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L. M. FIELD ET AL

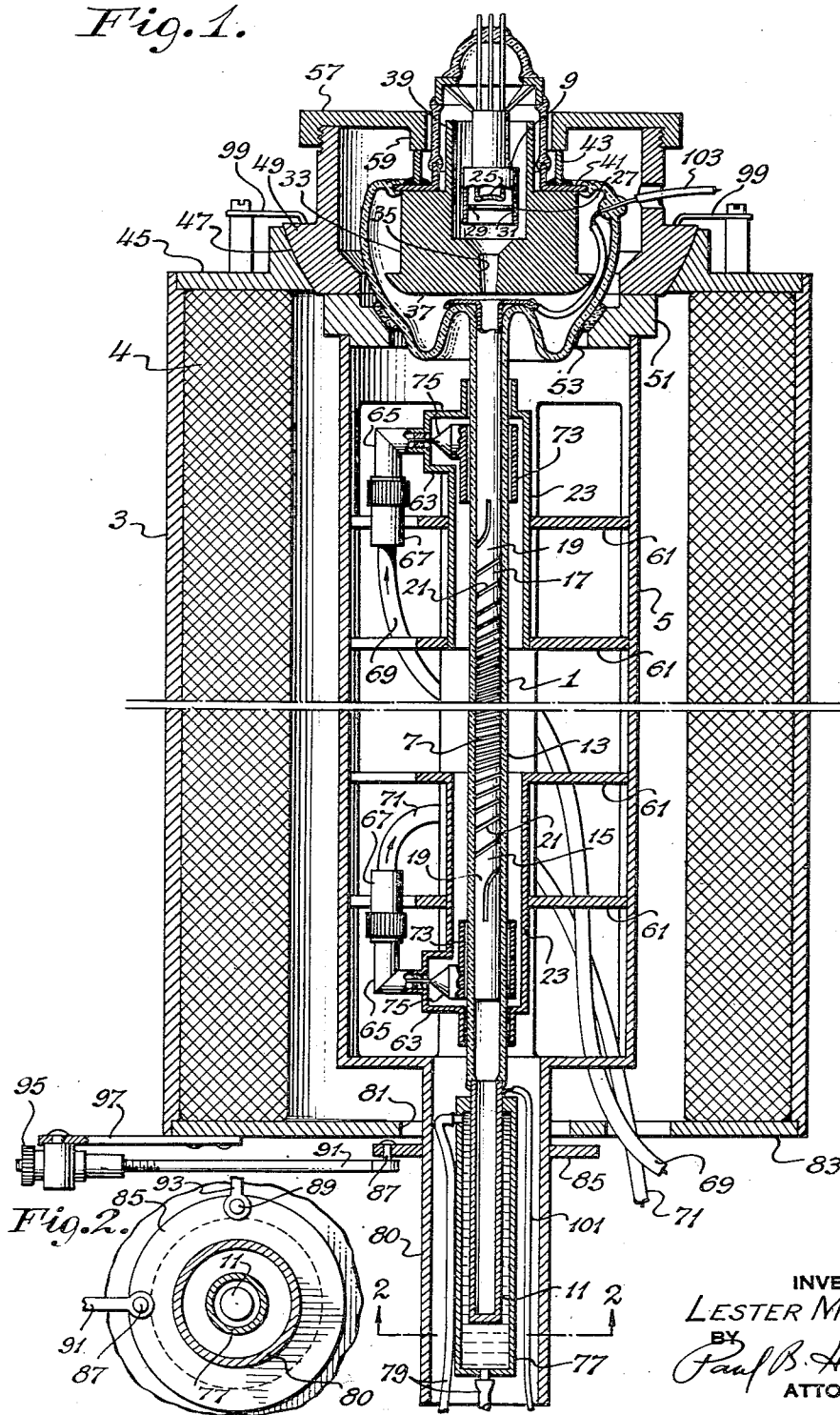
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TRAVELLING WAVE TUBE APPARATUS

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2 Sheets-Sheet 1

Fig. 1.



