

Jan. 8, 1946.

W. W. HANSEN

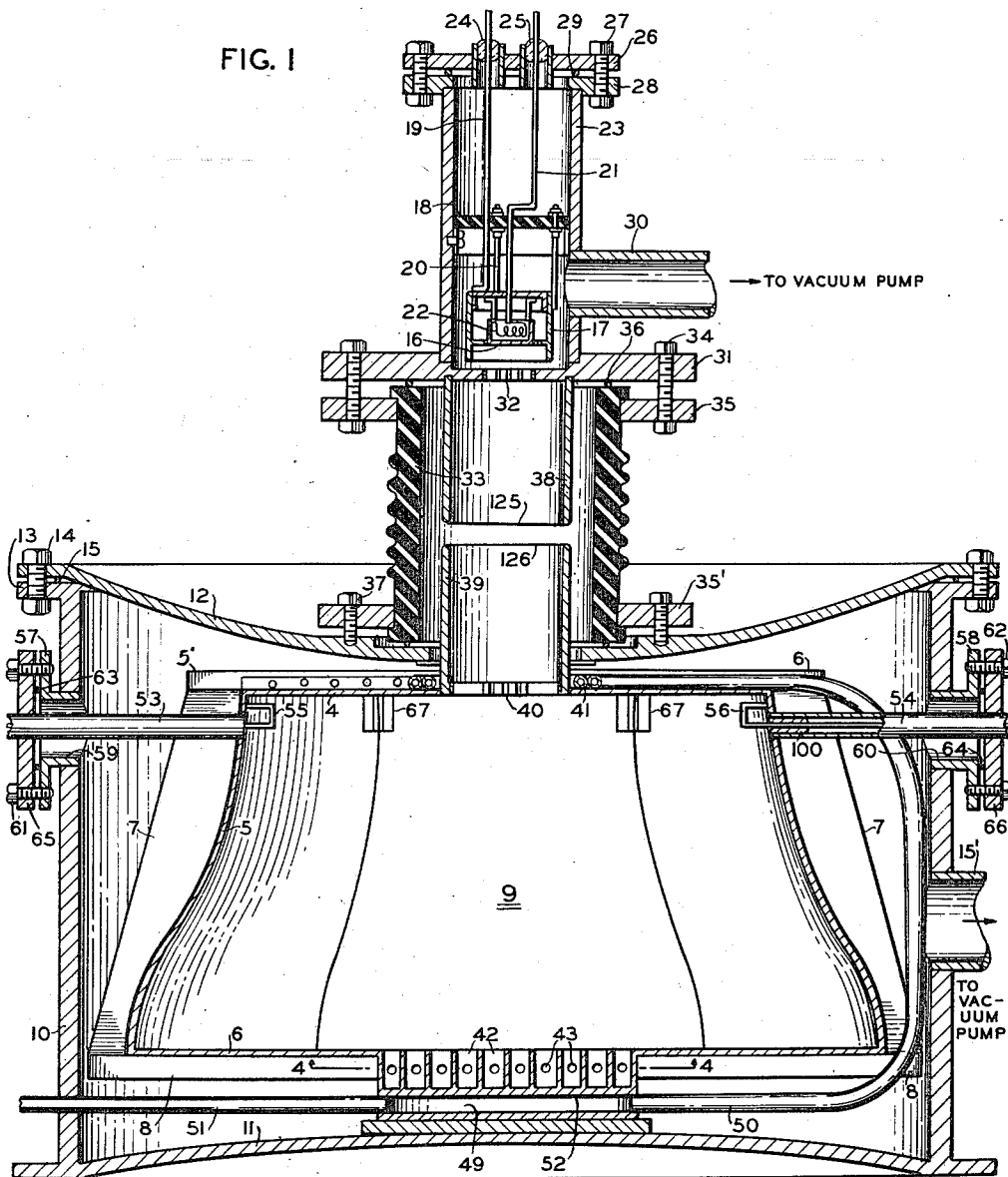
2,392,379

HIGH FREQUENCY ELECTRON DISCHARGE APPARATUS

Filed Nov. 28, 1941

4 Sheets-Sheet 1

FIG. 1



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4 Sheets-Sheet 2

FIG. 2

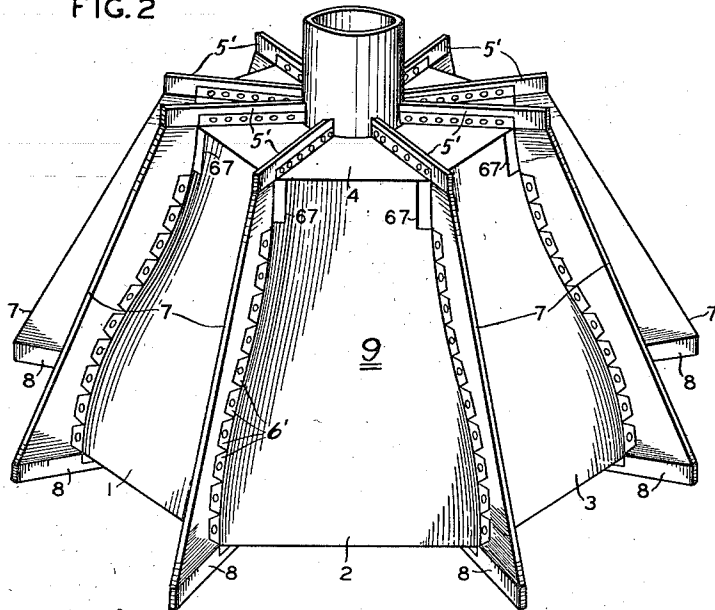


FIG. 3

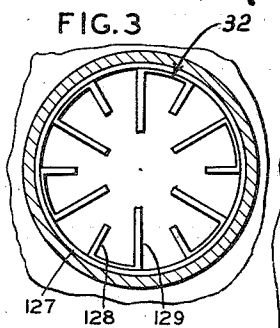
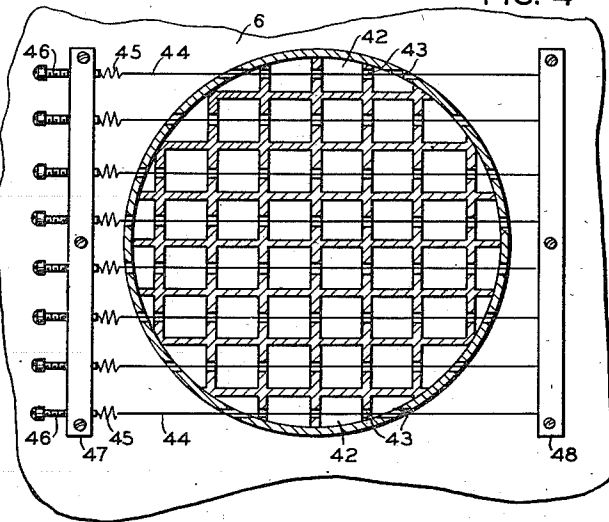


