Nov. 24, 1970 R. C. M. KING 3,543,195

TRAVELLING WAVE TUBES

Filed May 19, 1967

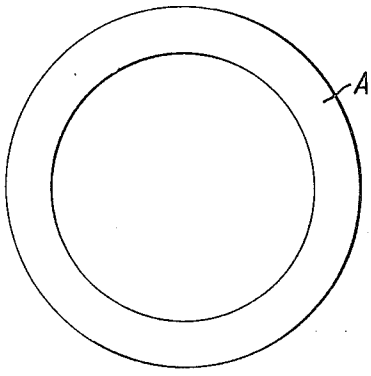


FIG. 1

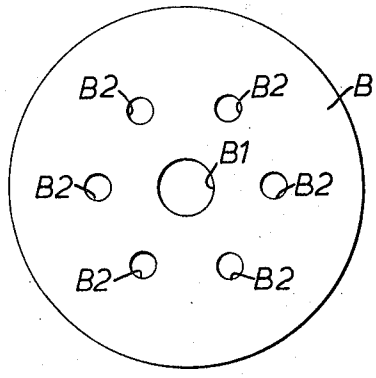


FIG. 2

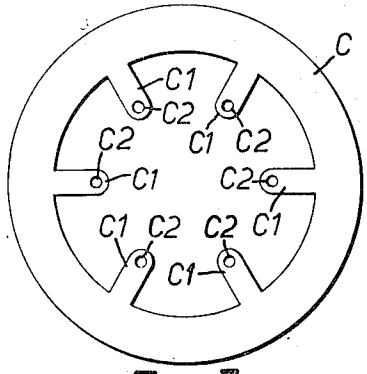


FIG. 3

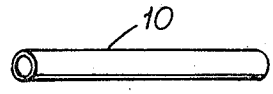


FIG. 5A

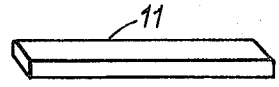


FIG. 5B

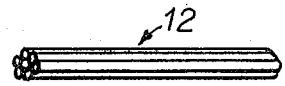


FIG. 5C

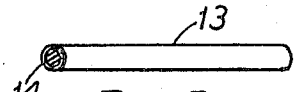


FIG. 5D

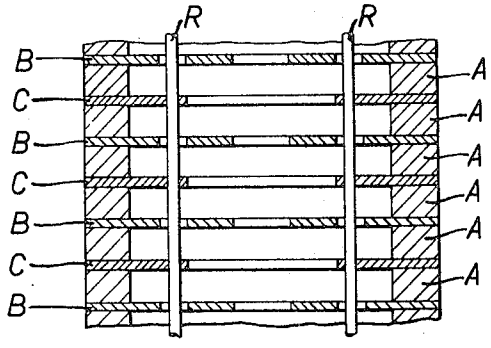


FIG. 4

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TRAVELLING WAVE TUBES

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Int. Cl. H03h 9/30
U.S. Cl. 333—31 7 Claims

ABSTRACT OF THE DISCLOSURE

Known resonant cavity types of slow wave structure consisted of a waveguide having transverse partitions with aligned central holes, the partitions being coupled by S-shaped loops. These structures were improved upon by a staggered coupling arrangement which used rods to connect partitions, half the rods connecting alternate partitions and the other half connecting the remaining partitions. Unfortunately, to obtain cavity resonance, the rods had to be long and the beam voltage at least 100 kv. These problems are overcome by a symmetrical arrangement in which alternate partitions have a ring of inwardly projecting fingers with which all the rods are in contact and the remaining partitions have a ring of holes through which the rods pass without making contact therewith.

This invention relates to travelling wave tubes and more specifically to travelling wave tubes of the kind in which the slow wave structure comprises a plurality of coupled resonant cavities. The object of the invention is to provide improved travelling wave tubes of this kind, suitable for use at high powers, which shall be as satisfactory electrically as known tubes of the said kind but easier and cheaper to manufacture than such known tubes of comparable performance.

