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BEAM COLLECTOR STRUCTURE FOR ELECTRON TUBES HAVING CONCENTRIC LONGITUDINALLY PARTITIONED COOLING ANNULI

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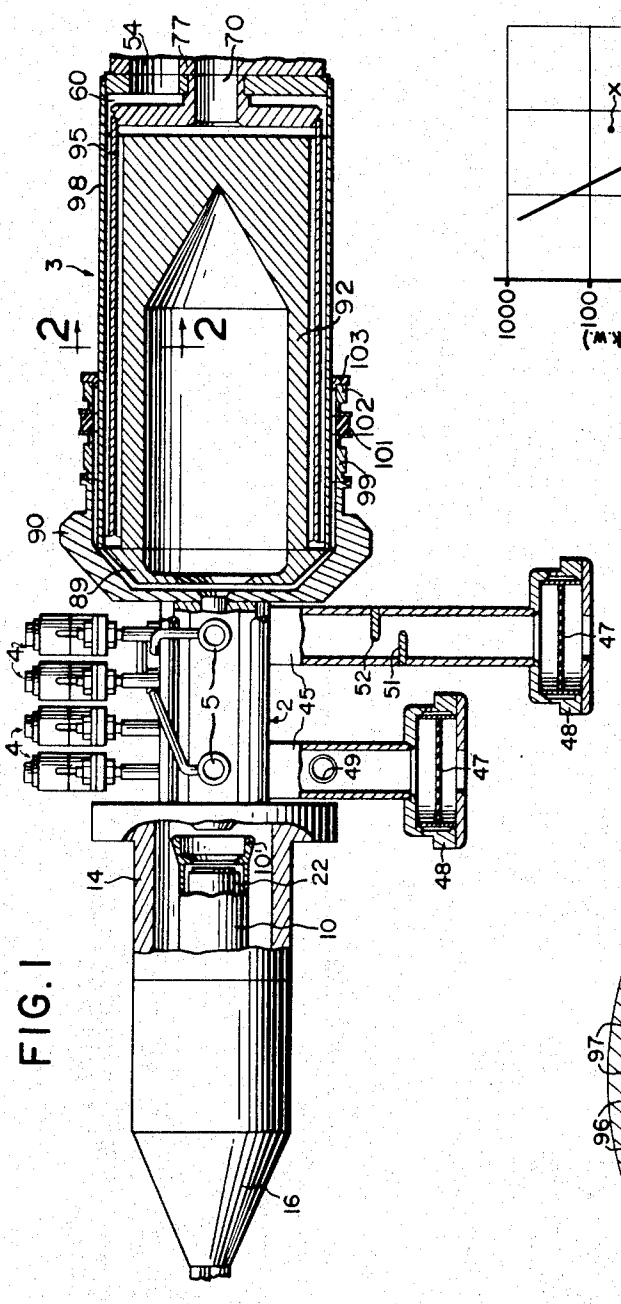


FIG. 1

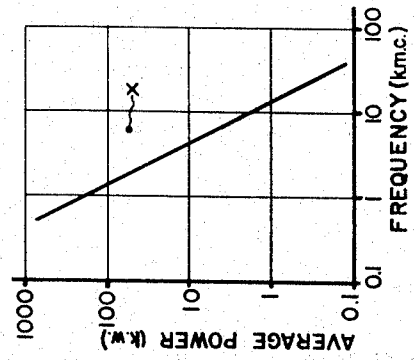


FIG. 3

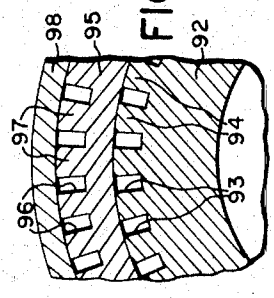


FIG. 2

INVENTORS
LOUIS T. ZITELLI
IRVING MALTZER

BY Harry E. Aine
ATTORNEY

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BEAM COLLECTOR STRUCTURE FOR ELECTRON TUBES HAVING CONCENTRIC LONGITUDINALLY PARTITIONED COOLING ANNULI

Louis T. Zitelli, Palo Alto, and Irving Maltzer, San Carlos, Calif., assignors to Varian Associates, Palo Alto, Calif., a corporation of California

Original application Oct. 30, 1961, Ser. No. 148,520, now Patent No. 3,281,616, dated Oct. 25, 1966. Divided and this application July 5, 1966, Ser. No. 574,857
4 Claims. (Cl. 315—5.38)

ABSTRACT OF THE DISCLOSURE

A beam collector structure for collecting and dissipating the energy of a high power microwave tube is disclosed. The collector structure includes a hollow collector bucket for catching the electron stream on the interior surfaces thereof. A multitude of fins are provided on the exterior of the collector bucket, the fins running longitudinally of the collector. A thermally conductive baffle surrounds the outer edges of the fins to define a longitudinally partitioned cooling annulus between the baffle and the collector bucket. The baffle is in turn provided with a multitude of longitudinally directed fins on the exterior surface thereof. The baffle fins are surrounded by a tubular member to define an exterior longitudinally partitioned cooling annulus. The interior cooling annulus and the exterior cooling annulus are connected together and a coolant manifold is provided for distributing a liquid coolant to the interior and exterior cooling annuli. In a preferred embodiment, the fins are thicker taken in the circumferential direction around the collector bucket than the coolant channels lying between adjacent fins. In addition, the fins are dimensioned to have approximately equal depth and width whereby the cooling fins provide the greatest efficiency for removing heat from the collector.

