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Lien et al.

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[54] **ELECTRON COLLECTOR HAVING MEANS FOR REDUCING SECONDARY ELECTRON INTERFERENCE IN A LINEAR BEAM MICROWAVE TUBE**

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[52] **U.S. Cl.** **315/5.38,** 315/3.5

[51] **Int. Cl.** **H01j 23/02**

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

[56] **References Cited**

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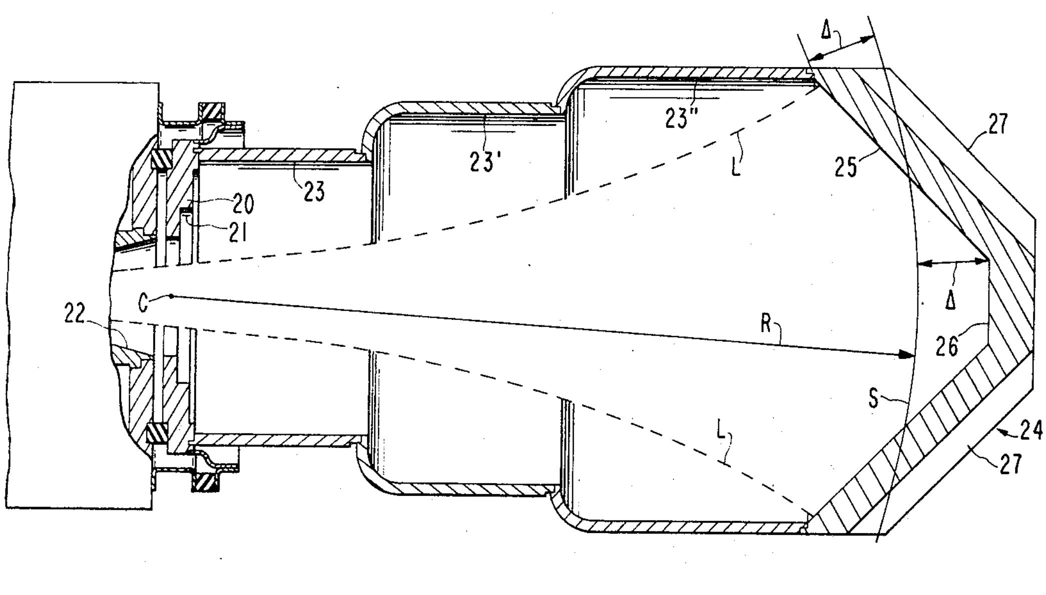
[57] **ABSTRACT**

The collector incorporates an impact surface portion at the downstream end for collecting substantially all the electrons in the electron beam. The impact surface portion closely approximates the locus of points equidistant from the constricted mouth portion of the collector. By this means amplitude modulation of the few secondary high-velocity reflected electrons returning from the collector and refocused back through the beam tunnel is reduced.