The coupled resonant cavity type of slow wave structure offers, theoretically, promise of being very satisfactory electrically for high power travelling wave tubes and a number of structures of this type have been proposed for such use. Such structures as so far proposed, are, however, very difficult and expensive to make. Two such structures, both very good from the electrical point of view, are described in a paper No. 2681R presented by A. F. Pearce, Ph. D., at the International Convention on Microwave Valves on May 22 1958, and published by the Institution of Electrical Engineers in December 1958. One of these structures, referred to in the said paper as being a structure using reversed loops, a "negative-mutual-inductance-coupled structure" consists of a circular wave guide having therein transverse disc like members with aligned central apertures through which the beam passes, and which are coupled by S-shaped loops. A number of these loops, each of which resembles, when viewed in a transverse direction, a sinusoidal wave form, is provided as part of each disc member, lying between an inner portion of the disc member surrounding the central beam-passing aperture and an outer portion of the disc member adjacent to the wall of the wave guide so that each disc member consists of the said inner and outer portions and a number of radially disposed S-shaped loops between them, adjacent S-shaped loops in a disc being oppositely bent. Another of these structures, referred to in the said paper as being a structure using non-reversed loops, again consists of a circular wave guide having therein transverse disc members with aligned central apertures through which the beam passes but there are no S-shaped loops and, instead, there are, in association with each disc member, a number of loops, semicircular in shape and each

fixed to the wave guide wall at both ends, passing through slots in the disc member. For further information with regard to these known structures reference is directed to the aforesaid paper by A. F. Pearce. These structures, though very good electrically, are obviously exceedingly difficult and expensive to manufacture with the result that so far as the present applicant is aware, they have not been used to any material extent (if at all) in commercially available factory manufactured travelling wave tubes.

The invention in the specification accompanying British application No. 3,720/66 now published British Pat. Spec. 1,113,767 seeks to provide an electrical performance comparable to that of the Pearce structures but without their manufacturing and mechanical defects. According to the said invention in the said British patent specification a travelling wave tube has a slow wave structure of the coupled resonant cavity type and comprising a length of wave guide, a plurality of spaced partition members hasing aligned central holes to pass the electron beam, said partition members being transversely arranged with respect to the guide, and a plurality of coupling loops each extending over the length of two successive cavities and each of which is constituted by a conductor extending between and connected to two alternate partition members lying between the points of connection of said conductor and the guide wall.

According to a feature of the invention of the aforesaid British patent specification a travelling wave tube has a slow wave structure of the coupled resonant cavity type and comprising a length of wave guide, a plurality of transverse disc-like spaced partition members having aligned central holes to pass the electron beam and an even number of longitudinally arranged connecting conductors in a ring coaxial with the longitudinal axis of the structure, half of said conductors being connected to alternate partition members but not to the other partition members and the other half of said conductors being connected to said other partition members but not to said alternate partition members.

It is an essential feature of the invention of the aforesaid British patent specification that the conductors, normally rods, shall contact with alternate partition members, which are the inter-cavity walls, in order that the coupling elements shall be resonant. The result is a non-symmetrical circuit arrangement, or what may be termed a "staggered" circuit arrangement. It can be shown that a staggered circuit arrangement alters the shape of the TM_{01} dispersion curve so that, in the case of a voltage-tuned travelling wave tube a substantially flat gain-frequency characteristic results. However, because the cavity coupling elements of an arrangement in accordance with the aforesaid British patent specification have to be resonant at a frequency which is below the fundamental cavity resonance frequency, the rods employed cannot be short and this fact puts a restriction on the permissible reduction of the cavity height (i.e. length in the axial direction) and this in turn necessitates the use of high electron beam voltages. Experiment indicates that the electron beam voltage, in a typical practical case, has to be at least 100 kv.

Accordingly, the full benefits of a staggered coupling arrangement are not obtained because voltage tuning is not wanted with such a high beam voltage. In fact there is the defect that the practical working frequency band of the tube is reduced. As will be appreciated, the electrons in the beam will synchronise with the coupling element pass band at one frequency because this pass band must be below the main cavity pass band. As is known, the resultant oscillations will be easier to

damp out if the lower pass band has a forward wave fundamental but this condition cannot exist with a staggered arrangement since no "partial resonance" condition exists. If, however, the coupling arrangement is not a staggered one but a symmetrical one, then, provided the coupling pass band is below the "partial resonance" frequency, this pass band will be forward wave.