FIG. 4



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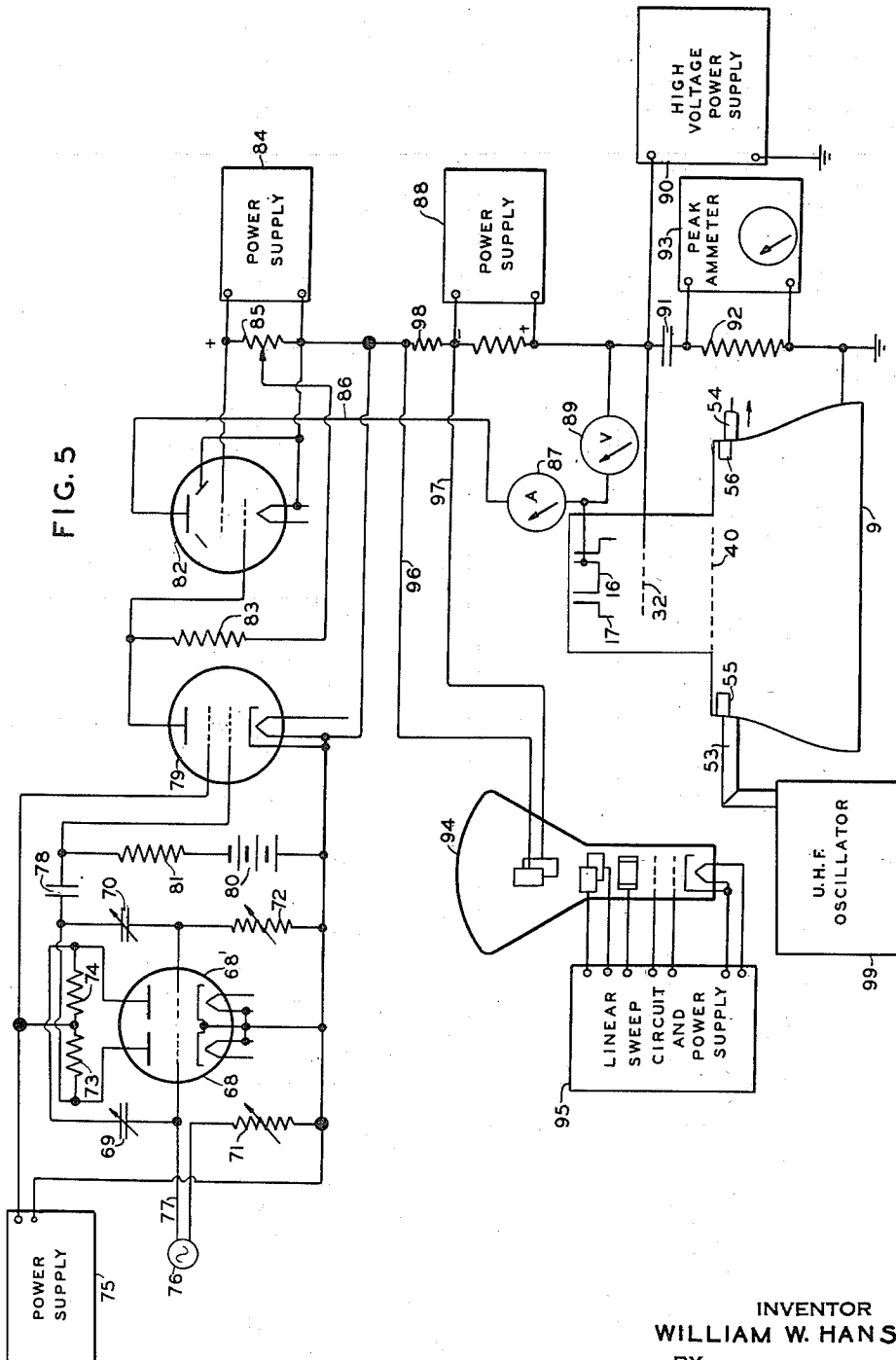
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HIGH FREQUENCY ELECTRON DISCHARGE APPARATUS

