

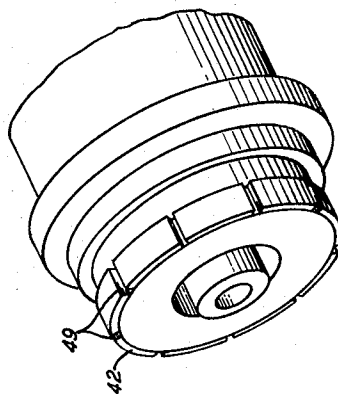
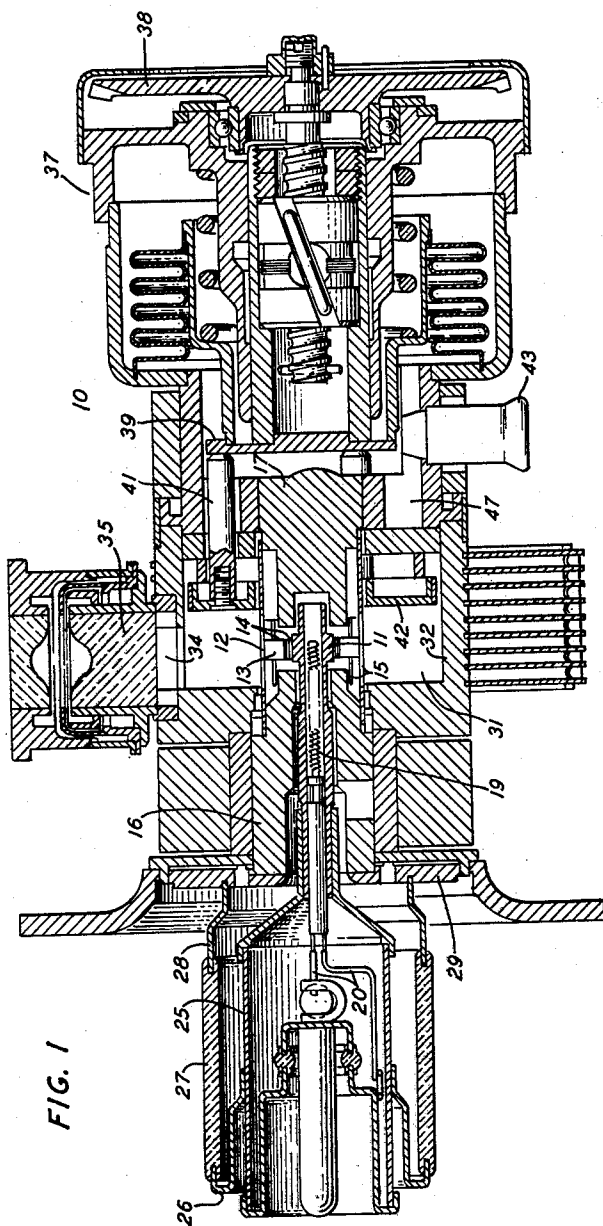
Nov. 17, 1964

H. M. OLSON, JR., ETAL

3,157,818

COAXIAL CAVITY MAGNETRON TUNING RING

Filed Oct. 18, 1961



INVENTORS H. M. OLSON, JR.
L. J. SMITH
BY
David P. Kelley
ATTORNEY

1

3,157,818 COAXIAL CAVITY MAGNETRON TUNING RING

Hilding M. Olson, Jr., Mohnton, and Lawrence J. Smith,
Wayne, Pa., assignors to Bell Telephone Laboratories,
Incorporated, New York, N.Y., a corporation of New
York

Filed Oct. 18, 1961, Ser. No. 146,038
4 Claims. (Cl. 315—39.77)

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 more or less 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 at 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 the desired π mode, high efficiency can be attained without producing instability.

