United States Patent [19]

Shelton et al.

[11] **3,921,027**

[45] **Nov. 18, 1975**

[54] **MICROWAVE BEAM TUBE**

[76] Inventors: **Joe Shelton,** 700 Tatom St. NW., Huntsville, Ala. 35805; **Jerry W. Hagood,** 307 Mountain Gap Road SE., Huntsville, Ala. 35803; **Ralph L. Norman,** 3644 Marymont Drive NW., Huntsville, Ala. 35810

[22] Filed: **Sept. 13, 1974**

[21] Appl. No.: **505,827**

[52] **U.S. Cl.** **315/5.39;** 313/309; 313/336

[51] **Int. Cl.**[2] **H01J 25/10**

[58] **Field of Search** 313/336, 309; 315/3.5, 315/5.39, 5.41

[56] **References Cited**

UNITED STATES PATENTS

3,091,719	5/1963	Dyke et al.	313/336 X
3,109,123	10/1963	Spencer	313/336 X
3,489,943	1/1970	Denholm	315/5.39 X
3,489,944	1/1970	Denholm et al.	315/5.39 X
3,783,325	1/1974	Shelton	313/336

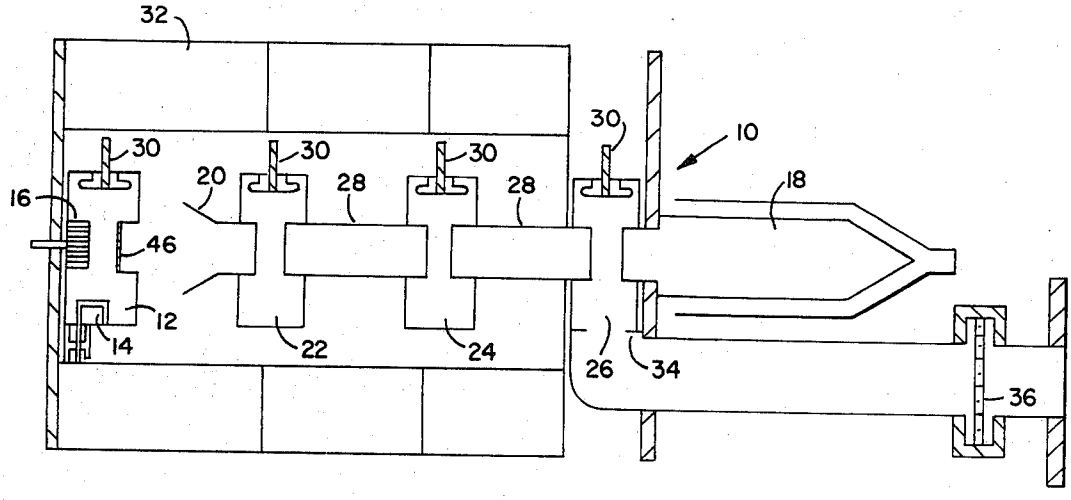
Primary Examiner—Saxfield Chatmon, Jr.

Attorney, Agent, or Firm—Eugene E. Stevens, III; Jack W. Voigt

[57] **ABSTRACT**

The improved microwave tube is a tube such as a klystron wherein bunches of electrons are produced by the input cavity of the tube. These electron bunches are well defined and are produced only when the input signal exceeds a level determined by the tube design. The bunches of electrons are obtained from a field effect electron emitter which forms a portion of one wall of the input cavity of the tube. The device is capable of instant response immediately upon input signal application and results in improved output signal energy and quality.

