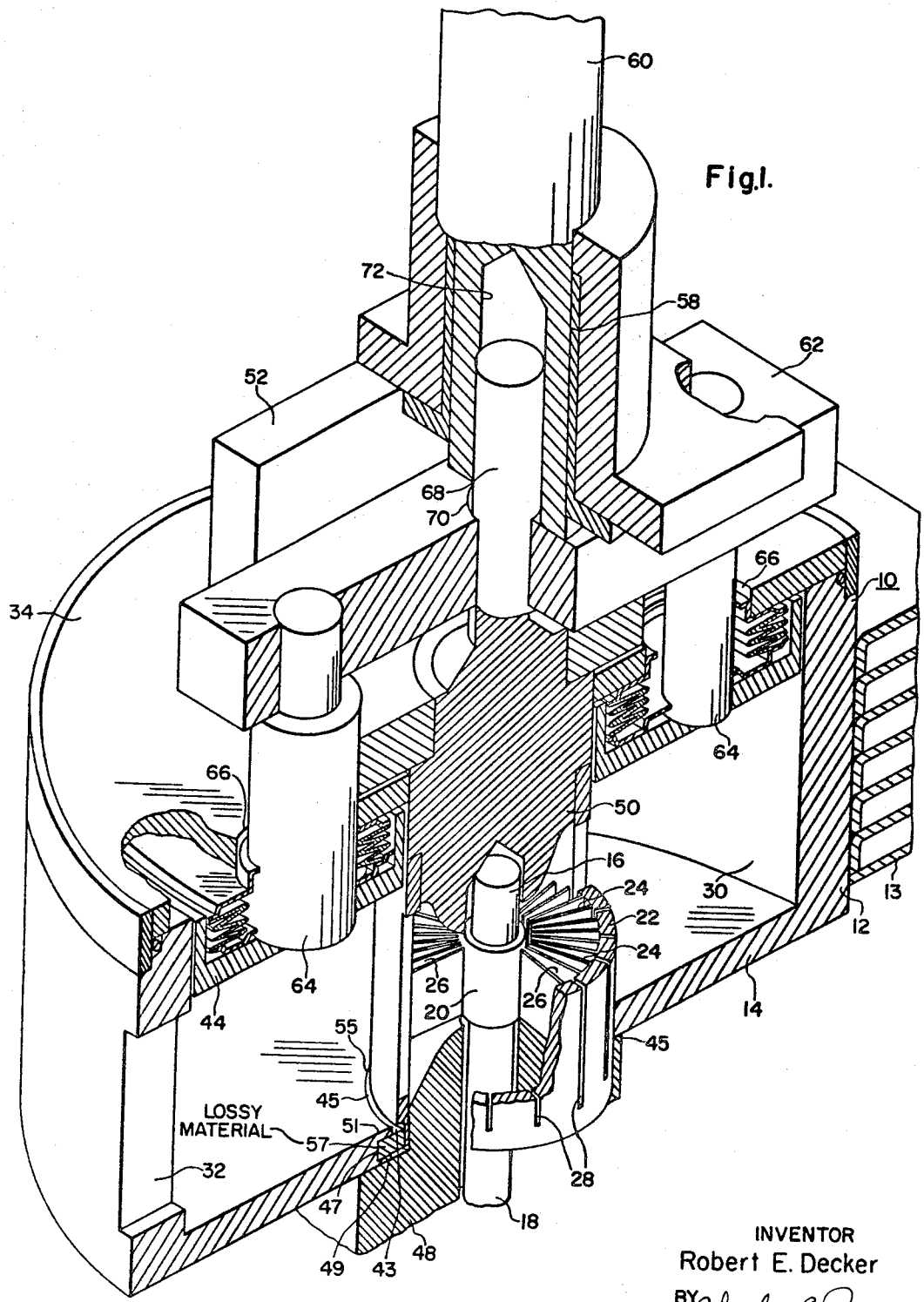
July 30, 1968 R. E. DECKER 3,395,314

COAXIAL MAGNETRON HAVING ATTENUATOR MEANS FOR SUPPRESSING UNDESIRED MODES

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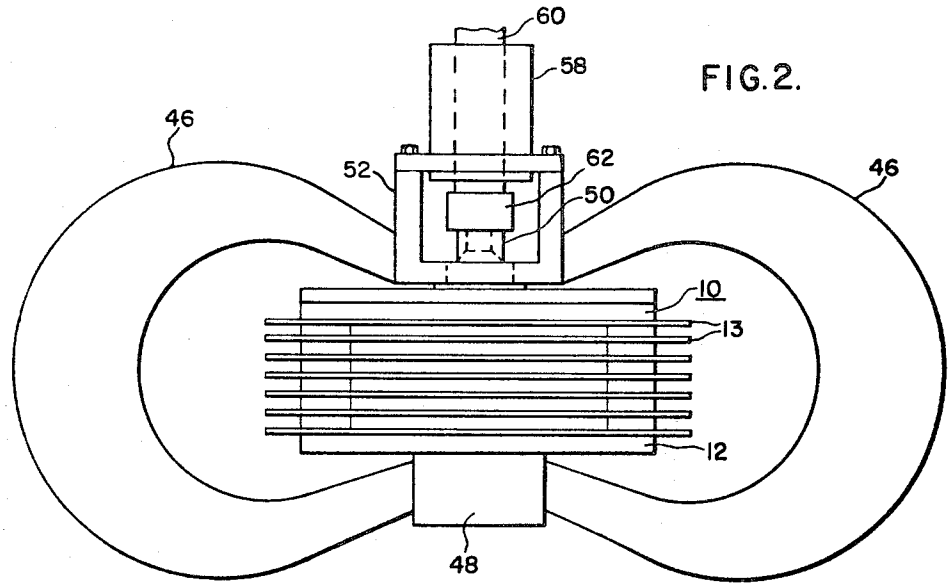
Fig.1.



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FIG. 2.



United States Patent Office 3,395,314 Patented July 30, 1968

3,395,314

COAXIAL MAGNETRON HAVING ATTENUATOR MEANS FOR SUPPRESSING UNDESIRED MODES

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Filed Nov. 24, 1964, Ser. No. 413,586
3 Claims. (Cl. 315—39.75)

ABSTRACT OF THE DISCLOSURE

The invention relates to a coaxial magnetron having an inner resonator system and an outer cavity resonator which is adapted for maximum energy storage of the TE_{011} mode. The suppression of undesired modes in the outer cavity resonator is provided by an energy absorbing member within a groove provided in the lower surface of the end plate and situated within an annular cavity defined between a groove on the inner peripheral surface of the end wall and an undercut portion of the anode wall.

This invention relates to electron discharge devices of the magnetron type and more particularly to coaxial magnetron type.

In the R. J. Collier and J. Feinstein U.S. Patent 2,854,603 issued Sept. 30, 1958, there is described a coaxial magnetron structure which comprises an inner and outer resonant system. The inner resonant system includes a cylindrical anode wall together with a plurality of anode vanes radially extending inwardly therefrom. These vanes define a circumferential array of inner, or anode cavity resonators. An outer cavity resonator is defined between an outer wall and the cylindrical anode wall and forms the outer resonant system. The two systems, namely the inner resonant system and the outer cavity resonator, are coupled by a circumferential array of slots provided in the