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MAGNETRON BEAM SWITCHING TUBE

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FIG. 1

FIG. 2

FIG. 3

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MAGNETRON BEAM SWITCHING TUBE
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This invention relates to multi-position magnetron beam switching tubes and, particularly, to improved electrode arrangements for such tubes.

One type of multi-position beam switching tube operates with crossed electric and magnetic fields and includes a cathode and a plurality of groups of electrodes surrounding the cathode, each group of electrodes comprising a position at which an electron beam may be formed and from which an output signal may be derived. Each group of electrodes includes a target or output electrode which defines the electron beam and provides an output signal therefrom, a spade electrode which forms and holds the electron beam on its associated target electrode, and a switching electrode which is used to switch an electron beam from one position or group of electrodes to the next. A longitudinal magnetic field is used in operation of this type of tube, and the magnetic field may be provided by a cylindrical magnet secured to and surrounding the tube envelope or by a plurality of magnet rods positioned within the electrode assembly or in any other suitable manner.

One problem which has faced users of beam switching tubes results when an attempt is made to draw unusually large target currents. Because of the fact that the targets have a pentode-type operating characteristic which is desirable in general, the potential of a target must be maintained in a relatively narrow range of positive potentials for stable operation. If the potential of a target is reduced below this range of potentials, then the target is unstable and spurious switching of an electron beam, from this target to the next, takes place. This instability arises from the fact that a target, when lowered to a certain level of potential, is unable to collect all of the electrons in the electron beam which flows to it. The excess electrons spread out, flow to adjacent electrodes, and ultimately cause spurious switching. Methods are known for overcoming this problem; however, such methods require comparatively complicated and expensive circuitry.

Another problem in the use of the above-described beam switching tubes results from the physical relationship of the target and switching electrodes in any group of electrodes. Since the target and switching electrodes are adjacent to each other electrically and the electric field of one affects the other, the potential on a target electrode at any instant affects the operation of the switching electrode. Thus, the switching characteristics of the tube are affected by the target potentials.

Accordingly, the principles and objects of the present invention are concerned with the provision of an improved multi-position magnetron beam switching tube in which the operating stability and the efficiency of the switching operation are generally independent of target voltage.

The purposes and objects of the invention are accomplished by means of a novel electrode arrangement in a magnetron beam switching tube. The tube includes a central cathode and a plurality of groups of electrodes surrounding the cathode. Each group of electrodes includes a spade electrode which is closest to the cathode. The space between adjacent spades defines a path for an electron beam. A target or output electrode lies behind the spade with an unobstructed current flow path provided between each target and the cathode. Each group of electrodes also includes a rod-shaped electrode and an auxiliary electrode which occupy the space between adjacent groups of electrodes. The rod-shaped electrode may be used essentially as a switching electrode and the auxiliary electrode may be used essentially as a shield electrode which makes the switching electrode substantially independent of the target electrically.

The invention is described in greater detail by reference to the drawings wherein:

FIG. 1 is a perspective view of a magnetron beam switching tube embodying the invention;
FIG. 2 is a plan view of the electrode assembly of the tube of FIG. 1;
FIG. 3 is a schematic representation of the tube of FIG. 1 and a circuit in which it may be operated;
FIG. 4 is a graph illustrating the characteristics of one aspect of the operation of a tube embodying the invention;
FIG. 5 is a graph illustrating the characteristics of another aspect of the operation of a tube embodying the invention;
FIG. 6 is a schematic representation of the tube of FIG. 1 and another circuit in which it may be used;
FIG. 7 is a schematic representation of the tube of FIG. 1 and still another circuit arrangement in which it may be used; and
FIG. 8 is a schematic representation of the tube of FIG. 1 and still another circuit arrangement in which it may be used.

Referring to FIGS. 1 and 2, the principles of the invention are embodied in a magnetron beam switching tube 10 which includes an envelope 12 which contains an electrode assembly 14 comprising a central longitudinally elongated indirectly heated electron emitting cathode 16 and ten groups of elongated electrodes spaced radially from and surrounding the cathode.

