Aug. 28, 1962 T. J. MARCHESE 3,051,865

PULSED BEAM TUBE

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Fig. 4

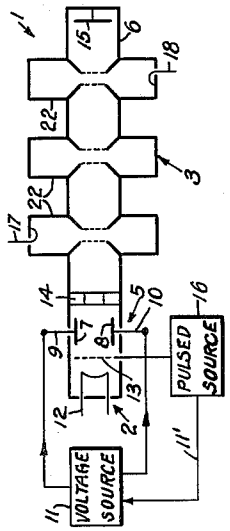


Fig. 5

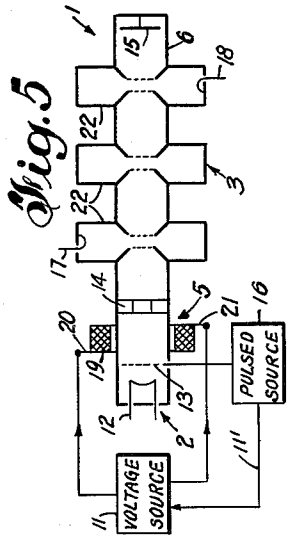


Fig. 6

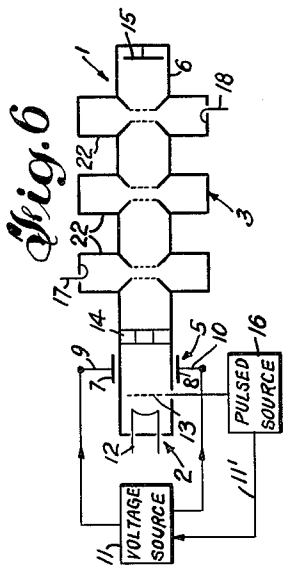


Fig. 1

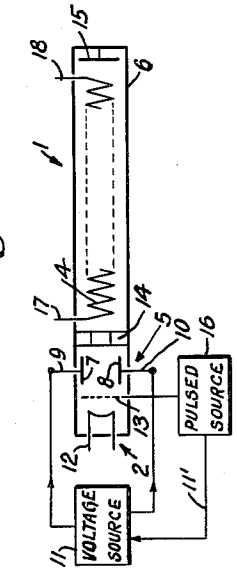


Fig. 2

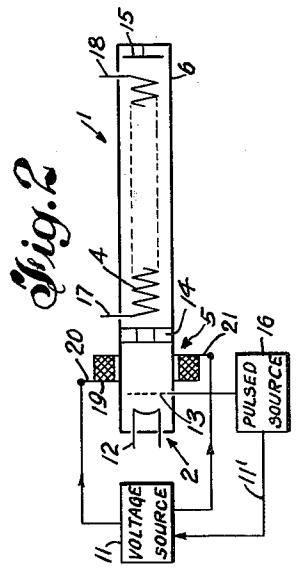
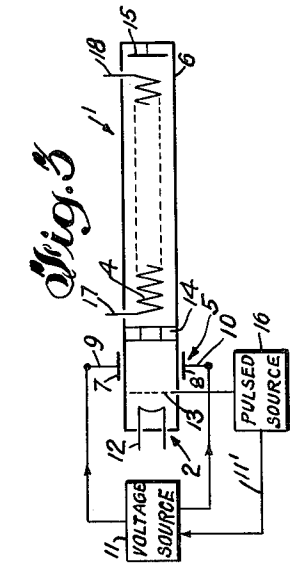