cylindrical anode wall which connects the outer resonant system with the inner resonator system. The inner resonant system is normally designed to oscillate in the pi-mode, while the outer system is dimensioned for maximum energy storage of the TE_{011} mode. The two systems are effectively locked together by the coupling slots provided between the inner resonant system and the outer cavity resonator.

The TE_{011} mode in cylindrical and coaxial cavities is often called the circular electric mode since the electric field exists only in a circular pattern and there is no radial or axial directed electric field. There are other modes that can exist in the right circular coaxial cavity as well as the TE_{011} such as TE_{121}, TE_{211} and TE_{221}. In addition TM modes also can exist within the cavity. These modes may be separated into competing and interfering modes. The TE modes are the most important since they couple into the vane structure of the inner resonant system. The TE_{011} mode coaxial cavity generates a pi-mode. In a like manner the TE_{121} mode generates a pi-1 mode field. As previously indicated, the current in the outer cavity in the TE_{011} mode is everywhere circumferentially and tends to be stronger at the central regions of the cylindrical anode, the outer cylinder and the end covers therefor. The currents at the corners of the cavity are very small, and circumferential. In the TE_{121} mode, which is the most potential competing mode, currents move axially and radially and there are strong currents moving across the junctions of the cylindrical anode cylinder and the end covers. If one of these junctions is broken, it is possible to match a damping resistor or attenuator to the undesired TE_{121} mode with virtually no damping on the desired TE_{011} mode. The net effect is to greatly lower the TE_{121} mode Q to the point where it will not sustain oscillations.