Each group of electrodes represents a position at which an electron beam may be formed and from which a corresponding output signal may be derived. An electron beam may be switched from position to position under the influence of crossed electric and magnetic fields within the electrode assembly. The direction in which an electron beam tends to switch is determined by the orientation of these fields and may be clockwise or counter-clockwise. The electrode configuration shown is adapted for clockwise movement of an electron beam. The configuration may be reversed for counter-clockwise movement. A position which is ahead of an electron beam at any instant is known as a leading position, and its electrodes are leading electrodes. A position which is behind the beam is known as a lagging position, and its electrodes are lagging electrodes. In addition, the terms "leading" and "lagging" are applied to appropriate portions of the individual electrodes in each group of electrodes.

According to the invention, each group of electrodes includes four electrodes rather than three as in prior art commercial magnetron beam switching tubes. This advance provides added flexibility and utility in magnetron beam switching tubes so that they are now able to perform operations which, heretofore, could not be performed satisfactorily.

Referring to FIGS. 1 and 2, each group of electrodes in the tube 10 includes a spade electrode 18 which is substantially the same in structure and function as the spade electrode in prior art magnetron beam switching tubes such as the type 6700 tube. Each spade electrode serves to form and hold an electron beam on its associated target electrode. The spade electrodes are generally U-shaped and each includes a base portion 20 which is closest to the cathode and from which two arms 22 and 24 extend substantially radially in a direction away from the cathode.
The spade electrodes are generally elongated and are disposed parallel to the cathode aligned on a circle having the center of the cathode 16 as its center. The spade electrodes are the closest electrodes to the cathode and adjacent spades provide, between them, a space or path through which an electron beam may flow.

Each group of electrodes also includes a target or output electrode 26 which is intended to be the primary receiver of an electron beam and from which an output signal is derived. In the embodiment of the invention shown in FIGS. 1 and 2, this target electrode also performs the function of providing the required longitudinal magnetic field within the envelope. Accordingly, the target is a permanent magnet and is preferably in the form of a rod.

Any other suitable means for providing a longitudinal magnetic field may also be used. The targets are oriented parallel to the cathode and lie on a circle having the center of the cathode as its center. The target rods are more remote from the cathode than the spade electrodes 18 and are positioned to receive an electron beam flowing from the cathode. In the embodiment of FIG. 1, each target rod is positioned substantially between the arms of the associated spade electrode but closer to the leading arm so that, if the leading arm were extended radially, it would strike the target rod at about the most leading portion of its surface or somewhat in the lagging direction thereof.

The target is thus radially aligned with its spade and is positioned favorably to receive an electron beam without being undesirably close to a rod-like switching grid electrode 28 which is also provided in each group of electrodes.

The switching grids 28 are parallel to the cathode and lie on a circle having the center of the cathode as its center. Each switching grid is substantially radially aligned with the lagging arm of the adjacent leading spade electrode and is immediately adjacent to that arm. In any one group of electrodes, the switching grid associated with that group of electrodes is at the leading side of the group.

According to the invention, each group of electrodes also includes generally a L-shaped auxiliary electrode 30 which, in the tube 10, is called a shield grid because one of its important functions is to shield each target electrode 26 from the associated switching electrode 28. The auxiliary electrode 30 is positioned between and occupies the space between each target 26 and its switching grid 28 and thus serves to electrically isolate the latter two electrodes from each other. The resultant advantages of this construction are described below. The auxiliary electrode is shaped and positioned so that it performs its function without interrupting the electron flow path between the cathode and a target electrode.

The L-shaped auxiliary electrode 30 includes a first generally radial arm 32 which includes a leading end 34 and a trailing end 36. The radial arm 32 is substantially aligned with the lagging arm 22 of the adjacent leading spade 18, and the leading end 34 of the radial arm is closely adjacent to the switching electrode 28 which lies between it and the lagging arm of the leading spade. The auxiliary electrode 30 also includes a transverse arm 38 which defines the radial extent of each group of electrodes.

The transverse arm 38 extends perpendicularly from the trailing end 36 of the radial arm 32 and extends in a lagging direction, to close to the target rod 26 with which it is associated. The transverse arm thus closes the space between adjacent target rods 26.

