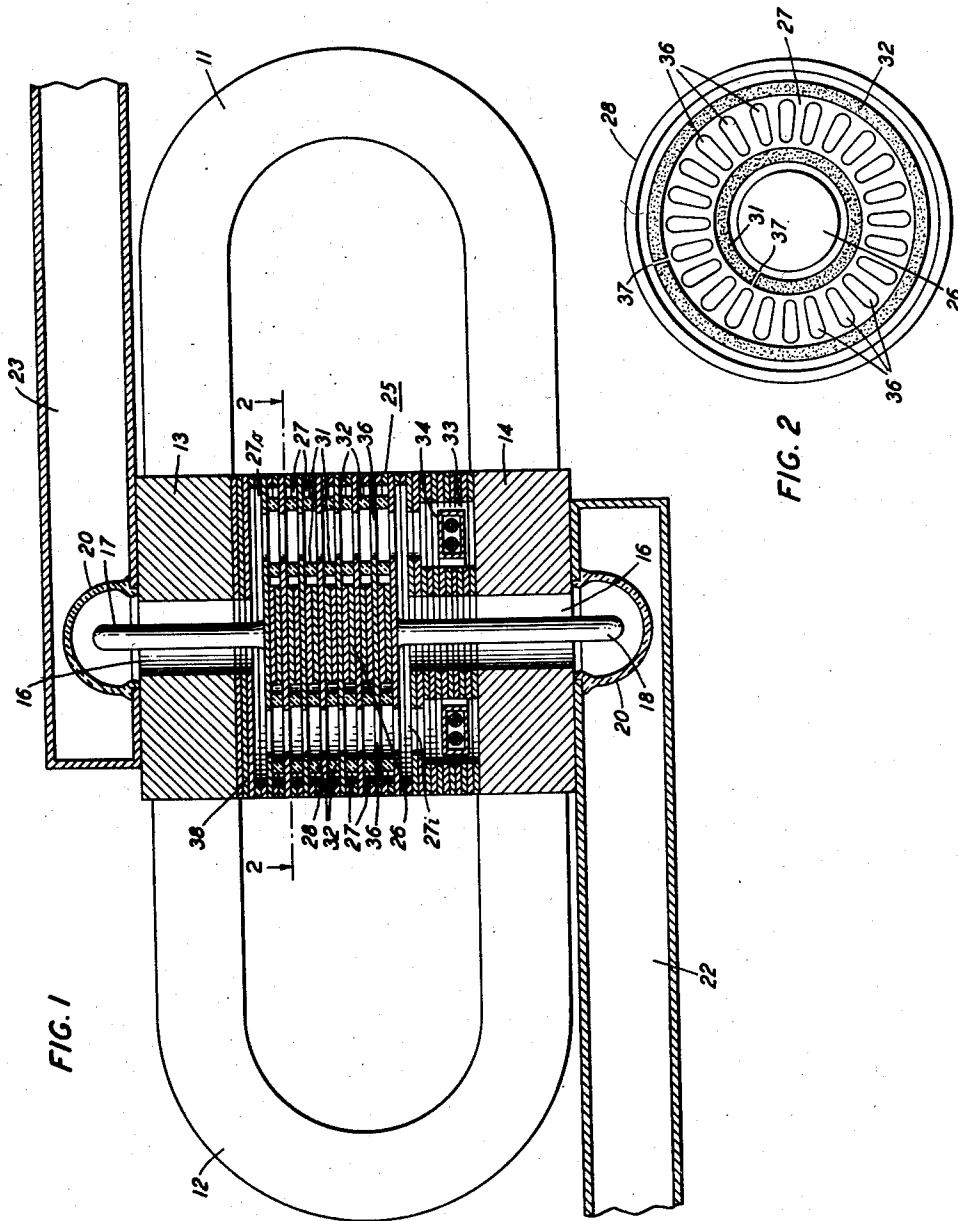


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ELECTRON DISCHARGE DEVICES
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ELECTRON DISCHARGE DEVICES

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This invention relates to electron discharge devices and more particularly to such devices having a plurality of resonant cavities through which an electron stream passes successively.

Such devices, which are of the klystron type, have priorly been limited in their employment as amplifiers due to narrow bandwidth characteristics. The bandwidth of useful amplification is dependent upon the impedance of the resonant cavities, the lower the impedance of the resonant cavities the broader the bandwidth of useful amplification. However, as is known in the art, it is also desirable that the ratio between the beam impedance and the impedance of the resonators should be a small number, in devices of these types, if high efficiency and high gain are to be attained. Reduction in the impedance of the resonant cavities to attain the desired broad bandwidth, has, therefore, priorly not been attainable except at a considerable sacrifice in gain and efficiency.

