Jan. 10, 1967 A. D. LA RUE ETAL 3,297,907

ELECTRON TUBE WITH COLLECTOR HAVING MAGNETIC FIELD ASSOCIATED THEREWITH, SAID FIELD CAUSING ELECTRON DISPERSION THROUGHOUT THE COLLECTOR

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FIG. 1

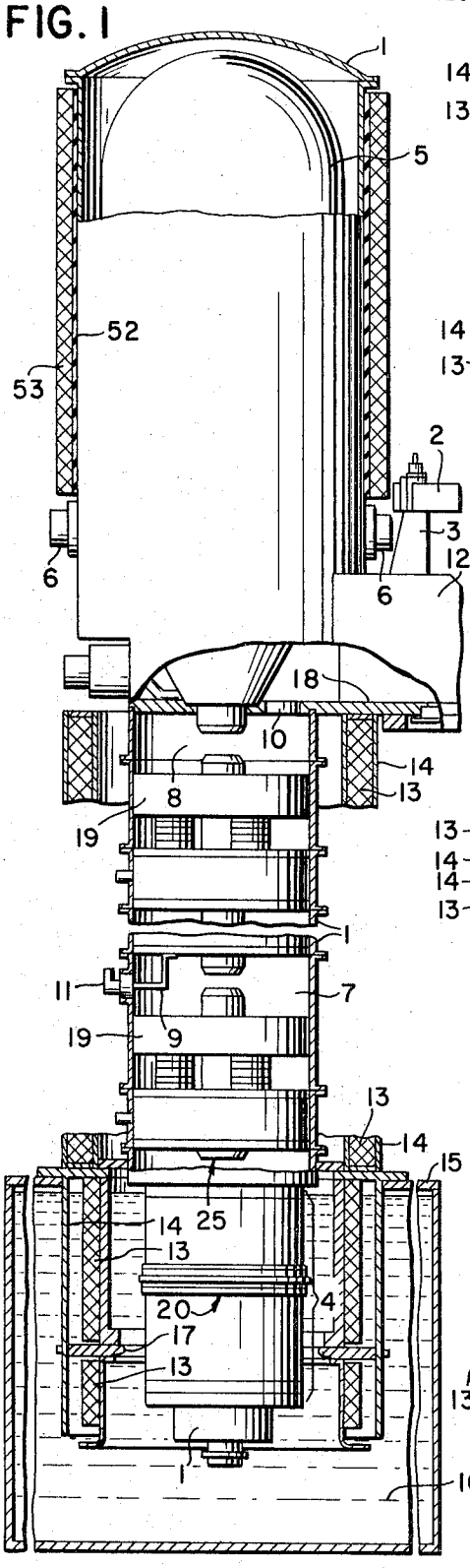


FIG. 2A

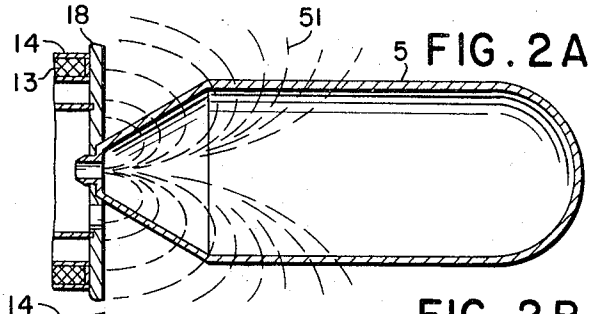


FIG. 2B

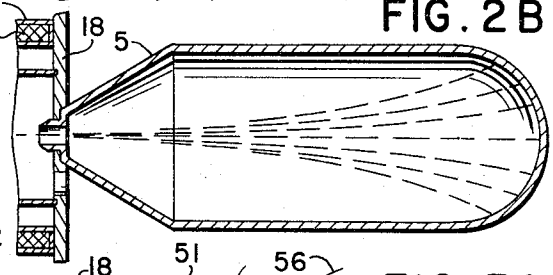


FIG. 3A

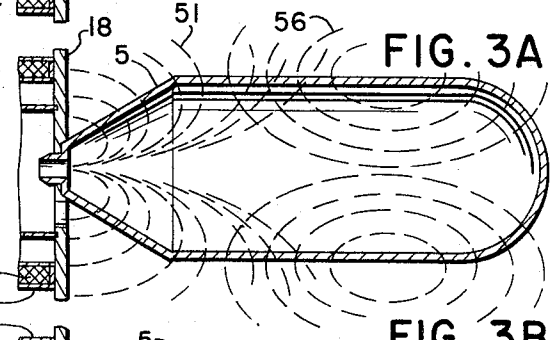


FIG. 3B

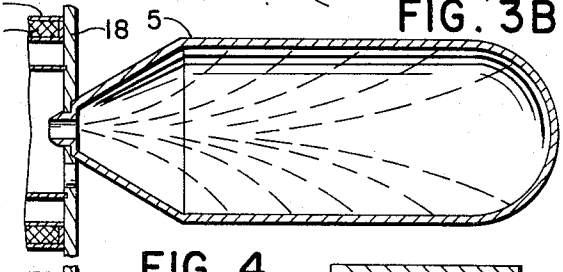
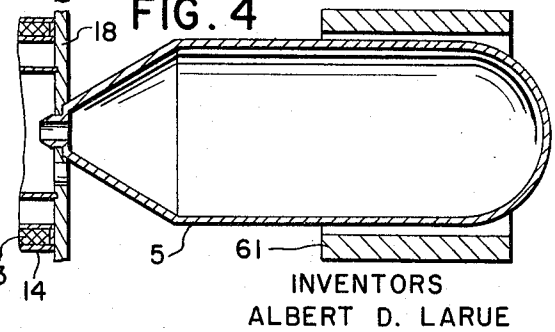


FIG. 4



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ELECTRON TUBE WITH COLLECTOR HAVING MAGNETIC FIELD ASSOCIATED THEREWITH, SAID FIELD CAUSING ELECTRON DISPERSION THROUGHOUT THE COLLECTOR

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This invention relates generally to a high power electron tube apparatus and more particularly to a collector assembly for electron tube apparatus. Such a collector assembly is useful for high power devices employing electron beams, for example, high power klystron amplifiers.

In the design of high or super power electron tube apparatus employing electron beams, the collectors are made relatively large in comparsion to the beam diameter so that the high power of the beam can be dissipated over a large collector surface area. Power dissipation problems are encountered in such tubes when the beam power density is in the order of or greater than 100 times the desired collector surface power density. By way of example, the beam may be one inch in diameter with a power density of greater than 50 kw. per square cm. projecting into a collector 20 or more inches in diameter. A typical beam focus field is 1000 gauss throughout the beam interaction path length. It is, therefore, essential that when the beam enters the collector it be dispersed so that the electrons impinge over substantially the entire surface of the collector. However, when high power, small diameter beams are employed, it is not practical because of weight consideration to shape the magnetic pole pieces such that the leakage beam focus field in the collector is essentially reduced to zero. This small leakage field serves to keep the beam focused thereby preventing it from spreading out uniformly over the collector surface due to space charge effects.

It has been the practice to shield the collector region by means of magnetic shields so as to eliminate stray focusing fields in the collector. This has been successful in some cases, and in others, only partially successful. For example, collector dissipation tests were carried out in one unshielded high power tube and burn-out occurred near the end of the collector at about 36% of the specified average beam power. In a second test with magnetic shielding introduced, the fields in the collector were reduced and burn-out occurred at about 71% of power. Although the latter is an improvement, further improvement is desirable.

Observations showed that the beam did not expand rapidly enough upon entering the collector. Consequently, the whole collector surfaces did not intercept the beam. One solution for collecting over a large area of the collector is to make the collector relatively long so that there is considerable surface available after the beam has expanded due to space charge defocusing forces. This is not a practical solution since it would greatly increase the overall length of the electron tube apparatus.

It is an object of the present invention to provide an improved high power electron tube of the type including a collector having means for dispersing the beam at the collector.

One feature of the present invention is the provision of means for setting up dispersing magnetic fields in the beam collector structure for dispersing the beam uniformly over the interior surface of the beam collector.

Another feature of the present invention is the provision of a high power electron tube apparatus including a relatively large collector which has in cooperation therewith means setting up a magnetic field in opposition to the beam focusing leakage fields for dispersing the beam in the collector.