This invention is a divisional application divided out of parent application 148,520, filed Oct. 30, 1961, and assigned to the same assignee as the present invention now Patent No. 3,281,616 and relates in general to CW klystron amplifiers and, in particular, to a novel high power, high frequency klystron amplifier adapted, for example, for use in space communications, radio astronomy, CW illuminators and forward scatter.

During the past few years there has been an increasing demand for higher CW power, for example, in the order of 50 kilowatts or more at X-band frequencies (7.125 to 8.5 kmc.). The graphic result of a recent survey by L. S. Nergaard, RCA Review, December 1960, on power limitations of microwave transmitting tubes is depicted in FIG. 3 of the drawings. This graph shows a plot E of expected power output as a function of frequency. The article by Nergaard states that increases in power output have not been large and that a major breakthrough may be required to achieve order of magnitude improvements.

The klystron amplifier of the present invention has generated about one order of magnitude more average power than any known microwave device at X-band frequencies. Its performance data is superimposed, by an X, on the Nergaard graph of FIG. 3 and shows that an order of magnitude improvement has been obtained over the prior art. This would indicate that a major breakthrough in the state of the art has been achieved.

One of the problems associated with increasing the power output of X-band klystrons is as follows:

Extremely large amounts of heat must be dissipated in the collector portion of the tube due to the greatly increased beam current density developed in a tube producing such a high power output.

It is the object of the present invention to provide a novel high power CW klystron amplifier tube of high frequency which is adapted for use in high power CW systems.

Still another feature of the present invention is the use of a novel cooling system for the collector which includes use of an outer baffle positioned around and spaced apart from the collector body, the baffle having a plurality of longitudinally directed cooling channels on its outer surface defining a plurality of longitudinally directed cooling fins for enhancing cooling of the collector to give greater efficiency in removing heat therefrom.

Other features and advantages of this invention will become apparent from a perusal of the following specification taken in connection with the accompanying drawings wherein,

FIG. 1 is a longitudinal partial cross sectional view of the novel klystron of the present invention,

FIG. 2 is a fragmentary enlarged cross sectional view of FIG. 1 taken at line 2—2 in the direction of the arrows,

FIG. 3 is a graph of average power output of state of the art transmitter tube as a function of frequency.

Referring now to the drawings, the novel multicavity klystron tube of this invention comprises three main portions: a beam producing section **1** followed by a central beam interaction section **2**, wherein interaction between the beam and the applied radio frequency wave takes place to produce the amplification, and a collector section **3** where the electrons of the spent beam are collected.

The electron beam collector section **3**, as seen in FIG. 1, is preferably mounted in a second cup-shaped pole piece **90** of a magnetic material having a tapered bore **91** extending essentially through its base and adapted to register with the aligned drift spaces **41** of drift tubes **40**. The cup shaped pole piece **90** is brazed in position at the output end of the beam interaction amplification section of the tube, so as to accommodate the electron beam.

The novel collector section includes a hollow, open-ended cylindrical collector member **92**, as of, for example, copper, closed off at one end. Formed, as by machining, in the exterior walls of collector **91** are a plurality of narrow, deep, parallel, longitudinally directed channels **93** (see FIG. 2), which form therebetween a number of fins **94** extending over most of the length of the collector **92**.

It has been found that it is most desirable to have the fins **94** to be of approximate equal depth and width and to have the width of the channels **93** smaller than the width of the fins **94**. This is because the fins of approximate equal width and depth provide the greatest efficiency for removing heat and small channels will permit a greatest number of fins to be utilized to give additional efficiency in removing heat.

Closely fitting over the fins **94** is a novel hollow open-ended cylindrical baffle **95**, as of, for example, copper or some other good thermal conductor. Baffle **95** has a number of channels **96**, similar to channel **93**, machined therein, which define a plurality of fins **97**, similar to fins **94**. By making baffle **95** of copper, for example, and providing it with cooling fins, the entire collector and baffle are of a good thermal conducting material and water cooled thereby giving the greatest possible efficiency for a given amount of water. Surrounding fins **97** is a cylindrical outer wall jacket **98**. Fins **94** and **97** extend longitudinally a distance slightly short of the entrance end of collector member **92**, while outer jacket **98** extends to the open end of the collector **92**. A bevel cup member **98** fits over the open end of collector **92** in alignment with the opening of tapered bore **91** to support the outer wall jacket **98** and to reverse the direction

of the fluid flow through the coolant channels **93** and **96**.

