

May 1, 1962

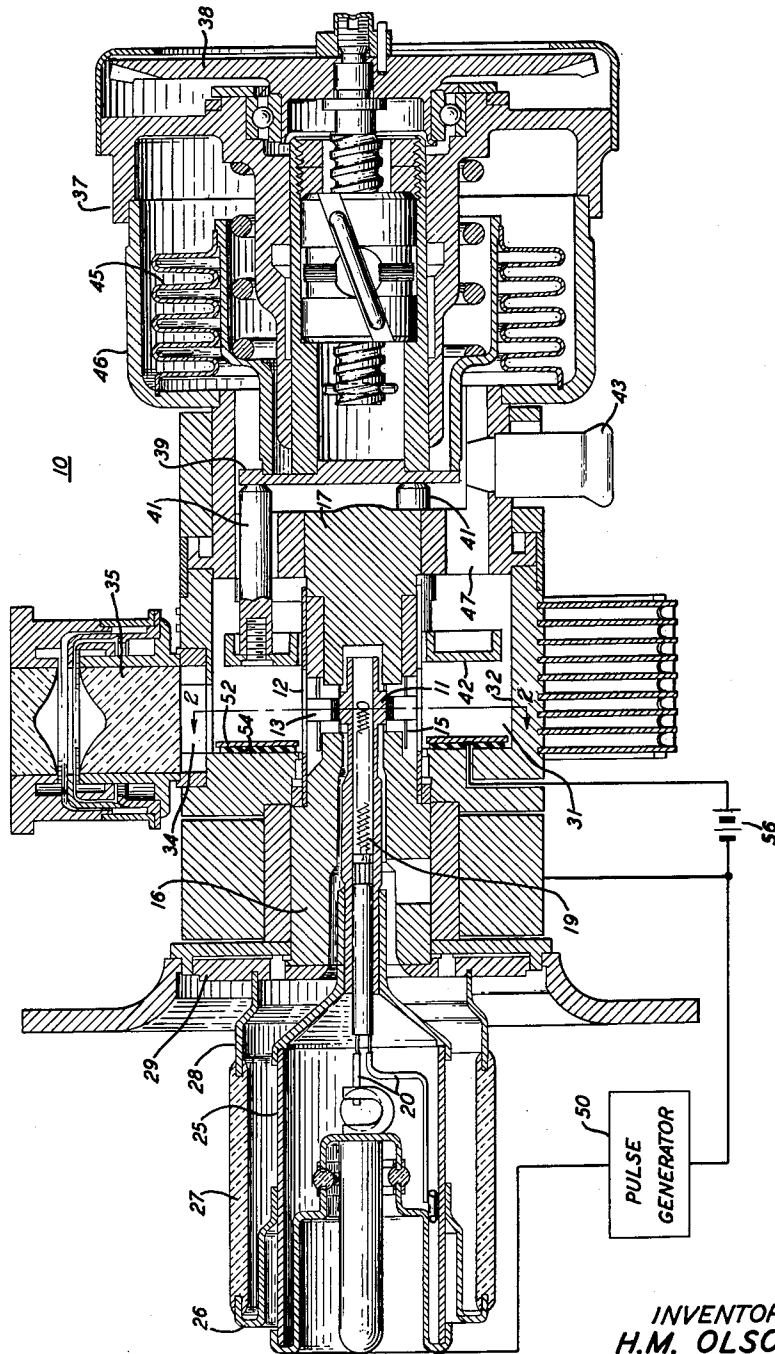
H. M. OLSON, JR
COAXIAL CAVITY MAGNETRON

