July 9, 1946. A. D. BLUMLEIN 2,403,782

RESONATOR FOR DISCHARGE TUBES

Filed June 13, 1942

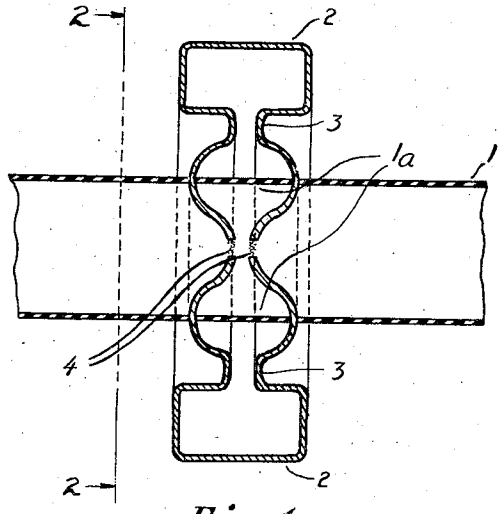


Fig. 1.

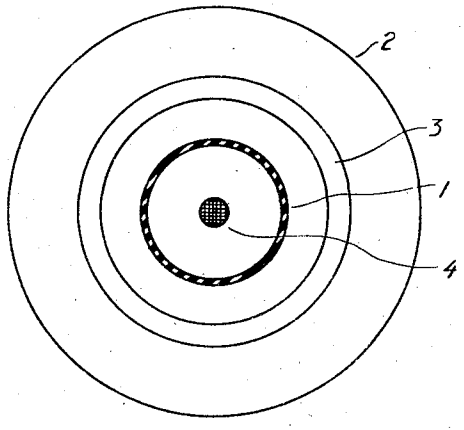


Fig. 2.

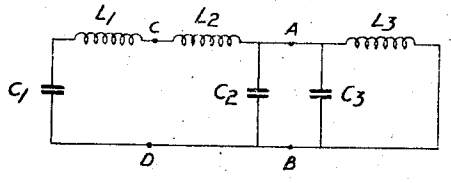


Fig. 3.

INVENTOR
Alan Dower Blumlein
BY
Loyd Hall Sutton
ATTORNEY

Patented July 9, 1946

2,403,782

UNITED STATES PATENT OFFICE

2,403,782

RESONATOR FOR DISCHARGE TUBES

Alan Dower Blumlein, Ealing, London W. 5, England; Doreen Blumlein, executor of Alan Dower Blumlein, deceased, assignor to Electric & Musical Industries Limited, Hayes, England, a company of Great Britain

Application June 13, 1942, Serial No. 446,974

In Great Britain September 23, 1940

1 Claim. (Cl. 315—5)

1

This invention relates to hollow electrical resonators and to electron discharge devices of the type employing such hollow resonators, said devices being particularly suitable for operation at ultra high frequencies.

Such devices comprise in general an evacuated envelope, means for generating a beam of electrons and a hollow resonator through which the electron beam is caused to pass. The hollow resonator can be employed for imparting velocity modulation to the electrons in the beam or for abstracting energy from a charge density modulated beam and one or more of such resonators may be used.

In employing devices of the type referred to, electric waves are set up within the hollow resonator and in order that the amplitude of the electric waves shall be as large as possible it is necessary to tune the resonator. Tuning may be effected by adjusting the size of the resonator so as to modify its own distributed capacity or inductance by deformation of the resonator, or by the insertion of metal plugs through the periphery of the resonator. It is difficult to effect such adjustments if the resonator is entirely within the evacuated space of the electron discharge device. Placing the resonator entirely outside the evacuated space reduces the coupling between the resonator and the electron stream and hence efficiency is low. It is therefore desirable to seal the resonator into the walls of the electron discharge device so as to retain good coupling with the electron stream and at the same time to permit the tuning of the resonator in a convenient manner. This latter arrangement usually involves the enclosure of a part of the envelope of the discharge device within the resonator, so that dielectric losses may be introduced and the efficiency of the resonator therefore reduced.

