

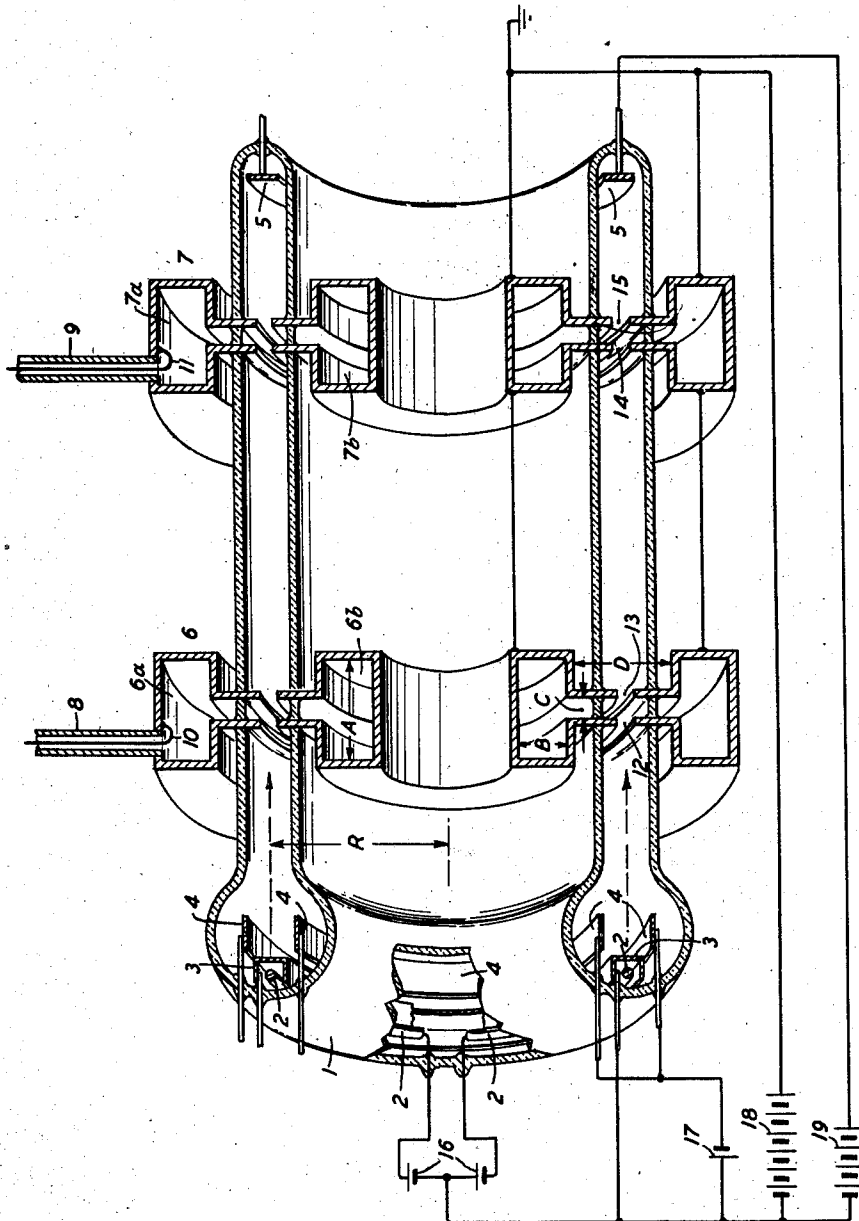
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ULTRA-HIGH FREQUENCY ELECTRONIC DEVICE

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ULTRA HIGH FREQUENCY ELECTRONIC
DEVICE

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This invention relates to devices whereby ultra-high frequency waves may be generated, amplified or translated, and is particularly directed to increasing the power capacity of such a device at the higher frequencies.

The invention is especially applicable to devices of the class in which an interchange of energy takes place by direct action between an electron stream and an electromagnetic wave as, for example, where the wave exists within the interior of a resonant cavity and is sustained by energy supplied to it by an electron stream entering or passing through the cavity.

Devices of the type described are usually subject to the disadvantage that as the operating frequency is made higher the physical dimensions of the resonator become smaller in direct proportion to the frequency and the size of the electron stream which can be made economically to interact with the resonator is reduced accordingly. As a result, the power capacity of the device will ordinarily tend to be inversely proportional to the operating frequency.