3,032,680

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2 Sheets-Sheet 1

FIG. 1



INVENTOR
H. M. OLSON, JR.
BY *David P. Kelley*
ATTORNEY

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FIG. 2

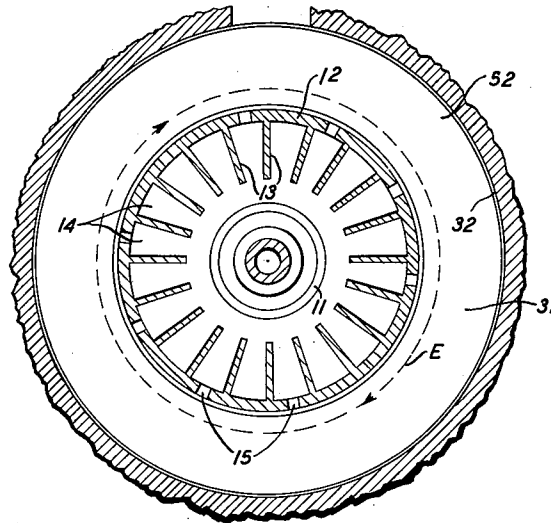


FIG. 3

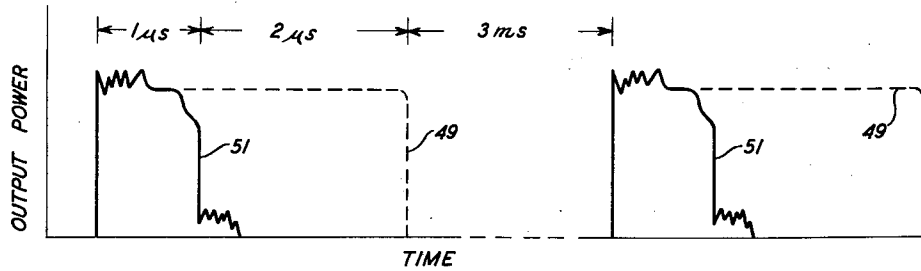
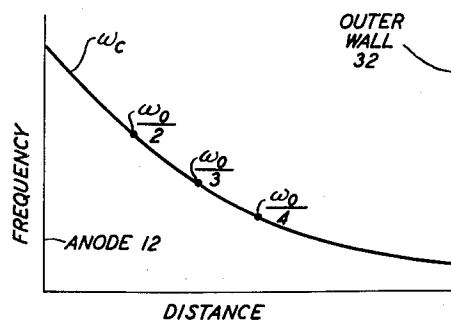


FIG. 4



INVENTOR
H.M. OLSON, JR.
BY
David P. Kelley
ATTORNEY

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3,032,680

COAXIAL CAVITY MAGNETRON

Hilding M. Olson, Jr., Mohnston, Pa., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

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5 Claims. (Cl. 315—39.61)

This invention relates to magnetrons and, more particularly, to coaxial cavity magnetrons.

The conventional magnetron is an electron discharge device for producing R.-F. oscillations in the microwave region. It comprises a cylindrical cathode surrounded by a circular array of anode resonators defined within an anode. A magnetic field is produced along the axis of the device, which, together with an electric field produced between the cathode and anode, causes emitted electrons to follow a circular path between the cathode and the anode. Energy from the beam of electrons is coupled to the anode resonators where it oscillates at a characteristic frequency and thereafter is transferred to a load.

One of the most serious drawbacks of the conventional magnetron has been its necessarily inadequate compromise between efficiency and stability. The efficiency can be enhanced by coupling the anode resonant system heavily to the load. Such heavy loading, however, increases the sensitivity of the magnetron to load changes and therefore results in instability.

A solution to the efficiency and stability problem is offered by the coaxial cavity magnetron. In this device, the anode resonant system is coupled to an outer annular resonator which surrounds the cylindrical anode, rather than being coupled directly to the output. The outer resonator supports a TE_{011} mode of oscillation and is coupled with alternate anode resonators by axially extending slots. This construction provides proper conditions for the formation of a desired " π " mode of oscillation in the anode resonant system. With the anode resonators isolated from the load and also effectively locked in a desired π mode, high efficiency can be attained without producing instability.