Thus, in the previously mentioned Collier and Feinstein patent a quarter wave circular choke was provided within an end cover adjacent to and coaxial with the cylindrical anode wall. The interior of the choke was lined with soft iron to provide magnetic losses.

Another problem associated with the coaxial magnetron is providing proper cooling of the tube. The vane tips which are subject to electron bombardment are the members primarily heated. The heat must flow through the vanes, the anode cylinder, the end covers and finally to the heat radiator which is positioned on the outer wall of the cavity resonator. It is therefore important that a continuous thermal path of good thermal conductive material be provided from the vane tips to the heat radiator. This heat problem must be considered in determining the proper suppression means used within the magnetron. The heat flow path normally is provided particularly in a tunable type cavity through the bottom of the anode structure. The top of the anode should be undisturbed to provide a top locating surface.

It is accordingly an object of this invention to provide an improved electron discharge device.

It is another object to provide an improved coaxial magnetron structure.

It is another object to provide an improved mode attenuator for competing modes in a coaxial magnetron.

It is another object to provide an improved mode suppressor for the TE_{121} mode within the cavity of a coaxial magnetron.

Briefly, the present invention provides a coaxial magnetron having an inner resonator system and an outer cavity resonator which is adapted for maximum energy storage of the TE_{011} mode. This suppresssion is accomplished by provision of an energy absorbing member within a groove that is below the surface of the end cover and extends below the surface of the cylindrical anode.

Further objects and advantages of the invention will become apparent as the following description proceeds, and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of the specification.

For a better understanding of the invention, reference may be had to the accompanying drawings, in which:

FIGURE 1 is a perspective view, partially in section and partially broken away of a coaxial magnetron illustrating one specific embodiment of the invention; and

FIG. 2 is a side view in elevation of the device in FIG. 1 to which appropriate magnets have been added.

Referring now to the drawings, there is shown a tunable coaxial magnetron. The coaxial magnetron is comprised of a body member **10** which is substantially cup-shaped and includes a cylindrical side wall or outer wall **12** and a bottom end plate or cover **14**. The mamber **10** is of a suitable electrically and thermally conductive material such as copper. Heat radiating fins **13** are provided on the outer surface of the outer wall **12**.

Centrally disposed with the body **10** is a cathode **16** which includes a sleeve member **18** of a suitable material such as molybdenum. The sleeve member **18** is provided with an electron emissive coating **20** on the outer surface. Suitable heating means (not shown) is provided with the cathode sleeve **18**.

A cylindrical anode **22** of a suitable electrically and thermally conductive material such as copper surrounds the cathode **16**. A plurality of radially extending vanes **24**, also of suitable conductive material, are provided on the inner surface of the anode cylinder **22**. The vanes **24** extend axially along a small portion of the length of the anode cylinder **22**. The vanes **24** define an array of inner cavity resonators **26**. Slots **28** extends along the anode cylinder **22** for a greater length than the vanes **24** and

are substantially parallel to the vanes **24**. The slots **28** are located in alternate anode resonators **26** and provide communication between the inner cavity resonators **26** to an external or outer cavity resonator **30**.

The cylindrical wall portion **12** of the body **10**, the cylindrical anode **22**, the bottom end plate **14** and an annular tuning member **44** define the cavity resonator **30**. Extending through the wall **12** to communicate with the outer cavity resonator **30** is an output coupling opening **32**. The opening **32** serves as means through which energy may be removed from the outer cavity resonator **30** and has been shown in its simplest form.

Positioned atop the cup-shaped body member **10** is a substantially disk shaped cover means **34**. The cover **34** is of a suitable non-magnetic material such as stainless steel and is vacuum sealed at its periphery to the cylindrical wall portion **12**. The inner periphery of disk shaped end cover **34** is sealed to a pole piece **50**.