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4 Sheets-Sheet 3



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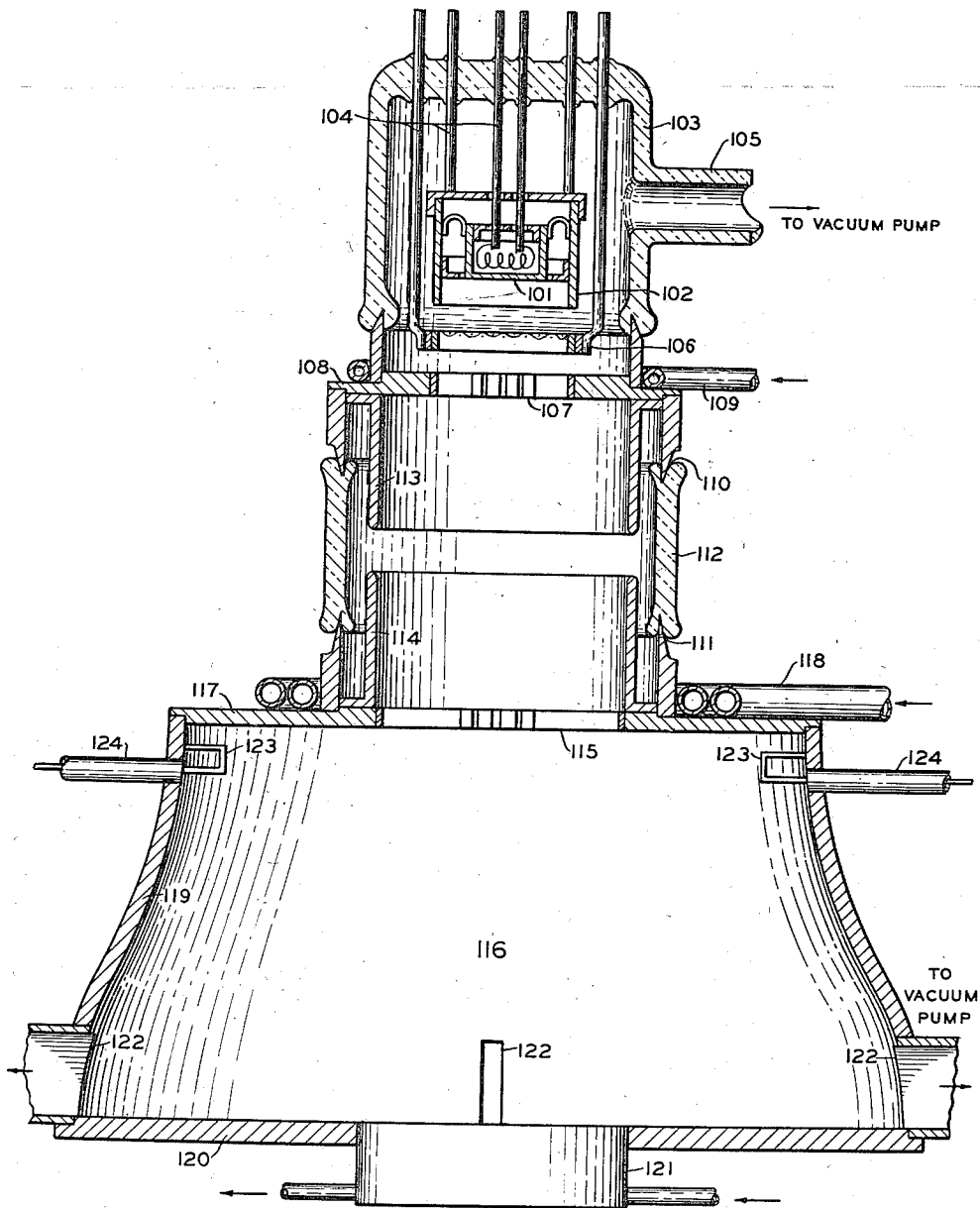
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HIGH FREQUENCY ELECTRON DISCHARGE APPARATUS

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4 Sheets-Sheet 4

FIG. 6



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HIGH FREQUENCY ELECTRON DISCHARGE APPARATUS

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Application November 28, 1941, Serial No. 420,769

33 Claims. (Cl. 315—5)

This invention relates, generally, to ultra high frequency apparatus for the production of high voltage or high power output, or both high voltage and high power output, at very high frequencies, and more particularly to high frequency apparatus of the type disclosed in copending application of William W. Hansen, the present inventor, and Russell H. Varian, for Electron beam oscillator, now Patent No. 2,269,456, dated January 13, 1942.

In the above-mentioned patent there is disclosed an ultra high frequency electron discharge device of the general type shown in U. S. Patent No. 2,242,249, for Electrical converter, issued May 20, 1941 in the names of Sigurd F. Varian and William W. Hansen, and in U. S. Patent No. 2,242,275, for Electrical translating system and method, issued May 20, 1941, in the name of Russell H. Varian, but using only a single resonating chamber, which device is adapted to operate as an ultra high frequency amplifier, detector, oscillator, modulator, frequency multiplier, or any other use mentioned in the above cited patents. Such single resonator devices have been termed "monotrons."

The present invention is directed toward an improved and simplified type of resonator suitable for use in electron discharge devices of the above type, and toward an improved excitation system and method for such a device, useful for producing high values of ultra high frequency voltage such as are adapted for the production of high voltage X-radiation, in the manner shown in the copending application of Russell H. Varian, William W. Hansen and Lindsay M. Applegate, for High frequency electrical apparatus, now Patent No. 2,272,165, dated February 3, 1942, and for producing large amounts of ultra high frequency power suitable for radio communication, radio control, radio therapy, etc.

The principal object of the present invention is to provide improved means for exciting a hollow resonator type of electron discharge apparatus suitable for the economical and efficient production of very high voltage or very high power ultra high frequency oscillations therein.

Another object of the present invention is to provide improved excitation means for hollow resonator electron discharge devices, wherein exciting energy may be supplied periodically but discontinuously, thereby effecting substantial economy in the required capacity of the energizing equipment.

Still another object of the invention is to provide improved means for driving such a hollow resonator device by high voltage pulses.

A further object of the present invention is to provide improved excitation means for hollow resonator devices wherein low level oscillating energy is supplied continuously, and high level

energy is applied periodically and discontinuously, as in pulses, whereby lesser amounts of high level energy may be used, and oscillations will build up more rapidly and reliably in the resonator.

Another object of the present invention is to provide an improved intermittent control for the electron beam of a hollow resonator electron discharge device, substantially independent of the beam accelerating voltage.

A further object of the present invention is to provide a device for pulsing the electrons energizing a hollow resonator substantially independently of the means for accelerating these electrons for use in the resonator.

Another object of the present invention is to provide an improved form of hollow resonator suitable for use with the above-mentioned system, which is designed for ease of construction, being made of a plurality of substantially flat slightly curved sides suitably clamped together.

A further object of the present invention is to provide an improved form of axially symmetrical "monotron" resonator having a transverse cross-section in the form of a regular polygon.

Still another object of the present invention is to provide an improved form of hollow resonator formed of a plurality of joined pieces, the joints extending along the lines of current flow within the resonator, whereby these joints have substantially no effect upon the oscillatory condition of the resonator.

A still further object of the present invention is to provide an improved form of hollow resonator adapted to be contained in an evacuated housing, the resonator being apertured to facilitate evacuation of both the resonator and housing, these apertures being positioned at points of low field intensity of the resonator whereby the resonator action is not impaired.

Still another object of the present invention is to provide improved means for cooling the grids and electron collecting electrodes of electron discharge devices of the present type.

A further object of the present invention is to provide an improved housing for a hollow resonator device of the present type especially adapted for the application of a high speed pump whereby high vacuum may be maintained.

Another object is to provide improved means in such a resonator device for the suppression of secondary electrons whereby the efficiency of the device is improved.

Still another object is to provide a resonator device having improved focussing means to maintain an electron beam of proper diameter.

A further object is to provide a system for driving an oscillator having means for adjusting the duration of high velocity electron pulses supplying energy to said oscillator.

Yet another object is the provision of means for controlling the average electron current flowing into a resonator device of the present type and means for indicating all the voltages and currents involved and the duration of the driving electron pulses.