The beam impedance is defined as the ratio of the beam voltage to the beam current. Generally in present devices of the klystron type, electron beams of high impedance are employed and therefore the resonant cavities must also be of high impedance to attain high gain and high efficiency. A resonant cavity having a high impedance employs a sharply tuned resonant structure with a high resonant Q and therefore a narrow bandwidth.

The above relations may be summarized by the following equations:

$$\text{Beam Impedance} = \frac{\text{Beam Voltage}}{\text{Beam Current}} \quad (1)$$

$$\text{Cavity Impedance} = \frac{\text{Loaded } Q}{2\pi (\text{frequency}) (\text{capacitance})} \quad (2)$$

$$\text{Bandwidth of Cavity} = \frac{\text{Resonant frequency}}{\text{loaded } Q} \quad (3)$$

It is a general object of this invention to provide an improved electron discharge device of the klystron type.

More specifically objects of this invention include increasing the bandwidth of an amplifier employing resonant cavities and attaining a high gain and a high efficiency.

These and other objects of this invention are attained in one specific illustrative embodiment wherein a broad-band power amplifier is realized having a high gain and a high efficiency by employing resonant cavities in which the stored electric field energy is most advantageously utilized to modulate the electron stream at the input and to extract kinetic energy from the electrons at the output. In one specific illustrative embodiment of this invention, a plurality of resonant cavities through which the electron beam passes are perforated over a substantial portion of their surface area, permitting the use of a very high electron beam current and a lower electron beam voltage. As the beam current is considerably larger than that priorly employed in such devices, the beam impedance will be considerably lower, thus permitting the employment of lower impedance resonant cavities while nevertheless attaining a high amplifier gain and efficiency.

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In accordance with one aspect of this invention, a broader bandwidth of useful amplification is thus attained through the employment of lower impedance resonant cavities. Furthermore, in this specific illustrative embodiment of the invention, a large number of resonant cavities are positioned in a sandwich relationship, between the input and output cavities, and the use of this large number of intermediate resonant cavities of the same general low impedance type enables high gain to be attained by multiple interaction with the electron stream.

In the intermediate cavities the impedance is intentionally lowered by positioning therein power absorbing elements. These elements advantageously may be rings of an insulating material, such as ceramic, having a lossy coating thereon or lossy material distributed therethrough. By employing these lossy rings of power absorbent material, the desired low impedance, and hence broad band, characteristics of the intermediate resonant cavities are attained. The low impedance characteristics of the end cavities, i. e., the input and output cavities are attained through a coaxial line coupling to the external circuitry, which may advantageously comprise input and output wave guides.

It is therefore a feature of this invention that very high beam currents at low voltages are usable, permitting the use of low impedance, low Q, resonant cavities with a resultant broad bandwidth of useful amplification.

Further it is a feature of this invention that high gain and high efficiency be attainable with a broad bandwidth of amplification. In accordance with this feature of the invention, the relationship for which high gain and high efficiency is attainable, i. e.

$$\frac{(\text{Beam Impedance})}{(\text{Cavity Impedance})} =$$

$$\left(\frac{\text{Beam Voltage}}{\text{Beam Current}} \right) (2\pi) \left(\frac{\text{capacitance}}{\text{bandwidth}} \right) = (\text{a small number})$$

is satisfied and the ratio kept small through the employment of large beam currents even though a large bandwidth is attained. This relationship may readily be derived from the general relationships of Equations 1, 2 and 3.

It is a further feature of this invention that a plurality of resonant cavities be positioned between the input and output cavities to increase the gain of the discharge device and that each of these intermediate cavities be a low impedance cavity to attain the desired broad bandwidth of the device as an amplifier.

It is a still further feature of this invention that power absorbent elements be positioned in each of these intermediate resonant cavities to reduce the characteristic impedance thereof.

It is a still further feature of this invention that these cavities be juxtaposed with common intermediate wall members and that these wall members be perforated over a substantial portion of their area to allow passage through each of the cavities in succession of a large number of distinct electron beams, thereby attaining a very large beam current. More specifically, it is a feature of one particular embodiment of this invention that the common intermediate walls of the resonant cavities have beam slots aligned along the walls and extending therethrough.

It is a still further feature of this invention that the resonators be annular and positioned between a center post, connected to the center conductors of coaxial input and output lines, and an outer wall portion, connected to the outer conductors of the coaxial input and output lines.

