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OSCILLATION GENERATOR OF THE VELOCITY MODULATION TYPE

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Fig. 1.

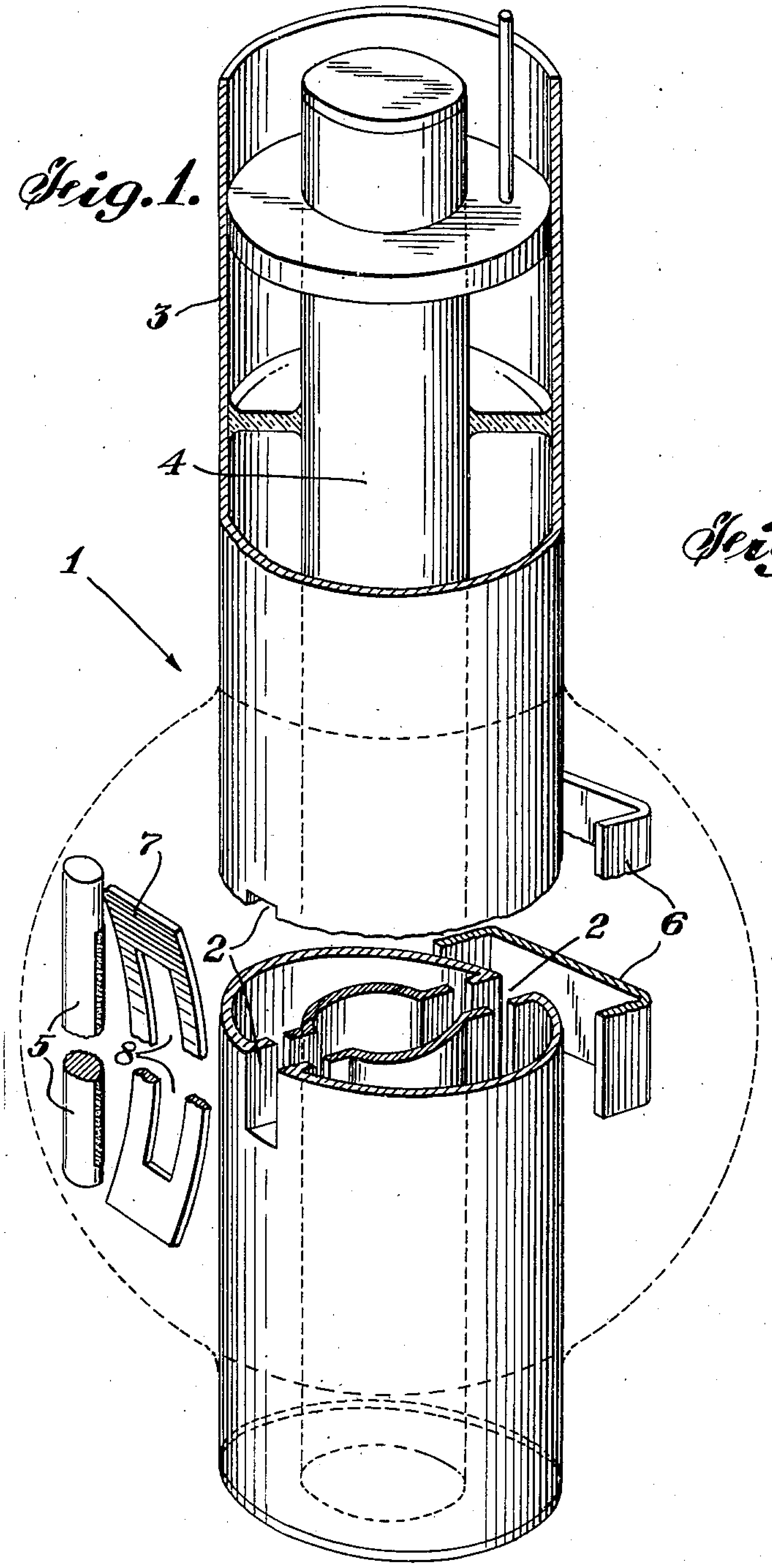
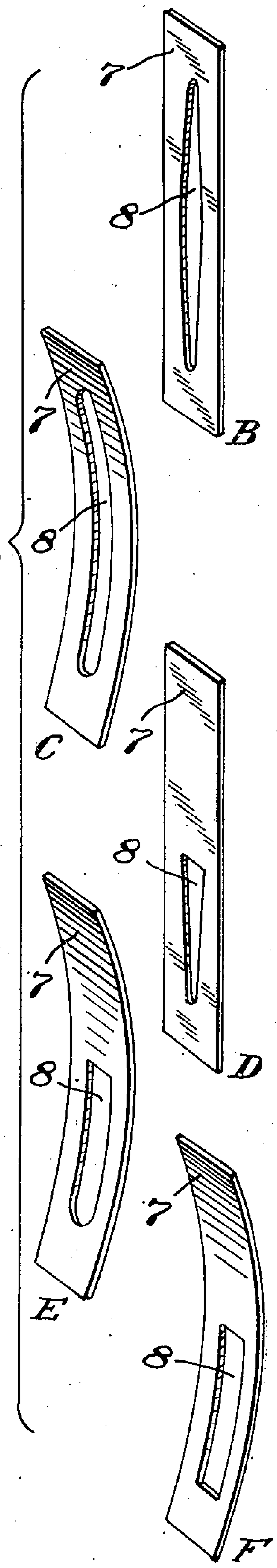


