

The present invention relates to a method for producing a delay line for a broadband travelling-wave tube, which delay line contains spacers and pole shoes arranged coaxially with respect to an electrically conducting cylinder, which delay line also contains a helix placed in the electrically conducting cylinder and fixed with respect to this cylinder in coaxial orientation by holding rods and which delay line furthermore contains loading bars, arranged axially parallel, which adjoin the electrically conductive cylinder and leave free, towards the helix, a gap of only a few tenths of a millimetre with a low tolerance in its gap width, wherein the loading bars are integrally connected to the internal wall of the electrically conductive cylinder. A travelling-wave tube of this type is, for example, described in an article by J.L. Putz and J.J. Cascone, see IEDM 1979, p. 422-424. The loading bars are not, however, integrally connected to the internal wall of the electrically conductive cylinder.

In travelling-wave tubes of this type, extremely stringent requirements for the dimensional accuracy of the loading rods and of the helix of the travelling-wave tube are demanded. The separations between the helix and the loading rods are in the range of a few tenths of a millimetre and must be maintained accurately to within a few μm over a length of, for example, 10 cm.

The fundamental object of the present invention consists in specifying a method with which such delay lines can be produced with satisfactory precision and reproducibly. This object is achieved by virtue of the features of Patent Claim 1 and in an advantageous embodiment by virtue of the features of Claim 1, it being intended to retain the sequence of procedural steps but it being possible to implement the measures of a procedural step in a different sequence.

Loading rods integrally connected to the internal wall of the electrically conductive cylinder are optimally fixed in their mutual position and avoid tolerance variations which cannot be avoided in each

soldering process and in each adhesive bonding of two parts. An inclination of the axis of the cylinder with respect to the symmetry axis of the pole shoes, which is unavoidable, for example, when soldering in or adhesively
5 bonding in the spacers and pole shoes affects the delay line and the loading bars to the same extent. The mutual position of these parts is not altered. Focusing magnets are subsequently inserted between the pole shoes. As a result of this the mutual position of the said parts is
10 no longer affected.

A vacuum-tight embodiment is obtained in a simple manner in that the spacers and magnetizable pole shoes lying between the latter are soldered to one another and have coaxial bores, in that these bores on the external
15 diameter of the electrically conductive cylinder are accurately matched and in that the metal cylinder is pushed into these bores and is soldered to the spacers, which are used for centring the focusing magnets, and to the pole shoes.

20 Three holding rods are advantageously provided, one of the holding rods being supported against the internal wall of the electrically conducting cylinder by a spring.

It has been found that the requisite extremely
25 high precision in the dimensions of the loading bars and of the cylinder can be achieved by means of wire spark-erosion. The specified sequence of procedural steps furthermore allows completely delay-free formation of the desired profile and exact adjustment of the beam rela-
30 tively to the magnets. Wire spark-erosion furthermore allows the production of complex designs of loading bars. The sequence: first installing the tube and then forming the loading bars by wire spark-erosion furthermore makes it possible to introduce insulating rods with a relative-
35 ly high contact pressure, which is obtained, for example, by means of a relatively stiff spring, since the wall of the cylinder is additionally reinforced by the spacers and pole shoes after installation of the cylinder and a relatively high pressure on the internal wall of the

cylinder can consequently be withstood. It thus guarantees particularly highly developed and advantageous dissipation of heat from the helix. One of the substances BN, BeO, Al₂O₃ are particularly suitable as material for the holding rods. The high thermal conductivity of the holding rods, which may also consist of diamond material for very high loads, can here be exploited particularly advantageously.

The production method according to the invention also guarantees high reproducibility, since the influence of the soldering processes is completely excluded, in that the final shape is produced only after soldering.

In this way an accuracy of $\pm 5 \mu\text{m}$ over a length of 100 mm can be maintained without particular difficulty and can be reproduced as often as desired, even if the internal diameter of the inserted tube is only approximately 2 mm.

Holding of the helix can furthermore, by virtue of the particularly advantageous installation described, also be carried out using known methods such as, for example, contraction or soldering.

The invention will next be described in further detail with the aid of three figures. It is not restricted to the examples shown in the figures.

