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Bretting

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[54] **TRAVELING-WAVE TUBE HAVING IMPROVED ELECTRON COLLECTOR**

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[51] **Int. Cl.²** **H01J 25/34**

[58] **Field of Search** 315/3.5, 3.6, 5.35, 5.38, 315/39.3

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[57] **ABSTRACT**

In a traveling-wave tube composed of a periodic permanent magnet electron beam focusing device and an electron collector disposed downstream of the focusing device, relative to the direction of electron beam flow, and composed of two collector electrode arrangements disposed in succession along the beam path and electrically insulated from one another, a device producing an additional magnetic lens focusing field is disposed in the transition region between the two collector electrode arrangements to increase the energy efficiency of the tube and to render the energy loss substantially independent of the energy output level.

11 Claims, 2 Drawing Figures

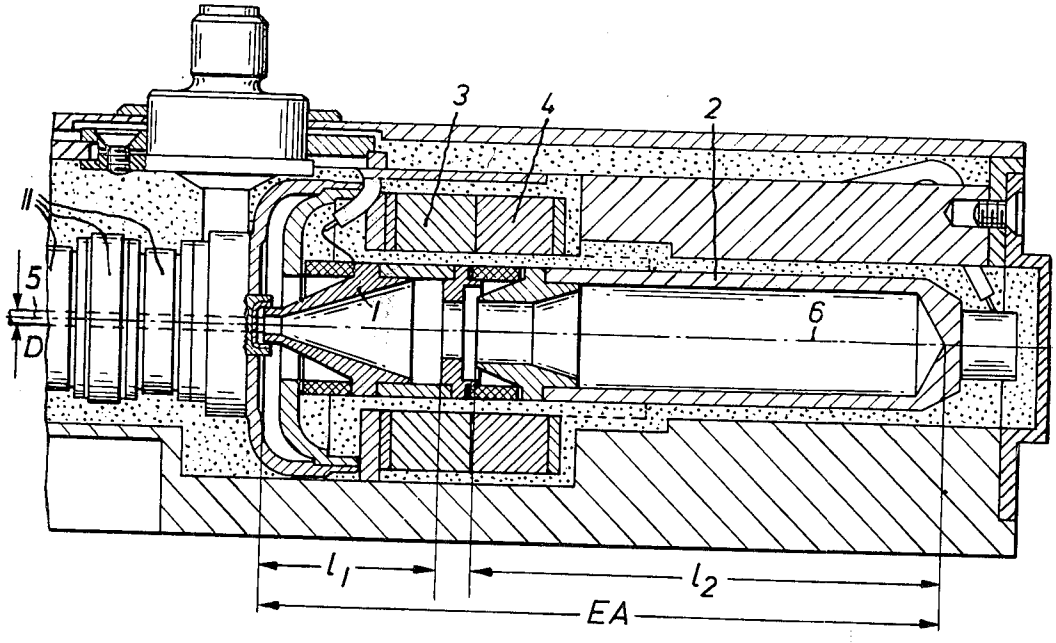


FIG. 1

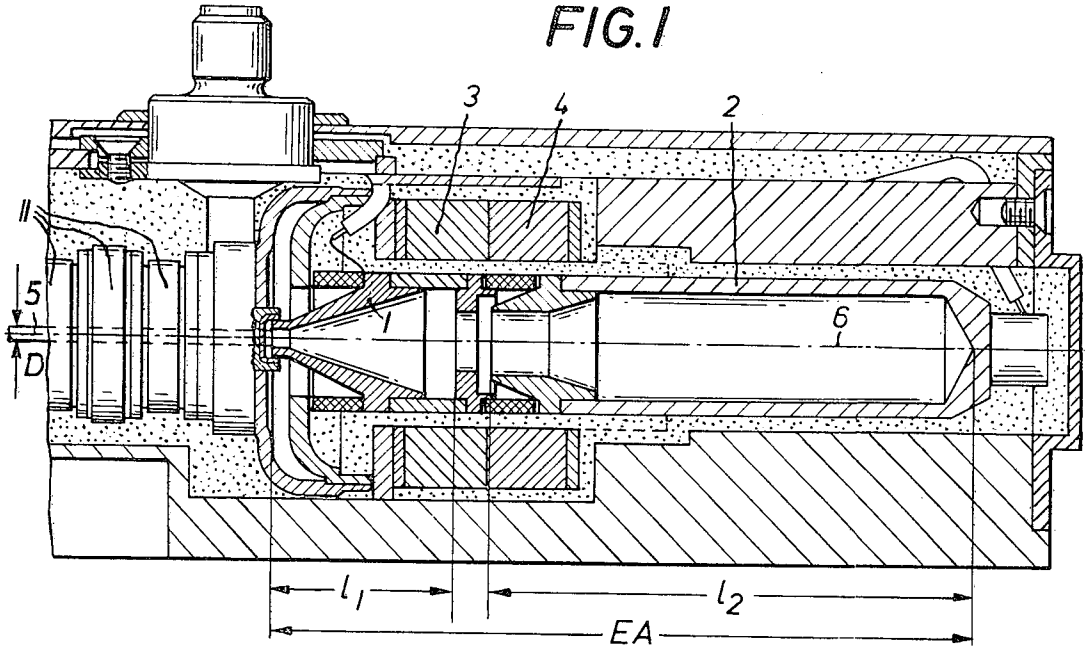
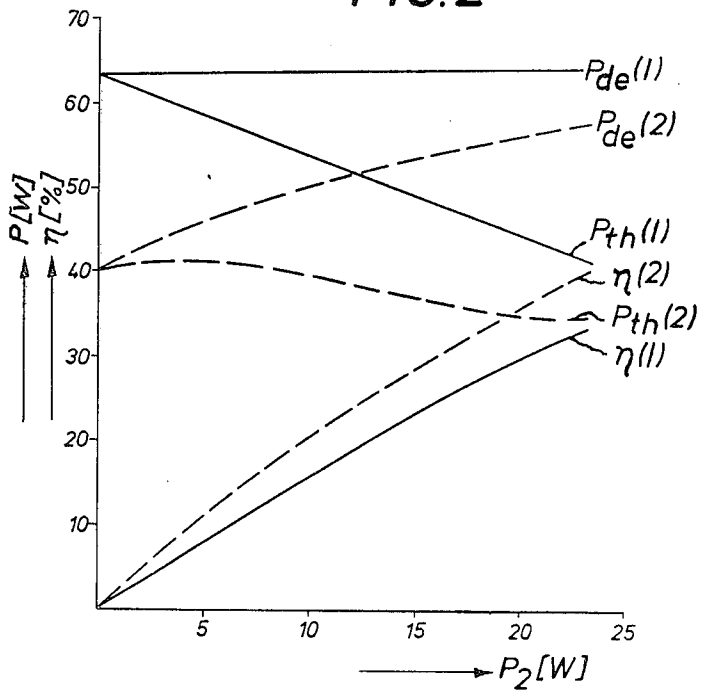

3
4
2
5
D
1
6
l_1
l_2
EA

FIG. 2


70
60
50
40
30
20
10
P[W]
η[%]
$P_{de}(1)$
$P_{de}(2)$
$P_{th}(1)$
η(2)
$P_{th}(2)$
η(1)
5
10
15
20
25
P_2[W]

TRAVELING-WAVE TUBE HAVING IMPROVED ELECTRON COLLECTOR

BACKGROUND OF THE INVENTION

The present invention relates to a traveling-wave tube of the type including a periodic permanent magnet (ppm) electron beam focusing device and an electron collector which is provided with two collector electrode arrangements disposed in series in the direction of the beam and electrically insulated from one another, which arrangements enclose the electron beam along part of its path.

It is known to guide the electron beam of a traveling-wave tube along its path with the aid of a so-called ppm electron beam focusing device. Such ppm focusing devices employ permanent magnets to produce a periodic beam positioning field which includes substantially a plurality of magnetic concentrating, or focusing, lenses arranged in series in the direction along the beam path. A frequently used apparatus of this type includes a plurality of axially magnetized permanent magnet rings within which the traveling-wave tube is disposed, the rings being attached so that their like polarity end surfaces face one another.