The present invention seeks to provide improved travelling wave tubes having the mechanical and manufacturing advantages of tubes in accordance with the invention of the aforesaid co-pending specification but which shall employ a symmetrical instead of a staggered circuit arrangement and which will not, therefore, have the defects above mentioned.

According to this invention a travelling wave tube has a slow wave structure of the resonant cavity type providing a symmetrical circuit arrangement of loops including longitudinal conductors and transverse plate members, alternate plate members having inward projections with which the said conductors are in electrical contact and the remaining alternate plate members having holes through which said conductors pass without electrical contact therewith.

According to a feature of this invention a travelling wave tube has a slow wave structure providing a symmetrical circuit arrangement said structure comprising a stack of ring members of relative large inner diameter and transverse plate members, alternate plate members in the stack consisting each of a ring also of relatively large inner diameter but having a plurality of inward radial projections each adapted to receive a conductor at or near its inner end, the remaining alternate plate members consisting each of a ring of relatively small internal diameter adapted to pass an electron beam and having a circle of holes therethrough, a ring member being disposed between each two successive plate members and longitudinal conductors being provided in good electrical contact with said projections at or near their inner ends, said conductors passing through the holes of the circles of holes but out of contact therewith.

The longitudinal conductors may be rods for example rods of circular section. This is, however, not essential, for, instead of rods being of circular or other section the longitudinal conductors could be angle section bars; or lengths of sheet material folded into any desired sectional shapes to present the required stiffness; or lengths of flat strips; or lengths each of a number of wires or other conductors in parallel; or deposits of metal electrolytically or otherwise deposited on longitudinal non-conductive members, such as rods or tubes, to provide necessary stiffness and rigidity.

Preferably also the ring members and transverse plate members are all of the same outer diameter, each of the transverse plate members having holes lying in a circle of the same diameter the holes in the plate members having radial inward projections being near the inner ends of said projections.

The invention is illustrated in the accompanying drawings which show, so far as is necessary to an understanding of the invention, one embodiment. The parts of the travelling wave tube illustrated by the accompanying drawings are as known per se except for the retarding wave structure, and, accordingly, only the said structure is shown. In the drawing, FIG. 1 is a face view of a ring member incorporated in the retarding wave structure; FIGS. 2 and 3 are face views of the two forms of transverse plate members used in the structure; and FIG. 4 is a diametrical section, shown broken away at the ends, of the assembled retarding wave structure. FIGS. 5A through 5D are pictorial views of conductors which may be used in the travelling wave tube illustrated in FIGS. 1 through 4.

Referring to the drawings the retarding wave structure therein shown includes an aligned stack of members so shown in FIGS. 1, 2 and 3. They consist of simple

ring members A (FIG. 1); plate members B each with a central hole B1 to pass the electron beam of the tube, and a circle of holes B2 (six such holes are shown by way of example); and a plate member C consisting of a ring with inward radial projections C1 (again there are, by way of example, six) each having a conductor receiving hole C2 close to its inner end.

All the members A, B and C are of the same outer diameter. Member A is of a relatively large inner diameter which is the same as that of the ring part of member C from which the inward radial projections C1 project. Member B has a relatively small inner diameter large enough to pass the electron beam of the tube which is generated by the usual electron gun structure (not shown) of the tube and is projected through the slow wave structure to a collector electrode (not shown). This structure has the customary input and output means (not shown) at its ends. The holes B2 lie on a circle of the same diameter as the holes C2 but are individually of larger diameter than the said holes C2.

The members A, B and C are assembled in an aligned stack (see FIG. 4) with the holes B1 aligned and the centres of the holes B2 and C2 in six lines of alignment. R are conducting rods of substantially the same diameter as the holes C2, so as to provide electrical contact between rods R and plate member C, and are fitted tightly in those holes, passing also through the holes B2 but out of contact therewith. Conductors R may also be tubes, bars, or strips. They may be made of sheet material, or non-conductive support members having conductive deposits thereon. Each may be composed of a plurality of component conductors in parallel.