Figures 1 and 2 show an example of a delay line according to the invention in sectional view, the diameter measurements having been greatly altered with respect to a scale representation for the purpose of clarity. Figure 3 shows another example of a delay line according to the invention in sectional view.

A tube body 11 is assembled from annular, nonmagnetic spacers 1 and from pole shoes 2 consisting of magnetizable material. The pole shoes 2 extend beyond the spacers 1 in the radial direction, so that focusing magnets can easily be fitted between every two adjacent pole shoes. Such a tube body 11 is expediently assembled by threading the spacers 1 and the pole shoes 2 onto a tube and subsequently soldering the individual rings. The internal diameter of this tube body 11 is matched to

the external diameter of a cylinder 5. The cylinder 5 is fixed in the tube body 11, for example by soldering. Loading bars 4 are integrally connected to the cylinder 5. The loading bars 4 leave free, towards the coaxially arranged helix 9, an accurately defined gap 12 in their width. The helix 9 is supported and fixed with respect to the internal wall of the cylinder 5 by holding rods 6 and 8. In this case the rods 6 lie directly on the cylinder 5, whereas the bar 8 is designed somewhat shorter and is kept under pressure by a tension spring 7. This pressure produces excellent heat transmission between the helix 9 and the holding rods 6 and 8 and between the holding rods 6 and the cylinder 5, or between the holding rod 8 and the tension spring 7, respectively. Maximum precision for the position of the helix 9 is simultaneously produced, since the holding rods are ground very exactly to size.

In the case of increased requirements for heat dissipation, three or more holding rods 6 may even be used, it then being recommended to solder these holding rods 6 into the cylinder 5.

An advantageous method for producing such a delay line consists in first producing the tube body 11 from the spacers 1 and the pole shoes 2 and honing the internal wall of this tube body 11 to the required size, in then pushing a thick-walled tube 3 into the tube body 11 and fixing, in particular soldering, it there and in, after fixing the tube 3, producing the desired profile using a wire spark-erosion process, that is to say an electric discharge machining process in which a wire is pulled through the tube and is simultaneously moved in a plane perpendicular to the tube axis so that the desired contours are cut out from the wall of the tube. Loading bars having any desired cross-section can be machined using this process. In this case the end faces of the loading bars 4 and the internal wall of the cylinder 5 are produced using the same tool, so that maximum accuracy in the mutual position of the said parts is obtained over their entire length. Maximal positional

accuracy of the helix 9 which is adjusted with respect to the internal wall of the cylinder 5 using the holding rods 6 and 8 is correspondingly also achieved. Honing the tube body 11 promotes whole-surface coverage and uniform distribution of the solder during soldering in.

In an advantageous embodiment of the method according to the invention, the spacers 1 and the pole shoes 2 are threaded onto a thick-walled nonmagnetic tube 3 and are soldered thereto and to one another in a working step. The loading bars 4 of the cylinder 5 are then machined using wire spark-erosion from the thick-walled tube 3 and the holding rods 6 and the, if applicable, the [sic] holding rods 8 and the tension spring 7 are pushed in. This embodiment of the method is relatively cost-efficient and in many cases can be carried out sufficiently precisely. The focusing magnets required in the travelling-wave tube can be inserted between the pole shoes, adjusted to give optimum magnetic field distribution in the cylinder 5 and adhesively bonded and soldered to the pole shoes. This also produces no disruptive influence on the geometry of the delay line.

Since in the case of the design according to the invention and, in particular, when using the specified method, soldering and adhesively-bonding connections are in no way involved in the tolerance of the mutual position of the helix, of the cylinder wall and of the loading bars, any danger of alteration of the mutual position in the radial direction between these parts during assembly is completely ruled out. The design and the method therefore guarantee that a tolerance of, for example, only $\pm 5 \mu\text{m}$ over a length of 10 cm, which can be reproduced in batch production, can be maintained.

The design according to the invention also makes it possible to use complex shapes of the loading bars as, for example, exhibited by the loading bars 10 in Figure 3. Even these bar shapes can be produced with high precision and reproducibility if the tube 3 is inserted into the stable tube body 11 and fastened there beforehand.