It may be desirable for other reasons to enclose within the resonator insulating material which extends between facing surfaces of the resonator. In such a construction dielectric losses may likewise be introduced.

It is the object of the present invention to provide a hollow electrical resonator or an electron discharge device of the type employing such a resonator in which the dielectric losses due to the enclosure of insulating material within the resonator are substantially reduced.

According to one feature of the invention a hollow electrical resonator which can be used with an electron discharge device is provided in which insulating material is arranged in the interior of the resonator and wherein said material is disposed in a position substantially coinciding with a region where, in operation, the intensity of the oscillatory electric field is a minimum so that the dielectric losses due to said insulating material are reduced.

2

According to another feature of the present invention there is provided an electron discharge device of the type referred to in which the resonator is arranged partly within and partly outside the envelope of the device so that a portion of said envelope is enclosed within said resonator and wherein said portion is arranged so that it substantially coincides with a region where, in operation, the intensity of the oscillatory electric field is a minimum, so that the losses due to said portion of the envelope are reduced.

Preferably, a constriction is provided in that portion of the resonator lying outside the evacuated envelope whereby the resonator can be readily deformed for tuning purposes and in the preferred construction of the resonator the latter and the constriction are circularly symmetrical about the axis of the envelope.

In order that the said invention may be clearly understood and readily carried into effect it will now be more fully described with reference to the accompanying drawing which illustrates the invention as applied by way of example to a construction in which the resonator lies partly within and partly outside the envelope of an electron discharge device.

In said drawing:

Figure 1 shows a cross section of a part of an evacuated envelope and a resonator in a plane passing through the axis of said envelope,

Figure 2 is a cross section of the apparatus shown in Figure 1 taken along the line 2—2, and

Figure 3 shows a diagram of the equivalent electrical circuit of said resonator.

Referring to Figures 1 and 2, a portion of the evacuated envelope 1 of insulating material is shown and a hollow resonator 2 which has circular symmetry about the axis of the envelope 1 and is provided with a circular constriction 3, is sealed into the envelope 1 so as to enclose the portion 1a thereof. The resonator 2 is provided with two oppositely disposed apertures 4, which may, if desired, be constituted by grids, through which a cathode ray beam developed in the envelope 1 may pass and either be modulated in velocity by potential differences set up between the aperture 4 or serve to set up such potential differences by reason of charge density modulation in said beam in known manner.

In operation, electric waves flow over the inner surfaces of the resonator **2**, and it is found that the presence of portions **1***a* of the envelope within said resonator gives rise to damping due to the dielectric losses in the material of which said envelope is composed. It is nevertheless possible according to the invention, to reduce these losses by locating the portion **1***a* so that it coincides substantially with a region where, in operation, the intensity of the oscillatory electric field is a minimum. The position of the part of the envelope not enclosed by the resonator is relatively immaterial since the oscillatory electric field is only set up in operation in the interior of the resonator.

The shaping of the resonator **2** and the constriction **3** may be determined from considerations of the equivalent electrical circuit shown in Figure 3. Referring to Figure 3, capacity C_1 and the inductance L_1 represent the equivalent lumped capacity and inductance respectively of that portion of the resonator **2** enclosed within the evacuated container **1**. The inductance L_2 represents the equivalent lumped inductance of that portion of the resonator **2** lying between the outer surface of the evacuated container **1** and the constriction **3**, and the inductance L_3 represents the equivalent lumped inductance of the portion of the resonator **2** lying outside the constriction **3**. The capacity C_2 represents the equivalent lumped capacity of the portion of the resonator lying outside the envelope up to and including the constriction **3** this capacity being mainly concentrated at the restriction, and the capacity C_3 represents the equivalent lumped capacity of the portion of the resonator **2** lying outside the constriction **3**. Let it be assumed that the inductance L_3 and the capacity C_3 of the portion of the resonator lying outside the constriction **3** are resonant at the frequency of operation f. Then the circuit comprising these two elements L_3 and C_3 will have a high impedance as viewed from the points A and B and consequently will have little effect upon the remainder of the circuit. If, in addition, it be assumed that the inductance L_2 and the capacity C_2 of that portion of the resonator **2** lying between the envelope **1** up to and including the constriction **3** are also resonant at the frequency f, then a very low impedance will be presented at the points C, D, so that in operation currents flowing in the system due to oscillations set up in the inductance L_1 and the capacity C_1 of the portions of the resonator **2** enclosed within the envelope **1** will only give rise to a small voltage at the points C, D. Thus, a voltage node is formed in the neighbourhood of the ends of the portion **1***a* of the envelope and the intensity of the oscillatory electric field set up in the region of said enclosed portion **1***a* of the envelope is thus substantially zero and the dielectric losses therein diminished.