In accordance with the invention a tubular-shaped electron beam of relatively large radius is used in conjunction with an annular or toroidal-shaped resonator also of large radius, but of relatively small cross-sectional area. It is found that the electromagnetic waves in such a resonator may readily be excited to an appropriate mode of oscillation such that the operating frequency is determined substantially by the cross-sectional dimensions independently of the radius of the annulus or toroid. Accordingly, it is to be expected that the cross-sectional area of the electron stream that can be used may be increased to any desired amount by increasing the radius of the electron beam while the operating frequency may be made as high as desired by reducing the cross-sectional area of the resonator.

The invention will be described with reference to a preferred embodiment shown in cross-sectional view in the single figure of the drawing.

Referring to the drawing, 1 is an evacuated insulating envelope of glass or other suitable material containing at one end an annular-shaped electron gun otherwise similar in arrangement and function to electron guns of well-known form. The gun includes a heating element 2 which may comprise an insulated rod or filament, and a cathode or electron emitting element 3 which may be of channel shape with the active portion of its surface coated with a highly electron emissive substance in well-known manner. A pair of annular-shaped focusing electrodes 4

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are provided both of which may be connected to a biasing source at the potential of cathode 3, or slightly more negative than the cathode, for the purpose of concentrating the electrons into a bundle. In the present case, the electron bundle is in the form of a hollow tube of average radius that will be denoted by R. At the other end of the envelope 1 is an annular-shaped collector electrode 5. The active surface of the cathode may comprise all of that portion of the cathode that faces the electrode 5. Intermediate between the electron gun and the collector electrode are shown two toroidal resonators designated generally 6 and 7, respectively. The resonator 6 may be in two portions, 6a and 6b, and the resonator 7 may comprise parts 7a and 7b. Each resonator is sealed into the walls of the envelope 1 in such a position as to encompass the tubular electron beam along its entire circumference. The resonator portions 6a and 6b, and likewise portions 7a and 7b, are slightly separated, forming therebetween annular slots 12, 13, 14 and 15 to permit passage of the electron beam through the interior of each resonator preferably at a restricted or reentrant section of the resonator. Coaxial transmission lines 8 and 9 respectively are provided for the transmission of electromagnetic waves to or from each resonator. The transmission lines terminate in the coupling loops 10 and 11, respectively, extending interiorly of the resonators through relatively small apertures in the walls.

The filament 2 may have its ends brought out through the envelope at adjacent points where the ends may be connected to a battery 16 or other suitable source of heating current. The cathode 3, the focusing electrodes 4 and the collector 5 may be supported in any suitable manner as, for example, by means of metal rods welded to the respective elements and brought out through the glass in the case of a glass envelope. Certain of the supporting rods may be used for establishing electrical connection to the elements inside the envelope and the rods may be hermetically sealed into the envelope in any suitable manner. The resonators 6 and 7 have flange-like portions at the restricted sections which may be set into the walls of the envelope 1 and hermetically sealed in accordance with known technique of copper-glass seals or in any other suitable manner. These flange-like portions, by their juxtaposition form the slots 12, 13, 14 and 15 between their respective edges.

Biasing and accelerating potentials may be supplied to the various electrodes by means of

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batteries or other suitable sources. The heating battery 16 may be divided into two balanced parts, if desired, and the mid-point connected to the cathode 3. The cathode may be connected to the focusing electrodes 4 through a low voltage battery 17, the negative terminal of the battery being connected to the focusing electrodes. In some cases, the electrodes 4 may be directly connected with the cathode 3. Electron accelerating potentials may be provided by means of a high potential battery 18, the positive terminal of which may be grounded and connected to the resonator portions 6a, 6b, 7a and 7b by means of suitable interconnecting leads as shown. The collector electrode 5 is preferably operated at a somewhat more negative potential than the battery 18. In this case, a battery 19 may be connected to the electrode 5, the voltage of the battery 19 being somewhat less than that of the battery 18. The negative terminals of batteries 18 and 19 may both be connected with the cathode.

In the operation of the system, the filament 2 is heated until the cathode 3 emits a suitable stream of electrons, in this case in the form of a tubular beam or cylindrical sheet, concentrated and focused by means of electrodes 4. The electrons are accelerated toward the collector by the direct current potential difference between the resonators 6, 7 and the cathode 3. If the arrangement is to be employed as an amplifier, electromagnetic waves to be amplified are supplied to the resonator 6 through the line 8 and coupling loop 10. The resonator is preferably of suitable dimensions to resonate at the frequency of the incoming wave. In this case standing waves will exist in the interior of the resonator and these waves will impress a velocity variation upon the electrons as the electron stream passes through the region between the slots 12 and 13. The space between the slots 13 and 14 constitutes a substantially field-free drift space in which the electrons gradually become arranged substantially into groups due to the velocity variations which have been impressed upon them. The grouped electrons, in passing through the space between the slots 14 and 15, will initiate amplified waves in the resonator 7 at the frequency of the waves impressed upon the resonator 6. The resonator 7 is also preferably of suitable dimensions to be resonant to this operating frequency. Waves may be led off from the resonator 7 through the line 9 which is coupled to the resonator by means of the loop 11. After passing the slot 15, the electrons are intercepted by the collector electrode 5.