The coaxial cavity magnetron has been used primarily as a pulsed magnetron rather than a continuous wave generator. In this type of operation the electrons are emitted as a series of pulses, rather than being continuously emitted. The envelope of the R.-F. output oscillations is thereby intended to take the form of a series of approximately square pulses. Experiment has shown, however, that the duration of each output pulse is sometimes considerably lower than intended. Each output pulse is initiated properly, but it either cuts off or tapers off before the pulse of electrons is terminated. Output pulses of certain magnetrons that were intended to have a duration of 3 microseconds have been found to have an actual duration of only one microsecond. This undesirable phenomenon, termed "trailing edge collapse," is even more disastrous in continuous wave operation because the output oscillations may cease altogether.

It is an object of this invention to permit the output oscillations of a coaxial cavity magnetron to be sustained over any desired period of time.

More specifically, it is an object of this invention to eliminate trailing edge collapse in a coaxial cavity magnetron.

These and other objects of my invention are attained in a coaxial cavity magnetron of the type described above. Generally, the outer resonator of such a device is defined by the cylindrical anode, a cylindrical wall surrounding the anode and coaxial therewith, an annular tuning plunger, and an annular wall opposite the tuning plunger. The frequency of output oscillations can be adjusted by moving

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the tuning plunger which is between the cylindrical anode and the outer cylindrical wall.

Through my investigation of the coaxial cavity magnetron, I have determined that trailing edge collapse results from a glow discharge that takes place within the outer resonator. This discharge is produced by the collision of stray electrons with gas molecules in the outer cavity. The glow discharge is formed after the R.-F. oscillations are initially excited and it subsequently acts as a load on the anode resonators, thereby dissipating a large quantity of R.-F. power. This accounts for the accurate initial formation of the output pulse and the trailing edge collapse that occurs thereafter.

It is a feature of this invention that a positively biased conductive plate be inserted in the outer resonator. This plate collects negatively charged electrons and repels positively charged ions, thereby breaking up the chain-reaction ionization process that would otherwise produce a glow discharge.

It is another feature of this invention that the conductive plate be mounted on the annular wall opposite the tuning plunger and be insulated therefrom. By this arrangement, the conductive plate will not interfere with the TE_{011} mode of oscillation of the outer cavity.

These and other objects and features of the present invention will be better appreciated from a consideration of the following detailed description, taken in conjunction with the accompanying drawing in which:

FIG. 1 is a sectional view of a coaxial cavity magnetron illustrating an embodiment of this invention;

FIG. 2 is a view taken along lines 2—2 of FIG. 1;

FIG. 3 is a graph of output power vs. time in the device of FIG. 1; and

FIG. 4 is a graph of the cyclotron frequency vs. distance of a free electron in the outer resonator of the device of FIG. 1.

Referring now to the drawing, the specific illustrative embodiment of my invention shown in FIG. 1 comprises a magnetron 10 having a cylindrical cathode 11 surrounded by a cylindrical anode 12. Extending inwardly from anode 12 are a plurality of anode vanes 13 which define therebetween a plurality of anode resonators 14 as is best seen in FIG. 2. A plurality of slots 15 extend through the anode 12 along a major portion of its length and parallel to its axis. As seen in FIG. 2, slots 15 communicate with alternate anode resonators 14.

Positioned at one end of anode 12 is a magnetic pole piece 16 through which extends the cathode 11. Positioned at the other end of the anode is a second magnetic pole piece 17 having a magnetic polarity opposite that of pole piece 16. A heater element 19 extends within cathode 16 and is connected to a pair of leads 20. Cathode 11 is mounted by a supporting cylinder 25 secured to a metallic cylindrical section 26 which, in turn, is supported by a vitreous cylindrical insulating section 27, a metallic cylinder section 28 and a pole piece member 29.

Encompassing anode 12 is an outer cavity resonator 31 which is defined between the anode and an outer cylindrical wall 32. The outer resonator 31 is connected through a basically H-shaped transformer section 34 to a glass filled output waveguide section 35, through which the output energy of the magnetron is transmitted to external circuitry.

