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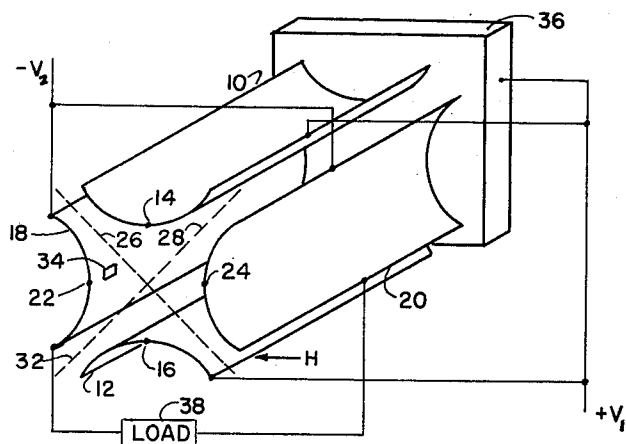


FIG. 1

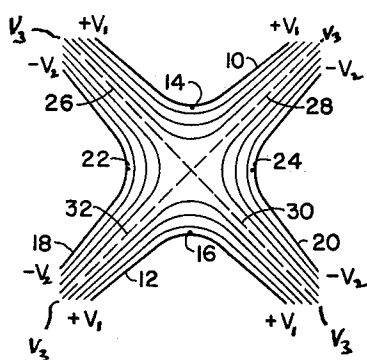


FIG. 2

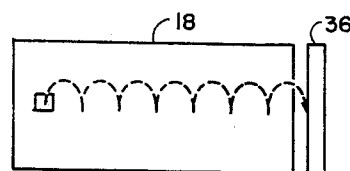


FIG. 3a

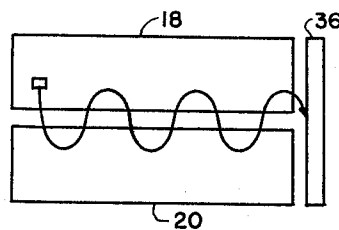


FIG. 3b

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3 Claims. (Cl. 315-18)

My invention is directed toward strophotron oscillators.

A strophotron oscillator is a multitransit electron tube adaptable for use in the VHF and UHF frequency ranges and is described, for example, in an article entitled "A New Electron Tube: The Strophotron" by Hannes Alfvén and Dag Romell, published in the Proceedings of the I.R.E., page 1239, vol. 42, No. 8, August 1954.

In my copending application Serial No. 680,761, filed August 28, 1957 I disclosed a new and improved strophotron provided with an elongated accelerator having a uniform cross section defining an upper branch of an hyperbola. This strophotron further includes first and second separated plane reflectors so positioned as to coincide with corresponding portions of the first and second asymptotes of the upper hyperbola branch, the reflectors and the accelerator extending in the same direction.

The accelerator is maintained at a high positive potential relative to the reflectors, thus establishing an electric field therebetween. This field, due to the geometry of the accelerator and reflectors, creates an hyperbolic electric potential distribution within the entire region bounded by the accelerator and the reflectors. Stated differently, the potential V of any point within this region is proportional to the quantity $(y^2 - x^2)$, wherein y is the vertical separation between this point and the intersection of the first and second asymptotes and x is the horizontal separation between this point and this intersection.

A uniform magnetic field is established within this region, the magnetic field vector pointing in a direction perpendicular to a plane of symmetry extending equidistantly between the reflectors and passing through the central point of the upper hyperbola branch.

A cathode is mounted in one of the reflectors adjacent one end of the accelerator, and an anode or collector maintained at a high positive potential relative to the reflectors is positioned adjacent the other end of the accelerator. A load, which can be for example a resistor or a resonant circuit tuned to the oscillator frequency, is coupled between the two reflectors.

Under these conditions, electrons emitted from the cathode will migrate toward the collector along a curved path and will exhibit the characteristic strophotron behavior; i.e. the projection of this path onto the plane of symmetry resembles a trochoid, while the projection of this path onto a second plane, perpendicular to the plane of symmetry and extending in the direction of the reflectors, resembles a damped sinusoid having an axis defined by the intersection of the two planes.