Tuning is provided in the coaxial magnetron shown by axially moving the annular member **44** within the outer cavity resonator **30**. In the specific embodiment shown, this conductive member **44** is an annular member of a suitable electrically conductive material such as copper. The member **44** defines one boundary surface of the cavity resonator **30**. The tuning member **44** is substantially U-shaped in cross sectional area. The tuning member **44** is actuated by means of two rod members **64** which extend through suitable apertures **66** within the end cover **34**. The rods **64** have one end fixed to the annular member **44** and the other end fixed to a cross bar member **62**. The upper pole piece **50** is provided with an extended portion **68** which extends through an aperture **70** centrally located within the cross bar member **62** and into a centrally extending bore **72** within an actuating rod **60**. The rod **60** is attached to the cross bar member **62** and is slidably mounted in a sleeve member **58** surrounding the rod **60**. The sleeve member **58** is secured to a magnetic spacer member **52**. The rod **60** may move within the sleeve **58** and provide movement of the annular member **44** to adjust dimensions of the cavity resonator **30**. In this manner, tuning of the magnetron is accomplished.

The magnetic circuit in the present device shown in FIG. 2 is inclusive of two substantially identical horseshoe magnets **46**, a bottom pole piece **48** and the upper pole piece **50**. Also included in the magnetic circuit is the magnetic spacer **52** which is substantially a U-shaped member in which serves to connect the upper poles of the magnets **46** to the upper pole piece **50**. The magnetic spacer **52** also serves as a support means for the tuning drive mechanism. Pole pieces **48** and **50** and spacer **52** may be of a suitable magnetic material such as soft iron.

The outer cavity resonator **30** is capable of sustaining a number of different modes of operation. In this particular application, the cavity resonator **30** is dismensioned to provide maximum storage of the TE_{011} mode at the operating frequency. The electric currents flow circumferentially on the outer surface of the anode wall **22** and along the inner surface of the outer wall **12** of cavity resonator **30**. The inner resonant system defined by the resonators **26** will tend to oscillate in both the pi and various degenerate modes. Thus, the outer cavity resonator **30** and the inner anode resonators **26** can be considered as two distinct resonant systems; however, when the two systems are placed together they can be considered to be a single composite system. Current produced by the outer cavity resonator mode flows along the anode wall **22** in a direction perpendicular to the slots **28**. The anode vanes **24** are approximately a quarter wave length in radial length at the operating frequency such that the high impedance termination at the free end of the anode vanes **26** is reflected back to the slots **28** as a low impedance and accordingly the electric current flows into the resonator **26** and down the adjacent vane **24**. These high voltages appear across alternate anode vanes **24** at a given time because only alternate inner cavity resonators **26** are coupled by the slots **28** to the outer cavity resonator **30**. Voltages at other alternate anode vanes are provided by mutual inductance resulting in such voltage being 180° out of phase with the adjacent vanes. This is the proper condition for maintenance of the pi-mode oscillation with the inner resonant system. The electron beam of the inner resonant system due to the crossed electric and magnetic fields induces voltages in the tips of the vanes **24**. These voltages in turn produce currents which flow out through the slots **28** into the outer cavity resonator **30**. The resonators **26** are normally constructed so as to support a frequency outside the frequency range of the outer cavity resonator **30** such that the natural resonant frequency of the inner structure has little effect on the tuning of the outer cavity or of the frequency of oscillation of the outer cavity.

The outer cavity resonator **30** is capable of sustaining a number of different modes of operation. In accordance with this invention, however, it is dimensioned as well known in the art, for maximum storage of the TE_{011} mode. In this type of mode, the magnetic field lines are radially along the upper and lower plates of the cavity resonator **30** and the electric field lines are entirely circumferential. Electric currents induced within the external cavity resonator **30** flow circumferentially along the outer surface of the anode wall **22** along the inner surface of the outer wall **12** the inner surface of the tuning element **44** and the end plate **14**. Currents induced by other modes such as the TE_{121} will have an axial component which may be damped by this invention. This is shown in FIG. 1. The anode cylinder **22** is reduced in its outer diameter at the lower end portion to provide an annular groove **43** at a point just below the slots **28**. The thickness of the anode wall **22** at the groove **43** is about one-half the thickness of the remaining portion of the anode wall **22** which has a thickness of about .060 inch. The lower annular end plate **14** is to provide an aperture **45** for receiving the lower pole piece **48**. The surface of the aperture **45** is provided with an annular groove **47**. The groove **47** has a lower lip **49** and an upper lip **51**. The diameter of the lip **49** is substantially the same as the inner diameter of the anode **22**. The lower edge of the anode **22** is brazed to the upper surface of the lip **49**. The upper lip **51** has a diameter greater than the outside diameter of the anode **22**, and defines an annular gap **55**.