Positioned adjacent magnetic pole piece 17 is a tuning mechanism 37. Mounted thereon is a tuning disc 38 which controls the axial movement of yoke 39. Extending through pole piece 17 are three tuning shafts 41 (only two of which are shown), which are connected to yoke 39 and are movable therewith. The shafts 41 extend into the outer resonator 31 and support a tuning plunger 42 for motion within resonator 31 to tune the magnetron.

An exhaust tubulation 43 extends into the region of pole piece 17 for exhausting the device in a manner known in the art. Sylphon bellows 45 are attached to a wall 46 and cooperate with exhaust holes 47 to maintain a near vacuum within the magnetron.

The cathode 11 is periodically biased at a negative potential with respect to the rest of the device by means of a pulse generator 50. Electrons are then emitted from the cathode and are constrained to flow in a circular path between the cathode and anode 12 by the crossed-field focusing action of the electric field between the cathode and anode 12, and the magnetic field between pole pieces 16 and 17. The beam then excites electric fields in anode resonators 14. These fields oscillate in the π mode at a characteristic frequency determined by the anode resonators. This energy is then coupled to outer resonator 31 by coupling slots 15. The electric fields produced in resonator 31 oscillate in the TE_{011} mode at a frequency determined by the position of tuning plunger 42. The TE_{011} mode is characterized by R.-F. electric fields that flow circumferentially around anode 12, as shown by the electric field path E of FIG. 2.

The duration of the output oscillations released through waveguide 35 are limited by the duration of the input pulses to the cathode from pulse generator 50. FIG. 3 shows a graph of output power versus time as displayed on an oscilloscope connected to the output waveguide 35. If the input pulses to the cathode each have a duration of three microseconds, the envelope of the output R.-F. oscillations should also have a duration of three microseconds, as shown by dotted curve 49 of FIG. 3. Oscilloscope observation shows, however, that the actual duration of the output pulse may be as little as one microsecond, as shown by the solid curve 51. For illustrative purposes, the duration between successive pulses is shown as being three milliseconds. By experiment, I have verified that trailing edge collapse of the output pulses is caused by the ionization of gas molecules in outer resonator 31, which produces a glow discharge. This glow discharge constitutes a heavy load on the energy within anode resonators 14 and thereby dissipates a large quantity of R.-F. power.

Experiment has also shown that a glow discharge may be formed within resonator 31 even if the device has been evacuated until the gas pressure therein is less than 10^{-6} millimeters of mercury. Ordinarily one would not expect such a low gas pressure to support the chain-reaction ionization necessary for a glow discharge. A brief discussion of the initiation of the glow discharge will therefore be presented.

Two conditions cooperate to initiate the glow discharge: some electrons emitted by cathode 11 inevitably filter through slots 15 into outer resonator 31; in the absence of elaborate shielding, magnetic fringing fields from pole pieces 16 and 17 will extend into resonator 31. These fringing fields are at right angles with R.-F. electric fields produced in resonator 31. Whenever an electron is in a magnetic field, a force transverse to the magnetic field will make the electron rotate at an angular frequency given by:

$$\omega_c = B\eta \quad (1)$$

where ω_c is referred to as the cyclotron frequency, B is the magnetic field and η is the charge-to-mass ratio of the electron. If the frequency of the transverse forces exerted on the free electrons by the R.-F. field is a harmonic of the cyclotron frequency, a condition called cyclotron resonance occurs whereby kinetic energy is continuously imparted to the electron. This phenomenon is treated in more detail in the application of Gordon, Serial No. 821,434, filed June 19, 1959.

The magnetic fringing fields in resonator 31 are stronger near anode 12 than at the outer wall 32. The cyclotron frequency ω_c therefore varies with distance from anode 12 to outer wall 32, as shown by the graph of FIG. 4.