A suitable circuit for operating the tube 10 is shown in FIG. 3. The tube is shown schematically in linear form with only five groups of electrodes or beam positions illustrated. In the circuit, the cathode 14 is connected to ground. Each of the spade electrodes 18 is connected through a suitable spade plate resistor 40 to a common spade bus bar 42 which is suitably coupled by lead 44 to a positive D.C. power supply Vp of about 250 volts. A suitable zero-set circuit for setting an electron beam at the "0" position after the tube has been cleared is provided. This may be simply a switch 45 connected between the "0" spade and ground. Each target rod electrode 26 is connected through a suitable target load resistor 46 to a target bus bar 48 which is coupled to a suitable positive D.C. power supply Vp of about 300 volts. Each target is also provided with a terminal 50 which may be connected to any suitable utilization device, for example, an indicator tube, a printing mechanism, or the like. The auxiliary electrodes 30 are connected together and are connected by lead 51 to the spade bus 42 whereby the positive spade bus potential is applied thereto. The switching grid electrodes 28 are connected in two sets, with the electrodes at the even-numbered positions in one set and the electrodes at the odd-numbered positions in the other set. Each set of switching electrodes is connected to one of the output terminals of a suitable flip-flop 56. A source 58 of suitable switching pulses is coupled to the input of the flip-flop. The switching electrodes are biased at a small positive voltage, for example, about 25 volts in any suitable manner. This bias may be applied through the flip-flop circuit.

In operation of the circuit of FIG. 3, each input pulse from the source 58 to the flip-flop 56 provides an output pulse which is coupled to one of the sets of switching grids which thereby causes the electron beam in the tube 10 to be switched by one position. As an electron beam flows to a position, most of the electrons in the beam are collected by the target rod electrode usually aligned with the target and are disturbed users of beam Switching tubes in the past. It has been customary, in many applications, to couple each target under circumstances where the target electrode is reduced to a considerably low potential, such as cathode potential, a target may not be able to collect all of the electrons which are available to it. This represents a condition of instability and ordinarily would cause spurious switching of the electron beam to the next leading position. However, the auxiliary electrode 30 associated with the target electrode which is receiving an electron beam is able to collect any electrons which cannot be collected by the target so that stability is maintained. Thus, the target may be reduced to substantially a zero potential without adversely affecting stable operation of the tube.

The significance of the auxiliary electrode 30, also known as a shield grid, may be clearly illustrated by reference to FIG. 4 in which curve Ia shows the variation in target current with target potential and curve Ib shows the variation in shield grid current with target potential. In prior art magnetron beam switching tubes, the stability of the tube depends to a considerable extent upon the level of target voltage. At low target voltages (voltages below the knee of the target characteristic curve Ia), the tube tends toward instability because all of the available current cannot be collected by a target and some current leaks to other tube elements. This current leakage is able, if not controlled, to cause spurious switching of an electron beam from one position to the next. FIG. 4 illustrates how, according to the invention, this leakage current is collected in tube 10 by the shield grid 30 as the target voltage falls below the knee of its characteristic curve. It is this function of the shield grid that makes operation of tubes embodying the invention substantially independent of target voltage. Previously, operation below the knee of the target characteristic curve was possible to a limited extent by means of comparatively complex circuit arrangement; however, with the addition of the shield grid, operation without such circuitry and with target potentials as low as zero volts is possible.

The above-described function of the auxiliary electrodes 30 has solved a problem which often disturbed users of beam switching tubes in the past. It has been customary, in many applications, to couple each target
of a beam switching tube to one of the cathodes of a cold cathode gaseous indicator device such as the 6844A indicator tube. Such a tube has a characteristic gas ionization time, which accompanies cathode glow, and this time may be of the order of two to five microseconds. During this time interval, the indicator tube represents an extremely high impedance. Thus, there is a strong tendency for the target to "bottom," that is, to drop to cathode potential. If it were not for the shield grid, this "bottoming" would result in excessive current leakage and spurious switching. However, as illustrated by Fig. 4, during this short time interval when the target has "bottomed," the shield grid 30 effectively absorbs the excess leakage current and prevents spurious switching due to instability. Finally, when the indicator tube fires, the target potential rises to a level at which it can collect the electrons in a beam. This new operating characteristic of the tube of the invention is equally useful in the operation of all non-linear devices, such as gas discharge tubes, relays and pulse transformers.