4 Claims, 2 Drawing Figures



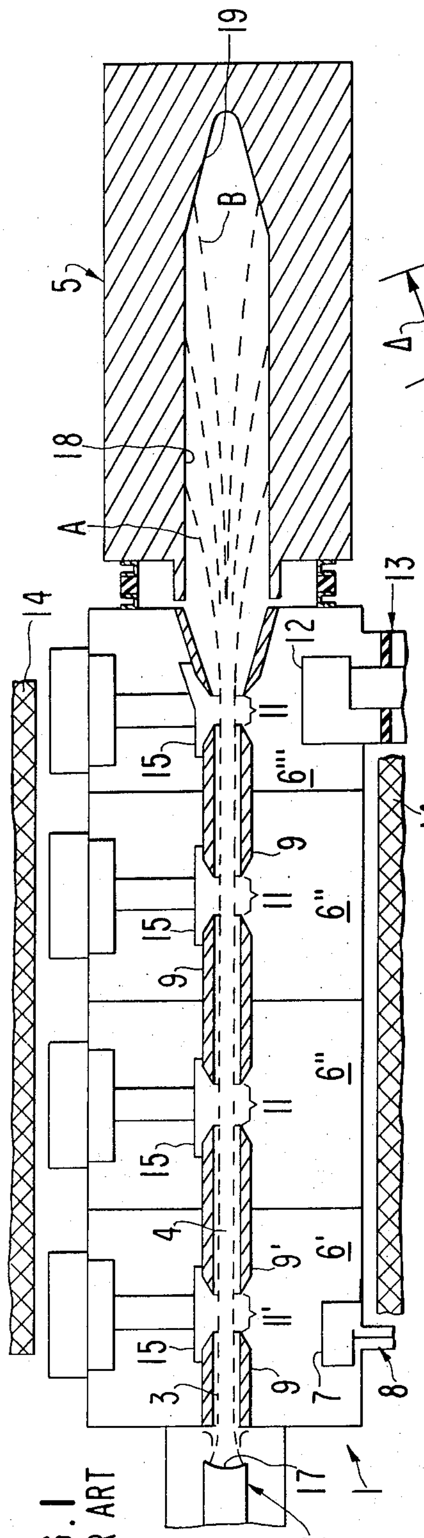


FIG. 1
PRIOR ART

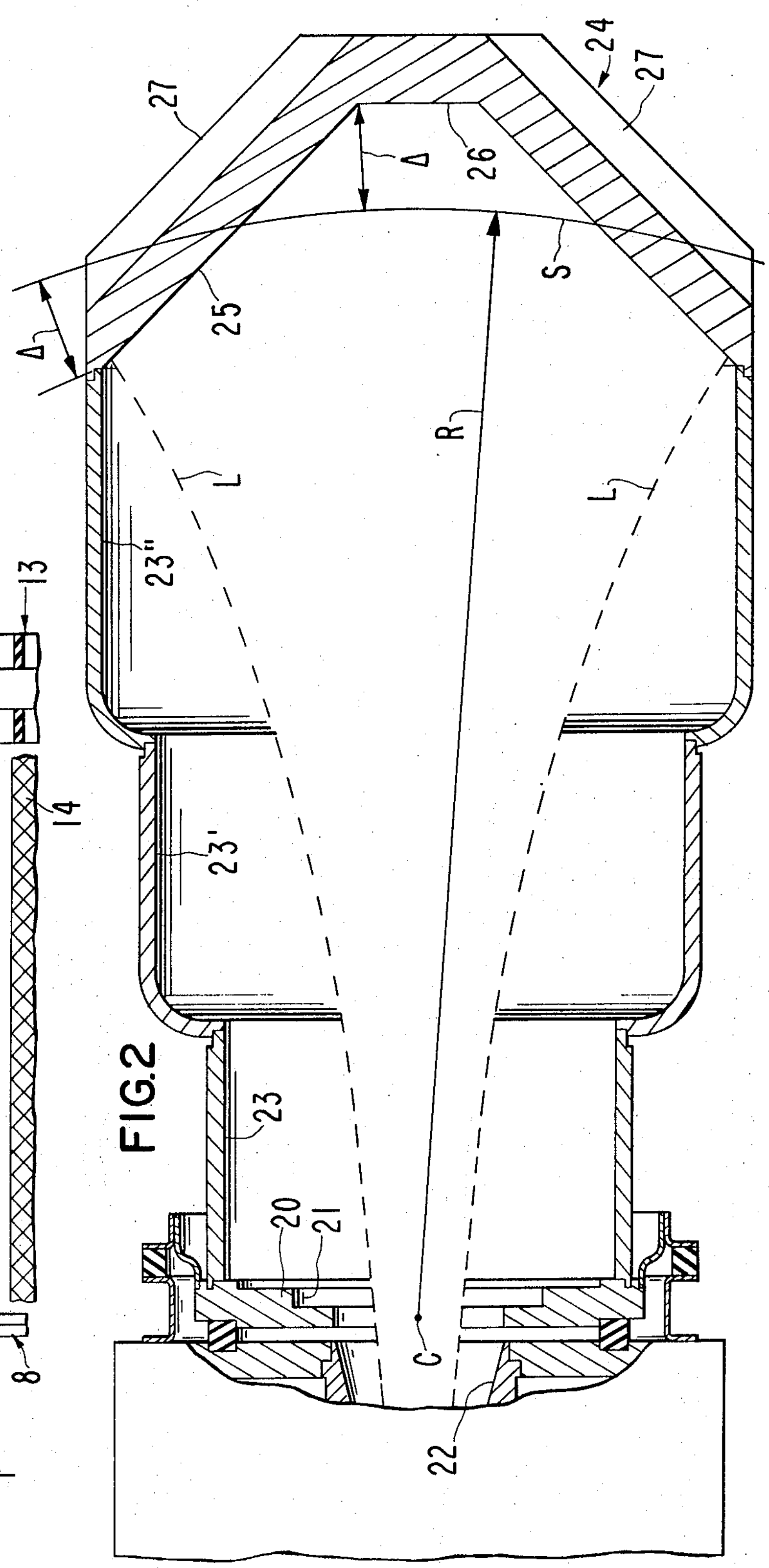


FIG. 2

ELECTRON COLLECTOR HAVING MEANS FOR REDUCING SECONDARY ELECTRON INTERFERENCE IN A LINEAR BEAM MICROWAVE TUBE

BACKGROUND OF THE INVENTION

UHF video transmitter tubes operating in the frequency range of 450 mHz. to 900 mHz. have suffered from spurious signals and oscillation caused by secondary (impact-produced) electrons returning from the collector of the tube, and sometimes even reaching the input end of the tube. These secondary electrons, generally divisible into high speed and low speed types, are produced by the energy of impaction of the primary electrons of the beam within the collector. By mechanisms which will become clear from what follows, the high speed secondary electrons which are potentially the most damaging display amplitude modulation at the same frequency as the amplitude modulation of an impressed signal in the tube. For this reason they cause spurious signals falling within the passband of the tube.

Once this phenomenon is recognized, the approaches for eliminating or significantly reducing the number and effect of high speed secondary electrons returning from the collector fall into three categories: (1) reduction of the number of high speed secondary electrons produced by beam impact within the collector; (2) reduction of the percentage of high speed secondary electrons produced in the collector which can escape into the interaction section of the tube; (3) reduction of the modulation on the secondary electrons, or at least that portion of it which falls within the frequency range of interest. The measures introduced according to the present invention attack the secondary electron problem along each of these three lines.

DESCRIPTION OF THE PRIOR ART

U.S. Pat. No. 3,368,104 by J. A. McCullough, assigned to the same assignee as the present invention, illustrates a collector having a domed end portion bearing a superficial resemblance to the collector of the present preferred embodiment. However, in the McCullough patent the domed end portion is not dimensioned and positioned so as to receive the impact of all of the beam electrons, some of which spread onto the cylindrical sidewalls of the collector giving rise to some of the problems solved by the present invention.

