35** of tapered diameter and a few turns **37** of relatively large diameter helix connected between the end of the tube helix **1** and the axial portion of the coupling conductor **15**, as shown in Figs. 3 and 4. Fig. 5 shows a modification wherein the coupling conductor **15** is connected to the helix **1** at a distance of a few turns from the end thereof. The free turns **39** act as an impedance transformer, as in C. W. Hansell Patent No. 2,584,802, dated February 5, 1952.

In the claims, the expression "substantially from" (the end of the helix) is intended to cover the connection shown in Fig. 5, as well as those shown in Figs. 2 and 3.

What is claimed is:

1. A traveling wave electron tube comprising an elongated dielectric envelope containing an elongated conductive helix, an electron gun close to one end of said helix for projecting a stream of electrons along said helix for interaction with waves traveling thereon, and means for inductively and capacitively coupling said end of said helix to an external input transmission line, said means including a coupling ring surrounding and spaced from said helix and a conductor extending laterally substantially from said end and back over said helix away from said electron gun and connected to said coupling ring, said coupling ring and conductor being located entirely within said envelope.

2. A traveling wave electron tube comprising an elongated dielectric envelope containing an elongated conductive helix, means for projecting a stream of electrons along said helix for interaction with waves traveling thereon, means for coupling an external input transmission line to the end of said helix adjacent to said projecting means, a collector electrode in the path of said stream close to the opposite end of said helix, and means for inductively and capacitively coupling said opposite end to an external output transmission line, said last-named means including a coupling ring surrounding and spaced from said helix and a conductor extending laterally substantially from said opposite end and back over said helix away from said collector electrode and connected to said coupling ring, said coupling ring and conductor being located entirely within said envelope.

3. A traveling wave electron tube comprising an elongated dielectric envelope containing an elongated conductive helix, an electron gun close to one end of said helix for projecting a stream of electrons along said helix for interaction with waves traveling thereon, a collector electrode in the path of said stream close to the opposite end of said helix, and means for inductively and capacitively coupling the two ends of said helix to external input and output transmission lines, said means including a pair of axially spaced coupling rings surrounding and spaced from said helix and a conductor extending laterally substantially from each of said ends and back over said helix toward each other and each connected to one of said coupling rings, said coupling rings and said conductors being located entirely within said envelope.

4. A traveling wave tube according to claim 1, wherein said conductor includes an impedance transformer section.

5. A traveling wave tube according to claim 4, wherein said impedance transformer section comprises a spiral section of tapered diameter.

6. A traveling wave tube according to claim 1, wherein said conductor is connected to said helix at a point spaced from the end thereof by a few turns.

7. A traveling wave electron tube comprising an elongated dielectric envelope containing an elongated conductive helix and an electron gun close to one end of said helix for projecting a stream of electrons along said helix for interaction with waves traveling thereon, and means for coupling an external high frequency signal transmission line to said end of said helix, said means including a pair of conductors external to said envelope spaced along said helix adjacent said end thereof and adapted to be coupled to said line to establish a high frequency electric field between said pair of conductors and parallel to the axis of said helix, a coupling conductor located entirely within said envelope and extending laterally substantially from said end and back along said helix parallel to said axis to couple inductively with said field through said envelope, and a low impedance inductively coupling between said coupling conductor and one of said pair of conductors.

8. A traveling wave tube comprising an elongated dielectric envelope containing an elongated conductive helix and a coupling ring surrounding and spaced from said helix, a section of waveguide of rectangular cross section external to and extending transversely of said envelope and having a pair of apertures in opposite walls

thereof through which said envelope extends, said helix extending through at least one of said apertures and having one end positioned close to and in alignment with the other aperture, a coupling flange on said waveguide around said one aperture and capacitively coupled to said coupling ring through said envelope, a coupling conductor extending laterally substantially from said helix end and back along said helix away from said other aperture for inductively coupling through said envelope with the transverse high frequency electric field within said waveguide, the end of said conductor remote from said helix being connected to said coupling ring, and an electron gun in said envelope close to said helix for projecting a stream of electrons along said helix for interaction with waves traveling thereon, said coupling ring and conductor being located entirely within said envelope.

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