However, in common with the known strophotrons, the above described strophotron suffers from certain common disadvantages. For example, for a fixed cathode position, the magnetic field intensity required increases as the oscillation frequency increases, and eventually the required intensity becomes prohibitively high.

The required magnetic field intensity can be reduced by increasing the vertical separation between the cathode and the central point of the hyperbolically shaped por-

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tion of the accelerator. However, as this separation is increased, the direct potential at the point at which the emitted electrons intersect the plane of symmetry will decrease and eventually will be substantially equal to the direct reflector potential. The power output of the strophotron for a fixed tube geometry and fixed values of applied potentials, varies directly with the difference in direct potential between the reflectors and this point of intersection. Hence, as the vertical separation between the cathode and the central point of the hyperbola portion decreases, the power output of a strophotron also decreases.

I have invented a new type of strophotron which overcomes these difficulties.

Accordingly it is an object of the present invention to provide a new and improved strophotron of the character described.

Another object is to improve strophotron operation by reducing the magnetic field intensity required for operation at any given frequency within the strophotron frequency range.

Still another object is to increase the power output of a strophotron having a fixed tube geometry and fixed values of applied potentials.

These and other objects of my invention will either be explained or will become apparent hereinafter.

In accordance with the principles of my invention, I provide first and second separate, electrically conductive, elongated accelerators, each of which has a uniform cross section defining a branch of an hyperbola. The accelerators are placed parallel to each other and are so oriented as to respectively form upper and lower branches of an hyperbola. Hence, the two accelerators are disposed about a first plane of symmetry which extends in the same direction as the accelerators and which passes through the central points of both hyperbola branches.

I further provide first and second separate, electrically conductive, elongated reflectors extending in the same direction as the accelerators, each reflector having a uniform cross section defining a branch of an hyperbola. The two reflectors are symmetrically disposed about opposite sides of the first plane of symmetry. Hence, the two reflectors are disposed about a second plane of symmetry perpendicular to the first plane of symmetry and passing through the central points of both reflectors. Each reflector together with its adjacent accelerator defines a common hyperbolic asymptote therebetween.

The accelerators are maintained at a high positive potential relative to the reflectors, thus establishing an electric field therebetween. This field, due to the geometry of the accelerators and the reflectors, establishes an hyperbolic electric potential distribution within the electron interaction region bounded by the reflectors and accelerators. More particularly, the potential V at any point within this region is proportional to the quantity $(y^2 - x^2)$ wherein y is the perpendicular separation between this point and the second plane of symmetry and x is the perpendicular separation between this point and the first plane of symmetry.

A uniform magnetic field is established within the electron interaction region, the magnetic field vector pointing in a direction perpendicular to the first plane of symmetry.

A cathode is mounted in one of the reflectors at a point intermediate the central point of the said one reflector and one of the accelerators and adjacent one end of both accelerators. An anode or collector maintained at a high positive potential relative to the reflectors is positioned adjacent the other end of both accelerators. A load is coupled between the two reflectors.

Under these conditions, electrons emitted from the

cathode will migrate toward the collector along a curve confined between said one accelerator and the second plane of symmetry and will again exhibit the characteristic strophotron behavior; i.e. the projection of this path onto the first plane of symmetry resembles a trochoid, while the projection of this path onto the second plane of symmetry resembles a damped sinusoid having an axis defined by the intersection of the two planes.

By virtue of this arrangement, for a given power output, the required magnetic field intensity can be substantially reduced over that hitherto required. Conversely, for a given field intensity, the power output can be substantially increased over that hitherto obtainable.

An illustrative embodiment of my invention will now be described with reference to the accompanying drawings, wherein

Fig. 1 is an isometric view of a strophotron in accordance with my invention;

Fig. 2 is a graph of the electric potential distribution between the accelerators and the reflectors shown in Fig. 1; and

Figs. 3a and 3b are graphs of the motion of favorably phased electrons in the interaction region between the accelerators and the reflectors.