Fig. 3



INVENTOR.
THEODORE J. MARCHESE
BY Philip M. Bolton
ATTORNEY

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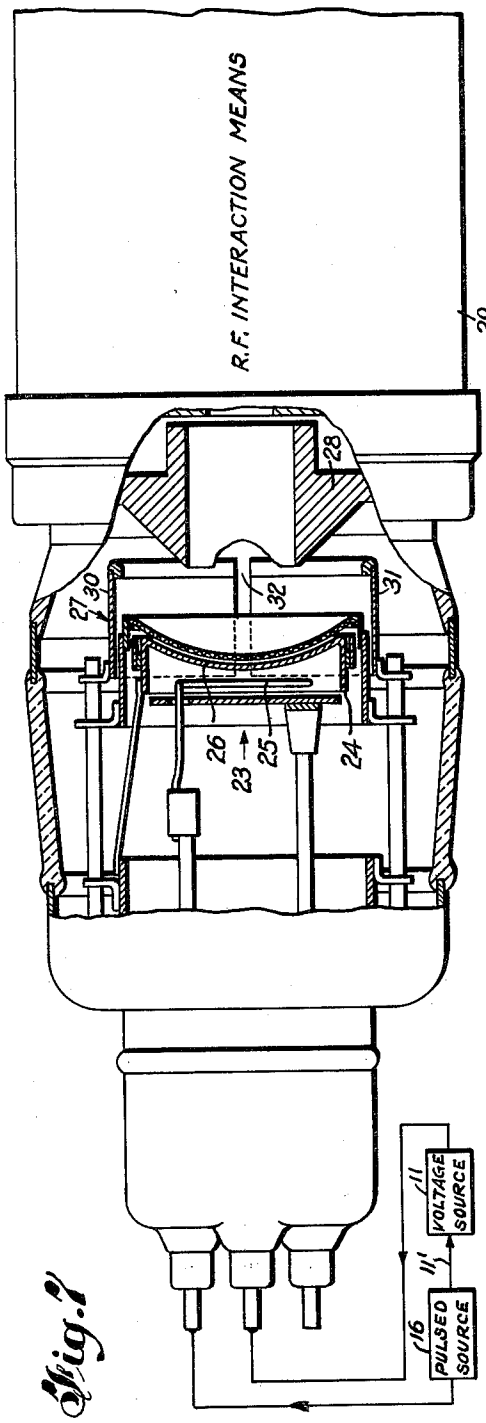


Fig. 7

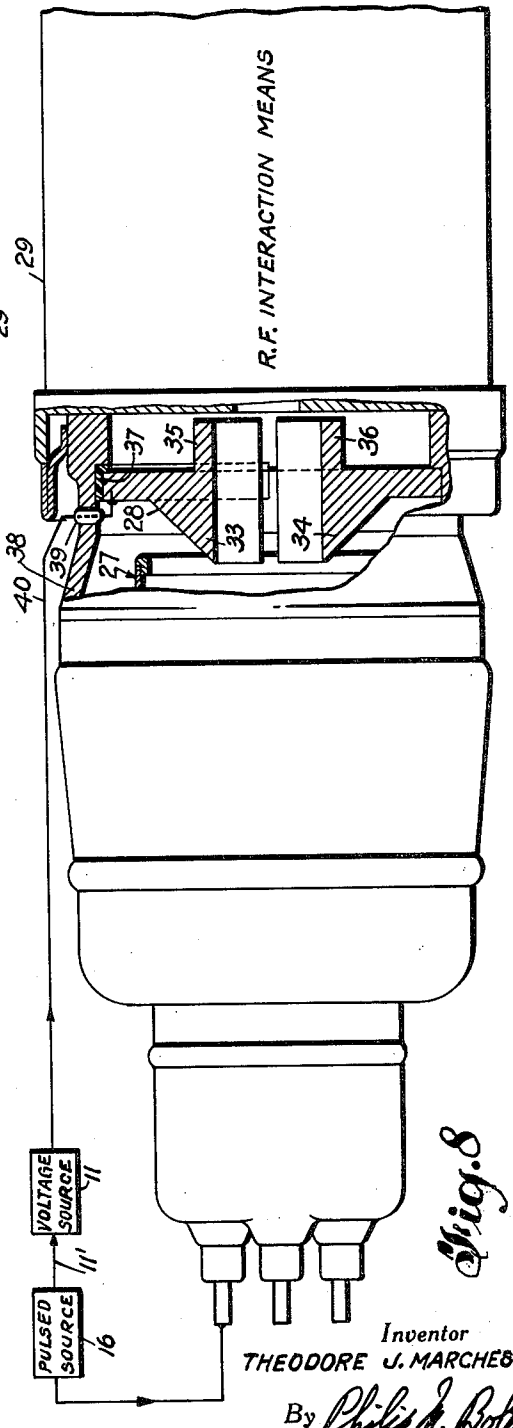


Fig. 8

Inventor
THEODORE J. MARCHESE
By Philip M. Bolton
Attorney

United States Patent Office

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PULSED BEAM TUBE

Theodore J. Marchese, Nutley, N.J., assignor to International Telephone and Telegraph Corporation, Nutley, N.J., a corporation of Maryland