It will be seen that the structure illustrated by the drawings is in symmetrically coupled arrangement and is electrically the same as the symmetrically coupled arrangements of A. F. Pearce as described in the paper 2681R (supra). However it is of much simpler construction mechanically, the square section loops including the lengths of rod R between successive plates C and the inward projections of those plates. The resonant frequency can be controlled by suitably choosing the size of the holes in the ring members A, which is a simple matter to do. For a given case the rods R can be about only half the length of the longitudinal rods in the constructions described in the aforesaid British patent specification, the necessary extra inductance being provided by the projections C1.

As pointed out above, the conductors may take a number of forms. The conductors may be in the form of a tube **10** as illustrated in FIG. 5A, a bar or strip **11** as illustrated in FIG. 5B, or a plurality of component conductors **12** in parallel as shown in FIG. 5C. As illustrated in FIG. 5D, each of the conductors may be constituted by conductive deposits **13** on a longitudinal non-conductive support member **14**.

I claim:

1. A travelling wave tube having a slow wave structure providing a symmetrical circuit arrangement, said structure comprising a stack of ring members of relatively large inner diameter and transverse plate members; alternate plate members in the stack consisting each of a ring also of relatively large inner diameter but having a plurality of inward radial inductive projections each adapted to receive a conductor at or near its inner end, the remaining alternate plate members consisting each of a ring of relatively small internal diameter adapted to pass an electron beam and having a circle of holes therethrough, said remaining alternate plate members forming walls of a plurality of resonate cavities, and said holes having at least one side wall; a ring member disposed between each two successive plate members; and a plurality of longitudinal conductors, each conductor being in good electrical contact with a single inward radial inductive projection on each of the first said alternate plate members at or near the inner ends of respective

inductive projections, each of said conductors passing through a single hole of said holes of the circles of holes on each of said remaining alternate plate members but out of contact with all of said remaining alternate plate members thereby providing capacitance between said each conductor and the said at least one sidewall of each hole through which it passes, each length of each conductor between each two of said radial inductive projections with which it is in contact on successive ones of the first said alternate plate members and the said each two of said projections forming a coupling loop between adjacent resonate cavities of saaid plurality of resonate cavities.

2. A tube as claimed in claim 1 wherein the longitudinal conductors are bars or strips.

3. A tube as claimed in claim 1 wherein the longitudinal conductors are constituted each by a plurality of component conductors in parallel.

4. A tube as claimed in claim 1 wherein the longitudinal conductors are of sheet material.

5. A tube as claimed in claim 1 wherein the longitudinal conductors are constituted by conductive deposits on longitudinal non-conductive support members.

6. A tube as claimed in claim 1 wherein the ring members and transverse plate members are all of the same outer diameter, each of the transverse plate members having holes lying in a circle of the same diameter the holes in the plate members having radial inward projections being near the inner ends of said projections.

7. A travelling wave tube having a slow wave structure providing a symmetrical circuit arrangement, said structure comprising a stack of flat members having a relatively large inner aperture therein and transverse plate members; alternate plate members in the stack consisting each of a flat member also having a relatively large inner aperture but having a plurality of inward inductive projections each adapted to receive a conductor at or near its inner end, the remaining alternate plate members consisting each of a flat member having a relatively small internal aperture adapted to pass an electron beam and having a row of holes therethrough, said remaining alternate plate members forming walls of a plurality of resonate cavities, and said holes having at least one side wall; a spacing member disposed between each two successive plate members; and a plurality of longitudinal conductors, each conductor being in good electrical contact with a single inward inductive projection on each of the first said alternate plate members at or near the inner ends of respective inductive projections, each of said conductors passing through a single hole of said holes of the row of holes on each of said remaining alternate plate members thereby providing capacitance between said each conductor and the said at least one sidewall of each hole through which it passes, each length of each conductor between each two of said inductive projections with which it is in contact on successive ones of the first said alternate plate members and the said each two of said projections forming a coupling loop between adjacent resonate cavities of said plurality of resonate cavities.

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U.S. Cl. X.R.

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