It is also known to design the electron collectors of traveling-wave tubes with multiple stages. Such multiple stage collectors include, for example, a plurality of electrically insulated annular electrodes to which different potentials are preferably applied. (Okoshi et. al. The Tilted Electric Field soft Landing Collector and its Application to TWT, IEE-Trans. on ED Vol-ED-19 No. 1, January 1972; Neugebauer W., Mikrom T.G. Multistage Depressed Electrostatic Collector for Magnetically Space born Klystrons NASA Contract Nas-3-115 32, July 1970)

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a novel traveling-wave tube of the above-described type which has improved efficiency and in which the energy loss occurring in the tube is less dependent on the modulation of the tube.

These and other objects according to the invention are accomplished by the provision of a unit establishing an additional magnetic lens concentrating field in the transition region between the two collector electrode arrangements.

It has been found that the electron collector according to the invention leads, on the one hand, to an increase in efficiency of about 20 to 30% and, on the other hand, enables the energy loss in the tube to be kept approximately constant and substantially independent of the modulation of the tube.

A further advantage of the present invention is that it leads to the possibility of designing the two series arranged collector electrode arrangements with an inner diameter which is as large as possible and of keeping the electron entrance apertures for the electron beam as small as possible. This provides an advantageous mode of operation for the tube in that secondary electrons which occur in the second, or downstream, collector electrode arrangement are prevented from reaching the first collector electrode arrangement.

It is particularly advisable for the first stage of the collector to have an axial length which is about five to 50 times, but preferably 10 to 30 times, and most preferably 20 times, the diameter of the electron beam

entering the collector and to employ an additional magnetic lens which has a maximum axial field intensity of about 0.3 to 0.6 times the peak value of the periodic permanent magnet beam focusing field. This additional magnetic lens is advisably arranged in the region of the electron collector so that its maximum field intensity value is reached between the two electrode arrangements, or stages, of the electron collector.

It is further advantageous for the polarity of the magnetic field of the additional magnetic lens to be opposite to the polarity of the last, or downstream, field peak of the periodic permanent magnet beam focusing field.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional side view of a preferred embodiment of a traveling-wave tube according to the invention.

FIG. **2** is a graph presenting a set of curves illustrating the improvement according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a cross-sectional view of the electron collector end of a traveling-wave tube constructed according to the invention. With the aid of the periodic permanent magnet focusing arrangement **11**, which can be of any known type, the electron beam **5** is focused and positioned within the tube so that it enters the electron collector EA approximately with a diameter D. Approximately the entire length of the electron collector EA is constituted by a first stage **1** with a length l_1 and a second stage **2** with a length l_2. Each stage includes an electrode arrangement of a plurality of preferably axially symmetrical electrode parts. The longitudinal axis of symmetry of the tube is indicated at **6.**

According to the present invention a magnetic focusing lens is provided essentially in the region between the first stage **1** and the second stage **2** and this lens produces a magnetic focusing field which refocuses the electrons of the electron beam.

In the illustrated embodiment this magnetic focusing lens includes two magnetic rings **3** and **4** which are axially magnetized and are arranged in such a manner that opposite polarity end surfaces thereof face one another. The arrangement of this additional magnetic confining, or focusing, lens is preferably selected so that its maximum field intensity occurs in the region between the two stages of the electron collector.

The length of l_1 of the first stage of the electron collector is advisably 10 to 20 times that of diameter D of the electron beam. The entrance aperture of the first collector electrode arrangement is advisably not made much larger than required for receiving the electron beam. The two electrode arrangements of stages **1** and **2** are electrically insulated from one another and advisably a different voltage is applied to each, it being further advisable to have the voltage of the first stage 1.7 to 2 times the magnitude of the voltage of the second stage.