If the R.-F. field in resonator 31 oscillates at a frequency ω_0 , the cyclotron frequency at various distances along the resonator is very likely to be a subharmonic of ω_0 . Typical examples are shown in FIG. 4 wherein the cyclotron frequency is one-half, one-third, and one-fourth of the R.-F. frequency ω_0 along various distances in the resonator. At these points, the R.-F. field is in synchronism with the cyclotron frequency and large quantities of kinetic energy will be transferred to any stray electrons. The exceedingly high energy level of some of the stray electrons can therefore be sufficient to produce a self-sustaining ionization breakdown with a resulting glow discharge.

According to my invention, this undesirable glow discharge phenomenon is prevented through the insertion of an annular plate 52 in the outer resonator 31. Plate 52 is mounted on the side wall 53 opposite the tuning plunger 42, and is insulated from the side wall by means of a washer 54 of insulating material. Annular plate 52 is biased at a positive D.-C. potential with respect to the rest of the magnetron by means of a D.-C. voltage source 56. Because of its positive D.-C. potential, plate 52 acts as an electron collector. It also repels any positively charged ions which may be formed within resonator 31. By this action, it prevents further collision between electrons and gas molecules and ions that is responsible for the glow discharge. The position of plate 52 does not interfere with the TE_{011} mode in resonator 31 because the R.-F. electric field lines flow circumferentially about anode 12, as shown in FIG. 2. As is explained in the patent of Collier et al. 2,854,603, issued September 30, 1958, the TE_{011} mode is accompanied by currents which flow on outer wall 32 and the outer portion of anode 12. Plate 52 likewise does not interfere with these currents which support the TE_{011} mode.

It is intended that the specific embodiment described be merely illustrative of the general process of the invention. Various other arrangements may be devised by one skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. A magnetron comprising: a cathode; a plurality of anode resonators adjacent said cathode; an outer cavity resonator adjacent said anode resonators, said outer cavity resonator and said anode resonators having a common wall portion; means for coupling certain anode resonators to said outer cavity resonator comprising a plurality of slots in said common wall portion; a conductive plate in said outer cavity resonator; means for biasing said cathode at a first electrical potential; means for biasing said common wall portion at a second electrical potential; and means for biasing said conductive plate at a third electrical potential.

2. A magnetron comprising: a cylindrical cathode for forming and projecting a stream of electrons; a cylindrical anode surrounding said cathode and coaxial therewith; an array of anode vanes extending radially inwardly from said anode and defining a plurality of anode resonators; means including said anode for defining an outer cavity resonator; a conductive plate in said outer resonator; and means for producing a D.-C. potential difference between said conductive plate and said anode.

3. A magnetron comprising: a cylindrical cathode; a cylindrical anode surrounding said cathode and coaxial therewith; an array of anode vanes extending radially inwardly from said anode wall and defining a plurality of anode resonators; means for defining an outer resonator; said last-mentioned means comprising said cylindrical anode; a cylindrical wall surrounding said anode and coaxial therewith; an annular tuning plunger, and an annular wall; an annular insulator contiguous with said annular wall; an annular conductive plate contiguous with said insulator; and means for biasing said plate at positive D.-C. potential with respect to said anode and said cylindrical wall.

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4. An electron discharge device comprising: means for forming and projecting a beam of electrons along a path; an outer wall; a conductive member interposed between said path and said outer wall, said conductive member comprising means for extracting energy from said electron beam; said conductive member and said outer wall defining an output region therebetween; openings in said conductive member for permitting said energy to flow into said output region, said openings also permitting certain stray electrons to pass into said output region; and means for prohibiting said stray electrons from initiating a glow discharge in the output region; said prohibiting means comprising a conductor in said output region that is biased at a positive D.-C. potential with respect to said conductive member and said outer wall.

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5. The electron discharge device of claim 4 wherein: said output region has the shape of a hollow cylinder and is further defined between an annular tuning plunger and an annular side wall; said output region being capable of supporting a TE_{011} mode of electromagnetic wave oscillation, and wherein said conductor is mounted on said side wall and insulated therefrom, whereby said conductor does not interfere with the TE_{011} mode of oscillation.

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