INVENTOR
LESTER M. FIELD
BY
Paul B. Hunter
ATTORNEY

Dec. 11, 1956

L. M. FIELD ET AL

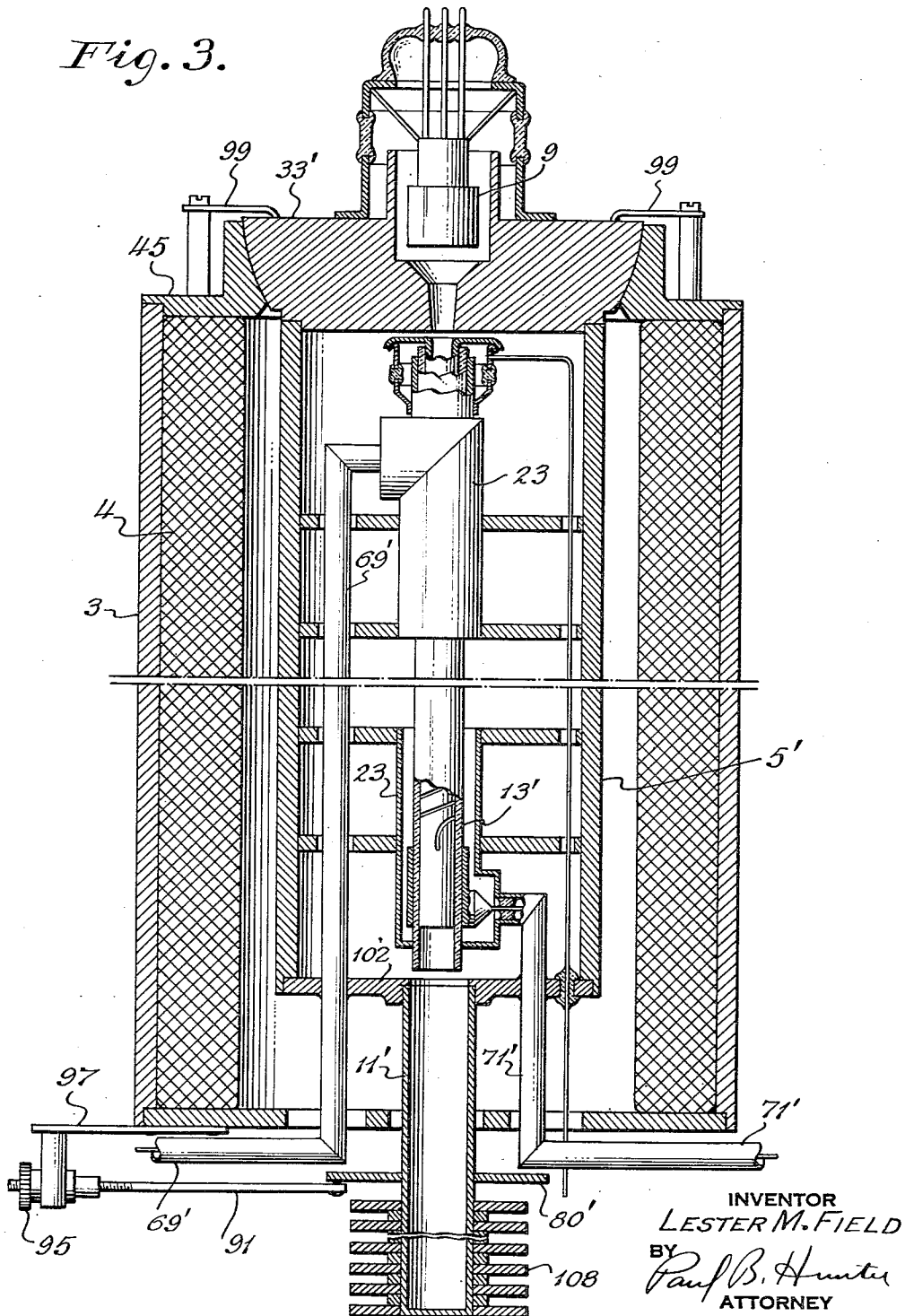
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Fig. 3.