Other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is a cross-section elevation view of one form of the invention.

Fig. 2 is a perspective view of the hollow resonant conducting member of Fig. 1.

Fig. 3 is a detail of Fig. 1 showing one form of grid structure.

Fig. 4 is a fragmentary cross-section taken along the line 4—4 of Fig. 1.

Fig. 5 is a schematic wiring diagram of the driving and auxiliary circuits of the present invention.

Fig. 6 is an elevation cross-section view of a modified form of the device of Fig. 1.

Similar characters of reference are used in all of the above figures to indicate corresponding parts.

The hollow or cavity resonators referred to herein are hollow bodies comprising a closed or nearly closed envelope having an inner conducting surface and surrounding a space in which, upon suitable excitation, standing electromagnetic waves are set up due to the reflecting properties of the inner surface. A device of this type is said to be "space resonant," since the resonant frequency is determined by the dimensions of the space in which the standing waves exist. In Patent No. 2,269,456, above referred to, which discloses cavity resonators symmetrically formed with respect to an axis along which an electron stream flows, it is shown that an increasing electric field in the direction of electron flow is desirable for efficient operation. It is also therein disclosed that if a cylindrical hollow conducting resonator be distorted properly, such a desired field may be obtained, so that electrons projected into the resonator may be acted upon by a weak oscillating electric field existing in one portion of the resonator to velocity modulate the electrons, may be velocity grouped as they travel along the resonator axis, and may then give up high frequency energy to a stronger field existing in an opposite portion of the resonator, thus maintaining the energy level of the electromagnetic field and oscillations in the resonator from energy supplied to the electron beam prior to its entry into the resonator.

The present invention includes an improved form of resonator suitable for use in the system described in the above-mentioned Patent No. 2,269,456. Referring to Figs. 1 and 2, resonant member 9 of the present invention is shown as made up of eight similar conducting sections, which are adapted to be formed from flat metallic sheets, and are, therefore, readily and simply fabricated. These may therefore be termed developable sections. Each section, such as 1, 2, or 3, consists of a substantially trapezoidal top 4, as seen in Figs. 1 and 2, a curved side 5, and a triangular bottom 6. Each of the eight sections may be clamped to its adjacent section by means of top clamps 5', side clamps 7, and bottom clamps 8, these clamps serving to hold the sections together by means of projecting ears 8' preferably formed integrally with the side, bot-

tom and top members. Clamps 5', 7 and 8 thereby give resonator 9 rigidity and hold the conducting side members 5 in proper shape and position. The shape of the side portions is seen at 5 in Fig. 1 and in Fig. 2 to be substantially perpendicular to the top and bottom members, respectively, at the junctions therewith and to be curved intermediate said junctions in a manner theoretically and empirically found to give the optimum characteristics to the electromagnetic oscillating field to be generated therein as described in the aforementioned Patent No. 2,269,456.

Because of the use of identical sections, the joints between the sections 1, 2, 3, et cetera, of the resonator 9 may all be positioned parallel to the direction of flow of the high frequency currents flowing on the walls of resonator 9, thus introducing substantially no losses from currents traversing high resistance joints.

Although resonator 9 has been illustrated as formed of eight sections, it is to be understood that any other suitable number of sections or even a complete surface of revolution may be used, depending upon the electrical and practical requirements of the device. Thus, the poly-sided form offers many practical advantages in the matter of construction over the surface of revolution form. However, it is found that the resonant wavelength of such a poly-sided resonator is less than that of the surface of revolution type, being related thereto by the equation

$$\lambda' = \lambda \left(1 - \frac{1}{n^2} \right)$$

where λ' is the wavelength for a form having n sides, and λ is the wavelength for the form having circular cross-section.

Surrounding resonant member 9 and providing a vacuum chamber therefor is shown a circular cylindrical metal tank having a cylindrical portion 10, bottom 11, and removable top 12. The removable top 12, which is clamped to flange 13 of cylindrical portion 10 by means of bolts 14 against a malleable wire or other suitable gasket 15, and bottom 11 are made concave to provide greater resistance to atmospheric pressure. Pipe 15' communicates with the vacuum chamber and provides means for attaching suitable vacuum pumps for maintaining proper vacuum in the vacuum chamber.

An electron beam is projected into resonator 9 along its axis of symmetry from an emitter surface 16, which may be oxide coated, and which is mounted within a focusing shield 17. Shield 17 is supported from an insulator 18 by means of lead wires 19, 20, 21 which supply proper voltages to a heater 22, emitter 16 and shield 17. The entire cathode structure is mounted in a tubular member 23, leads 19 and 21 passing out through glass-to-metal seals 24 and 25 in an end plate 26. Plate 26 is clamped to a flange 28 on tubular member 23 as by means of bolts 27, which compress a malleable wire gasket 29 placed between plate 26 and flange 28. Exhaust pipe 30 is provided communicating with the interior of tubular member 23 so that additional vacuum pumps may operate to provide high pumping speed in the vicinity of cathode 16.

Since resonator 9 is to be operated at ground potential, as will be further shown, cathode 16 will be at a very high negative voltage, so that suitable insulating means must be provided between exhaust pipe 30 and its associated vacuum system, or provision must be made to operate said pump

at high voltage. Such insulating means may be in the form of rubber hose connecting pipe 30 to its pumps.

Tubular member 23 is sealed at its end opposite to end plate 26 in a heavy flange 31, which contains a central aperture of diameter approximately equal to that of cathode emitter surface 16. This central aperture may contain a grid structure 32, which as shown in Fig. 3, consists of ring 127 and alternate short and long radial grid bars 128 and 129, respectively, and which may be formed in the manner described in copending application Serial No. 342,912 for High frequency tube structure, filed June 28, 1940, in the names of William T. Cooke, Joe J. Caldwell, Jr., and David G. Clifford. Any other suitable type of grid structure may also be used.

A moderate accelerating voltage is applied between grid 32 and cathode surface 16, as will be described with respect to Fig. 5. A high accelerating voltage is applied between grid 32 and an entrance grid 40 of the resonator 9, a hollow open cylindrical insulator 33 providing the necessary voltage insulation. Insulator 33 is clamped to flange 31 by means of a flange 35, bolts 34 and fuse wire gasket 36. Insulator 33 is similarly clamped to the top 12 of the vacuum tank by flange 35' and bolts 37.