Similarly, U.S. Pat. No. 3,450,930 to E. L. Lien and assigned to the assignee of the present invention, shows a collector having a domed end surface portion. Once again, however, the collector is dimensioned in such a way that beam divergence causes impact well up on the virtually cylindrical sidewall of the collector.

Additionally, collector designs are known in which the end wall of of the collector is a portion of a sphere, particularly a hemisphere. However, in each of these designs known to applicant, a substantial portion of the electrons impact on the cylindrical sidewall of the collector.

SUMMARY OF THE INVENTION

According to the present invention, the effect on the performance of linear beam microwave tubes of secondary electrons emanating from the collector can be eliminated or substantially reduced by providing, at the

downstream end of the collector, an electron impact surface which is substantially the locus of points equidistant from the constricted upstream mouth of the collector. By locating such surface so that substantially all of the primary beam electrons strike such impact surface portion and avoiding impact of any of the beam electrons on the cylindrical sidewalls of the collector, secondary electrons will be produced as far away from the mouth of the collector as possible. Thus, the percentage of the secondary electrons that are produced within the collector and which can return to the interaction section of the tube is reduced, because the region wherein these secondary electrons are generated is removed as far as possible from the mouth of the collector. Furthermore, modulation of the beam of electrons, which causes a proportional degree of spreading of the beam within the collector at the modulation frequency, does not result in a corresponding modulation of the secondary electrons. Finally, a significant reduction in the total number of high speed secondary electrons produced is realized by coating the impact surface portion of the collector with a material of low atomic weight.