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TRAVELLING WAVE TUBE APPARATUS

Lester M. Field and Stanley F. Kaisel, Palo Alto, Calif.; said Field assignor to The Board of Trustees of The Leland Stanford Junior University, Stanford University, Calif., a legal entity of California having corporate powers

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11 Claims. (Cl. 315—3.5)

This invention relates to improvements in travelling wave amplifiers, and more particularly to devices of the type wherein a beam of electrons is directed along the axis of a slow wave propagating structure, such as a helix, in energy exchanging relationship with waves travelling along said structure. Tubes of this type have been used to provide substantial amplification of ultra high frequency energy throughout very wide bands (for example from 2000 to 4000 megacycles per second) but in the past have suffered from the disadvantage of having small power outputs, of the order of one watt at 3000 megacycles.

The principal object of the present invention is to provide ultra high frequency amplifiers of the travelling wave type having high power capabilities and high efficiency.

One of the chief factors which determine the power handling ability of a traveling wave tube is the attainable beam density. With dense beams, the mutual repulsion between electrons tends to make the beam spread out as it travels along the wave propagating structure. This lowers the efficiency by reducing the length of the effective interaction space, and also causes heating of the wave propagating structure and adjacent supporting members by electron bombardment.

Accordingly, a specific object of this invention is to provide devices of the described type wherein electric and magnetic fields are used in combination to form and maintain, substantially without diffusion, an extremely dense electron stream along the axis of a slow wave propagating structure.

Another object is to provide improved magnetic focusing structures for travelling wave tubes, including an apertured pole piece which is at least partially within the vacuum envelope and serves as an accelerator electrode as well as part of the magnetic circuit.

It is also an object to provide improved means for obtaining exact alignment between the magnetic focusing field and the axis of the wave propagating structure in a travelling wave tube.

A further object of the invention is to provide improved coupling structures for connection between the internal wave propagating means of a travelling wave tube and an external coaxial transmission line.

The invention will be described with reference to the accompanying drawings, wherein:

Fig. 1 shows a longitudinal section of a travelling wave tube embodying the invention,

Fig. 2 is an end view of a portion of the structure of Fig. 1, showing part of the means for aligning the electron stream with the magnetic field, and

Fig. 3 shows a longitudinal section of a modification of the device of Fig. 1.

The assembly shown in Fig. 1 includes a travelling wave tube 1, a focussing magnet 3, and a supporting structure 5 for holding the tube 1 in correct alignment with the field of the magnet 3, as well as providing mechanical protection for the tube. The magnet 3 may be an electromagnet provided with an exciting winding 4,

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as shown, or may be a permanent magnet. The tube 1 includes a conductive helix 7, a cathode assembly 9 at one end of the helix, and a collector electrode 11 at the other end of the helix, all enclosed in a vacuum tight envelope 13. The central tubular portion of the envelope 13, which closely surrounds and supports the helix 7, is preferably made of quartz or similar low loss material capable of resisting high temperature. The ends of the envelope 13 may be made of glass, sealed to the quartz tube in known manner by a series of rings of glass having graded temperature coefficients of expansion.

The ends of the helix 7 are provided with transition or transformer sections 15 and 17 respectively of the type described and claimed in copending U. S. patent application Serial No. 97,070, filed June 3, 1949 by Calvin E. Quate, and entitled High Frequency Coupling Device, now abandoned. Each of these transition sections comprises a tubular conductor 19 of the same outside diameter as the helix 7, provided with a slot 21 whose width is substantially the same as the spacing between turns of the helix. The pitch of the slot 21 varies, from substantially that of the helix at its point of connection thereto, to substantially infinity at the end of the tubular conductor 19 remote from the helix.

This structure affords a smooth reflection-free transition between the longitudinal electric mode of wave propagation on the helix and the radial electric mode at the outer extremes of the transitions 15 and 17. Said radial electric mode is the characteristic or principal mode in a coaxial line. The supporting structure 5 includes tubular conductive members 23 surrounding the tube in the vicinities of the transitions 15 and 17. The members 23 act as outer conductors to support the coaxial line mode of propagation on the inner tubular conductors 19.