The upper surface of the lip **51** is in the same plane as the remaining inner surface of the end cover **14** and is above the groove **43** in the anode wall **22**. The annular groove **43** opposed the annular groove **47** and defines a region or cavity within the junction of the anode **22** and the end cover **14** wherein an annular ring **57** suitable lossy material such as carbon impregnated alumina, silicon carbide, or resistive film coated ceramic may be positioned. It is found that by making the thickness of the lip oprtion **51** of a thickness of about .010 inch and the annular gap **55** between the lip **51** and the outer diameter of the larger portion of the anode **22** of about .010 inch the resulting TE_{121} mode unloaded Q is very low with little effect on the unloaded pi-mode Q. The heat flow path from the vanes **24**, through anode cylinder **22** is still provided by means of the restricted portion of the anode **22** at the groove **43** and through the end plate **14** to the outer cylindrical wall **12**.

The radial currents of the TE_{121} anode cannot jump the gap **55** and are attenuated as I^2R losses as they pass around the walls of the grooves **43** and **47** holding the attenuator ring **57**. The cutback in the diameter of the anode **22** and the long thin lip **51** increases the discontinuity of the current path. This utilizes nearly the entire surface of the attenuator ring **57** which fits into the copper cavity formed by grooves **43** and **47**. Even though there is little pi-mode current in area, narrowing the gap **55** increases the pi-mode unloaded Q by making the cavity appear more perfect at the anode cavity junction.

The long narrow lip **51** or the cutback anode alone will aid in attenuating the TE_{121} mode but the combination thereof achieves the most desirable result.

While there have been shown and described what are presently considered to be the preferred embodiment of the invention, modifications thereto will readily occur to those skilled in the art. It is not desired, therefore, that the invention be limited to the specific arrangement shown and described and is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A coaxial magnetron comprising a cylindrical anode wall member, a plurality of vanes extending inwardly from said anode wall member and defining a plurality of anode cavity resonators within said anode wall, a cathode positioned centrally of said anode wall member, the outer surface of said anode wall member defining one wall of an annular output cavity resonator, said output cavity resonator coupled through openings in said anode wall to said anode cavity resonators, said outer cavity resonator including a lower annular end wall member having a portion of its inner periphery secured to the lower end of said anode wall member, said anode wall member having a reduced outer diameter portion about one half the thickness of the remaining portion of said anode wall member and below the upper surface of said end wall member, the upper surface of said end wall member provided with a first annular opening therein to an annular chamber, said annular chamber defined by said reduced diameter portion and a groove provided in the inner periphery surface of said annular end wall, the wall between said chamber and said output cavity resonator within said end wall having a thickness of about .010 inch and an attenuator means positioned within said chamber.

2. A magnetron comprising a cylindrical wall member, a plurality of vanes extending inwardly from said wall member and defining inner cavity resonators, a cathode positioned centrally of said wall member, means including said wall member defining an outer cavity resonator encompassing said inner cavity resonators, means for coupling said inner cavity resonators to said outer

cavity resonator, said outer cavity resonator including a lower end plate member secured to the lower end of said wall member, said wall member having a reduced outer diameter portion to provide a wall thickness of about one half the thickness of the remaining portion of said wall member, at the lower end thereof, said reduced outer portion below the plane of the inner surface of said lower end plate and an attenuator ring positioned about the reduced diameter portion of said wall member and below the plane of the inner surface of said lower end plate member.

3. A magnetron comprising a cylindrical anode member, a plurality of vanes extending inwardly from said anode member and defining anode cavity resonators, a cathode positioned centrally of said anode member, means including said anode defining an outer cavity resonator encompassing said anode cavity resonators, means for coupling said anode cavity resonators to said outer cavity resonator, said outer cavity resonator including a lower end plate member electrically and thermally connected to the lower end of said anode member and forming a junction therewith, said anode having a reduced outer diameter surface below the upper surface of said lower end plate member, an annular slot provided in the upper surface said end plate member, said annular slot having a diameter greater than said outer surface of said anode wall member, said annular slot communicating with an annular cavity within the junction of said anode wall and said end plate member beneath the upper surface of said end plate member, the walls of said chamber defined by the reduced diameter surface portion of said anode wall and a groove in the surface of said end plate member facing said reduced outer diameter portion of said anode member and an attenuator ring positioned within said annular cavity.

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