To prevent radial defocusing of the electron beam from emitter 16 after leaving grid 32, electrostatic focusing is provided by conductive tubular members 38, 39, said members being concentric with insulator 33 and acting as an electrostatic lens in the region of their respective rounded adjacent ends 125, 126. Tubular member 38 is fastened to flange 31 concentric to the aperture therein containing grid structure 32. Tubular member 39 is fastened axially to the top 4 of the hollow resonator 9, concentric with a central aperture formed therein and having a diameter equal to the inner diameter of focusing tube 39.

A grid structure 40, which may be similar to grid structure 32, or which may be hollow and water cooled, is placed in the lower end of tubular member 39, flush with the inner surface of the top 4 of resonator 9. Grid 40 may be further cooled by means of a suitable coolant circulated through pipes 41 positioned on top 4 adjacent to tube 39.

As will be described, means are provided for accelerating a high velocity beam of electrons into resonator 9, thereby generating and maintaining high frequency electromagnetic oscillations in this resonator in the manner described in said Patent No. 2,269,456. As therein shown, these electrons after passing through the resonator impinge upon bottom 6 opposite grid 40, and may still have considerable energy, thus heating bottom 6 and also causing emission of secondary electrons. These secondary electrons are undesirable since, on the average, they absorb energy from the electromagnetic field in the resonator rather than aiding in maintaining the field.

As shown in Fig. 1, and more clearly in Fig. 4, means are provided for suppression of this secondary emission effect. Flush with the bottom wall 6 of resonator 9 and in a central location is placed a metallic baffle structure 52 containing numerous individual cells 42 similar to those of an egg crate. The individual cells 42 of the structure extend axially below the bottom wall 6 of resonator 9 far enough to cut down the solid angle through which secondary electrons may emerge by a large factor. One set of the partitions forming the cells has holes 43 centrally located in each cell and a fine grid wire 44 runs lengthwise

through each of the holes 43 in each of the rows of cells. Grid wires 44 are insulated from structure 52 as by being maintained in tension by means of springs 45, and are positioned by screws 46 set in an insulating block 47, which is fastened to the under side of bottom wall 6. The opposite ends of grid wires 44 are clamped in an insulating member 48, also bolted to the under side of resonator 9. The grid wires 44 are kept at a potential slightly positive to the outside of resonator 9, which is preferably at ground potential, thereby collecting many of the remaining secondary electrons. The production of secondaries is further suppressed by preventing heating of the bottom of the cellular structure 52 by means of coolant flowing through a chamber 49, of which member 52 forms one surface, the coolant is supplied by a pipe 50 and removed by a pipe 51. The bottom wall of chamber 49 rests on the inside of vacuum chamber bottom 11, thereby providing support for resonator 9.

High frequency energy may be introduced into or removed from resonator 9 by means of coaxial line elements 53 and 54 which terminate inside of resonator 9 in coupling loops 55 and 56, respectively. Coaxial line elements 53 and 54 pass out of the vacuum container through plates 65, 66 which are clamped to flanges 57, 58, on pipes 59, 60, by means of bolts 61, 62, and malleable wire gaskets 63, 64, respectively. Additional port holes similar to those for coaxial line leads 53, 54 may be provided for coolant pipes and for auxiliary equipment, such as vacuum gauges, et cetera.

As seen in Figs. 1 and 2, holes 67 may be provided adjacent to the top of resonator 9 and to each joint for facilitating removal of gases from the interior of said resonator, thus improving the over-all pumping speed of the system. As shown by the inventor in a paper entitled "A Type of Electrical Resonator," Journal of Applied Physics, volume 9, page 654 (1938), radiation losses from such holes are very slight when they are positioned where the field is known to be weak.

As discussed in the aforementioned copending application, now Patent No. 2,269,456, an oscillator as therein disclosed operates at best efficiency at a certain optimum voltage and power input. Theory predicts that for best operation at a given wave-length, that the transit time should be about $n + \frac{1}{4}$ periods, where n may be any integer. Since transit time depends on driving voltage, this predicts several driving voltages at which the resonator will oscillate.

The present invention provides this optimum voltage and power with substantial saving in energy supplied. Thus, it has been discovered that, because of the inherent high merit factor Q and high shunt impedance of the resonators used, the device of the invention will continue to oscillate for a substantial time interval after the driving voltage is removed. Accordingly it is proposed to apply driving voltage only periodically, in the form of voltage pulses of duration sufficient to permit full build-up of the circuit to an oscillatory condition. By so doing, the resonator is maintained in oscillation, and yet full power is supplied only part of the time, effecting a substantial saving, since the average power is decreased considerably.

To increase this saving, it is desirable to cut the pulse duration as short as possible. However, if the pulse duration is too short, less than the build-up time of the resonator, oscillations are no longer built up to full intensity during pulses, and the device fails to oscillate as desired.

To overcome this difficulty, the resonator is made to oscillate continuously at a low level by the introduction of a small amount of high frequency energy from an auxiliary oscillator, thus providing a "background" oscillation defining a predetermined minimum energy level for the resonator oscillations from which the energizing pulses may readily and rapidly build up the oscillations to the desired high intensity. This has been found to permit a substantial reduction in pulse duration, accompanied by a substantial decrease in the power supply rating required, the power saving due to the reduction in the pulse duration exceeding the power supply from the auxiliary oscillator.

It will thus be seen that through the use of energizing pulses of duration sufficient to permit full building up of the desired oscillatory state, or by the use of pulses of substantially reduced duration coupled with a continuously supplied low-level background oscillation, a high-level ultra-high frequency oscillation is produced and sustained in the resonator.

In the following description of the driving circuit of the present invention the energizing pulse duration has been selected for maximum saving of power, thus necessitating the employment of background oscillations for the sustenance of high-level oscillation. It will be understood, however, that where pulses of longer duration are desired or required and where the additional cost may be tolerated, the high-level oscillation may be obtained and sustained even without background oscillations, as hereinbefore described.

Referring to Fig. 5, there is shown a pulse generator for controlling the current through the resonator without being introduced into the source of high voltage. Vacuum tube 68, 68' acting as a multivibrator, is of the twin triode type. When a unidirectional voltage from power supply 75 is supplied to the plates of tube 68, 68' the associated circuit, which is essentially composed of two resistance-coupled amplifiers, in which the output of each amplifier is fed to the input of the other, causes square wave oscillation at a frequency primarily determined by the grid leak resistances 71, 72 and the grid condensers 69, 70. Either section 68 or 68' of the twin triode will conduct for a period depending on the RC time constant of its associated amplifier circuit. Thus, the output from either section of the tube 68 is a square wave pulse which can be varied in length by altering the values of resistors 71, 72.