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6 Claims. (Cl. 315—3)

This invention relates to pulsed beam tubes and more particularly to those which are adapted to reduce the noise level during interpulse intervals, including traveling wave and klystron tube types.

It is well known in the prior art that the existence of noise in electronic systems from any source is undesirable. This is true particularly in systems which obtain information from reflected signals which are only a minute portion of the transmitted power. Much time and energy has been spent in discovering and eliminating sources of noise from both transmitters and receivers used in the above type systems. Because of the requirements for the detection of small targets at long ranges in present day and future systems, much time and energy will be spent to provide for further noise reductions. It has been noticed, however, that recent advances in noise reduction techniques have been rather complex and expensive and, in some cases, only desirable because of the extreme necessity for reducing noise levels.

Present day radar systems of the pulse type may incorporate either a traveling wave tube or a klystron as the output stage of the transmitter. These electron discharge devices are generally of extremely high power for long range applications. Their range, however, is often limited by the fact that received signals are submerged in noise from various sources. One source of noise is due to the environment in which the radiating antenna is placed. This noise may be termed thermal or ambient noise and it exists because all objects in the ordinary environments radiate energy due to their molecular activity. Very little can be done to eliminate this type of noise. Another source of noise exists, however, which contributes greatly to the overall noise being presented to the receiver. This noise, which is also thermal in nature, exists in the output tube of the transmitter and is due to three conditions in the region of the electron gun of the output tube. In pulsed output tubes, a convenient way to apply pulse modulation to a radio frequency wave is to utilize a modulation anode or grid to turn on and cut-off the tube electron beam. These modulation anodes or grids, however, due to geometrical imperfections are not 100% effective in cutting off the beam during the transmitter off-time and a small portion of the beam leaks through to enter the interaction region of the electron discharge device where it is amplified and presented to the receiver as noise. This is one source of noise. The second source of noise in the output tube is the modulating anode or grid. The electron beam in passing through this element heats it up and primary emission due to the heating takes place and continues during the transmitter off-time. A third source of noise, which provides a second order effect is due to secondary emission from the grid. The noise due to incomplete beam cut-off and to primary and secondary emission may be termed residual noise to distinguish it from the ambient noise. Since the ambient noise is relatively uncontrollable, one

approach in the reduction of the overall noise figure, not shown heretofore in the prior art, would be to reduce the residual noise due to incomplete beam cut-off and primary and secondary emission during the off-time of radar transmitters.

It is therefore an object of this invention to provide a pulsed electron discharge device in which residual noise during the interpulse interval is substantially reduced.

It is another object of this invention to provide a pulsed electron discharge device system which has an improved signal-to-noise ratio as compared with prior art systems.

It is a further object of this invention to provide a pulsed electron discharge device in which the residual beam current is prevented from entering the interaction region of the electron discharge device.

A feature of this invention is the utilization of an electron discharge device having means for projecting an electron beam along a given path and interaction means for deriving energy from the beam disposed along the electron beam path. In addition, the electron discharge device incorporates deflection means to deflect the electron beam from the given path when it is desired to preclude interaction with the aforesaid interaction means.

Another feature is the utilization of deflection means disposed intermediate the beam generation means and the interaction means, either internally or externally of the vacuum envelope to preclude interaction of the electron beam with the interaction means when desired.

A further feature is the utilization of either a split first anode or a split focusing electrode coupled to a voltage source to deflect the residual electron beam to preclude interaction of the beam with the interaction means.

A still further feature of this invention is the utilization of skirt portions on the first anode to collect the deflected residual beam current.