Thus, the principal object of the present invention is to provide an improved linear beam microwave tube in which the number and effect of secondary electrons returning from the collector region to the interaction region of the tube is significantly reduced.

OBJECTS

A further object is to provide a tube according to the first object in which the electron collector includes an impact surface defined by the locus of points substantially equidistant from the center of the midplane of the constricted mouth of the collector.

A further object is to provide a tube according to the preceding objects wherein the impact surface portion comprises a peripheral truncated conical surface having the large end facing upstream and an end plate closing the downstream end.

These and other objects, features and advantages of the present invention will become more apparent upon reading the following detailed description and examining the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view partly in schematic line diagram form of a prior art UHF multicavity klystron amplifier;

FIG. 2 is an enlarged detailed view of an electron collector illustrating the principles of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, one type of prior art UHF multicavity klystron amplifier 1 is shown. The tube 1 includes a conventional electron gun assembly 2 for forming and projecting a beam of electrons 3 over an elongated beam path 4 to the conventional beam collector assembly 5. A plurality of cavity resonators 6, successively arranged along the beam path 4, together form a wave-beam interaction circuit for electromagnetic interaction with the beam 3.

An input signal to be amplified is fed into the input cavity resonator 6' via input coupling loop assembly 7 and input coaxial line 8. A segmented drift tube tunnel 9 through which beam 3 passes, communicates between successive cavity resonators **6**. The mutually opposed ends of the drift tube tunnel segments, projecting into each of the cavity resonators **6**, define electronic interaction gaps **11**.

An input signal supplied to the input cavity resonator **6'** excites resonance of the input cavity **6'**, developing an alternating electric field across input gap **11'**. The electric field of gap **11'** velocity modulates the beam **3**. In the succeeding drift tube tunnel segment **9'** this velocity modulation is converted within the drift space to current density modulation which excites resonance of the next two driver cavities **6''**. These two succeeding driver cavities further velocity modulate the beam **3** which velocity modulation is converted in drift tunnel **9** into increased current density modulation of the beam **3** as the electrons move toward the collector **5**.

In the output cavity resonator **6'''**, current density modulation of beam **3** produces within the cavity an amplified output signal which is extracted by means of output coupling loop **12**. The output signal is then fed to a suitable load such as a transmitting antenna, not shown, via output coaxial line **13**. A solenoid **14** surrounds tube **1** to provide an axial magnetic field B which confines the electrons of the beam to the desired beam path **4**. Capacitive tuning plates **15** bridge the gaps **11** within cavities **6** for mechanically tuning the operating frequency of the tube within a desired range of frequencies such as, for example, 470 mHz. to 560 mHz.

In a typical example of a prior art tube of FIG. **1**, the electron gun tube produced a beam **3** having a beam voltage of 18 kv. and 4.8 amperes with a perveance of 2×10^{-6}. The cathode emitter **17** had an emission density of 0.8 amps/centimeter sq. of emitting surface. The cavities **6** were cylindrical with an inside diameter of 8 inches and a length of 5.4 inches. The drift tube tunnel segments **9** were of copper and had an internal diameter of 0.875 inches and an outside diameter of 1.475 inches.

Turning now more specifically to the collector region of the prior art tube shown in FIG. **1**, it is seen that the collector **5** comprises a solid cylindrical block, as of copper, having a central cylindrical bore **18** terminating in a tapered end portion **19**, the whole being insulatedly mounted from the main body of the tube **1**. In use the collector would typically be operated at ground (Ov) potential, and would be provided with a liquid cooling means surrounding its exterior surface (not shown). Since the collector region comprises an electric-field-free space which additionally has a very low value of magnetic field strength, the beam rapidly diverges upon entering the collector region under the influence of space charge forces.