The addition of a small alternating voltage from a source 76 in series with resistor 71 provides frequency stability. If we assume for purposes of illustration, that the desired length of current pulse through the resonator is one-tenth of a cycle of the voltage of source 76, which may be the 60-cycle line supply, the grid condensers 69 and 70 are chosen with capacitances in the ratio of 1 to 10. To allow some variation in this ratio, resistors 71 and 72 are made variable. If a change in resistor 71 shortens the output pulse, the resultant change in the total time constant of the oscillator may be counteracted by changing resistor 72 until the system is again controlled by the synchronizing 60-cycle alternating voltage supplied across leads 77 in series with resistor 71.

The output square wave voltage from section 68' of the multivibrator tube is passed through condenser 78 to the input circuit of a beam power tube 79 which acts as a buffer amplifier in the

present system. Amplifier 79 is normally biased in such a manner by battery 80 and resistor 81 that the voltage swing of multivibrator 68 causes tube 79 to conduct during the portion of the cycle in which it is desired to suppress the electron beam in resonator 9; i. e., in the case of the previous illustration, tube 79 conducts during nine-tenths of the cycle. Direct current power for buffer amplifier 79 is supplied from power supply 75 and power supply 84.

The output of amplifier 79 is directly connected to the control grid of power tube 82, which is biased by tapping from resistor 85 a sufficient portion of the voltage supplied by regulated unidirectional voltage power supply 84 to make tube 82 deliver maximum current. During most of the cycle, buffer tube 79 maintains a negative voltage across bias resistor 85 and prevents current flow in tube 82. The plate of tube 82 is connected by lead 86 through ammeter 87 directly to the cathode 16 of the ultra high frequency resonator device, the positive side of power supply 88 being connected directly to grid 32 of the resonator, thus providing a closed path for the pulsed driving voltage from power supply 88. Thus a pulsed electron current is projected from cathode 16 through grid 32 for the desired length of time. The voltage output of supply 88 may be on the order of 3,000 volts. A peak reading voltmeter 89 of conventional design may be connected to read the voltage of grid 32.

Power supply 90, which may furnish a voltage on the order of 50,000 volts, is connected between grid 32 and the entrance grid 40 of resonator 9, thus providing high voltage for accelerating the pulses of electrons projected through grid 32. Peak ammeter 93, which is of conventional vacuum tube design, may be supplied for reference purposes across a resistor 92, placed in parallel with high voltage power supply 90 in series with condenser 91. Condenser 91 may be the last condenser of the filter system of power supply 90. The pulsing device then functions as a valve which allows the high voltage power supply 90 to store up energy in filter condenser 91 for the major portion of the cycle and to discharge it during the small remainder of the cycle whereby the rating of the power supply 90 may be materially reduced. However, the pulse control circuit is independent of the high voltage supply, merely controlling the effect of the latter.

The amount of current flowing through resonator 9 may be controlled by several methods, such as control of the current through heater 22 of cathode 16, by variation of the position of the tap applied to resistor 85 which controls the bias on the control grid of amplifier 82, by control of the grid bias on amplifier 82 by varying the output of buffer 79 through changing the voltage applied to its screen grid from power supply 75, or by changing the plate voltage across power amplifier 82 by changing the voltage of power supply 88.

The size of the pulse as well as its duration may be observed by means of a cathode ray oscillograph tube 94. Exciting voltages and sweep voltage to be applied across the horizontal plates of cathode ray tube 94 may be obtained from a power supply 95. The vertical deflection plates of cathode ray tube 94 are supplied by means of leads 96, 97 with the voltage built up across resistor 98 due to the pulses of current flowing between cathode 16 and grid 32, thus registering a square wave on the fluorescent screen of cath-

ode ray tube 94. Meter 87 provides a means of reading the absolute current flowing. These two devices are useful in ordinary operation and also in outgassing processes occurring after the high frequency resonator has been disassembled for repair. The peak reading ammeter 93 affords a means of reading the actual amount of current reaching the entrance grid 40 of resonator 9.

It is seen that the entire pulse generator, including power supplies, controls and indicators are at a high potential above the grounded vacuum tank surrounding the high frequency resonator 9, so that adequate means for providing voltage insulation and isolation transformers in the leads to the power supplies must be provided, as may be done by methods well known to the art.

As previously mentioned, it may be found economical to use a second means in addition to the pulsing device above described for maintaining oscillations in the resonator. Due to the high ratio of energy stored in the oscillating electromagnetic field to energy lost per cycle in load and ohmic losses, the oscillations may have a build-up time comparable to the pulse duration. Under some conditions, such a factor may actually prevent the generation of oscillations. If an oscillating voltage of the same frequency as the resonant frequency of the resonator and of the order of a few volts were constantly maintained across the resonator by some external means, it may readily be theoretically and empirically shown that the build-up time of oscillations in resonator 9 may be cut by a factor of 5. The use of a low power oscillator to independently excite the resonator to a small constant amplitude therefore would allow a very short pulse length to build up maximum oscillations, thereby requiring a pulsing device of considerably less power than required if the pulsing device were used alone. In addition to considerations involving initial and operation costs, a great improvement in vacuum would result, as smaller power in electron beam form is introduced into the vacuum system. For this purpose, an external oscillator 99, which may be any well known type of low power source of ultra high frequency, is used to feed energy into resonator 9 by means of concentric line 53 and coupling loop 55. A second coupling loop and concentric line may be provided to feed energy back into oscillator 99, thus providing frequency stability if desired.

The low power oscillator 99 provides another advantage in that it maintains the high amplitude oscillations in the same phase relation during successive high power pulses under conditions where the pulses by themselves might not maintain continuous oscillations in the resonator. If oscillator 99 were disconnected, the ultra high frequency oscillations in the resonator might, during one power pulse, build up in a phase indeterminately different from that during a different pulse. Oscillator 99 assures that the phase of oscillations during all power pulses is the same. This may be termed "coherent" oscillations, as distinguished from otherwise "incoherent" pulsed oscillations.

A concentric line 54 and loop 56 coupled into resonator 9 may be used with any well known types of vacuum tube voltmeters to provide a measure of the voltage built up in the resonator or to measure the electromagnetic energy stored therein. Line 54 and loop 56, or another similar line and loop, positioned at a point of high field intensity may be used for removal of energy from the resonator when the device is to be used as a

source of high power ultra high frequency energy. The concentric lines, of course, must be provided with proper vacuum seals, as at 100 (Fig. 1).

