Dec. 8, 1959 T. D. SEGE 2,916,659

ELECTRON BEAM FORMING APPARATUS

Filed March 28, 1956

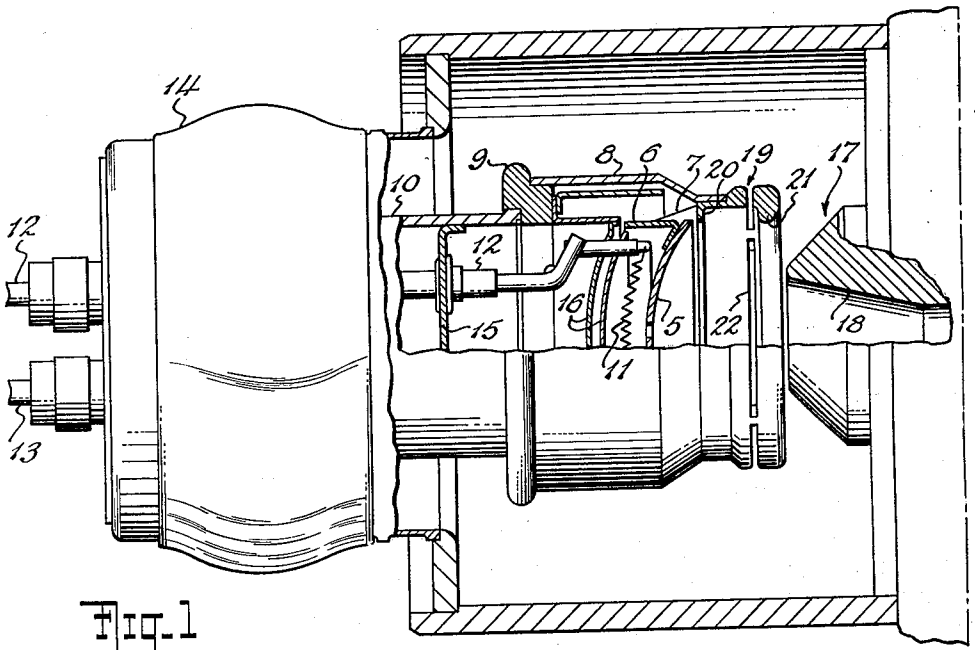


FIG. 1

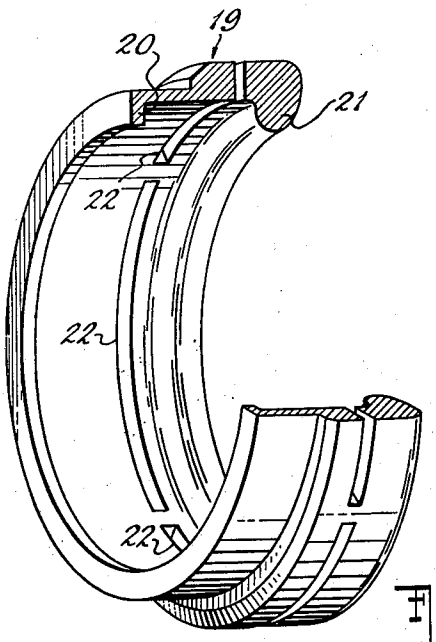


FIG. 2

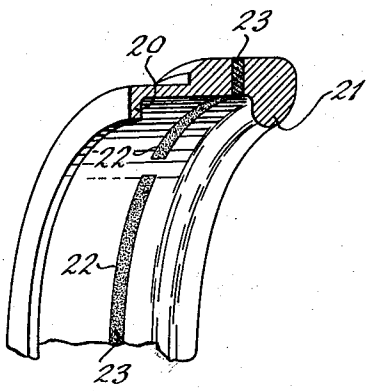


FIG. 3

INVENTOR
THOMAS D. SEGE
BY
L. C. Craddock
ATTORNEY

United States Patent Office

2,916,659

Patented Dec. 8, 1959

2,916,659

ELECTRON BEAM FORMING APPARATUS

Thomas D. Sege, Westbury, N.Y., assignor to Sperry Rand Corporation, a corporation of Delaware

Application March 28, 1956, Serial No. 574,503

5 Claims. (Cl. 315—5.34)

This invention relates to electron beam forming apparatus for high power, high frequency electron tubes. More particularly, the invention concerns improvements in electron guns of the type employing electrostatic focusing apparatus intermediate the cathode and anode elements of such guns.