Fig. 2.



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OSCILLATION GENERATOR OF THE VELOCITY MODULATION TYPE

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8 Claims. (Cl. 315—5)

This invention relates to oscillation generators of the velocity-modulation type which are intended to be tunable over a wide frequency range.

In the case of velocity-modulated tubes it is necessary to readjust the voltage of the anode or resonator, that is, the electron accelerating voltage, whenever the frequency is changed due to the readjustment of the tuning of the resonant chamber circuit, the relation being in the case of a coaxial line type resonant chamber that the electron accelerating voltage increases as the square of the frequency.

The greatest energy exchange between the resonator field and the beam is when the beam is projected across the field of the resonant chamber at a voltage anti-node.

Notwithstanding the provisions of arranging for the beam to be acted upon by the electric field of the resonant chamber at an anti-nodal point, to obtain a current large enough to operate the tube it is necessary to pass a beam current across a finite length of the operating field, the voltage anti-node being situated somewhere within the length through which the beam current is passed. Under these conditions the efficiency with which H. F. energy is extracted from the beam is approximately proportional to the square of the amplitude of the alternating voltage across the resonant circuit or chamber.

When a velocity-modulated tube is operated at the low-frequency end of its range the electron accelerating voltage is low and it is difficult to pass sufficient current across the high-frequency field to operate the tube. To avoid the use of positive grids to produce greater current densities, it is sometimes convenient to increase the length of the portion of the chamber through which current passes, i. e. to increase the length of the cathode and width of the beam. This provision makes it possible to obtain a greater total current without an unduly large current density, since the cross-sectional area of the beam has been increased. Although in this case the length of the field across which current flows is extended, the wavelenth is long since the frequency is low, and the current passes across a length of the resonant chamber over which the voltage amplitude is not greatly different from that at the anti-node.

However, when such a tube is operated at higher frequencies, the electron accelerating voltage is higher and there is no difficulty in obtaining the current necessary to operate the tube. In fact it is normally necessary to limit the current by means of a negative grid or other arrangement to a value which is consistent with

the maximum heat dissipation of the electrode upon which the current finally impinges. Now in this case the wavelength is short and the voltage at the ends of the section of the chamber across which the current passes is considerably less than that obtaining at the anti-node. Consequently the mean efficiency with which H. F. energy is extracted from the electron beam is low. Thus, in the circumstances, it would be advantageous to employ a short cathode, by this means ensuring that all the current passes reasonably close to the voltage anti-node, as the necessary current is readily obtainable from a small area because of the high electron accelerating voltage employed.

An object of this invention is to provide an arrangement in which the conflicting conditions for utilising a velocity modulation tube at high and low frequencies set out in the last two preceding paragraphs are reconciled.

According to the invention an oscillation generator of the velocity modulation type is provided with means for automatically variably controlling the strength of the electron beam current in accordance with variations in operating frequency. This means may comprise means for varying the cross-sectional area of the electron beam, for example, by varying the dimension of the beam parallel to the standing waves which interact with the beam to velocity modulate the latter, and the variation may be effected under the control of a factor determined by the desired operating frequency.

In one embodiment of the invention a long cathode is used and located parallel to the direction of the standing waves, for example, in the resonant chamber when such is used, and in front of this cathode a special retarding electrode is placed. This special retarding electrode is so constructed that the control exerted thereby on the electrons leaving the cathode is strong at the end (ends if a double-ended system, e. g. a coaxial resonant chamber, is used) of the cathode and becomes progressively weaker, reaching its point of least control where it covers that point on the cathode opposite to the voltage anti-node. Such a retarding electrode may for example be a grid of the well known variable mu type. The bias on the grid is a factor determined by the desired operating frequency, and the bias is so controlled that at low frequencies the grid voltage is zero or only slightly negative, and current from the whole length of the cathode is used. On the other hand, at high frequencies a much larger negative voltage with respect to the cathode is applied to the grid, and, due to the varying control of the grid along its length, current is automatically cut off from those parts of the resonator remote from the voltage anti-node, while it still flows at points near to the position of least control of the grid; that is near to the voltage anti-node of the chamber. Conditions are thus obtained which are similar to those occurring if a short cathode were used when the frequency is high, but which are also similar to those occurring when a long cathode is used when the frequency is low. By suitable design of the grid the conditions applying at intermediate frequencies may also be made satisfactory.