The cathode assembly 9 includes an emitter 25 and an electrostatic focussing electrode 27. Preferably the emitter 25 is spherically concave about the longitudinal axis of the tube, and the electrode 27 is formed of an apertured disc 29 and a hollow cylindrical member 31 surrounding the emitter, as described in copending U. S. patent application Serial No. 81,480, filed March 15, 1949 by Chao Wang, and entitled Charged Particle Beam Forming Apparatus, now U. S. Patent No. 2,564,743, issued August 21, 1951.

A body 33 of ferromagnetic material, such as iron, is provided with a central aperture 35 which may be of frusto-conical shape as shown. The body 33 is provided with a flat face 37 and is adapted to act as a pole piece for magnetic focussing of the electron beam. A skirt 39 of magnetic material extends from the piece 33 back over the cathode assembly 9 to shield the cathode from the field of the magnet 3.

The pole piece 33 is also adapted to function as an anode or accelerator electrode, and for this purpose it is electrically connected through a metallic insert 41 in the end of the tube to a terminal ring 43. The structure and arrangement of the pole piece 33 and the cathode 9 are similar to those described in copending U. S. patent application Serial No. 117,187, filed September 22, 1949 by Charles E. Rich et al. and entitled High Frequency Beam Tube Device, now U. S. Patent No. 2,687,490, issued August 24, 1954.

The end wall 45 of the magnet 3 adjacent the cathode end of the tube 1 is provided with a concave spherical surface at 47, adapted to engage closely the mating outer spherical surface of a member 49 which is made of iron or other magnetic material. The member 49 is hollow, as shown, to contain the bulb portion of the tube 1 surrounding the cathode assembly 9 and the pole piece 33. The member 49 is secured to a ring 51 which

is in turn secured to the tube supporting structure 5. The ring 51 as well as the structure 5 are preferably of non-magnetic material such as brass.

The inside surface of the ring 51 carries a pad 53 of felt, sponge rubber, or other suitable material. The bulb of the tube 1 is held against the pad 53 by a cap 57 which is threaded on the end of the member 49 and provided with an internal flange 59 for engagement with the terminal ring 43.

The supporting member 5 is provided near its ends with internal transverse walls 61 which support the tubular conductors 23. The conductors 23 include, near their respective outer ends, lateral extensions 63 which carry fittings 65 adapted to engage standard coaxial line terminals 67 at the ends of coaxial transmission lines 69 and 71. The lines 69 and 71 may be of the flexible solid dielectric type, and they pass through openings in the walls of the support 5 and the magnet 3 to external source and utilization devices respectively, not shown.

Conductive sleeves 73 are arranged to surround closely the envelope 13 of tube 1 outside the ends of the transition sections 15 and 17, and are capacitatively coupled to said transition sections through the envelope 13. Conical conductors 75 connect the sleeves 73 to the inner conductors of the coaxial line fittings 65. The proportions of the conductors 75 are substantially as shown to minimize impedance discontinuities in the connections between the relatively large coaxial lines formed by the conductors 23 and 73, and the relatively small coaxial lines of the fittings 65.

The collector 11 may be enclosed in a jacket 77 for cooling by liquid, e. g., water, circulated therethrough by way of hoses 79. An extension 80 of the supporting member 5 goes through an opening 81 in the end wall 83 of the magnet 3 and surrounds the collector assembly. The extension 80 carries a flange 85 which is pivotally connected at points 87 and 89 to rods 91 and 93 respectively (see Fig. 2) which extend out radially and substantially at a right angle to each other.

The rod 91 is threaded at its outer end, and goes through an adjusting nut 95 pivotally supported on an arm 97 secured to the wall 83 of the magnet 3. The rod 93 is arranged for adjustment in like manner so that the end 80 of the tube supporting member may be moved radially in any direction. Thus the tube 1 in its support 5 may be swivelled about the center of curvature of the mating spherical surfaces of the parts 45 and 49 to place the axis of the helix 7 in exact alignment of the magnetic field which runs between the surface 37 of the pole piece 33 and the inside of the end wall 83. Leaf springs 99 at the upper end of the structure hold the parts 45 and 49 in engagement at 47.