Referring now to Fig. 1, enclosed in an evacuated tube envelope (not shown) is a pair of first and second, vertically displaced, electrically conductive, elongated accelerators 10 and 12. Each accelerator has a uniform cross section defining a branch of an hyperbola. The first accelerator 10 forms an upper hyperbola branch having a central point 14, while the second accelerator 12 forms a lower hyperbola branch having a central point 16. Thus, the two accelerators are disposed upon a first plane of symmetry which extends in the same direction as the accelerators and which passes through central points 14 and 16.

Further provided are first and second horizontally displaced, electrically conductive, elongated reflectors 18 and 20 extending in the same direction as accelerators 10 and 12. Each reflector has a uniform cross section defining a branch of an hyperbola. The two reflectors are symmetrically disposed about opposite sides of the first plane of symmetry so as to define left and right hand hyperbola branches; the left hand branch having a central point 22, the right hand branch having a central point 24. Hence, the two reflectors are disposed about a second plane of symmetry perpendicular to the first plane of symmetry and extending through the central points 22 and 24.

A uniform magnetic field is established within the region bounded by the accelerators and reflectors, the magnetic field vector pointing in a direction perpendicular to the first plane. (Means for establishing this field are conventional and are not shown here.) Each reflector together with its adjacent accelerator defines a common hyperbola asymptote therebetween; consequently, there are four asymptotes 26, 28, 30 and 32.

The two accelerators 10 and 12 are coupled to a point of positive direct potential $+V_1$. The two reflectors are coupled to a second point of negative potential $-V_2$. As a result, the electric field established between the accelerators and reflectors establishes an hyperbolic electric potential distribution within the electron interaction region. (Note that the accelerators and the reflectors are extended sufficiently to substantially eliminate fringe electric fields.)

A cathode 34 is mounted in reflector 18 at a point intermediate the central point 22 of this reflector and accelerator 10, the cathode being adjacent one end of both electrodes. An anode or collector 36 maintained for convenience at the same potential as the accelerators 10 and 12, is positioned adjacent the other end of both accelerators. A load 38 which can be purely resistive, but, in this example, is a resonant circuit tuned to the oscillation frequency, is coupled between reflectors 18 and 20.

Electrons are emitted from the cathode at an extremely low velocity and enter the interaction region. Many of these electrons then drift toward the collector along a curved path and exhibit the characteristic strophotron behavior.

More particularly, the projection of this path onto the first plane of symmetry resembles a trochoid as shown in Fig. 3a. Further, the projection of this path onto the second plane of symmetry resembles a damped sinusoid as shown in Fig. 3b. The sinusoidal frequency is the oscillation frequency and is primarily determined by the electric field established between the accelerators and the reflectors; the trochoid frequency is determined by both the magnetic and electric fields and is independent of the oscillation frequency. (The magnetic field intensity is adjusted to a value at which electrons are prevented from impinging on and being collected by the accelerator.)

The hyperbolic electric field distribution between the accelerators and the reflectors is plotted graphically in Fig. 2. As will be seen from Fig. 2, the electric potential V for any point P between the accelerators and the reflectors is proportional to the quantity $(y^2 - x^2)$, where y is the vertical separation between point P and a line 50 extending between central points 20 and 22, and x is the horizontal separation between point P and a line 52 extending between central points 14 and 16. The equipotential surfaces 54 are families of right hyperbolas with the lines $y = \pm x$ as asymptotes 26, 28, 30, 32. Note that since the accelerators define surfaces of $+V_1$ potential and the reflectors define surfaces of $-V_2$, the asymptotes 26, 28, 30 and 32 define lines of an intermediate potential V_3 .

The oscillation frequency, as indicated previously, is determined by the electric field. Further, the electrons, in moving toward and away from the reflectors, induce an alternating voltage of oscillator frequency across the load, and this voltage acts on the electrons to produce the damping action. More specifically, when an electron leaves the cathode and enters the interaction region at such times as to be in phase with the induced voltage (such an electron is termed a favorably phased electron), it will oscillate back and forth between the planes in the manner indicated. The electrons will enter the interaction region at such times as to be out of phase with the induced voltage impinge on a reflector on the first or second pass, and are thus removed from the interaction region. Hence, only the favorably phased electrons remain in the interaction region for an appreciable period, and the oscillator voltage appearing across the load is not substantially affected by out of phase electrons.