Using the invention, the specified structures can be produced, for example in a tube 3 having an external diameter of less than 2 mm.

In so far as a particularly low thermal resistance between the holding rods and the cylinder wall is necessary, holding rods 6 having the same width as one another in the radial direction can also be fixed in the cylinder 5 by means of a contraction technique which is known per se. In this case, before fitting the helix 9 and the holding rods 6, a temperature difference is produced, in the case of which the tube body 11 and the cylinder 5 are hotter than the helix 9 and the holding rods 6. After fitting, the temperature equilibrates, and the helix is placed under pressure and thus held. This holding in no way produces positional deviations, of which there was a risk in the case of soldering. On the other hand, for example, combination of the contraction technique with an additional soldering is logical, in so far as the mechanical fastening by the contraction process is carried out and the solder merely reinforces the heat transfer in this case.

For example, copper or a metal having a high electrical resistivity are suitable as material for the cylinder. Ceramic, in the case of relatively low requirements and diamond material, in the case of relatively high requirements for thermal dissipation are recommended as material for the holding rods, since diamond material has a considerably higher thermal conductivity than the other suitable materials.

30 5 [sic] Patent claims
3 Figures



Patent claims

1. Method for producing a delay line for a broadband travelling-wave tube, which delay line contains spacers (1) and pole shoes (2) arranged coaxially with respect to an electrically conducting cylinder (5), which delay line also contains a helix (9) placed in the electrically conducting cylinder (5) and fixed with respect to this cylinder (5) in coaxial orientation by holding rods (6, 8) and which delay line furthermore contains loading bars (4), arranged axially parallel, which adjoin the electrically conductive cylinder (5) and leave free, towards the helix (9), a gap of only a few tenths of a millimetre with low tolerance in its gap width, wherein the loading bars (4) are integrally connected to the internal wall of the electrically conductive cylinder (5), having the following procedural steps:
 - a) the spacers (1) and pole shoes (2) are first arranged in an alternating sequence, are soldered to one another and are provided with coaxial bores,
 - b) the coaxial bores are then matched to the diameter of the electrically conducting cylinder (5) such that the latter can be pushed in and soldered in,
 - c) a thick-walled, electrically conductive tube (3) is then pushed into the coaxial bores and soldered in, the internal diameter of which tube is at least no larger than the smallest mutual radial separation of the loading bars (4) and the external diameter of which tube corresponds to that of the electrically conductive cylinder (5),
 - d) the loading bars (4) are subsequently machined from the internal wall of the electrically conductive tube (3) by means of a wire spark-erosion process,
 - e) and the holding rods (6, 8) and the helix (9) are finally inserted and fixed.
2. Method according to Claim 1, characterized in that the coaxial bores in the spacers (1) and pole shoes (2) are honed before pushing in.
3. Method for producing a delay line for a broadband



- travelling-wave tube, which delay line contains spacers (1) and pole shoes (2) arranged coaxially with respect to an electrically conducting cylinder (5), which delay line also contains a helix (9) placed in the electrically
- 5 conducting cylinder (5) and fixed with respect to this cylinder (5) in coaxial orientation by holding rods (6, 8) and which delay line furthermore contains loading bars (4), arranged axially parallel, which adjoin the electrically
- 10 conductive cylinder (5) and leave free, towards the helix (9), a gap of only a few tenths of a millimetre with low tolerance in its gap width, wherein the loading bars (4) are integrally connected to the internal wall of the electrically conductive cylinder (5), having the following procedural steps:
- 15 a) The spacers (1) and pole shoes (2) having corresponding bores are first threaded onto a thick-walled electrically conductive tube (3) whose internal diameter is no greater than the smallest mutual radial separation of the loading bars (4).
- 20 b) The spacers (1), the pole shoes (2) and the thick-walled electrically conductive tube (3) are then soldered to one another.
- c) The loading bars (4) are next machined from the internal wall of the electrically conductive tube (3) by
- 25 means of a wire spark-erosion process.
- d) The holding rods (6, 8) and the helix (9) are finally inserted and fixed.