1 Claim, 3 Drawing Figures



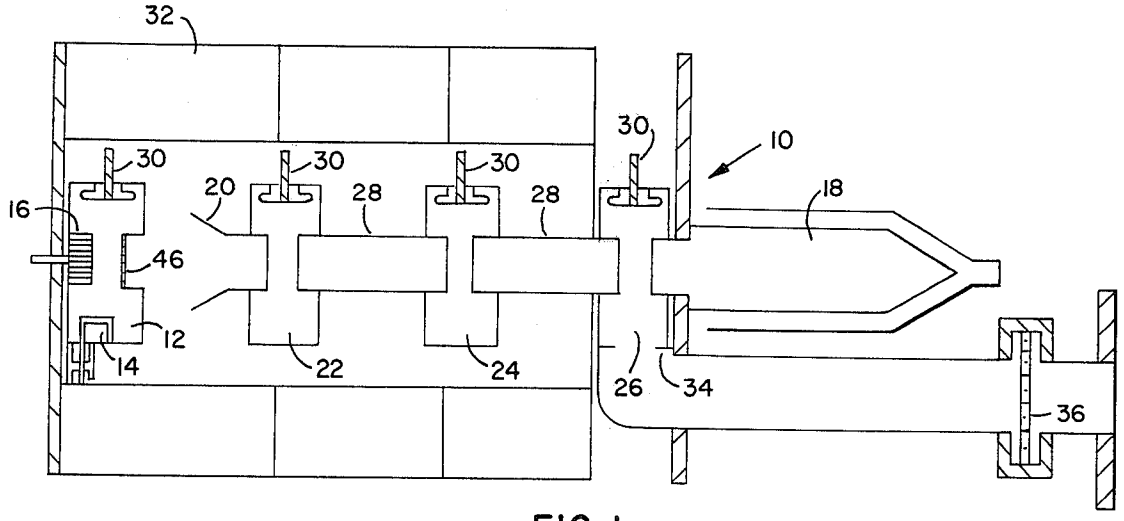


FIG. 1

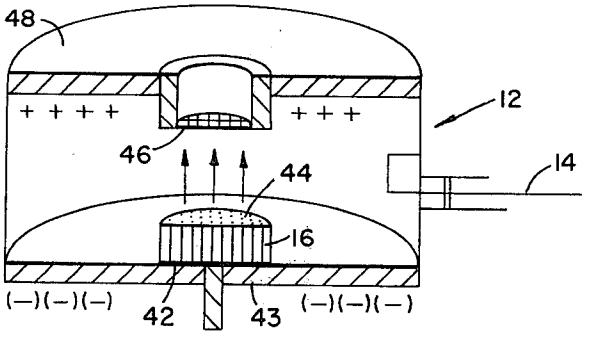


FIG. 2

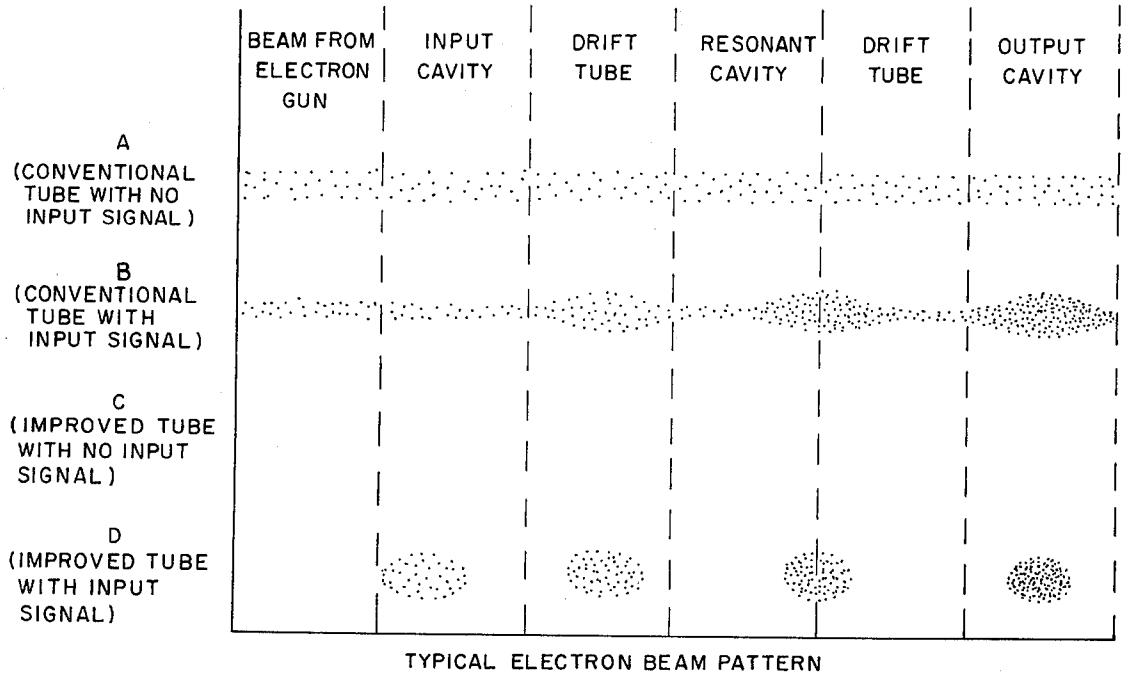


FIG. 3

MICROWAVE BEAM TUBE

DEDICATORY CLAUSE

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without payment to us of any royalty thereon.

BACKGROUND OF THE INVENTION

In the conventional klystron tube a steady stream of electrons is developed from an electron gun consisting of a thermionic emitter and a beam acceleration anode. The constant beam is directed through an input cavity toward a collector. A signal applied to an input loop causes oscillations in the input cavity, resulting in a varying signal on the sides of the input cavity which causes bunching of the electrons. Additional cavities cause the electrons to be formed into more compact and distinct bunches. Microwave energy is extracted from an output cavity just before the stream of electrons reaches the collector. The output energy is obtained in essentially the reverse manner that energy is applied to the input cavity. This microwave energy is coupled through an output iris and an output window to some load such an an antenna. Tuning diaphragms associated with each cavity allow precise tuning of the respective cavities.