Improved switching characteristics are closely associated with the improved target characteristics described above. Practice and theory show that the position of a target electrode with respect to its associated switching electrode and the relative electrical potentials of these electrodes affect the efficiency of operation of the switching electrode in performing a beam switching operation. It has been found in prior art beam switching tubes that the amplitude of the switching pulse applied to the switching electrodes from the flip-flop to cause a beam to switch positions is dependent, in general, upon the potential of the target to which a beam is flowing at any instant. This means that, as the target voltage is increased a larger switching pulse amplitude is required to effect proper switching action. This results essentially from the fact that a more dense, more compact electron beam is associated with high target potentials. Conversely, as the target potential is lowered, the electron beam becomes less compact, leakage currents increase, and a smaller amplitude switching pulse is required to effect switching.

However, in the tube embodying the invention, each switching electrode 28 primarily sees the potential of the auxiliary electrode 30 and is thus primarily influenced thereby. The switching electrodes are, accordingly, substantially unaffected by target potential. This aspect of the invention is illustrated in Fig. 5, in which curves A and B represent switching voltage and target voltage at different switching grid positive bias voltages, for example, approximately 25 and 15 volts, respectively. The curves show that, for a particular bias voltage, substantially the same magnitude of switching pulse will cause a beam to switch although the target voltage may vary over a relatively wide range.

It is also known that the potential of the target electrode, in general, has its electrical effect on the switching electrode and thus has its influence on the switching operation. This is particularly evident at higher frequencies of tube operation. In normal operation of a beam switching tube, when an electron beam is switched and flows to a target electrode, the potential of the target is reduced to some low level. Later, when a switching pulse is applied to the associated switching electrode to cause the beam to switch to the next position, the switching operation is aided by this relatively low potential on the target. However, as the speed of operation of the tube is increased, the resistance-capacitance time constant of the target circuits prevent a target from dropping to this favorable low potential when it receives a beam before the next switching pulse is applied. The faster the operation, the higher the target potential remains. Thus, since the target is at an undesirably high potential at the time the switching operation is to occur, the switching operation is made more difficult and a larger driving pulse is required.

However, in the tube 10 embodying the invention, since each switching electrode always sees primarily the potential of the auxiliary electrode 30, it is substantially unaffected by target potential. Thus, the tube 10 is characterized by uniform operation independent of the frequency of operation.

In addition to the usual operations for which tube 10 may be employed, the auxiliary electrodes 30 may be utilized in many different ways. For example, referring to Fig. 6, which is assumed to include all of the necessary connections shown in Fig. 3, a source of negative switching pulses 60 is shown coupled to the auxiliary electrodes 30. The source of switching pulses is adapted to apply a negative pulse to the auxiliary electrode associated with the target electrode which is receiving an electron beam at the same time that a switching pulse is applied to the associated switching electrode to cause the electron beam to switch to the next position. A negative pulse applied to an auxiliary electrode in this manner promotes a condition of instability of the type described and aids the switching operation.

In Fig. 7, each of the auxiliary electrodes 30 is provided with an output terminal 62 which may be used to obtain an output signal when an electron beam is switched from one position to another. The output pulse thus provided may be used, for example, to drive a subsequent tube in a cascade counter or for any other suitable purpose.

In Fig. 8, each auxiliary electrode 30 is electrically connected to the lagging spade electrode immediately adjacent thereto by a lead 64. This connection causes a negative pulse to be applied to the lagging spade electrode during a beam switching operation. This arrangement imparts desirable characteristics to the electron beam and improves tube operation.

The principles and advantages of the invention are clearly illustrated in the foregoing discussion of the invention. The requirements of the various electrodes and the tube in general are clear, and those skilled in the art will appreciate that various modifications might be made in the tube structure and in the associated circuitry within the scope of the invention.

What is claimed is:

1. A magnetron beam switching tube of the type utilizing crossed electric and magnetic fields to control the flow of an electron beam and operating to switch an electron beam in a direction determined by the orientation of said fields and known as the leading direction, said tube having an electrode assembly including a cathode for providing a stream of electrons and a plurality of groups of electrodes surrounding the cathode, each group of electrodes defining an electron beam receiving region and including a target electrode for receiving an electron beam and providing an output signal therefrom, a spade electrode lying between said cathode and the target electrode for forming and holding an electron beam thereon, said spade and target electrode receiving region, a switching electrode spaced from said target and spade electrodes and lying generally at one side of said electron beam receiving region, a switching electrode spaced from said target and spade electrodes and lying generally at the other side, the leading side, of said beam receiving region, and an auxiliary electrode lying outside of the current flow path from cathode to target and substantially completely enclosing the space between said target electrode on one side and both said switching electrodes on the other side and the target electrode of the next leading group, the auxiliary electrode thus being positioned to collect leakage current from an electron beam flowing to a target and to provide a favorable electric field configuration to render a target able to receive an electron beam over a wide range of target potentials.