Fig. 6 shows an alternate form of the structure shown in Fig. 1, especially adapted to the higher pumping speeds and gas free properties desirable for use with higher power exciting electron beams. Emitter 101, surrounded by focusing shield 102, is supported from glass bell jar 103 by means of conducting leads 104, which supply energizing voltages to the cathode and shield. Exhaust pipe 105 is provided for removal of gases near the cathode structure. In front of emitter 101 is shown a grid 106, which may be used for control, modulation, or other purposes. The electrons are projected through a grid 107 in a flange 108, which may be cooled by circulation of coolant through a pipe 109. Flange 108 is supported above the resonator top by means of glass to metal seals 110 and 111, these seals being spaced by an insulating cylinder 112 at a distance sufficient to prevent spark over between the electrostatic focusing rings 113 and 114 connected respectively to grid 107 and to the resonator 116. The electron beam then passes through a grid 115, positioned centrally in the top 117 of resonator 116. Top 117 may be provided with cooling pipes 118 for removal of heat from grid 115, if desired.

The sides 119 of resonator 116 may be of a curvature similar to side 5 of resonator 9 of Fig. 1. Resonator 116 may also be made poly-sided, but is shown in Fig. 6 as of circular transverse cross-section. The top 117, sides 119, and bottom 120 of resonator 116 are made of thick conducting material, and now serve the dual purpose of functioning simultaneously as a hollow resonant member and as a vacuum chamber. A plurality of coupling loops 123 and concentric lines 124 operate as previously described. Gas may be evacuated from resonator 116 through a plurality of rectangular pipes 122, which have their greatest dimension in the direction of flow of the ultra high frequency currents on the walls of resonator 116. Secondary electron suppressor 121 may be exactly similar to the suppressor 52 shown in Figs. 1 and 4.

It is, of course, evident, that either of the devices shown in Figs. 1 and 6 may be operated by means of a high voltage electron beam which is continuous, rather than pulsed by the system of Fig. 5. In such a case, the grid 106 of Fig. 6 may be used as a modulator, or a modulation voltage may be used in series with the voltage between accelerating grid 107 and entrance grid 115, or between cathode 16 and grid 32, or between grid 32 and grid 40 of Fig. 1. A control grid similar to grid 106 of Fig. 6 may also be used in the device shown in Fig. 1.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. High frequency apparatus comprising a cavity resonator of the single chamber space-resonant type having an axially symmetrical shell interiorly defining a substantially continuous current conducting surface, and means coupled to said resonator for exciting a predetermined mode of oscillation therein defining paths of current flow on the inner surface of said resonator, said shell having a polygonal cross-section transversely

of the shell axis, the loci of the vertices of successive cross-sections taken along the axis extending along said paths of current flow.

2. A cavity resonator adapted upon suitable excitation to sustain a standing wave pattern defining predetermined paths of current flow on the inner surface of said resonator, and comprising a plurality of joined sections of conducting material forming a substantially continuous conducting envelope, each of the joints extending along the direction of current flow in said envelope, whereby said joints do not impair resonator action.

3. A cavity resonator adapted upon suitable excitation to sustain therewithin a standing wave field comprising a plurality of preformed joined sections of conducting material forming a curvilinearly flaring axially symmetrical shell defining a substantially continuous conducting envelope, and means for projecting a beam of electrons through said resonator, said shell having a transverse cross-section increasing in the direction of flow of said electrons and further having portions at the ends thereof substantially parallel to said axis, whereby the curve of said flare provides increasing field intensity in the direction of projection of said beam through the resonator.

4. High frequency apparatus comprising a cavity resonator having a pair of flat end pieces positioned transversely of the axis of said resonator and a plurality of developable sections joining said ends, and means coupled to said resonator for exciting a predetermined mode of oscillation therein defining paths of current flow on the inner surface of said resonator, said sections being joined along some of the paths of current flow in said resonator.

5. High frequency apparatus comprising means defining a hollow resonator adapted to contain an oscillating electromagnetic field, means adjacent said resonator for projecting an electron beam through said resonator in energy exchanging relation with said field, and reticulated pocket means on a wall of said resonator for intercepting said beam after passage through said field, whereby secondary electron emission within the resonator is suppressed.

6. High frequency apparatus comprising means defining a hollow resonator of the single chamber space resonant type, means adjacent said resonator for projecting an electron beam through said resonator, said resonator providing an increasing electromagnetic field intensity along the path of said beam within said resonator, and pocket means located beyond the region where said beam exchanges energy with the stronger field portions for intercepting said electron beam and for suppressing secondary electron emission within said resonator.

7. The apparatus defined in claim 6, including collector electrode means in the path of said beam adjacent said last named means.

8. The apparatus defined in claim 6, wherein said last named means comprises a cellular baffle restricting the solid angle of secondary emission electron trajectories.

9. Apparatus for suppressing the emission of secondary electrons in an electronic discharge device having an evacuated envelope, means for projecting an electronic beam therein and a collector electrode for receiving said beam; comprising a grid structure in the path of the beam formed of relatively thin leaf members of conducting material having the planes thereof parallel to the di-

rection of primary electron flow and a collector positioned in the interstices of said grid.

10. An electron discharge device comprising a hollow resonator, means in said device for projecting a beam of electrons through said resonator, means in the path of said beam for intercepting said beam after passage through the resonator and for suppressing the emission of secondary electrons comprising a lattice member positioned transverse to and having substantial thickness in the direction of said electron beam, said lattice member thereby decreasing the solid angle of possible secondary electron projectories, and collector electrode means comprising a plurality of conductors insulated from and extending through said lattice member transversely of said beam.

11. Cavity resonator electron discharge apparatus comprising a resonator, electron beam means adjacent said resonator for creating oscillations within said resonator, and intermittent energizing means coupled to said beam means for energizing said electron beam means in a continually interrupted manner whereby a saving in energy applied to said resonator is effected.

12. A cavity resonator electron discharge device as in claim 11, wherein said energizing means is adapted to produce energized periods having duration at least equal to the oscillation build-up time of said resonator.

13. High power apparatus for obtaining ultra high frequency voltages for producing X-ray and like radiation comprising means defining a cavity resonator of the single chamber space resonant type adapted to contain an oscillating electromagnetic field, means in said apparatus for projecting an electron beam through said resonator for interaction with said field, and intermittent energizing means in said apparatus for introducing energy into said resonator in a continually interrupted fashion for producing and maintaining relatively high level oscillation in said resonator.