Carried on the closed end of the outer jacket **98** is a fluid coolant distribution manifold **77**, which distributes and collects fluid for the channels **93** and **96** of the coolant system of the collector **92**. A cooling fluid, normally water, enters distributor manifold **77** through an input aperture **70** and then passes through a plurality of channels **60** radially extending outward from the end of the collector **92** and aligned with channels **93**. The fluid then flows along channels **93** to the open end of the collector whereupon the flow is reversed by cup **89** and travels back through the coolant channels **96**, thence the coolant is collected and passes out aperture **54**. It is noted that fluid flow could be reversed by having it enter through aperture **54**, if desired.

The collector assembly **3** is carried from the annular magnet pole piece **90** via a hollow cylindrical collector adapter **99**, flanged at one end and is sealed in a vacuum tight manner to an annular insulating ring **101** as of, for example, ceramic. The other side of insulating ring **101** is sealed in a vacuum tight manner to an annular frame **102** of Kovar for example. Kovar frame **102** is sealed as by, for example, a weld to an annular metal ring **103** brazed to the coolant jacket **98**.

The collector assembly **3** is insulated from the main body **2** via insulator **101**. A current meter (not shown) could be connected across insulator **101** such that the interception of the beam current on parts of the tube excluding the collector which is insulated from the grounded tube body may be monitored.

An electromagnet (not shown) operates on a power requirement of approximately 1520 watts to produce a magnetic field strength of approximately 3500 gauss. The magnet is fitted on the ends of the pole pieces **34** and **50** to provide an axially directed beam focusing magnetic field.

In operation, a beam of electrons emitted from the cathode button **11** is accelerated through the bore **13** and into the small axially aligned cylindrical drift spaces **41** and the drift tubes **40**. The radio frequency signal, to be amplified, is fed into the first or "buncher" cavity resonator through the input wave-guide **45**. The radio frequency electric field produced across the resonator gap in this first cavity resonator velocity modulates the electrons, that is, the electrons are slowed down and speeded up, depending on the phase of the radio frequency field across the interaction gap **43** at the time of gap transit of the electron. In the field free drift space defined drift tube member **40**, the velocity modulation forms the beam into groups or bunches of electrons, which at their point of sharpest bunching, pass through the resonator gap in the second cavity resonator.

The cavity resonators are initially tuned during assembly by the proper positioning of the drift tube members **40** to establish correct resonator gap spacing, the cavities threreafter are fine-tuned by means of the tuning structure **4** and tuning diaphragm **55** as described above. All of the cavity resonators between the first, or input, resonator cavity and the last or output resonator cavity, serve to improve the bunching of the electron beam initiated in the first resonator cavity so that optimum bunching is produced before the beam passes through the resonator gap in the last or output resonator cavity. In the output resonator cavity, amplified radio frequency electromagnetic energy is extracted and coupled out through the output iris and propagated through the output waveguide **45** and output window **47** to a load (not shown).

It is noted that in the present tube ½ watt radio frequency drive power is sufficient to drive the tube to slightly less than 24 kilowatts at an efficiency of 38%. The tube is designed to operate over a limited tuning range of plus or minus 30 mc. about a frequency in the X-band (7.125 to 8.5 kilomegacycles).

Several of the manufactured tubes have been tested with a C.W. R.F. power output of 41 and 43 kw. This is an improvement over "state of the art" X-band C.W. tubes in the order of one magnitude.

Since many modifications and variations in the described arrangement can be obviously made without departing from the scope of the invention, it is intended that all matter in the foregoing description or shown in the accompanying drawing should be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electron discharge device comprising means for forming a beam of electrons; means for collecting the beam of electrons; electromagnetic wave supporting structure arranged along a beam path defined between said beam forming and collecting means for electromagnetic interaction with the beam of electrons passable therethrough; means for extracting R.F. energy from the device; said means for collecting the beam of electrons comprising a tubular collector for receiving the beam incident therein, a plurality of longitudinally directed collector fins on the outer surface of said collector defined by a plurality of peripherally spaced-apart longitudinally directed collector channels, a tubular baffle surrounding said collector fins whereby said collector fins and said baffle define an interior, longitudinally partitioned annulus, said tubular baffle member having a plurality of longitudinally directed baffle fins, defined by a plurality of peripherally spaced-apart longitudinally directed baffle channels on the exterior surface of said tubular baffle, a tubular outer jacket surrounding said baffle whereby said baffle fins and said tubular outer jacket define an exterior longitudinally partitioned annulus, means for connecting said interior and exterior cooling annulus, and means communicating with said interior and exterior annulus for distributing an input and output flow of liquid coolant therethrough to remove heat dissipated in said collector by the beam of electrons.

2. The device according to claim **1** wherein said fins are of approximately equal depth and with to enhance the efficiency of said cooling fins.

3. The device according to claim **2** wherein said collector and baffle channels are of less width than the width of said collector and baffle fins to enhance the cooling efficiency of said collector.

4. The device according to claim **3** wherein said collector and said baffle are made of copper.

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HERMAN KARL SAALBACH, *Primary Examiner.*

ELI LIEBERMAN, *Examiner.*

S. CHATMON, JR., *Assistant Examiner.*