2. The tube defined in claim 1 wherein said electrode assembly includes permanent magnet providing a longitudinal magnetic field in said tube.
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3. The tube defined in claim 1 wherein each auxiliary electrode is provided with an output terminal whereby it may be selectively employed as an output electrode which receives an electron beam.

4. The tube defined in claim 1 wherein the electrode means in each group of electrodes is electrically connected to the adjacent lagging spade electrode.

5. The tube defined in claim 1 wherein one electrode in each group of electrodes is a permanent magnet.

6. The tube defined in claim 1 wherein each target electrode is a permanent magnet.

7. The tube defined in claim 1 wherein all of the tube electrodes are longitudinally elongated and are parallel to each other and wherein, further, each spade electrode has a generally U-shaped cross section with the base of the U facing away from the cathode, and a great majority of the electrode surfaces facing away from the cathode, each target electrode disposed at least in part in the open end of its associated spade electrode, there being no obstructed current flow path between each target and the tube cathode.

8. A magnetron beam switching tube including an electrode assembly including a cathode for providing a stream of electrons; and a plurality of groups of electrodes surrounding the cathode; each group of electrodes including a target electrode for receiving an electron beam and providing an output signal therefrom, a spade electrode lying between said cathode and the target electrode for forming and holding an electron beam thereon, said spade and target electrodes being substantially in radial alignment, a switching electrode spaced from said target and spade electrodes, and an auxiliary electrode for the most part more remote from said cathode than said spade and the electron collecting area of said target and essentially lying across and occupying substantially all of the space between a target electrode on one side and both its associated switching electrode and the adjacent leading target electrode, said auxiliary electrode being accessible to electrons from an electron beam but not obstructing the normal flow of an electron beam to the target electrode.

9. The tube defined in claim 8 wherein each spade electrode is generally U-shaped in cross-section and is oriented with the open portion thereof facing away from the tube cathode, each target electrode is in the form of a rod and is positioned in the open end of and close to the associated spade electrode and accessible to electrons from the cathode, each switching electrode lies closely adjacent to the adjacent spade electrode, and each auxiliary electrode is generally L-shaped in cross-section and includes a first arm which extends from close to its target electrode across the space between adjacent target electrodes to close to the next leading target electrode, the auxiliary electrode includes a second arm which lies closely adjacent to the leading target electrode and extends substantially radially to terminate close to its switching electrode, the auxiliary electrode being thus adapted to receive leakage current from an electron beam and to render its target operable in normal fashion to receive an electron beam over a relatively wide range of operating target voltages.

10. The tube defined in claim 8 wherein each auxiliary electrode is provided with an output terminal.

11. The tube defined in claim 8 wherein each auxiliary electrode is electrically connected to the adjacent lagging spade electrode.

12. The tube defined in claim 8 wherein said auxiliary electrodes include means for applying switching pulses thereto.

13. An electron tube for operation with crossed magnetic and electric fields comprising an elongated envelope, an elongated cathode centrally disposed therein, an array of similar elongated spade electrodes disposed adjacent to said cathode and adapted to form and hold an electron beam, each of said spades having a trough-shaped transverse cross-section, the sides of said spades extending generally away from said cathode, an array of similar elongated target electrodes disposed adjacent to said array of spades and on the side thereof which is more remote from said cathode, each spade being substantially radially aligned with its target and said cathode, an array of elongated auxiliary electrodes, each lying adjacent to one of said targets on the leading side thereof, each of said auxiliary electrodes having a beam receiving surface facing said cathode and one side member angularly disposed therewith and extending radially inwardly toward said cathode, the beam receiving surface of each auxiliary electrode being disposed in the space between adjacent target electrodes and the side member of each auxiliary electrode extending radially inwardly toward the lagging side of the adjacent leading spade electrode, and an array of switching electrodes in the form of rods each positioned between the side member of its auxiliary electrode and the side member of the adjacent leading spade electrode, each group of electrodes thus provided being adapted to form an electron beam on its target electrode with the auxiliary electrode being adapted to receive leakage current not collected by its target electrode whereby tube operation is stabilized and optimum control of an electron beam is achieved.

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