Considerable work has been done on the coaxial cavity magnetron in an effort to improve the fidelity of the output oscillations. Many improvements have been made, for example, in the anode slot structure for damping the effects of spurious energy that is stored in these slots. In spite of these improvements, spurious frequency modes are occasionally excited which degrade the performance of the device.

It is an object of this invention to eliminate spurious frequency oscillations in the coaxial cavity magnetron.

This and other objects of our 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 ring and an annular wall opposite the tuning ring. The frequency of output oscillation is adjusted by moving the tuning ring which is between the cylindrical anode and the outer cylindrical wall.

Through our investigations of the coaxial cavity magnetron, we have determined that spurious oscillations within the output frequency band are created between the tuning ring and the outer cylindrical wall. Efforts to shift the frequency of these spurious oscillations outside of the output frequency band by adjusting the diameter of the tuning ring have been largely unsuccessful as will be explained later.

It is a feature of this invention that the tuning ring

2

contain equally spaced axial slots along its periphery. By this expedient, the spurious oscillations that would otherwise be excited between the tuning ring and outer wall are prevented because of the unfavorable conditions at the boundaries of the region.

Reflection of energy between adjacent slots may set up other spurious modes of oscillation within the output frequency band. To prevent the formation of such modes, the circumferential distance between adjacent slots should not be a multiple of any half wave length within the output frequency band. This condition will be met if the number of slots N in the tuning ring satisfies the inequality:

$$N > \frac{\pi D f}{c} \quad (1)$$

where D is the outside diameter of the tuning ring, c is the free-space velocity of light and f is the highest frequency in cycles per unit of time within the output frequency range. Accordingly, it is another feature of this invention that the number of slots in the tuning ring conform to the above formula.

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

FIG. 1 is a sectional view of the coaxial cavity magnetron illustrating the invention; and

FIG. 2 is a perspective view of the tuning ring of the magnetron of FIG. 1.

Referring now to the drawing, the specific illustrative embodiment of our 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. A plurality of slots 15 extend through the anode 12 along a major portion of its length and parallel to its axis to 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 an 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 a 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 ring 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.

While testing a magnetron of the type described above, it was discovered that the fidelity of the output oscillations was often impaired by the excitation of a spurious oscillation mode within the device. It was observed that

when teledeltos paper, a metallic oxide coated paper with microwave absorbing qualities, was placed around the periphery of tuning ring 42, the spurious mode was noticeably damped, which was interpreted as indicating that the mode probably resulted from a resonance condition between the tuning ring 42 and outer cylindrical wall 32. Efforts to increase the spurious mode frequency beyond the output frequency band by reducing the diameter of the tuning ring did not solve the problem because lower frequency spurious modes then were shifted into the output band. Microwave absorbing materials placed at or near the tuning ring periphery were successful in damping spurious modes in some cases, but in others it deleteriously interfered with the main oscillation mode.

A random number of equally spaced slots was inserted in the periphery of the tuning ring which destroyed the existing resonant condition between the ring and outer wall by upsetting the mode boundary conditions, but which also caused new spurious modes to appear.

It was postulated that these new modes were due to resonant conditions created between adjacent slots because the distance between adjacent slots was an integral number of half wavelengths long at some frequency within the output band. We then determined that the circumferential distance between adjacent slots will not be any integral number of half wavelengths long within the output frequency band if the number of slots N satisfies the inequality:

$$N > \frac{\pi D f}{c} \quad (1)$$

where D is the outside diameter of the tuning ring, c is the velocity of light, and f is the highest frequency in cycles per unit of time within the output band.

The number of slots in the tuning ring should be kept to a minimum in order to maximize its mechanical strength and to avoid leakage of energy into the portion of the outer resonator 31 lying behind the tuning ring 42. The minimum number of slots for producing effective spurious mode suppression is given by the smallest integer N which satisfies the inequality (1).