The amplitude of the sinusoidal motion of any electron is determined by the vertical displacement between this electron and the central point of the appropriate hyperbola branch, the amplitude decreasing as the displacement increases.

However, by virtue of the hyperbolic electric field distribution the oscillation frequency remains constant despite changes of vertical displacement.

It will be seen from a study of Figs. 1 and 2 that the potential at the point at which the electrons emitted from cathode 34 intersect plane A will vary between the limits of $+V_1$ and V_3 depending upon the separation between cathode 34 and the central point 22 of accelerator 10.

In the prior art of which I am aware the reflectors are maintained at ground potential; hence, in this situation, as the cathode is moved away from the accelerator, the potential of the point of intersection of plane A approaches V_3 and the power output (which varies directly with the difference in potential between this point and the reflectors) approaches zero. In contradistinction, in my invention the reflectors are maintained at a potential of $-V_2$, and as the cathode is moved away from the accelerator, the power output decreases at a much slower rate and ultimately attains a reasonably large finite value.

Further, for a given power output, the conventional

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cathode-accelerator separation must be substantially smaller than the separation required in my invention, and hence the required magnetic field intensity in my invention under these conditions is substantially less than that required by the prior art.

While I have shown and pointed out my invention as applied above, it will be apparent to those skilled in the art that many modifications can be made within the scope and sphere of my invention as defined in the claims which follow.

What is claimed is:

1. In a strophotron, first and second, vertically separated, electrically conductive, elongated accelerators extending in the same direction, each accelerator having a uniform cross section defining a branch of an hyperbola, said accelerators having positions at which, in cross section, said first and second accelerators respectively form upper and lower hyperbola branches; first and second horizontally separated, electrically conductive, elongated reflectors extending in said direction, each reflector having a uniform cross section defining a branch of an hyperbola, said reflectors having positions at which, in cross section, said first and second reflectors respectively form left hand and right hand hyperbola branches, any reflector together with any adjacent accelerator defining a common hyperbolic asymptote therebetween; first means coupled to said accelerators to establish a first direct potential thereon; second means coupled to said reflectors to establish a second direct potential thereon, said first potential being more positive than said second potential; means to establish a time invariant magnetic field about said reflectors and said accelerators, the magnetic field vector pointing perpendicular to a plane extending between the central points of the upper and lower hyperbolic branches in said direction; said first reflector being provided with a slot adjacent one end thereof; a cathode mounted within said slot; and a collector positioned adjacent said accelerators and said reflectors at the other end of said first reflector, said collector being coupled to said first means.

2. In combination, first, second, third and fourth separated, elongated, electrically conductive members extending in the same direction, each member having a uniform cross section defining a branch of an hyperbola, said first and second members being designated as accelerators and having positions at which the central points of their respective hyperbola sections face each other thereby defining a first plane of symmetry extending between said accelerator central points in said direction, said third and fourth members being designated as

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reflectors and being symmetrically disposed about opposite sides of said first plane, said reflectors having positions at which their respective hyperbola sections face each other thereby defining a second plane of symmetry extending between said reflector central points in said direction, said first and second planes being mutually perpendicular, means to establish a time invariant magnetic field having its field vector pointing perpendicular to said first plane, said third member being provided with a slot adjacent one end thereof; a cathode mounted within said slot; and a collector positioned adjacent said first, second, third and fourth members at the other end of said third member.

3. In combination, first, second, third and fourth separated, elongated, electrically conductive members extending in the same direction, each member having a uniform cross section defining a branch of an hyperbola, said members having positions at which said first, second, third and fourth members in cross section respectively define upper, lower, left hand and right hand hyperbola branches, any two adjacent members defining a common hyperbolic asymptote therebetween, said first and second member being electrically interconnected to a first point of direct potential, said third and fourth members being electrically interconnected to a second point of direct potential, said first point being more positive than said second point, means to establish a time invariant magnetic field about all of said members, the magnetic field vector pointing parallel to a line joining the central points of said left hand and right hand hyperbola branches, said third member being provided with a slot adjacent one end thereof; a cathode mounted within said slot; and a collector positioned adjacent said first, second, third and fourth members at the other end of said third member, said collector being coupled to a third point of direct potential, said third point being at least as positive as said first point.

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