14. A cavity resonator electron discharge device comprising a cavity resonator, a source of electrons adjacent said resonator, means adjacent said source for forming said electrons into a beam to excite said resonator to oscillation, and means for reducing the oscillation build-up time of said resonator, comprising a low power source of oscillations and means coupling said oscillation source to said resonator.

15. A cavity resonator electron discharge device comprising a source of electrons, a resonator adjacent said source, means coupled to said source for intermittently exciting said resonator by said electrons, and means coupled to said resonator for continuously producing a relatively weak alternating field therein at the resonant frequency thereof, whereby the duration of said intermittent excitation may be reduced.

16. An oscillator of the single chamber space-resonant type comprising a source of electrons, means adjacent said source for forming said electrons into a beam, a cavity resonator in the path of said beam, means adjacent said beam-forming means for accelerating and projecting said electrons into said resonator to excite said resonator to oscillation, and means comprising a low power source of oscillations coupled to said resonator for reducing the oscillation build-up time of said resonator.

17. An oscillator of the single chamber space-resonant type comprising a source of electrons, means adjacent said source for forming said electrons into a beam, comprising a grid structure and a source of low voltage coupled thereto, a cav-

ity resonator in the path of said beam, means comprising a second grid in the path of said beam and a source of high voltage coupled thereto for accelerating and projecting said electrons into said resonator to excite said resonator to oscillation, and means for causing said resonator to be excited by said electrons only intermittently, comprising means coupled to said low voltage source for intermittently blocking said low voltage source whereby substantial saving of low voltage and high voltage energy and capacity may be effected.

18. An oscillator of the single chamber space-resonant type comprising a cathode, a first grid adjacent thereto, means coupled to said grid for energizing said grid by an intermittent low voltage whereby said cathode is caused to emit a stream of electrons intermittently, a second grid in the path of said stream, means coupled to said second grid for applying a high voltage accelerating potential thereto whereby said stream is accelerated, a cavity resonator in the path of said stream, means for projecting said accelerated electron stream into said resonator to excite said resonator to oscillation at high voltage and high frequency, and means comprising an auxiliary low power source of oscillations coupled to said resonator for reducing the oscillation build-up time of said resonator, said first grid-energizing means being adapted to produce a duration of said intermittent stream at least as long as said reduced build-up time.

19. High frequency apparatus comprising a hollow resonator, means coupled to said resonator for continuously supplying oscillating electric energy at a low level to said resonator and means coupled to said resonator for periodically exciting said resonator by pulses of high level energy.

20. The method of exciting a cavity resonator into sustained oscillation at a high energy level comprising the steps of continuously maintaining a weak oscillation within said resonator and intermittently superimposing on said weak oscillation pulses of high energy content.

21. High frequency apparatus comprising a hollow resonator, means for introducing energy into said resonator to establish relatively low level oscillation therein, and means for intermittently introducing power pulses of relatively short duration into said resonator to periodically build up said oscillation to relatively high level.

22. In a method of exciting a hollow resonator, the steps of producing a relatively weak oscillating field within said resonator, and periodically building up said field to oscillate at a relatively high level.

23. Ultra high frequency apparatus comprising means defining a hollow resonator, means coupled to said resonator for producing a relatively weak oscillating field within said resonator, and means coupled to said resonator for periodically building up said field to oscillate at a relatively high level.

24. A high frequency device comprising a hollow resonator, a low power source of high frequency energy coupled to said resonator, and means for introducing intermittent power pulses into said resonator to periodically build up the oscillations therein to full intensity.

25. Ultra high frequency apparatus comprising a hollow resonator, means coupled to said resonator for producing a weak oscillating field within said resonator, and separate means coupled to said resonator for building up said field from said weak oscillation to full intensity.

26. The method of exciting a hollow resonator

to full oscillation which comprises the steps of exciting said resonator with low power for producing a relatively weak oscillating field within said resonator and then exciting said resonator with relatively high power to build up said weak field to full intensity.

27. Ultra high frequency apparatus comprising means defining a hollow resonator, means defining an apertured electrode in a wall of said resonator, a cathode for supplying a beam of electrons to be projected through said electrode into said resonator, a control electrode intermediate said first electrode and said cathode, a pulsed, relatively low voltage source connected between said cathode and said control electrode for energizing said cathode to periodically project a beam of electrons toward said control electrode and a relatively high voltage source connected between said control electrode and said apertured electrode for accelerating said beam of electrons prior to passage into said resonator.

28. High frequency apparatus for exciting a resonant circuit to high oscillation, comprising means coupled to said circuit for exciting said circuit to a low amplitude of oscillation, and separate means coupled to said circuit for recurrently exciting said circuit from said low amplitude to high oscillation.

29. The method of exciting a resonant circuit to high oscillation which comprises the steps of exciting said circuit with low power, thereby producing a relatively low amplitude of oscillation thereof, and then recurrently exciting said circuit with relatively high power to build up said low amplitude to the desired high amplitude of oscillation.

30. Apparatus for suppressing the emission of secondary electrons as in claim 9, further comprising means for maintaining said collector at a potential suitable to attract secondary electrons.

31. Apparatus for obtaining ultra high frequency voltages for producing X-ray and like radiation, comprising means defining a cavity resonator of the single chamber space resonant type adapted to contain an oscillating electromagnetic field, means in said apparatus for projecting an electron beam through said resonator for interaction with said field, means in said apparatus for establishing relatively low level oscillation in said resonator, and means in said apparatus for intermittently introducing energy into said resonator for producing and maintaining relatively high level oscillation in said resonator.

32. High frequency apparatus comprising means for producing a stream of electrons, a cavity resonator in the path of said stream and having electron-permeable walls permitting passage of said stream therethrough, and means in the path of said stream beyond said resonator for intercepting said stream and for suppressing emission of secondary electrons, said last-named means comprising a lattice member positioned transverse to and having substantial thickness in the direction of said electron stream, said lattice member thereby decreasing the solid angle of possible secondary electron trajectories, and collector electrode means beyond said lattice member.

33. The method of exciting a resonant circuit to high oscillation which comprises the steps of producing a relatively low amplitude of oscillation in said circuit and then recurrently exciting said circuit with relatively high power to build up said low amplitude of oscillation to the desired high amplitude of oscillation.

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