A complete understanding of these and various other features of this invention may be gained from con-

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sideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a sectional view of an electron discharge device in accordance with one specific illustrative embodiment of this invention; and

Fig. 2 is a sectional view along the line 2—2 of the embodiment of Fig. 1.

Turning now to the drawing, the specific illustrative embodiment depicted comprises a pair of focussing magnets 11 and 12 having a pair of pole pieces 13 and 14 between their pole faces. Each of the pole pieces has a central aperture 16 therethrough and through which extends a center conductor 17 or 18. A window 20 is sealed to each of the pole pieces 13 and 14 encompassing the outer end of the conductor 17 or 18 and defines portions of the vacuum envelope of the device. Windows 20 are advantageously of a dielectric material pervious to the flow of electromagnetic energy, as is known in the art, and are located within an input wave guide 22 and an output wave guide 23. Center conductor 18 and pole piece 14 thus define an input coaxial line, conductor 18 being a probe extending into the input wave guide 22, and center conductor 17 and pole piece 13 similarly define an output coaxial line.

Positioned between the two pole pieces 13 and 14 and sealed thereto to form the remainder of the vacuum envelope of the device is a metallic body 25 comprising a plurality of laminations. These laminations define a center post 26, to which the center conductors 17 and 18 are secured, as by brazing. The laminations also define a number of thin annular cavities 27 extending from the center post 26 to a wall portion 28. Positioned within each of these cavities 27 except the first and last is a first ring member 31 adjacent the center post 26 and a second ring member 32 adjacent the wall portion 28, these ring members being of a lossy material and advantageously being of ceramic coated with carbon or other lossy material. These rings 31 and 32 are further described below.

The laminations comprising the metallic body 25 also define an annular groove or aperture 33 in which is located an annular cathode 34.

Turning now to Fig. 2, which is a cross-sectional view of the device of Fig. 1 along the line 2—2 thereof and at the inner face of one of the annular cavities 27, each of the laminations forming a wall of the thin annular cavities 27 has a plurality of beam slots 36 therein extending in a circle around the center post 26 and between the post 26 and the wall portion 28. The electrons emitted by the cathode 34 are formed into narrow beams by the slots 36 and are collected by the end portion 38 of the body 25 secured as by brazing to the output pole piece 13.

By employing a plurality of resonant cavities 27 between the input and output cavities 27i and 27o, respectively, the gain of the device is increased and, in accordance with one feature of this invention, by providing that each of these cavities have a low impedance the high gain is attained with a broad bandwidth of amplification. The velocity modulation imparted to the electron stream emitted by the annular cathode 34 by the signal applied at the first or input cavity 27i, from the input wave guide 22 and input coaxial line, causes an electron current modulation of signal frequency to appear after the stream has drifted for an appreciable distance. As in the type of multicavity klystron tubes, subsequent resonant cavities are excited by this current modulation, causing radio frequency voltages to appear there. These in turn cause further velocity modulation of the electron stream and further current modulation farther along the tube. By these cumulative effects, the gain is increased by the intermediate resonant cavities 27. In accordance with one aspect of this invention, a plurality of intermediate cavities 27 is employed, each of low impedance and broad bandwidth characteristics, so

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that their combined effects will add together to produce an amplifier of high gain and broad bandwidth.

The electron streams are focussed, in the specific embodiment of the invention depicted in the drawing, by the focussing magnets 11 and 12. The electrons emanating from the cathode 34 are separated into distinct streams by the beam slots 36 in the plates or laminations that comprise the common side walls of the resonant cavities 27. By employing a large number of such distinct streams each traversing each of the intermediate resonant cavities 27, efficient utilization is made of the energy stored in the resonant cavities and a very high beam current is attained. The electrons after passing through the output resonant cavity 27o impinge on end portion 38 of the metallic body 25.

The impedance of each of the intermediate resonant cavities 27 is low due to the inclusion in each of these cavities of power absorbent elements comprising, in the specific embodiment depicted, the rings 31 and 32. Advantageously, these rings are positioned in the portions of the resonant cavities 27 between the center post 26 and the inner edge of beam slots 36 and the outer edge of beam slots 36 and the outer wall portion 28. The rings may be slit, as at 37, to be held against the center post 26 and outer wall portion 28 or may be held in position merely by the laminations defining the cavities 27.

An appreciation of the operating characteristics of devices in accordance with this invention may be attained from one specific structure in accordance with the specific embodiment of this invention depicted in the drawing and described above that advantageously may have a gain of over 30 db over a bandwidth of about 450 megacycles at about 9000 megacycles. Such a device could therefore advantageously be employed as a power amplifier.