Although "variable mu" grids normally are wire wound, the pitch of the winding changing along the length, the same effect may be obtained by using a "slot grid," the width of the slot varying along the length, or by other suitable arrangement.

In an alternative construction, the grid may be bowed. In this case the cathode to grid spacing is made to vary along the length of the grid. The grid in this case may also be of the variable pitch or slot width type or may be formed with uniform wire spacing or slot widths.

The accompanying drawings show by way of example some preferred embodiments of the invention.

In the drawings,

Fig. 1 shows diagrammatically in perspective view the essential elements of an electron discharge tube of the velocity modulation type, for example as described in the Patent No. 2,320,860, embodying the present invention.

Fig. 2 shows various alternative constructions of the grid.

In the type of tube shown in Fig. 1 the resonator, indicated by the reference number 1, is of the coaxial line type provided with slots 2 in the outer and inner conducting walls 3, 4 respectively of the chamber, in alignment along a diameter. On one side of the resonator is located the source of electrons, shown as a linear cathode 5, which may be directly or indirectly heated, so as to provide a rectangular beam of electrons to pass through the slots 2. Any other suitable source of electrons may be provided for producing a wide electron stream.

On the other side of resonator 1 is located the anode 6 in alignment with the cathode 5 and slots 2. For fuller description of the tube construction and mode of operation reference may be made to the aforesaid Patent No. 2,320,860.

In accordance with this invention, there is provided, between the cathode 5 and resonator 1 a control grid 7 of special type as hereinbefore described. As shown in Fig. 1 this grid 7 comprises a bowed metal strip having therein a rectangular slot 8 and the grid is positioned so that the slot 8 is in alignment with the slots 2 of the resonator and with the cathode 5.

In the type of tube illustrated, the frequency is varied by varying the length of the coaxial line, for example symmetrically with respect to the slot so that at all frequencies in the operating range the anti-nodal point is held midway along the length of the slots 2. It will then be observed that opposite the location of the anti-node, the grid is furthest away from the cathode so that its control on the electron beam from the cathode is least at that point, and greatest at the ends, progressively varying from the centre towards the ends. As hereinbefore described, the potential on the grid 7 is varied as the operating wave length is varied. For example, if the wave length is increased it is desired to increase the beam width and the grid 7 is made less negative with respect to the cathode 5 so that the grid in suppressing the flow of electrons is not so effective as for a more negative bias for the same distance of the grid from the cathode and the width of the electron beam is thereby increased. In addition, due to the smaller negative potential the intensity of the beam is increased, assuming the same electron accelerating voltage. Since therefore, the accelerating voltage is decreased for an increase in wavelength, the change in bias on the grid tends to compensate for the change in intensity of the beam due to the lower accelerating voltage and increases the beam width. Also the greater width of the beam allows a greater and more efficient interaction with the electric field of longer wave length, than if the beam had a constant width.

The opposite effects occur for a decrease in wave length, when the grid is made more negative with respect to the cathode.

A similar variation in control of the electron beam can be obtained by using a grid having the form shown at B, Fig. 2. In this case the grid is straight and is placed parallel to the cathode. The slot 8 tapers in width from the centre towards each end as shown. Then if the form of grid shown at B, Fig. 2, be bowed as shown at C, Fig. 2, the variation in control will be greater than in the case of the grid shown in Fig. 1 or at B in Fig. 2. A different slot contour, having tapered and rounded ends and substantially parallel sides, is also illustrated in Fig. 2, C.

Taking now the case in which one end of the resonator is open, for instance, so that radiation of the generated waves may take place, or be fed to a waveguide, then a voltage anti-node always exists at the closed end of the coaxial line, and the point of minimum control of the grid should be located opposite to this anti-node. Suitable forms of grid for such an oscillation generator are shown at D, E, and F, Fig. 2. Type D is a flat metal strip 7 having a slot 8 tapering in one direction only. The grid is placed parallel to the cathode with the widest end of the slot opposite to the anti-node location. Type E is similar to type D bowed, illustrating also a modified slot having substantially parallel sides and a rounded lower end, with the widest end of the slot at the mid point of the arc; and type F comprises a bowed metal strip having a rectangular slot 8 as shown. When types E and F are used, the grids are so located that the mid point of the arc is opposite the voltage anti-nodal point of the standing waves in the coaxial line. Whilst in types D, E, and F the slot 8 is shown as occupying only half the length of the strip 7, it will be understood that only the half provided with the slot need be employed. It will be observed that in the cases so far mentioned the grid is symmetrical with respect to the field anti-nodal point.