Electron guns employing electrostatic focusing have been described in a number of patents including U.S. Patents 2,268,196 and 2,564,743. Such focusing produces a concentrated stream of electrons by the agency of a suitably-biased electrode member or members disposed intermediate a cathode emitting surface and an accelerator anode, through which member or members the electron stream passes by way of a coaxially-located aperture or apertures.

While electrostatic focusing has been widely adopted to general advantage in the design of electron guns, a disadvantage has been noted in some cases which can preclude the use of electrostatic focusing where it would otherwise be highly desirable. This disadvantage is that the space defined in substantial measure by the electrostatic focusing apparatus can operate as a cavity resonator that will sustain oscillations initiated by the passage of the electron stream therethrough. Moreover, these oscillations are likely to occur in voltage modes that interact with the negative resistance region in the beam voltage vs. beam current characteristic, whereby to cause density or velocity modulation of the electron stream before it leaves the cathode-anode region of the electron gun. While the power in such oscillations usually is relatively small, the consequent beam modulation, when amplified through the cavities of a klystron or by a traveling wave tube, may become comparable to the power output of the amplifier.

One way of preventing offending oscillations within a particular electron gun structure would apparently be to modify the focusing electrode configuration so as to change the volume of the cavity it aids to determine. The volume change may then push the undesired voltage mode out of the resonant region of the cavity. However, in so doing, it may thereby introduce another voltage mode of different order into the same region. Therefore, changing the volume of the cavity is clearly an unsatisfactory approach toward solving the problem.

Another approach that would apparently prevent the offending electron gun oscillations would be the introduction of lossy material, such as lossy ceramic, into the electron gun structure. However, the amount and location of such material would be so critical and the mounting difficulties so great that this approach to solving the problem must be abandoned as being highly impractical.

By the present invention, a solution is presented which not only prevents the offending oscillations, but also achieves this desired end in a thoroughly practical and readily accomplished manner. The present invention recognizes that oscillations excited in the resonant frequency range of the electron gun cavity will interact deleteriously with the electron beam if the oscillations are

excited in one of the cavity modes that is characterized by electric fields in general alignment with the electron beam. This would apply to the TM modes in general, and the TM_{01} family of modes in particular. Due to asymmetries in the beam, interaction between the beam and the TM_{02} family of cavity modes may also be possible. All these modes are characterized by axial current flow in the cavity wall. The interacting mode is, accordingly, suppressed by interrupting this current flow with appropriately located slots or elongated apertures in the cavity structure, whereby to distort the fields tending to be produced by the mode and thus, in most cases, eliminate the likelihood of exciting the mode.

If, however, a particular case should arise where, due in part to the capacitive coupling across the slots, enough current can still flow to permit the mode to come into being, the problem is met by introducing a highly lossy material into the slots, such as by impregnating the slots with lossy porous ceramic. Thus, if the resultant Q of the electron gun cavity is not lowered enough by the slots themselves to eliminate the offending oscillations, then this is certainly accomplished by the slots together with lossy material therein.

The principal object of the present invention is to provide a novel arrangement for suppressing oscillations that tend to occur and be sustained in electron beam forming apparatus and which, if permitted to occur, would interact deleteriously with the beam formed by such apparatus.

Another object is the provision of an electron beam forming apparatus including an electrostatic focusing electrode wherein the space defined in substantial measure by said electrode is prevented by novel means from forming part of a cavity resonator that would otherwise tend to sustain oscillations deleteriously interacting with the electron beam.

Another object is to provide, in an electron beam forming apparatus, a focusing electrode having a plurality of elongated apertures or slots which are positioned to suppress beam-modulating current flows in the structure of the electrode.