In the operation of the described apparatus, the exposed structure including the shell of the magnet 3 is preferably grounded. This also maintains the anode or accelerator electrode 33 at ground, through the connection made by the terminal ring 43. The cathode assembly 9 is made highly negative with respect to ground, by suitable connection to an external source, not shown. The optimum potential of the cathode is determined by the design of the tube, and may be around 3000 volts in a typical case. The collector 11 may also be grounded through a lead 101, and the helix 7 may be maintained at ground or at some other potential by connection of a lead 103 to the proper point in the D. C. supply source.

The magnet winding 4 is also connected to a D. C. supply, not shown, and the adjusting nut 95 and the corresponding nut on the rod 93 are manipulated to make as much as possible of the cathode emission flow to the collector 11. This condition may be indicated by a current meter inserted in the connection of the lead 101 to ground.

After the tube has been aligned with the magnetic field, the field strength may be adjusted by variation of the current in the winding 4 to result in the best focussing

of the electron beam. It has been found in practice that a tube like that of Fig. 1, with a helix having an inner diameter of 0.110 inch and a length of 13 inches, may be operated with an electron beam of 200 milliamperes at 3000 volts with a loss of only one milliampere of beam current by electrons striking the helix or accelerator instead of the collector. This is about ten times the beam density commonly used in correspondng prior art travelling wave tubes, and a power output of over 60 watts has been obtained with the described tube operating in the 2000-4000 megacycle per second range.

In the modification shown in Fig. 3, the anode electrode, pole piece and the ball element of the swivel joint are constituted by a single member 33'. The part 5', which comprises a non-magnetic metallic member corresponding to the tube supporting structure 5 in Fig. 1, is made vacuum tight and serves as part of the vacuum envelope of the tube. The upper end of the part 5' is brazed or similarly secured to the piece 33', and the lower end is likewise affixed to a wall 102 comprising metallic means transverse the axis of the tube for supporting the collector 11'. In this instance the collector 11' is air-cooled as by fins 103, and it also carries the ring 80' for the radial adjusting rods 91 and 93.

The helix 7 and transition devices 15 and 17 are contained in and supported by a quartz tube 13' as in Fig. 1, but the tube 13' does not form part of the vacuum envelope in the device of Fig. 3. The input and output coaxial lines 69' and 71' may be of rigid construction, at least to the points where they emerge through the wall 102 in vacuum sealed relationship therewith.

In all other respects, the apparatus of Fig. 3 is substantially the same as that of Fig. 1, and the adjustment and operation is the same.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A travelling wave amplifier including a slow wave propagating structure, a cathode near one end of said propagating structure, a collector electrode near the other end of said propagating structure, a first magnetic pole piece structure in the vicinity of said cathode, a tubular member supporting said propagating structure, cathode, collector, and said first magnetic pole piece structure in fixed positional relationship to each other, a magnetic circuit including said first pole piece structure, a second magnetic pole piece structure and a magnetic bridging member, said second pole piece structure being in the vicinity of said collector electrode, said bridging member and said first pole piece structure having mating spherical surfaces, said magnetic circuit being arranged for the flow of a magnetic flux therethrough and across said mating spherical surfaces, and means for adjusting the position of said tubular supporting member with respect to said second pole piece structure.

2. The structure as set forth in claim 1, further including electrostatic focussing means adjacent said cathode for directing electrons emitted by said cathode toward said helix, and means for magnetically shielding said cathode.

3. The invention as set forth in claim 2, wherein said first mentioned pole piece structure includes an orifice coaxial with the axis of said helix and disposed between said cathode and said helix to act as an accelerator electrode.