It will be appreciated therefore that the resonator **2** and its constriction **3** should be so shaped and arranged that

$$L_1C_1=L_2C_2=L_3C_3$$

If desired, the inductances L_1, L_2, L_3 may be made equal and the capacities C_1, C_2, C_3 also made equal, but it is preferable to shape the resonator **2** and its constriction **3** so that

$$L_2=\frac{L_1}{n} \qquad C_2=nC_1$$

$$L_3=mL_1 \qquad C_3=\frac{C_1}{m}$$

where m and n are greater than unity, since, under these conditions the loss introduced by the resistance of L_2 and L_3 is maintained at a low value.

In practice, the capacity C_2 between the opposite walls of the constriction **3** is the most easily adjusted parameter of the system, and adjusting means of any known type are preferably provided for adjusting the spacing between said walls for this purpose. As far as possible, however, the resonator **2** and its constriction **3** should be shaped so that the desired relationship between the various capacities and inductances referred to shall hold without much adjustment of the capacity C_2 in this manner, as excessive adjustment of this capacity is likely to result in the voltage node becoming displaced from the region of the portions **1***a* of the envelope.

It will be appreciated that in an arrangement according to the invention the resonator is equivalent to a plurality of effective inductive elements and a plurality of effective capacitative elements and such a system is always capable of exhibiting a plurality of resonant frequencies. For example, the equivalent circuit shown in Figure 3 will exhibit a high resonant impedance across the capacity C_1 not only at the frequency at which approximately the individual capacities tune with the individual inductances, but also at a lower frequency where the total effective capacity resonates with the total effective inductance. Thus, in employing the electron discharge device according to the invention in an electric circuit it is necessary for the resonator to be excited at an appropriate frequency to ensure that a voltage node occurs in the vicinity of the ends of the insulating material enclosed by the resonator. In practice, of course the capacities and inductances referred to are not discretely lumped as shown in Figure 3, but are in the main finely distributed throughout the resonator. The circuit diagram of Figure 3 therefore serves mainly to show the basic principle of the device.

In the example shown in Figure 1, the electric lines of force are effectively straight in the region of the voltage node, but in some constructions of resonator the electric lines of force in the region of the voltage node may not be straight, in which case it may be desirable to shape the insulating material or the portion of the envelope of the device enclosed within the resonator so as to conform approximately to the shape of the electric lines in the region in which the intensity of the oscillatory electric field is a minimum.

It will also be appreciated that in order to maintain the dielectric losses very small it is not necessary that the insulating material should lie exactly in the region in which the intensity of the oscillatory electric field is zero since the losses can be substantially reduced providing the insulating material lies in a region in which the intensity of the oscillatory electric field is small.

Although in the above example a resonator having circular symmetry about the axis of the envelope has been shown, it will be appreciated that other shapes of resonator and apertures therein may also be used.

What I claim is:

An electron discharge device having an elongated envelope, a cavity resonator extending through and transverse of the envelope and having an axis of rotation coaxial with the axis of

said envelope, the transverse section of said resonator comprising a central hour-glass shaped portion surrounded by a cylindrical shaped portion, the hour-glass and cylindrically shaped portions communicating with each other through a

radially directed passageway, the walls of the envelope extending between the inner walls of the hour-glass shaped portion of the cavity resonator intermediate its smaller portions.

ALAN DOWER BLUMLEIN.