Another feature of the present invention is the provision of a high or super power klystron which includes a collector many times the diameter of the beam having means in association therewith forming dispersing magnetic fields in the collector for dispersing the beam therein.

The foregoing and other features of the invention will be more clearly understood from the following description taken in conjunction with the accompanying drawing:

Referring to the drawing:

FIG. 1 is a longitudinal foreshortened view, partially in section, of a high power electron tube incorporating features of the present invention;

FIGS. 2A–B show the leakage fields and the collector beam dispersion associated therewith;

FIGS. 3A–B show the collector magnetic fields including dispersing fields in accordance with the present invention; and

FIG. 4 shows another collector assembly embodying the invention.

Referring to FIG. 1, there is shown a high power electron tube apparatus, namely a klystron, incorporating the present invention. More particularly, the tube comprises an evacuated tubular envelope **1** evacuated to a suitable low pressure as, for example, 10^{-9} millimeters of mercury by an appendage pump **2**, such as an ion pjump, in gas communication with the interior of the envelope through suitable tubulation **3**.

An electron gun assembly **4** is disposed at one end of the tube envelope and serves to form and project a beam of electrons over a predetermined path directed axially and longitudinally of the envelope **1** and in cooperative relationship with the interaction structure which supports the electromagnetic energy disposed along the envelope. A collector **5** is disposed at the other end of the tube envelope to collect the electron beam. A coolant as, for example, water, is circulated through suitable ducts (not shown) in the collector structure **5**. The coolant is supplied to the ducts through the fittings **6**.

A plurality of re-entrant cavity resonators are disposed along the envelope and from the interaction structure. The input and output resonators **7** and **8** are shown arranged along the beam path in axially spaced relation so that the electromagnetic energy can interact with the electron beam passing therethrough. Input wave energy to be amplified is supplied to the input resonator **7** via the input loop **9** and coaxial line **11**. Amplified output wave energy is extracted in the conventional manner from the beam through the output resonator **8** and propagated to a suitable load (not shown) via the output iris **10** and output waveguide **12** sealed in vacuum-tight manner by means of a wave permeable vacuum-tight window.

An electric solenoid **13** coaxially surounds the elongated vacuum envelope **1** and provides an axially directed beam focusing magnetic field as, for example, a field having a strength of 1000 gauss. The magnetic field confines the beam to a predetermined beam diameter and directs the same axially along the tube. A hollow cylindrical magnetic shield **14**, as of soft iron, surrounds the solenoid for minimizing leakage of the magnetic field. At the gun end of the tube **1**, the shield **14** abuts an apertured plate **15**, as of soft iron, forming the top of an iron tank containing an oil bath **16** in which the gun end of the tube, including the solenoid **13**, is immersed. The iron of the tank forms a portion of the magnetic shield. The oil bath, having a higher dielectric strength than air, reduces the probability of arc-over across the insulators of the gun structure **4**.

Annular magnetic pole pieces **17** and **18** operating at

main anode potential respectively are carried at the ends of the magnetic shield **14** and confine the magnetic field substantially entirely within the solenoid **13**.

Axially movable tuning structures **19** are disposed within the cavity resonators **7** and **8**, respectively, for tuning the tube over the operating frequency range.

In operation, input signals are applied to the input resonator through the coaxial line **11**. The signals are amplified in successive resonators and an amplified output signal is derived from the tube at the waveguide **12**. A typical tube may utilize a beam voltage in the order of 140 kv. and a beam current in the order of 100 amperes with an average beam power in the order of megawatts to produce hundreds of kilowatts of average and many megawatts of peak ultrahigh frequency output power. In such power tubes, as previously described, with the average beam power of a megawatt or more, the electron beam entering the collector must be dispersed so that it impinges upon a large area of the collector; otherwise, the power cannot be dissipated by the cooling water and burn-out of the collector results with the consequent loss of vacuum and destruction of the tube.