Upon striking the collector surface **18 – 19**, the beam electrons give rise to a certain percentage of secondary (impact-produced) electrons which are liberated in the collector region space with varying velocities and directions. However, for reasons of no concern to the present invention, these electrons are rather sharply divided into a high speed group and a low speed group. A certain percentage of the high speed electrons will have sufficient energy and will be released in the proper direction to return to the interaction section of the tube, following a reverse path to that of the beam electrons.

Because the beam electrons arrive in the collector **5** in bunches or groups at the rf frequency and also because the rf frequency is modulated by the input signal in input cavity **6'** and rf energy is extracted from the beam, the density and velocity of elecrons arriving at the collector varies greatly with time. At instants when the beam density is very high and/or the axial velocity low at the collector mouth, the beam diverges rapidly in its travel down the collector under the influence of rather large space charge forces, in addition to the radial deflection produced at the exit from the magnetic focusing field. Accordingly, a relatively large number of electrons from the beam will strike the collector near the mouth as illustrated by the path marked A. Any high speed secondary electrons generated by the impact of beam electrons following the path A will be released relatively close to the mouth of the collector and will have a relatively high probability of returning to the interaction section of the tube **1**. Conversely, at instants of time when the beam density arriving at the collector is very low, or the axial electron velocity high, the beam divergence will be less, resulting in electron trajectories more nearly along the path B in FIG. **1**. High speed secondary electrons generated by beam electrons on path B will have a relatively low probability of returning to the interaction section of the tube. Since, as noted, the density of primary electrons will be modulated at both the rf and signal frequencies, it is clear from the above that the points at which the beam electrons hit the cylindrical surface **18** of the collector will vary in response to both frequencies. The result is that secondary electrons returning to the interaction section of the tube will do so with an impressed modulation at both the rf and signal frequencies. As is readily apparent, this situation leads to the production of spurious signals, oscillation and ringing on the output of the tube.

Turning now to FIG. **2**, a collector **5'** embodying the principles of the present invention is illustrated. The collector **5'** comprises a front plate **20** which is insulatedly and vacuum tightly joined to the body of tube **1** and defines a constricted central entrance opening **21** which is supported in registration with a tapered output drift tube tunnel section **22** of the tube **1**. To the downstream face of a front plate **20** are joined in succession a series of three substantially cylindrical ring members **23**. According to the present invention, an end wall assembly **24** closes the open end of member **23**. Members **20, 23** and **24** may be made of oxygen-free high conductivity copper brazed together.

Turning specifically to the design of the end wall assembly **24**, it is fundamentally comprised of a peripheral portion **25** which is substantially a right truncated section of a circular cone, with the larger end facing in an upstream direction. The smaller end of peripheral portion **25** is closed by a generally circular flat end section **26**. Generally the end wall assembly **24** is dimensioned and positioned with respect to the remaining parts of the tube such that under conditions of the maximum beam divergence to be encountered in the tube, indicated by limiting lines L, still all of the electrons of the beam will impact upon portion **24**. Practically speaking, this means simply that the further assembly **24** is positioned from mouth portion **21**, the larger assembly **24** must be.

A (second) design criterion is that all of the points on impact surface portion **24** should insofar as practicable lie on the locus of points equidistant from point C which is at the center of the midplane of the constricted mouth portion **21** of the collector. The importance of this criterion may be appeciated in view of the foregoing discussion of modulation of secondary electrons — in particular when different degress of beam divergence within the collector **5'** result in the generation of electrons over a relatively large range of distances from the mouth of the collector as in the prior art collector **5** of FIG. **1** those secondary electrons that are generated close to the mouth of the collector will have a substantially higher probability of returning to the tube. Thus, since beam divergence is a function of modulating frequency and also of the rf carrier frequency, it is important to avoid a situation where the distance of impact points from the mouth of the collector also varies at the rf and modulating frequencies. According to the present invention, this is accomplished by insuring that under all conditions of beam divergence electron impact occurs on a surface which is substantially equidistant from the mouth of the collector.