It is well established in prior art klystrons that the source of electrons is completely independent of the radio frequency input circuit. The constant stream of electrons from the electron source is introduced into the klystron buncher (input cavity) wherein the radio frequency field acts on the beam. The beam is velocity modulated in the buncher with subsequent drift spaces and cavity resonators enhancing the alternating component of the modulated beam by increased bunching as is well established in the art. For the electron velocity to be efficiently modified, the electrons must cross the capacitive section of each cavity in less than a half cycle. The electron gun, which generates the electron beam, includes a cathode that requires a non-inductive heater. This is important for AC operation to eliminate any magnetic field effect on the electron beam which would ultimately distort the output signal.

The operation and characteristics of beam tubes such as klystrons are well established in the art. Detailed descriptions are found in publications such as "Introduction to Klystron Amplifiers", Varian Associates Publication AEB No. 19 dated April 1963, by Bruce E. Nelson, and "Klystron Tubes" by A. E. Harrison, McGraw-Hill Book Company, Incorporated, 1947.

The field effect electron emitter is an oxide-metal matrix comprised of ordered metal fibers separated by an insulating oxide. The emitter may be comprised of several million fibers arranged in parallel for each square centimeter of emitter surface area with the ends of the fiber forming the emitter surface. The fiber ends are all of substantially the same diameter with the distance between adjacent fiber ends being substantially the same. With the field effect electron emitter, no low energy electrons are generated. Advances in field effect electron emitters are set forth in U.S. Pat. Nos. 3,745,402 and 3,746,905 by Shelton et al. and U.S. Pat. No. 3,783,325 by Shelton.

SUMMARY OF THE INVENTION

The apparatus of the instant invention relates to beam tubes, such as klystrons and similar microwave tubes. The tubes are improved by elimination of the electron gun assembly and the direct emission of electrons within the input cavity, resulting in increased efficiency, reduced size and weight, and instantaneous response to input signals. A field effect electron emitter lies within and forms a portion of the input cavity of the klystron tube. The emitter operation is a function of the input radio frequency signal to the input loop of the cavity. The emitter conducts during alternate half cycles of the RF input signal, producing electron bunches in well-defined, distinct groups when the input signal exceeds a level determined by the tube design, and results in improved output signal energy.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view in section of the inventive microwave tube with extraneous structure omitted.

FIG. 2 is a diagrammatic view of the input cavity of FIG. 1.

FIG. 3 is a view of typical waveshapes present on the electron beams of prior art tubes and the microwave tube of the instant invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 discloses a preferred embodiment of a klystron tube in accordance with the teachings of the instant invention. The basic operation is completely different from that of prior art klystrons. In this microwave tube, there is no conventional electron gun and the individual electrons are produced in distinct bunches rather than as a steady electron stream. FIG. 1 discloses an improved klystron tube **10** having an input cavity **12** at the base thereof. Cavity **12** has an input loop **14** coupled through the outer wall thereof for coupling RF energy thereto. A field effect electron emitter **16** is disposed within the cavity in electrical contact with one surface thereof and positioned for directing electrons substantially along the longitudinal axis of tube **10** toward a collector assembly **18.** An accelerating anode **20** is disposed adjacent to cavity **12** between field effect emitter **17** and collector **18** for developing the electric field between anode **20** and emitter **16** during operation of the tube. Additional coaxially disposed cavity resonators **22, 24** and **26** are serially disposed between anode **20** and collector **18** with a drift tube **28** disposed respectively therebetween. Tuning diaphragms **30** are positioned along the outer circumference of each cavity for fine tuning the respective cavities to a common frequency of oscillation, as is done in prior art tubes. A focus coil assembly **32** encompasses the cavity and drift tube assembly for maintaining the axial direction of flow of the electron beam. Cavity **26** functions as the output cavity in the preferred embodiment, having an output iris **34** thereof coupled to an ouput window **36** for coupling microwave energy received thereby to load circuitry.

As shown in FIG. **2,** the field effect electron emitter **16** of cavity **12** has a backing plate **42** electrically in common with a wall **43** of the cavity. The emitter protrudes into the cavity in the capacitive area thereof with emitting rods **44** disposed for emitting electrons from respective ends thereof toward the grid like opening **46** within the opposite cavity wall **48.** When wall **48**

is negative with respect to the wall **43** and the field effect emitter, no electrons flow from the field effect emitter. As shown, with wall **48** of the cavity positive with respect to surface or wall **43,** field effect emitter **16** is negative and the positive potential on wall **48** adds to the potential developed between anode **20** and cavity wall **43** to provide the additional potential difference necessary for emission, allowing the field effect emitter to emit electrons. Thus, when the potential between grid like opening **46** and emitter **16** reaches a value determined by the particular tube design parameters, electrons flow from emitter **16** through screen **46** and into the remainder of the tube assembly. The particular tube design parameters, at which electron flow occurs, includes the spacing between screen **46** and emitter **16,** the number of emitting fibers per unit area, and the electric field between the anode and emitter.