If it is desired to operate the device as an oscillator, a feedback connection may be established between the resonators 6 and 7 by connecting the lines 8 and 9, or in any other suitable known manner.

To make it possible to increase the power output of the arrangement by simply increasing the radius R and thus increasing the active cathode area in the same proportions, it is desirable that the resonators shall be capable of resonating at a given operating frequency regardless of the value of the radius R. From theoretical and experimental considerations, it has been found that resonators of toroidal or annular form will generally have a suitable mode of oscillation for which the resonant frequency is independent of the radius of the toroid or annulus and depends only upon certain cross-sectional dimensions. For example, in a resonator of the shape illustrated in the drawing, there is a suitable mode of

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oscillation available for which the frequency is substantially independent of the radius R and depends only upon the dimensions A, B, C, and D relating to the cross section as indicated on the drawing. It will be evident that a toroidal resonator having given values of the dimensions A, B, C, and D may readily be constructed with a large value of the radius R, thereby enabling the system to be used with a cathode of very large active area. In short, the cross-sectional dimensions of the resonator do not place any inherent limit upon the circumference of the cathode and hence no limit upon the area of the electron stream. Many other cross-sectional shapes may, of course, be substituted for the one shown herein.

It will be evident that the sheet of electrons need not be in the form of a circular cylinder, but may have the form of a cylindrical sheet of any desired configuration. Magnetic focusing coils or other suitable devices for focusing or restraining the electrons may be added as desired. Grid electrodes may be inserted for accelerating the electrons, if desired, instead of impressing the accelerating potential upon the resonators. Many other variations in the arrangements known to the art of ultra-high frequency electronic devices may be made and the device may have other functions than merely those of an amplifier or an oscillator without departing from the scope of the invention as defined in the claims hereto appended.

The device is particularly adapted for operation at the higher frequencies, for example, at wave-lengths of the order of a few centimeters. In this frequency range, the dimensions of resonators ordinarily employed are so small that it is difficult to handle any considerable amount of power. In accordance with the invention the power output of the present device may be compared with the output of a plurality of devices of the conventional type operated in parallel. Aside from eliminating the considerable difficulties of tuning a plurality of such devices for parallel operation, the arrangement of the invention reduces losses of energy which would occur in the increased area of resonator walls if a plurality of separate resonators were employed. If the individual resonators were excited by focused beams or pencils of electrons, the amount of electron current that could be got through the arrangement would be less by a considerable amount than could be sent through that segment of the tubular beam which is associated with the same resonating space. The tubular arrangement of the electron stream also has the advantage that focusing is required in the radial direction only. Also, there is no complexity or non-uniformity of action such as can occur at the ends of a plane sheet of electrons from a linear filament, the tubular beam being in effect endless.

What is claimed is:

1. A toroidal-shaped resonator having a relatively small cross-sectional area and a relatively large radius of revolution, an axially elongated toroidal-shaped envelope coaxial with said resonator and intersecting the same, said envelope enclosing an annular electron gun, said resonator being provided with circular gaps to permit the passage of the electron beam through and beyond said resonator.

2. An annular-shaped electron gun for producing a tubular-shaped electron stream, an axially elongated toroidal-shaped envelope enclosing said electron gun, a compact toroidal-shaped

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resonator set into said envelope concentrically with the axis thereof, said resonator being provided with apertures for the passage therethrough of said electron stream and a collector electrode in said envelope beyond said resonator.

3. An annular-shaped electron gun for maintaining a tubular-shaped electron stream, an evacuated envelope enclosing the electron gun, and a toroidal-shaped hollow resonator set into said envelope concentrically with the axis thereof and divided into evacuated and non-evacuated portions by said envelope, said resonator being

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mounted in position intersecting the path of the electron stream and being provided with apertures for the passage therethrough of said electron stream, the radius of the path of the tubular-shaped electron stream being determined by the radius of the said annular-shaped electron gun, said radius of the electron gun being relatively large compared with the cross-sectional dimensions of the resonator.

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