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ELECTRONIC TUBES FOR USE AS BACKWARD WAVE OSCILLATORS

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Fig. 1.

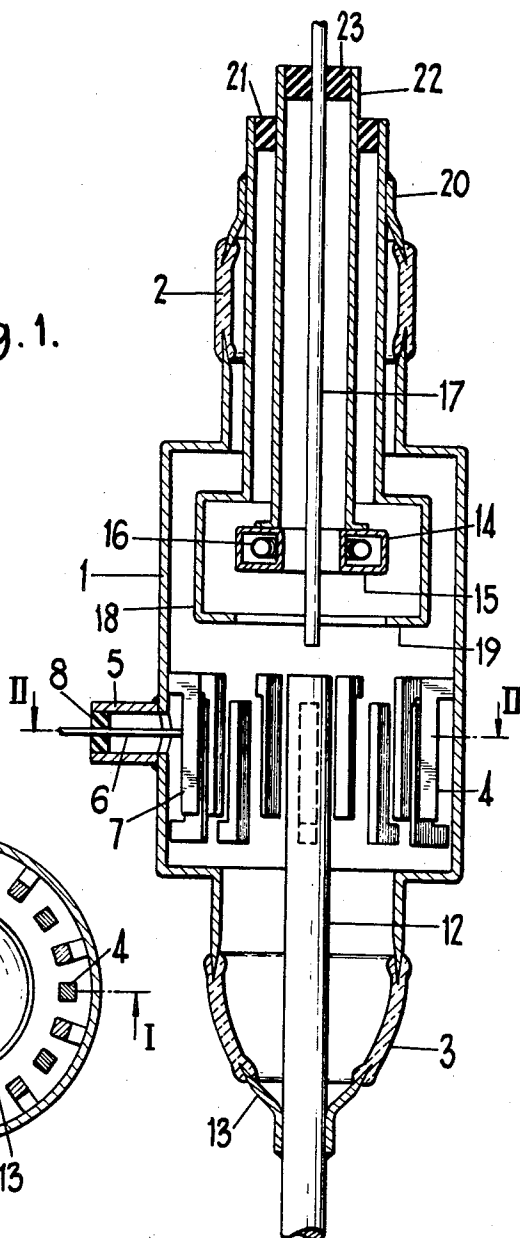
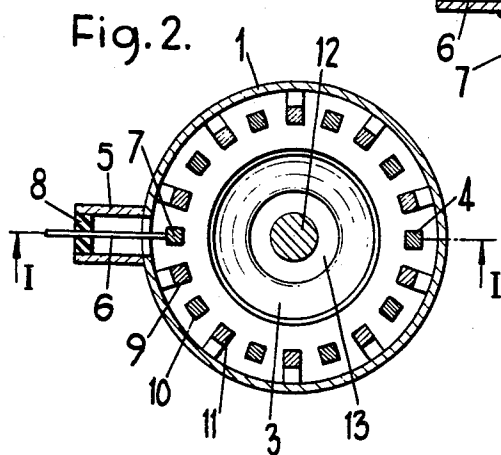


Fig. 2.



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2 Claims. (Cl. 315—39.3)

This invention relates to electronic tubes for use as backward wave oscillators.

In the operation of a tube of this kind oscillations are generated by virtue of interaction between an electron beam flowing adjacent to a delay line and an electromagnetic wave travelling along the delay line in a sense opposite to the direction of flow of the electron beam, the delay line being provided with an output connection at the end towards which the wave travels and a substantially reflectionless termination at the other end. The oscillation frequency is such that synchronism exists between the respective velocities along the length of the delay line of the electron beam and a backward component of the field associated with the travelling electromagnetic wave, the value of the oscillation frequency for any given beam velocity depending on the phase velocity/frequency characteristic of the delay line; the oscillator may therefore be readily tuned by variation of the electron beam velocity.

In one form of construction which has been used for such tubes, the delay line is arranged in the form of a ring with its ends electrically isolated from each other, a cylindrical electrode system comprising a cathode and a further electrode being disposed coaxially within the ring; the electron emissive surface of the cathode is disposed opposite the output end of the delay line, constituting only a small portion of the active surface of the central electrode system, and a separate beam-forming electrode is disposed adjacent the output end of the delay line. In operation the beam-forming electrode is maintained at a fixed positive potential with respect to the central electrode system, a potential difference is applied between the delay line and the central electrode system so as to establish a radial electric field in the interaction space between the delay line and the central electrode system, and an appropriately directed axial magnetic field is established in the interaction space by means of a suitable magnet; the electron beam furnished by the cathode under the control of the beam-forming electrode then rotates in the interaction space about the axis of the system in a sense corresponding to movement along the delay line away from the output end, the angular velocity of the electron beam being substantially directly proportional to the ratio of the strengths of the electric and magnetic fields, and consequently being readily variable for the purpose of tuning by variation of the potential difference applied between the delay line and the central electrode system.