In resonator systems in which one end of the resonator is fixed and the opposite end is movable for tuning purposes, the voltage anti-node moves along the system as the operating wavelength is changed. In this case, the point of least control of the grid is located opposite to the location of the voltage anti-node of the shortest wavelength to be used, and the type of grid used is of the symmetrical type for example as shown in Fig. 1 or at B and C in Fig. 2.

Instead of a grid comprising a strip of metal provided with a slot, other grid constructions may be used, for example a wire wound grid with varying pitch; and such a grid may be placed parallel to the cathode or at progressively varying distances from the cathode, being furthest away from the cathode at the point opposite the anti-node location. Furthermore, a wire wound grid of equal pitch but bowed may be used. The bowed types of grid need not necessarily be in the form of an arc of a circle. Alternatively they may have any desired curvature to suit conditions and may for example be linear and inclined to the cathode at any desired angle. Furthermore a desired variation of grid control on the electron stream may be obtained by a suitable combination of slot shape or in the case of wire wound grids, of pitch and curvature of the grid or angle of inclination to the cathode.

While some practical forms of grids have been described as embodied in an oscillation generator of the velocity modulation type having a coaxial resonator system, it will be understood that other resonator systems and other types of variable mu grids will occur to those skilled in the art and may be employed within the scope of this invention as defined in the appended claims.

What is claimed is:

1. A velocity-modulated electron beam tube comprising a cavity resonator provided with apertures for passage of an electron beam therethrough, means adjacent said resonator for projecting therethrough an electron beam a part thereof adapted to pass through the antinode of standing waves developed in said resonator and an outer part thereof through an adjacent portion of the waves, beam control means to control the beam between said resonator and said projecting means for cutting-off the outer part of said beam, said beam control means being positioned along the beam path and having progressively greater control over said beam towards said outer part, and means connected to said beam control means for applying thereto a potential varying inversely with the length of said waves whereby the size of said beam is decreased with shorter waves.

2. A tube as set forth in claim 1 in which said beam control means comprises a retarding electrode mounted progressively closer to the beam path toward the outer part of said path.

3. A tube as set forth in claim 1 in which said beam control means comprises a retarding electrode mounted progressively closer to the beam projecting means towards the part of said projecting means adjacent the outer part of said path.

4. A velocity-modulated electron beam tube comprising a cavity resonator provided with apertures for passage of an electron beam therethrough, means adjacent said resonator for projecting therethrough an electron beam its center adapted to pass through the antinode of standing waves developed in said resonator and its outer parts through adjacent portions of the standing waves, and an electron-retarding electrode

mounted between said resonator and said projecting means and provided with an elongated aperture extending transversely to the direction of the beam path for passage of the beam therethrough, the opposite sides of said elongated aperture being progressively closer together towards the outer parts of said beam path whereby said electrode cuts off progressively increased portions of said outer parts of said beam when progressively lower cut-off potentials are applied thereto.

5. A tube as set forth in claim 1 in which said beam control means comprises a retarding electrode of flat metal provided with a slot in the beam path and transversely to the direction thereof, the opposite sides of said slot being progressively closer together adjacent the outer part of the beam path.

6. A tube as set forth in claim 1 in which said beam control means comprises a retarding electrode provided with a slot in the beam path, said electrode being inclined to the direction of the beam path with the portion adjacent the outer part of the beam path located closer to the beam projecting means.

7. A velocity-modulated electron-beam tube comprising an elongated cavity resonator provided with a wide flat path extending diametrically therethrough, means mounted adjacent said resonator for projecting along said path a flat electron beam adapted to pass parallel to standing waves developed in the resonator and the center part thereof adapted to pass through the antinode of such waves, and an electron-retarding electrode mounted between said projecting means and said resonator and provided with an elongated slot aligned with said path for passage of the beam therethrough, said slot being narrower towards its ends whereby said electrode cuts off progressively increased end portions of said flat beam when progressively lower cut-off potentials are applied thereto.

8. A tube as set forth in claim 4 in which the retarding electrode comprises a flat metal member provided with an opening through which the beam path passes, the margins of said opening being curved in a plane transverse to the beam path with the concave side toward the means for projecting.

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