

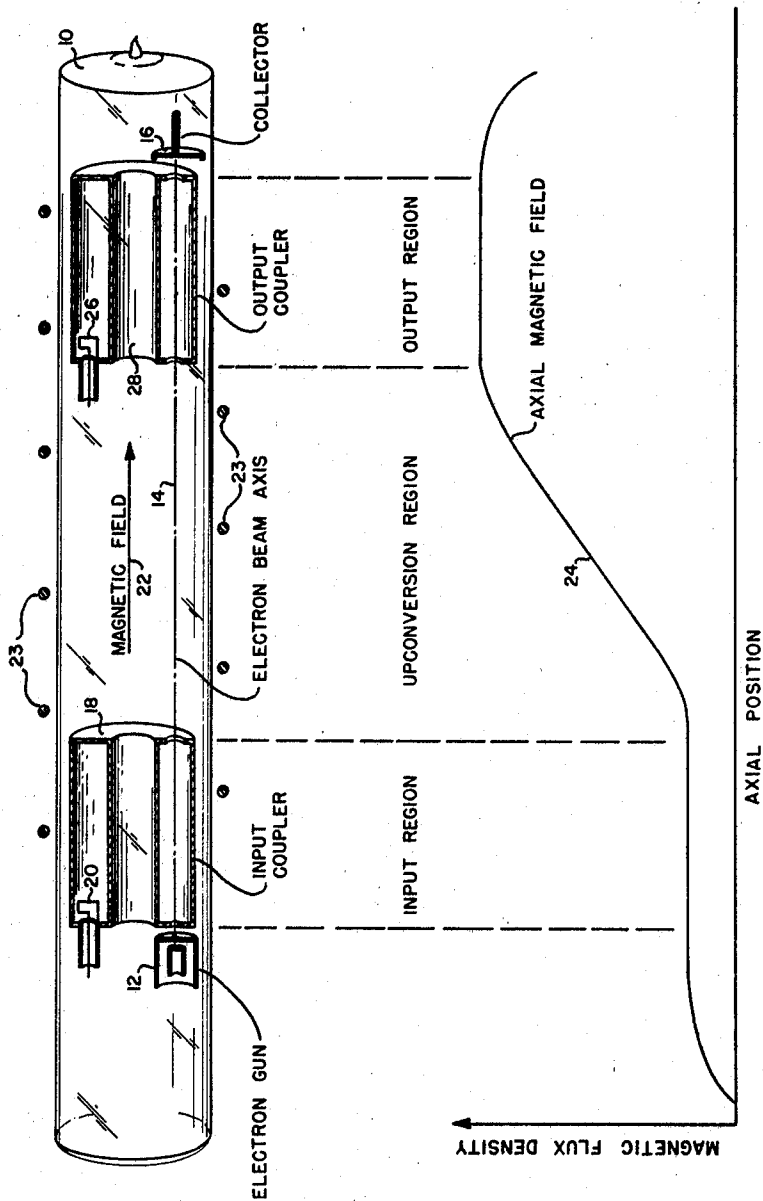
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CYCLOTRON WAVE UPCONVERTER

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CYCLOTRON WAVE UPCONVERTER

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5 Claims

ABSTRACT OF THE DISCLOSURE

Method and apparatus for generating millimeter and submillimeter waves utilizing the upconversion of a cyclotron wave wherein an electron beam is acted upon by a transverse R-F field and an axially varying magnetic field.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to the generation of millimeter and submillimeter waves and more particularly to a method and device wherein an electron beam is acted upon by a transverse R-F field and an axially varying magnetic field.

Description of the prior art

At the present time no fully satisfactory coherent power sources exist for areas within the submillimeter range (0.1–1.0 mm.) of the electromagnetic spectrum.

Conventional microwave tubes do exist which generate power at the longer wavelength end of the submillimeter range, but these tubes are generally unsatisfactory in that they are extremely expensive, are very fragile and have rather short lives. As the wavelength decreases, power generation by conventional microwave tubes becomes increasingly difficult (and unsatisfactory) since it is necessary to produce increasingly dense electron beams which must pass increasingly closer to progressively smaller R-F circuits.

The use of lasers to produce power in the shorter wavelength end of the submillimeter range is increasing. However, a satisfactory tunable (variable frequency) laser has not been developed and, as a result, the use of gas laser generators is limited to power generation at certain specific frequencies.

Harmonic generators have been used to some extent to produce signals in the submillimeter range but are generally considered to be unsatisfactory because of inherent inefficiencies.

SUMMARY OF THE INVENTION

The general purpose of this invention is to provide power in the submillimeter range of the electromagnetic spectrum. To attain the desired generation of submillimeter waves, the present invention contemplates a method and device wherein an electron beam is acted upon by a transverse R-F field and by an axially varying magnetic field. The variation of the strength of the magnetic field produces an upconversion of the cyclotron wave that is cooperatively produced by the R-F and magnetic fields.

It is, therefore, an object of this invention to provide a device which produces power in the submillimeter range of the electromagnetic spectrum.

Another object is to provide a method and apparatus

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for the generation of millimeter and submillimeter waves by the upconversion of a cyclotron wave.

A still further object of the invention is the generation of millimeter and submillimeter waves by a device having and R-F power gain and wherein a cyclotron wave is produced and upconverted by the interaction between an electron beam, a transverse R-F field and an axially varying magnetic field.