Such a form of construction has the disadvantage that the relatively small area of the emissive surface of the cathode imposes an undesirable limitation, which is particularly severe for tubes designed to operate at very high frequencies (say greater than 10,000 megacycles per second), on the maximum output power which can be obtained at a given operating frequency consistent with a reasonable cathode life. It has been proposed to improve the design in this respect by replacing the central electrode system with a cylindrical cathode whose electron

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emissive surface extends all round its circumference, the beam-forming electrode being dispensed with. The modified form of construction, however, has the disadvantage that variation of the potential difference applied between the delay line and the cathode for the purpose of tuning the oscillator leads to an undesirable variation of the magnitude of the electron beam current, and consequently of the output power.

It is accordingly an object of the present invention to provide an alternative form of construction for an electronic tube for use as a backward wave oscillator, which is improved in respect of these factors.

According to the invention, an electronic tube for use as a backward wave oscillator comprises a delay line arranged in the form of a ring with its ends electrically isolated from each other, one end being provided with an output connection, a cylindrical electrode disposed coaxially within the delay line so as to form an interaction space between it and the delay line, a cathode having an electron emissive surface disposed outside one end of, and extending substantially all around the axis of, the interaction space, and a further electrode system for guiding electrons emitted by the cathode into the interaction space.

In the operation of a tube according to the invention, a potential difference is applied between the delay line and the central electrode so as to establish a radial electric field in the interaction space, and an appropriately directed axial magnetic field is also established in the interaction space; suitable potentials are applied to the cathode and the further electrode system so as to inject electrons from the cathode into the interaction space from one end with a relatively low axial velocity, these electrons forming a beam which rotates in the interaction space about the axis of the interaction space at an angular velocity which is substantially directly proportional to the ratio of the strengths of the electric and magnetic fields established in the interaction space, the rotation of the electron beam being in a sense corresponding to movement along the delay line away from the output end. It will be appreciated that the oscillator may readily be tuned by variation of the potential difference between the delay line and the central electrode, and that the output of the oscillator may be readily amplitude modulated by variation of the electron beam current, which may be brought about by variation of the potential of an electrode in the further electrode system.

Since the axial velocity of the electrons is relatively low, they will remain within the interaction space for a time sufficient for substantially complete interaction to take place with the electromagnetic wave travelling along the delay line, the efficiency of the oscillator therefore being relatively unaffected by the existence of the axial velocity component of the electrons. Since the electrons may remain in the interaction space long enough to accomplish more than one complete revolution, it is desirable in order to avoid interference with the bunching of the electron beam that the circumferential electrical length of the interaction space should correspond approximately to an integral number of wavelengths, whatever the operating frequency. This requires that the phase velocity/frequency characteristic of the delay line should be such that the phase velocity is substantially directly proportional to frequency over the desired range of operating frequencies, which may be achieved by appropriate design of the delay line in accordance with the known properties of the type of delay line which is to be used; in this connection reference may be made for example to articles on pages 180 and 311 of volume 9 of "Annales de Radioelectricite" (1954), which deal with the properties of certain known types of delay line.

One electronic tube in accordance with the invention will now be described by way of example with reference

to the accompanying diagrammatic drawings, in which:

Figure 1 shows an axial section of the tube, taken along the line I—I in Figure 2; and

Figure 2 is a section along the line II—II in Figure 1.

Referring to the drawings, the tube is provided with an evacuated envelope, the main part of which is constituted by a cylindrical metal shell 1 whose ends are respectively sealed to tubular glass members 2 and 3. The tube incorporates a delay line of conventional interdigital form which is arranged in the form of a ring and is constituted by a series of L-shaped members such as 4 which are attached to the inside of the shell 1. One end of the delay line is provided with an output connection in the form of a coaxial line, which is constituted by a metal tube 5 sealed to the shell 1 in register with an aperture in the shell 1 and a metal rod 6 attached to one of the L-shaped members 7 and sealed through a plug 8 of electrically insulating material which is sealed in the outer end of the tube 5.

Some of the L-shaped members 9, 10 and 11 are coated with a suitable lossy material such as carbonyl iron powder attached by sintering, so as to provide electrical isolation between the ends of the line with respect to high frequency energy and to form a substantially reflectionless termination for the end of the line opposite the output end.