The output frequency band of the magnetron that was tested was 13.6 to 15.6 kilomegacycles per second and its tuning ring diameter was 1.93 inches. The width of each slot was made very small with respect to the wavelengths of the output frequency band, and in this case was .031 inch. Under these conditions, the smallest integral number that satisfies inequality (1) is $N=9$. Accordingly, nine equally spaced slots 49 were made in the tuning ring periphery as is best seen in FIG. 2.

With nine slots in a tuning ring of 1.93 inches diameter, the circumferential distance between adjacent slots is .674 inch. The half wavelengths at the extreme ends of the above-mentioned output frequency band are .434 inch and .378 inch. It can therefore be seen that with nine equally spaced slots, the distance between adjacent slots is not a multiple of any half wavelengths within the output band. On the other hand, if eight slots had been used, the circumferential distance between the slots would have been .759 inch, which is a multiple of one of the half wavelengths within the output frequency band. Ten slots could have been used, but the additional slot would have made the mechanical strength of the tuning ring weaker and would have resulted in greater leakage of energy out of the outer resonator.

Using nine slots, as described above, we found that all spurious tuning ring modes are effectively suppressed. Any spurious mode which tends to build up due to a resonance condition between tuning ring 42 and outer cylindrical wall 32 is prevented by the unfavorable conditions established at the boundary of the region. Because of the particular predetermined distance between slots 49, spurious modes cannot be formed between the slots that will affect the output frequency.

The foregoing embodiment is merely illustrative of the principles of the invention. Various 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. A magnetron comprising: a cylindrical cathode; a cylindrical anode wall surrounding said cathode; a plurality of anode resonators defined by a plurality of radially extending anode vanes and said anode wall; an output resonator defined by an outer wall and said anode wall; means for adjusting the resonant frequency of said output resonator within a predetermined range comprising a movable cylindrical tuning ring within said output resonator; and means for suppressing spurious modes in said output resonator comprising a circumferential array of equally spaced axial empty slots in the outer periphery of said tuning ring, the number of slots in the tuning ring being the smallest integral number N that will satisfy the inequality:

$$N > \frac{\pi D f}{c}$$

where D is the outside diameter of the tuning ring, c is the free-space velocity of light, and f is the highest frequency in cycles per unit of time within said predetermined frequency range.

2. A magnetron comprising: a cathode; an anode defining a plurality of anode resonators adjacent said cathode; an outer resonator defined between said anode and an outer wall; means for adjusting the resonant frequency of said outer resonator over a predetermined frequency band comprising a movable tuning element in the outer resonator having a first surface that is opposite said outer wall; and means for suppressing the formation of a spurious mode of oscillation between the tuning element and the outer wall comprising an array of equally spaced empty slots in the first surface of the tuning element; the distance between adjacent slots being the maximum distance that is not a multiple of any half wavelength within said predetermined frequency band.

3. A magnetron comprising: a cylindrical cathode; a cylindrical anode having thereon a plurality of vanes that extend toward said cathode; said vanes defining therebetween a plurality of anode resonators; an output resonator coupled to certain of said anode resonators; a movable tuning element within said output resonator for adjusting the resonant frequency of said output resonator over a predetermined frequency range; and a plurality of empty slots along one periphery of said tuning element; the distance between adjacent slots being a distance that is not a multiple of any half wavelength within said predetermined frequency band.

4. The magnetron of claim 3 wherein said periphery is substantially circular and wherein said slots are equally spaced and wherein the number of slots is the smallest integral number N that will satisfy the inequality:

$$N > \frac{\pi D f}{c}$$

where D is diameter of the circular periphery, c is the free-space velocity of light, and f is the highest frequency in cycles per unit of time within said predetermined frequency range.

References Cited in the file of this patent

UNITED STATES PATENTS

2,692,977	Koppel	Oct. 26, 1954
2,854,603	Collier et al.	Sept. 30, 1958
3,034,014	Drexler	May 8, 1962

FOREIGN PATENTS

727,742	Great Britain	Apr. 6, 1955
---------	---------------	--------------