With the foregoing and other objects in view, the present invention includes the novel elements and combinations and arrangements thereof described below and illustrated in the accompanying drawings, in which:

Fig. 1 is a side view, partly in section, of an electron gun embodying the present invention; and

Figs. 2 and 3 are like perspective views, partly in section, of a focusing electrode provided with slots according to the present invention, respectively with and without lossy material in said slots.

The electron gun depicted in Fig. 1 is assumed to be installed in a high power, high frequency electron tube such as, for example, the type including klystrons and traveling wave tubes. The cathode portion of the electron gun comprises a spherically concave electron emitting element **5** secured by supports **6**, **7** to a surrounding shell **8** rigidly fastened to a flanged portion **9** of the stem **10** of the gun. A heater element **11** for the concave emitter **5** may be energized by connecting a suitable potential source across the pins **12**, **13** which extend outwardly from the base of the neck **14** of the tube and inwardly of stem **10** through a supporting web **15** to connect to the respective end terminals of the heater element. A spaced pair **16** of heat shields are mounted directly behind the heater element so as to enhance the transfer of heat to emitter **5**.

An anode **17** having a frusto-conical tapered aperture **18** coaxial with the circular rim of emitter **5** and the longitudinal axis of the electron gun is axially spaced from the emitter and arranged so that it may be employed for accelerating the emitted stream of electrons in a path toward the main body of the electron tube. The wide

mouth of aperture 18 faces toward emitter 5 and is of lesser diameter than the emitter's rim.

In the space intermediate emitter 5 and anode 17 is an electrostatic focusing electrode 19 of generally hollow cylindrical configuration supported by and partially fitted within shell 8 so as to be coaxial with aperture 18 and the rim of the emitter. By this arrangement, the wall of electrode 19 describes a figure of revolution about the electron beam. The axial length of focusing electrode 19 is slightly less than the axial distance between emitter 5 and the wide mouth of the anode aperture 18. The focusing electrode's rim proximate the rim of emitter 5 is turned inwardly to form a rim portion 20 depending toward the axis of the electron gun and having an inner diameter substantially equal to the emitter's rim diameter. At the other end of the focusing electrode, the rim thereof proximate the wide mouth of anode aperture 18 is likewise turned inwardly to form a rim portion 21 depending toward the gun axis. But rim portion 21 has an inner diameter slightly less than that of rim portion 20, yet somewhat greater than that of the adjacent anode aperture.

Preferably, the wall of focusing electrode 19 is of increased thickness in the end region thereof including rim portion 21, so as to increase the heat-withstanding ability of electrode 19 in this region. Preferably, also, the possibility of voltage breakdown between rim portion 21 and anode 17 is reduced to a minimum by rounding off the edges that would otherwise be formed by the axially-depending sides of rim portion 21.

In accordance with well-known principles, rim portions 20, 21 and the cylindrical wall joining them are adapted to cooperate in electrostatically countering the space charge effect of the electron stream that tends to disperse the electrons from a desired highly dense converging path or beam of circular cross-section having a minimum convergence within anode aperture 18. From the view of electron-optics, focussing electrode 19 is an electrostatic converging lens in the path of the beam.

Generally in low power electron guns, the space outlined by the emitter, focussing electrode, and anode is quite lossy and, therefore, relatively unlikely to function as a resonant cavity. Moreover, the odds in favor of a resonance being obtained coinciding with the operating band of the electron tube are relatively low. In other words, it is in the case of high power, high density type electron guns, and especially those operating over a wide band that the space defined in substantial measure by the focussing electrode is most likely to operate as a cavity resonator having a resonance in the frequency range of the tube. Moreover, this resonance may occur in several different modes depending upon the manner in which the cavity is excited.

Assuming in Fig. 1 that emitter 5, focussing electrode 19, and anode 17 outline a resonant cavity, it is evident from the generally cylindrical configuration of the cavity longitudinally of the beam that if the cavity is excited by the traversal of the beam, such excitation will be in a TM mode. Thus, there will be mode-supporting oscillatory currents or electron flows in the cylindrical wall of focusing electrode 19 moving longitudinally of said wall and interacting with the beam to velocity modulate the same.