FIG. **2** is a graph in which the absorbed energy P_{de}, the percent overall efficiency η, and the energy P_{th} which has been converted to heat are plotted as a function of energy output P_2, are shown in solid lines (**1**) for a traveling-wave tube with a single-stage collector electrode and in broken lines (**2**) for the traveling-wave tube of FIG. **1** having a two-stage collector electrode and additional magnetic focusing lens. This graph indi-

cates that $P_{de}(1)$ for the tube with the single-stage collector is greater than the absorbed energy $P_{de}(2)$ in the traveling-wave tube of the present invention. It can also be seen that the efficiency $\eta(2)$ is higher by more than 20% than $\eta(1)$. Moreover this diagram shows that the energy converted to heat $P_{th}(2)$, in the tube according to the invention is lower, on the one hand, and substantially more constant, on the other hand, than the energy converted to heat $P_{th}(1)$ of a traveling-wave tube with single-stage collector. A preferred embodiment according to the invention was used in connection with a 20 W helix type TWT in the frequency range 11,7–12,2 GHz for a satellite system, having a 50 mA-beam of 0,6 mm diameter and a perveance of $0,3 \cdot 10^{-6}$ A/V3/2 focused by the magnetic field generated by the $SmCo_5$ - magnets **11** in such a manner that the beam boundary entering the collector is parallel to the axis of the whole system. Dimensions of a preferred used collector were $l_1 = 16$ mm, $l_2 = 47$ mm, max. internal diameter of collector **1** = 9 mm, internal diameter of collector **2** = 9 mm, separation of collector **1** and collector **2** = 3 mm, diameter of magnet ring **3** = 25 mm, diameter of magnet ring **4** = 25 mm.

By the combined action of the ALNICO magnet rings **3** and **4** a field of 300–700 Oe is produced refocus the beam when passing from the first to the second collector.

It will be understood that the above description of the present invention is susceptible to various modifications, changes and adaptations, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

I claim:

1. In a traveling-wave tube composed of a ppm electron beam focusing device and an electron collector disposed adjacent the focusing device and provided with two collector electrode arrangements disposed to enclose the electron beam over part of its path, said arrangements being spaced from one another by a transition region and being arranged in succession along the axis of the beam in the collector, the two arrangements being electrically insulated from one another, the improvement wherein said collector further comprises additional magnetic focusing lens field producing means disposed in the transition region between said two collector electrode arrangements and producing a concentrating field which refocuses the electrons in the beam in the region between said collector electrode arrangements.

2. Traveling-wave tube as defined in claim **1** wherein that one of said collector electrode arrangements which is disposed closer to said focusing device has a length of five to 50 times the diameter of the electron beam entering this collector electrode arrangment.

3. Traveling-wave tube as defined in claim **2** wherein the length of said arrangement is 10 to 30 times such beam diameter.

4. Traveling-wave tube as defined in claim **3** wherein the length of said arrangement is 20 times such beam diameter.

5. Traveling-wave tube as defined in claim **1** wherein the maximum axial field intensity of the field produced by said field producing means is located in a plane which lies between said two collector electrode arrangements.

6. Traveling-wave tube as defined in claim **3** wherein the maximum axial field intensity of the field produced by said field producing means is 0.1 to 1 times the peak value of the beam focusing field produced in the ppm device.

7. Traveling-wave tube as defined in claim **6** wherein such maximum axial field intensity is 0.3 to 0.6 times the peak value of the beam focusing field produced in the ppm device.

8. Traveling-wave tube as defined in claim **1** wherein the polarity of said additional focusing lens field is opposite to the polarity of that field peak which in the ppm beam focusing field device is closest to said electron collector.

9. Traveling-wave tube as defined in claim **1** wherein said field producing means comprises a permanent magnet arrangement for producing the additional focusing lens field.

10. Traveling-wave tube as defined in claim **9** wherein said permanent magnet arrangement comprises two coaxial and identically axially magnetized ring magnets.

11. Traveling-wave tube as defined in claim **1** wherein said electron collector has only two collector electrode arrangements.

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