4. The invention as set forth in claim 3, wherein said tubular supporting member includes an envelope of dielectric material surrounding said helix, and means for transferring radio frequency energy between said helix and a coaxial transmission line outside said tubular sup-

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porting member comprising a conductive sleeve surrounding said tubular supporting member adjacent the end of said helix, a substantially conical conductor connected at its base to said sleeve and connected at its apex to the inner conductor of said coaxial line, and an outer tubular conductor around said sleeve and connected to the outer conductor of said coaxial line.

5. The invention as set forth in claim 4, including a vacuum envelope surrounding said helix, cathode, and collector, said first mentioned pole piece constituting a portion of said vacuum envelope.

6. Apparatus including a wave propagating structure of generally cylindrical cross section, a tube of dielectric material enclosing said structure, and a coaxial transmission line outside said tube, and a coupling device for transferring radio frequency energy between said wave propagating structure and said coaxial line, comprising a conductive sleeve surrounding said tube at an end of said propagating structure, a substantially conical conductor extending radially outward from said sleeve connected at its base to said sleeve and connected at its apex to the inner conductor of said coaxial line, and an outer tubular conductor around said sleeve and means connecting said outer tubular conductor to the outer conductor of said coaxial line.

7. In a high frequency device including a wave propagating structure of generally cylindrical cross section, a conformally shaped tube of dielectric material enclosing said wave propagating structure, and a coaxial transmission line adapted to be connected to an external means: a coupling device for transferring radio frequency energy between said wave propagating structure and said coaxial line, said coupling device comprising a conductive sleeve surrounding said tube at an end of said propagating structure, a substantially conical conductor extending radially outward from said sleeve and connected at its base to said sleeve and connected at its apex to the inner conductor of said coaxial line, and an outer sleeve around said first mentioned sleeve and connected to the outer conductor of said coaxial line.

8. A travelling wave tube including a cathode, a collector electrode, and a helix extending between said cathode and said collector electrode, a body of magnetic material having an aperture between said cathode and said helix and a tubular skirt extending over and surrounding said cathode, and a tubular envelope surrounding said helix and sealed to said body to cooperate therewith as a vacuum enclosure, with at least one surface of said body outside said enclosure, said surface being substantially spherical with its center of curvature on the axis of said helix.

9. A travelling wave tube including a cathode, a collector, a helix extending between said cathode and said collector, and a tube of dielectric material surrounding and supporting said helix; a body of magnetic material having an aperture between said cathode and said helix,

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and a tubular envelope outside said dielectric tube and sealed to said body to cooperate therewith as a vacuum enclosure, with at least one surface of said body outside said enclosure, said surface being substantially spherical with its center of curvature on the axis of said helix.

10. A travelling wave tube including a cathode, a collector, and means for propagating a slow electromagnetic wave along a path between said cathode and said collector, said wave propagating means having an input coupling means at one end thereof and an output coupling means at the other end, an evacuated envelope enclosing said cathode and wave propagating means, said envelope having a first substantially cylindrical metallic portion, supporting means fixed to said cylindrical portion and arranged to support said wave propagating means, said envelope having a further cylindrical metallic portion connected to and supported by said first metallic portion and forming said collector, and two electromagnetic wave transmission means entering said first cylindrical metallic portion at regions near the collector and being respectively connected to said input and output coupling means.

11. A travelling wave tube including an electron gun for producing and directing an electron beam along a predetermined axis, a collector along said axis for receiving said electron beam, means along said axis in substantially coaxial relationship with said axis between said electron gun and said collector for propagating a slow electromagnetic wave for interaction with said electron beam, a substantially cylindrical non-magnetic metallic member enveloping said slow wave propagating means and extending beyond the ends thereof, means supported by said metallic member for supporting said wave propagating means within said metallic member, metallic means transverse said axis and affixed to an end of said metallic member farthest from said electron gun for supporting said collector, means including said metallic member and said transverse metallic means for defining an evacuated envelope for said electron beam, and first and second electromagnetic wave transmission means passing through said transverse metallic means in vacuum sealed relationship therewith and respectively coupled to opposite ends of said slow electromagnetic wave propagating means within said evacuated envelope.

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