While a specific embodiment of this invention has been described, it is to be understood that it is only illustrative of the application of the principles of the invention and that numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An electron discharge device comprising means defining an input resonant cavity, means defining an output resonant cavity, means defining a plurality of low Q juxtaposed annular resonant cavities between said input and output resonant cavities, said last-mentioned means including annular wall members common to adjacent cavities, each of said wall members having a plurality of beam slots radially and symmetrically disposed with respect to the axis of said wall members, the slots in successive wall members being aligned, means for projecting an electron beam of high current through the aligned slots of each of said cavities in succession from said input resonant cavity to said output resonant cavity for obtaining high gain and efficiency by multiple interaction, means for focusing said electron beam, signal input and output means coupled to said input and output resonant cavities, and resistive signal power absorbent elements positioned within said plurality of resonant cavities between said input and output cavities for reducing the characteristic impedance and increasing the effective bandwidth thereof, said absorbent elements being annular and positioned coaxially around the inner and outer edges of said radially disposed slots in each of said plurality of resonant cavities.

2. An electron discharge device comprising means defining an input resonant cavity, an output resonant cavity, and a plurality of juxtaposed annular resonant cavities positioned between said input and output resonant cavities, said means including wall members common to adjacent cavities and a center post encompassed by said cavities, each of said wall members having a plurality of beam slots therein and said beam slots in successive wall members being aligned, means for projecting electron

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beams through said aligned slots, said projecting means including an annular cathode and means for focusing said beam, signal input and output means coupled to said input and output resonant cavities, and annular signal power absorbent elements positioned within said plurality of resonant cavities for reducing the characteristic impedance thereof.

3. An electron discharge device comprising an input coaxial line, an output coaxial line, means for generating a focussing magnetic field between said lines, and means for amplifying electromagnetic energy between said lines, said last-mentioned means comprising means defining a plurality of flat thin annular resonant cavities, means for projecting a plurality of electron beams through each of said cavities in succession, said electron beams traversing a major part of the cross-sectional area of each of said resonant cavities, and electromagnetic energy power absorbent means positioned within said resonant cavities for lowering the impedance thereof whereby high gain is attainable by said amplifying means over a broad bandwidth.

4. An electron discharge device comprising a center post member, means including said center post member defining a plurality of juxtaposed annular resonant cavities encompassing said center post member, means including an annular cathode for projecting a plurality of streams of electrons through each of said juxtaposed annular resonant cavities in succession, signal input and output means coupled to the first and last of said resonant cavities, the coupling means comprising coaxial line means including an inner conductor connected to said center post member, and power absorbent means positioned in said resonant cavities.

5. An electron discharge device comprising a center post member, an outer wall portion around said center post member, means including said center post member and said outer wall portion defining a plurality of juxtaposed annular resonant cavities, means including an annular cathode for projecting a plurality of streams of electrons through each of said juxtaposed annular resonant cavities in succession, signal input and output means coupled to the first and last of said resonant cavities, the coupling means comprising coaxial line means including an inner conductor connected to said center post member and outer conductor means connected to said outer wall portion, and annular signal power absorbent means positioned in said resonant cavities.

6. An electron discharge device comprising a center post member, an outer wall portion around said center

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post member, means defining a plurality of juxtaposed annular resonant cavities, said means including said center post member, said outer wall portion, and wall plates common to adjacent ones of said juxtaposed annular resonant cavities, said wall plates each having a plurality of slots therein and said slots being aligned, means for projecting an electron beam through said aligned slots, said beam projecting means including an annular cathode and means for focussing said beams, signal input and output means coupled to the first and last of said resonant cavities, the coupling means comprising coaxial line means including an inner conductor connected to said center post and an outer conductor connected to said outer wall portion, and annular signal power absorbent elements positioned in each of said resonant cavities but the first and last thereof.

7. An electron discharge device comprising a pair of pole pieces, each of said pole pieces having an aperture therein, a center post member between said pole pieces, an outer wall member encompassing said center post member and secured to said pole pieces, means defining a plurality of juxtaposed annular resonant cavities, said means including said center post member, said outer wall member, and wall plates common to adjacent ones of said juxtaposed resonant cavities, said wall plates each having a plurality of slots therein and said slots in said wall plates being aligned, means for projecting an electron beam through said aligned slots, said beam projecting means including an annular cathode and magnetic means cooperating with said pole pieces for focussing said electron beams, signal input and output means coupled to the first and last of said resonant cavities, the coupling means comprising coaxial line means including an inner conductor connected to said center post and said pole pieces, said inner conductors extending through said apertures in said pole pieces, and annular signal power absorbent elements positioned in each of said resonant cavities but said first and last resonant cavities.

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