Ideally, of course, such a surface would have the configuration of a sphere centered at point C and such an imaginary surface has been indicated by line S drawn at a radius R from point C. R has been chosen in FIG. **2** such that the deviations Δ of the actual impact surface portion **25** are identical so that S can be considered as the trace of a median sphere representing an idealized impact surface.

In practice machining considerations, and especially the need to provide a set of cooling fins **27** on the external surface portions of impact portion **24** has dictated the use of a surface which approximates the ideal sphere. It has been discovered that for deviations Δ which amount to less than 15% of R ($\Delta/R=0.15$) a very substantial improvement over prior art collectors of the type such as shown in FIG. **1** which involve impaction on the cylindrical sidewalls of the collector, can be achieved.

This improved collector design avoids large changes in the distance between the electron impact point on the collector surface and the mouth of the collector as the beam divergence varies. Also, by causing the impact surface portion to form the end of the collector, all beam impaction occurs at a point significantly further removed from the mouth of the collector than in previous designs. Therefore, the quantity of secondary electrons returning to the tube is reduced. The quantity of secondary electrons can moreover be further reduced by applying a coating to the inner surface portions of impact portion **24** consisting of a material of a low atomic weight such as carbon.

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. A linear beam electron discharge device including, means for forming and projecting a beam of electrons over an elongated beam path extending from an upstream end of said device to a downstream end thereof, means forming a wave-beam interaction circuit arranged axially coextensive with and adjacent to a por-

tion of said beam path for electronic interaction with the beam to produce velocity modulation thereof, means for extracting an output radio frequency signal from said velocity modulated beam, and a collector means located at a downstream end of said device for collecting said beam of electrons and dissipating the energy thereof, said collector means including an impact surface portion at the downstream end thereof substantially aligned with said beam of electrons, and a constricted entrance portion at the upstream end thereof through which said beam of electrons enters said collector means, said impact surface being within 15 percent of the locus of points equidistant from the center of the mid plane of said constricted entrance portion, said impact surface portion being dimensioned and positioned to receive substantially all of the electrons of said beam.

2. The apparatus of claim **1** wherein said impact surface portion comprises a peripheral truncated conical surface portion having the large end thereof facing upstream, and an end plate portion closing the downstream end thereof.

3. The apparatus of claim **1** wherein said electron discharge device is a multicavity amplifier tube, and wherein said wave-beam interaction circuit comprises a plurality of cavity resonators aligned with and encompassing the beam path, and further including a series of axially aligned drift tube tunnels interconnecting adjacent cavities of said cavity resonator in alignment with the beam passing therethrough, said drift tube tunnels having mutually opposed end portions extending reentrantly into said cavity resonators to define electronic interaction gaps therebetween, and means at an upstream end of said wave-beam interaction circuit for introducing an input signal to be amplified.

4. In a linear electron beam microwave tube designed for operation within predetermined specifications; means for forming and projecting said beam of electrons over an elongated path extending to a downstream end thereof; means for velocity modulating said beam; and collector means located at the downstream end of said tube for collecting said velocity modulated beam of electrons, said collector means having a given longitudinal axis, electrons in said beam being dispersed in said collector means transversely of said axis according to the velocity modulation of said beam, said beam dispersal having a maximum for tube operation within said predetermined specifications, said collector means including an impact surface at the downstream end thereof, said surface being intersected by said axis, said collector means further including a constricted entrance at the upstream end thereof through which said beam of electrons enters said collector means, said impact surface being defined by the locus of points substantially equidistant from the center of the midplane of said entrance and extending transversely of said axis for a selected distance in proportion to said maximum beam dispersion, said collector means further including means for mounting said impact surface relative to said entrance such that substantially all of said electrons in said beam impact on said surface when said tube is operated within said predetermined specifications, said impact surface portion of said collector deviates from the locus of points equidistant from said center by less than 15 percent.

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