BRIEF DESCRIPTION OF THE DRAWING

Other objects and features of the invention will become apparent to those skilled in the art as the disclosure is made in the following description of a preferred embodiment of the invention as illustrated in the accompanying drawing which diagrammatically shows the invention and the variation of the magnetic field therein.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, there is shown an envelope 10, preferably made of glass and highly evacuated. Inside envelope 10 is an electron gun 12 which produces an electron beam 14 which eventually reaches collector 16. The electron beam 14, in addition to the conventional potential difference between the gun 12 and collector 16, is also acted on (and responsive to) a transverse R-F field produced in input coupler 18 by the R-F input signal on probe 20 and by an axial magnetic field 22 (produced by diagrammatically shown means 23) which increases in magnitude as shown by curve 24 in the drawing. Before reaching the collector 16, the energy of the beam 14 is coupled to output probe 26 in the output coupler 28.

The reader will by now realize that in the interest of clarity many conventional components of structure and circuitry have not been specifically illustrated or described. These omitted, and obviously necessary, features include the biasing, accelerating, focusing, heating and modulating potential sources and circuits.

Considering now the operation of the embodiment of the invention illustrated in the drawing, the electron beam produced by electron gun 12 passes successively through an input region, an upconversion region and an output region. This beam may obviously be either continuous or pulsed, depending on the requirements of the output load.

In the input region, characterized by the low level uniformity of the axial magnetic field and the presence of input coupler 18, the electron beam 14 receives the R-F power input (P_{in}) by interaction with the transverse R-F electric field produced in the coupler 18 by the signal on input probe 20. The frequency of the R-F input signal on probe 20, the (resonant cavity) frequency of the coupler 18 and the strength of the axial magnetic field in the input region are compatibly correlated to transform the electron beam produced by electron gun 12 into a coherent rotating beam at an input cyclotron frequency (f_{in}).

In the upconversion region, characterized by an adiabatic increase of the axial magnetic field from the lower level in the input region to the higher level in the output region, the beam 14 proceeds in free space. However, because of the increasing axial magnetic field and because of the conservation of momentum, in the upconversion region the forward speed of the electron beam is decreased and the rotational speed of the electron beam is increased to an output cyclotron frequency (f_{out}) which is, of course the output frequency of the device. It will be apparent that the output cyclotron frequency is not necessarily harmonically related to the lower input cyclotron frequency and that the theoretical maximum

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R-F gain of the device is defined by the relationship of the input and output cyclotron frequencies, i.e.

$$\text{R-F gain} = \frac{P_{\text{out}} (R-F)}{P_{\text{in}} (R-F)} = \frac{f_{\text{out}}}{f_{\text{in}}}$$

The theoretical maximum gain is (in practice) not realized because of coupling losses.

It is of interest to note that, as a design consideration, the rate of change of the axial magnetic field must not be too large (for any given beam velocity) or the beam will turn back on itself in the familiar way that "magnetic mirrors" or "magnetic bottles" contain plasma in fusion research.

In the output region, characterized by the high level uniformity of the axial magnetic field and the presence of output coupler 28, energy from the beam 14 is transferred, at the higher (output) cyclotron frequency, to the output probe 26. The coupler 28 is, of course, tuned to this higher cyclotron frequency. After passing through the coupler 28, the beam 14 impinges on the collector 16.

It is apparent that there has been disclosed a method and apparatus for generating millimeter and submillimeter waves wherein a cyclotron wave is produced and upconverted by the interaction between an electron beam, a transverse R-F field and an axially varying magnetic field.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. For example, it is obvious that other forms of couplings may be used. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. A cyclotron wave upconverter comprising:

a collector;

beam producing means to produce a continuous electron beam and to direct said beam in a direction toward said collector;

input region means adjacent said beam producing means for continuously subjecting said electron beam to a transverse R-F field and to a lower strength uniform magnetic field which is parallel to said beam;

upconversion region means adjacent said input region means of continuously subjecting said electron beam to a magnetic field which is parallel to said beam and gradually increases in strength from said lower strength and

output region means between said collector and said upconversion region means for continuously extracting energy from said beam.

2. A cyclotron wave upconverter as set forth in claim 1 wherein said collector, said beam producing means, said input region means, said upconversion region means

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and said output region means are all contained within an evacuated envelope.

3. A cyclotron wave upconverter comprising:

an evacuated envelope having an axis;

a collector located in said envelope;

beam producing means located in said envelope for producing an electron beam and for directing said beam parallel to said axis and toward said collector;

input coupling means located adjacent to said beam producing means for producing a transverse R-F field which interacts with said electron beam;

output coupling means located adjacent to said collector for extracting energy from said beam and

magnetic field producing means for producing a magnetic field in said envelope and parallel to said axis, said magnetic field being of a lower strength in the region of said input coupling means and gradually increasing in strength to be a higher strength in the region of said output coupling means.

4. A cyclotron wave upconverter as set forth in claim 3 wherein said input coupling means and said output coupling means each include a tuned cavity through which said beam passes and a probe coupled to said cavity.

5. A cyclotron wave upconverter as set forth in claim 4 wherein the frequency of said transverse R-F field, said tuned cavities and said lower and higher strengths of said magnetic field are correlated so that a lower frequency cyclotron wave produced in said input coupling means is increased in frequency and couples to the cavity in said output coupling means.

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