As previously described, the focusing magnetic field must be such as to efficiently focus the beam throughout its passage in the interaction structure since, if a small fraction of the beam impinges upon the structure, it will cause burn-out of the structure. Although the pole pieces **17** and **18** tend to confine the magnetic field within the solenoid, there are leakage magnetic fields within the collector. These fields tend to maintain the beam in focus as it enters the collector. As a result, the beam impinges on only a portion of the total collector surface area. The temperature can rise to excessive limits and cause burn-out.

The effect of leakage focusing magnetic fields in the collector may be more clearly visualized with reference to FIGS. 2A and 2B. In FIG. 2A, there is schematically shown the leakage magnetic fields associated with an electron tube device of the character described. These fields are shown by the dotted lines **51**. It is seen that the fields have an axial component. As is well known, the electrons tend to travel through a path which is in the same direction as the magnetic fields, and thus the beam will remain substantially in focus as shown in FIG. 2B. The beam impinges only on the end portion of the collector structure resulting in relatively high power per unit area as of, for example, greater than 2 kw./square cm.

In accordance with the present invention, there is provided about the collector a structure comprising a cylindrical support **52** which supports a plurality of turns of wire **53** which form a coil. With current flowing in the coil, a magnetic field is set up which encircles the coil as shown. This field also interacts with the electron beam within the collector. By suitably choosing the strength and direction of this field, it can form resultant fields with the leakage fields which efficiently disperse the electron beam.

Referring to FIG. 3A, there is shown the coaction of the stray focusing field **51** and the additional oppositely directed dispersing fields **56**. It is seen that the vector sum of these fields is a field which is directed radially outward from the axis of the electron tube. This causes the electrons to tend to follow the resultant field and disperse in the manner shown in FIG. 3B. The electrons impinge over a large area of the collector and the heat generated can be easily conveyed away.

In one particular example, an electron tube was operated with a beam voltage of 125 kv. with a beam current of 99 amperes. A collector beam dispersing coil was applied around the collector. Current was passed through the coil to give a current density of 5 ampere turns per centimeters of collector length along 32 inches of the upper part of a 20 inch diameter collector. Thus, a total of 400 ampere turns were used in the beam dispersing

arrangement to produce a dispersive bucking field of between 6 and 15 gauss on the beam axis. The X-rays coming from the collector were photographed and showed that the beam was efficiently dispersed over substantially the entire surface of the collector.

An alternate method of forming the dispersing magnetic fields is to employ a cylindrical permanent magnet such as the permanent magnet **61** shown in FIG. 4. The magnet would set up fields within the collector region which interact with the leakage fields to disperse the beam. However, in large collectors of the type under discussion, the weight of such a permanent magnet might be prohibitive and the preferred method of forming the dispersing fields is with a solenoid.

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 drawing shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electron tube apparatus comprising, an electron gun for projecting over an elongated beam path a beam of electrons having an average beam power greater than 100 kilowatts, a collector assembly spaced from said gun at the terminal end of the beam and disposed to collect said beam, an interaction structure for supporting electromagnetic energy and so disposed that the electromagnetic fields of said interaction structure interact with said beam, first means for generating a beam-focusing magnetic field for maintaining said beam in focus as it passes through said interaction structure, said beam-focusing means including a pair of apertured pole pieces axially spaced apart along the beam path and straddling said interaction structure for maintaining the beam-focusing magnetic field within the beam path, one of said pole pieces being disposed between the terminal end of said interaction structure and said collector assembly and being adapted to shield said collector assembly from the beam-focusing magnetic field but nevertheless permitting a leakage magnetic field to permeate said collector region, and a second magnetic field-generating means arranged to produce a static dispersing magnetic field in the region of said collector assembly which dispersing field is superimposed upon said leakage field in said collector assembly, said second magnetic field-generating means being such that the resultant magnetic field resulting from said superimposition has over a substantial part of the length of the collector assembly in the direction of the axis of said beam path a substantial radial component for dispersing the beam.

2. Apparatus according to claim **1**, wherein said second magnetic field-generating means comprises a solenoid.

3. Apparatus according to claim **1**, wherein said second magnetic field-generating means comprises a permanent magnet.

4. Apparatus according to claim **1**, wherein said collector has a cross-sectional area at least ten times that of said beam.

5. Apparatus according to claim **1**, wherein said interaction structure includes a plurality of resonators disposed along said electron beam and in operative relationship therewith.

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