The interaction is particularly harmful if the oscillations fall within the operating range of the tube served by the electron gun. And, further, if the oscillations do so fall, they may occur in more than one order of the TM mode. Hence, by suppressing the TM mode orders in which the objectionable oscillations tend to occur, such oscillations are prevented from coming into being.

Accordingly, the focusing electrode 19 (see Fig. 2) is provided with a plurality of elongated apertures or slots 22 in its periphery, which slots are circularly aligned in a plane substantially normal to the electrode's longitudinal axis. The axially normal plane of slots 22 is preferably located so that the slots are positioned in a region of the cylindrical wall where maximum objectionable oscillatory current tends to flow. This region may be deduced through analysis of the resonant cavity to determine the TM mode orders that will support resonant oscillations in the frequency range of the tube served by the electron gun.

The number of slots 22 and their length are not critical factors. It is preferable, however, to limit the spacing between adjacent slot ends to the minimum amount necessary to preserve structural rigidity in electrode 19, whereby the disruptive effect of the slots on the objectionable oscillatory currents that tend to flow in the cavity wall may be attained to the highest degree.

In a case where the minimum spacing that may be practicably provided between adjacent slot ends, together with the capacity coupling across the slots themselves, is sufficient to permit enough objectionable oscillatory current to flow, the slots may be filled with a highly lossy material 23 (see Fig. 3). A suitable material in this regard would be a porous ceramic, carbon impregnated, for example, which may be readily placed into the slots.

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. Electron beam forming apparatus including a focussing electrode having a wall describing a figure of revolution about the electron beam and defining in substantial measure the boundaries of a resonant cavity tending to be excited by said beam, said wall of said electrode having a plurality of elongated apertures whose length dimensions lie across the direction of current flow along the inner surface of said wall for undesired TM modes in the resonant cavity that modulate said electron beam, whereby said undesired modes are substantially suppressed.

2. An electron gun for a high power, high frequency electron tube having a predetermined range of operating frequencies, said gun including a focussing electrode having a longitudinally-extending wall outlining in substantial measure the boundaries of a cavity resonator of resonant frequency falling within said predetermined frequency range, said wall including a plurality of elongated slots aligned in a plane transverse to said wall and positioned so as to substantially prevent oscillatory currents of said resonant frequency from occurring in said wall.

3. In an electron beam forming apparatus of the type including a cathode and anode, a focussing electrode disposed intermediately of said cathode and anode, said electrode having a wall surrounding the electron beam, said wall being provided with a plurality of apertures arranged to suppress oscillatory currents of motion longitudinally of said beam that tend in the absence of such suppression to be excited in said wall by the passage of said beam from said cathode to said anode.

4. Electron gun apparatus for producing and directing an electron stream along a predetermined path, comprising a cathode electron emitter positioned at one end of said path, an anode positioned along said path in spaced relationship with said cathode, electrostatic focussing electrode means positioned along said path between said cathode and anode, said cathode, focussing electrode means and anode forming a boundary of a microwave cavity having undesired resonance properties in an electromagnetic wave energy mode which interacts with said electron stream, and means coupled to said cavity for inhibiting microwave cavity oscillations in said mode to thereby minimize modulation of said electron stream.

5. Electron gun apparatus as set forth in claim 4, wherein said focussing electrode includes a tubular wall extending along the path of said electron stream, and a plurality of apertures in said tubular wall in the path of electric current flow for TM mode electromagnetic energy to provide a high impedance to said current flow.

References Cited in the file of this patent

UNITED STATES PATENTS

2,303,166	Laico	Nov. 24, 1942
2,422,695	McRae	June 24, 1947
2,506,417	Kinzer	Mar. 14, 1950
2,527,619	Brehm et al.	Oct. 31, 1950
2,593,095	Brehm	Apr. 5, 1952
2,632,130	Hull	Mar. 17, 1953
2,647,220	Broadway et al.	July 28, 1953
2,811,667	Brewer	Oct. 29, 1957
2,822,501	Poulter	Feb. 4, 1958

FOREIGN PATENTS

645,756	Great Britain	Nov. 8, 1950