Coaxially disposed within the delay line is an electrode in the form of one end of a metal rod 12 of circular cross-section, an interaction space of annular cross-section thus being formed between the delay line and the rod 12. The rod 12 has sealed to it a metal flange 13 which is sealed to the end of the member 3 remote from the shell 1. Outside one end of the interaction space is disposed an indirectly heated cathode 14 having an annular electron emissive surface 15 which faces and is aligned with the interaction space, the cathode being heated by means of a heater 16. The tube also includes a further electrode system comprising two electrodes, one in the form of one end of a metal rod 17 coaxial with the rod 12, and the other in the form of one end of a tubular metal member 18 surrounding the cathode 14 coaxial with the rod 17; these two electrodes extend forward of the cathode 14 towards the interaction space, the end of the member 18 nearer the interaction space being provided with an inwardly directed annular flange 19. The member 18 has sealed to it a metal flange 20 which is sealed to the end of member 2 remote from the shell 1. The outer end of the member 18 is sealed by a plug 21 of electrically insulating material through which the cathode 14 is attached; likewise, the outer end of the member 22 is sealed by a plug 23 of electrically insulating material through which the rod 17 is sealed. Also sealed through the plug 23 are two leads (not shown) for the heater 16.

In operation of the tube, an axial magnetic field is established in the interaction space, for example by means of an electromagnet (not shown) disposed outside the envelope of the tube, and potentials are applied to parts of the tube as follows. Taking the potential of the rod 12 as zero, the delay line is maintained at a high positive potential applied via the shell 1, the cathode 14 is maintained at a relatively low negative potential applied via the member 22, the rod 17 is maintained at a relatively low positive potential, and the member 18 is maintained at a relatively low potential, which may be either positive or negative. The electrons emitted by the cathode 14 are thus focussed into an annular beam which is injected into the interaction space with a relatively low axial velocity, the beam current being variable by variation of the potential of the member 18 so as to amplitude modulate the output of the oscillator. On entering the interaction space, the electrons come under the influence of the crossed electric and magnetic fields, so that the electron beam rotates in the interaction space

about the axis of the interaction space at an angular velocity determined by the ratio of the strengths of these fields; the direction of the magnetic field is chosen so that the beam rotates in a sense corresponding to movement along the delay line away from the output end, that is clockwise in relation to Figure 2. Oscillations are thus generated by virtue of interaction between the rotating electron beam in the interaction space and an electromagnetic wave travelling along the delay line towards the output end such that a backward component of the field associated with the travelling wave has an angular velocity around the interaction space equal to the angular velocity of the electron beam. The output of the oscillator is of course derived via the output connection of the delay line, the oscillation frequency being variable as explained above by variation of the potential of the delay line. The delay line is designed, as explained above, in accordance with the requirement that over the desired range of operating frequencies the circumferential electrical length of the interaction space should correspond approximately to an integral number of wavelengths, whatever the operating frequency.

It will be appreciated that in a tube as described above, the area of the emissive surface of the cathode 14 may be made appreciably larger for a given size of delay line than is possible with the known form of construction referred to above, so that an appreciably higher output power may be obtained at a given operating frequency consistent with a reasonable cathode life. It will be further appreciated that variation of the potential of the delay line will have relatively little effect on the magnitude of the beam current, and therefore on the magnitude of the output power. An improvement of the tube in this latter respect may be brought about by coating appropriate parts of the tube with a substance, such as titanium, having a low secondary emission coefficient, in order to reduce the emission of secondary electrons into the interaction space; such secondary electrons can contribute to the useful current in the interaction space, their contribution, however, varying according to the value of the potential of the delay line and consequently giving rise to a variation of the output power as this potential is varied.

In an alternative arrangement to that described above, the reflectionless termination for the end of the delay line opposite the output end may be provided outside the envelope of the tube instead of being in the form of a coating of lossy material on segments of the delay line, a separate connection, which may suitably take the form of a coaxial line or a waveguide, being sealed through the envelope for the end of the delay line opposite the output end and the two ends of the delay line being electrically isolated by suitable screening. With this arrangement, energy at the desired oscillation frequency may be fed to the delay line via the termination so as to provide frequency locking.

I claim:

1. An electronic tube for use as a backward wave oscillator, comprising a delay line extending along a circular path and adapted to propagate an electromagnetic wave along said path from a first end of the delay line to a second end of the delay line, an output connection coupled to said second end of the delay line, means inhibiting direct transfer of high frequency energy between said ends of the delay line, a cylindrical electrode disposed coaxially within the delay line so as to form an interaction space between it and the delay line, a cathode having an electron emissive surface disposed outside one end of, and extending substantially all around the axis of, the interaction space, and a further electrode system for guiding electrons emitted by the cathode into the interaction space.

2. An electronic tube according to claim 1, in which over a range of operating frequencies the circumferential electrical length of the delay line corresponds approxi-

mately to an integral number of wavelengths, whatever the operating frequency.

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