During operation, an input signal is applied to input loop **14** of input cavities **12.** This signal causes the input cavity to oscillate which in turn causes the polarity of the potential across the cavity to periodically change. During the half cycle the field effect emitter potential is negative with respect to side **48** and electrons flow from the emitter through the cavity. Thus, the emitter emits electrons in bunches only during alternate half cycles of the input frequency on loop **14.** Each bunch of electrons is accelerated by anode **20** to the desired velocity. The bunches, evenly spaced apart, enter the resonant cavity **22** where they are bunched to a greater degree. The bunch then moves through drift tube **28,** through a third cavity **24,** and through another drift tube **28** into the output cavity **26.** Microwave energy is extracted from the electron bunch at the output cavity. Microwave energy is coupled through the output iris and the output window to a load such as an antenna. The electrons emerging from output cavity **26** are collected at collector **18** as in conventional tubes.

FIG. **3** provides a simplified comparison between prior art klystron operation (FIGS. **3A** and **3B**) and the improved beam tube operation (FIGS. **3C** and **3D**). With no input signal in the prior art klystron an unmodulated electron beam is generated as in A. With an input loop signal, bunching takes place as shown in B. No electron flow is shown in C, indicative of the improved beam tube operation with no input loop signal; and the electron beam is shown in D to be generated in bunches within the input cavity in response to the input loop frequency.

A primary difference in operation of the improved microwave beam tube as compared with the conventional klystron is that separate bunches of electrons are produced in the input cavity rather than using the input cavity to bunch a continuous stream of electrons as in the prior art. As shown in FIG. **3,** this results in short compact groups of electrons which allows either more compact groups of electrons to be provided for the same number of intermediate cavities as used in prior art klystrons or will allow elimination of some intermediate cavities while achieving the same results. The more compact bunching of electrons by the improved microwave beam tube and the elimination of stray electrons between bunches results in a greater amount of energy that can be coupled from the electron bunch in the output stage, as well as reducing output noise levels. Thus, electron emission is achieved within the input cavity as a function of the microwave frequency present on the cavity input loop, providing a cavity electron emission system that improves the output energy level.

Advantages of the improved microwave beam tube include reduction of weight and size of the beam tube due to more efficient design and elimination of auxillary components such as heater, heater transformer, electron gun assembly and associated control circuits. Because of the improved coupling resulting from more compact electron bunches the overall efficiency of the device is greater than prior art klystrons. There is no warm-up time required since the device is capable of instant response immediately upon input signal application. In the event that the input signal is lost for some reason, the apparatus is not harmed by an electorn beam since no electron beam can be generated unless the input signal is present in the input cavity. Conventional beam tubes require special protection circuits for the tube in the event of input signal loss to protect the tube from the continuous beam of electrons which is present regardless of whether an input signal is coupled to the input cavity or not.

A preferred embodiment of the invention has been chosen for purposes of illustration and description. The preferred embodiment illustrated is not intended to be exhaustive nor to limit the invention to the precise form disclosed. It is chosen and described in order to best explain the principles of the invention and the application thereof in practical use to thereby enable others skilled in the art to best utilize the invention in various embodiments and modifications as are best adapted to the particular use contemplated. It will be apparent to those skilled in the art that changes may be made in the form of the structure disclosed without departing from the spirit of invention as set forth in the disclosure. It is therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. Accordingly, it is desired that the scope of the invention be limited only by the claims appended hereto.

We claim:

1. In a microwave beam tube having an electron collector and a series of resonant cavities coaxially aligned for coupling an electron beam sequentially therethrough for obtaining velocity modulated output energy therefrom, the improvement of an input cavity electron emission system for providing periodic bunches of electrons emitted into the beam path and comprising: an input cavity resonator coaxially aligned with said resonant cavities and having an input loop for receiving alternating microwave input signals; a field effect electron emitter disposed for periodically releasing electrons into said input cavity toward said collector in response to said alternating microwave energy developed within said cavity, said emitter comprising a plurality of parallel, insulated, emitting fibers per unit area having a conductive backing plate in common with one wall of said input cavity, said plurality of insulated emitting fibers are several million parallel fibers per square centimeter forming a planar emitting surface for emitting electrons at prevailing ambient temperatures; an accelerating electrode, said accelerating electrode being coaxially aligned between said input cavity and a first cavity of said coaxial resonant cavities for developing an electric field between the emitter and electrode for directing electron beam flow from said emitter therethrough; and an electron drift space separating each of said coaxial resonant cavities from adjacent of said cavities.

* * * * *