The foregoing and other objects and features of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a schematic representation of an electron discharge device of the traveling wave tube type which operates in accordance with the principles of this invention;

FIG. 2 is a schematic representation of a traveling wave tube having externally disposed magnetic residual beam deflecting means;

FIG. 3 is a schematic representation of a traveling wave tube having externally disposed electrostatic residual beam deflecting means;

FIG. 4 is a schematic representation of a klystron tube which operates in accordance with the principles of this invention;

FIG. 5 is a schematic representation of a klystron tube having externally disposed magnetic beam deflection means;

FIG. 6 is a schematic representation of a klystron tube having externally disposed electrostatic beam deflection means;

FIG. 7 is a partial longitudinal cross-sectional view of a preferred embodiment which operates in accordance with the principles of this invention and;

FIG. 8 is a partial longitudinal cross-sectional view of an alternative preferred embodiment of this invention.

Referring to FIGS. 1, 2, 3, there is shown in each of the figures an electron discharge device **1** of the traveling wave tube type. Electron discharge device **1** includes means **2** for projecting an electron beam along a given path. Interaction means **3** in the form of a helical slow wave structure **4** is disposed along the given path and supports a radio frequency electromagnetic wave which derives energy from the electron beam through the agency of said interaction means **3**. Deflection means **5** which may be either electrostatic or electromagnetic is shown disposed either internally or externally of vacuum envelope **6** adjacent beam projecting means **2** to deflect the electron beam from the given path to preclude interaction of the electron beam with the interaction means **3** during a given interval.

In FIG. 1, deflection means **5** consists of two electrodes **7, 8** suitable for applying a difference of potential thereto. In this embodiment, electrodes **7, 8** are disposed internally of vacuum envelope **6** and between beam projection means **2** and interaction means **3**. Vacuum envelope **6** may be of metal, glass or ceramic. Terminals **9, 10** which penetrate vacuum envelope **6** are used to apply a difference of potential from voltage source **11** to deflect the residual beam during a given interval. The beam projection means **2** includes a cathode **12**, a grid **13** and a first anode **14** which cooperatively act to project an electron beam along a given path to collector **15**. A pulsed source of voltage **16** coupled to grid **13** applies pulses of the proper polarity to turn on and cut off the beam current so that a radio frequency wave introduced on input terminal **17** of interaction means **3** may be pulse modulated and delivered to output terminal **18** as an amplified pulsed radio frequency wave.

In FIG. 2 an electron discharge device **1** is shown which is similar in every way to the device of FIG. 1 with the exception that the deflection means **5** is disposed externally of vacuum envelope **6** and is electromagnetic in nature. All elements in this figure and in those which follow which are similar are indicated with the same number. Thus, in FIG. 2 deflection means **5** consists of an electromagnetic deflection coil **19** which acts to deflect the residual electron beam from the given path. Coil **19** is disposed between electron projecting means **2** and interaction means **3** and a difference of potential from voltage source **11** is applied to coil **19** across terminals **20, 21**.

FIG. 3 shows an electron discharge device **1** which is similar in every way to the device of FIG. 1 with the exception that deflection means **5** is disposed externally of vacuum envelope **6**. Further, vacuum envelope **6**, for this type of deflection should be glass or ceramic and not metal. A metal envelope, in this application, would shield the beam from the action of the electric field.

Referring to FIGS. 4, 5, 6, there is shown in each of these figures an electron discharge device **1** of the klystron tube type. As in FIGS. 1, 2, 3 the electron discharge device **1** includes means **2** for projecting an electron beam along a given path. Interaction means **3** in the form of a plurality of resonant radio frequency cavities **22** are disposed along the given path and are adapted to support a radio frequency electromagnetic wave which derives energy from the electron beam through the agency of resonant cavities **22**. Deflection means **5** in FIGS. 4, 5, 6 as in FIGS. 1, 2, 3 may be either electrostatic or electromagnetic and may be disposed either internally or externally of vacuum envelope **6** adjacent beam projection means **2** to deflect the electron beam from the given path to preclude interaction of the electron beam with interaction means **3**.

FIG. 4, then, is similar in every way to the device of FIG. 1 with the exceptions that the interaction means **3** in FIG. 4 consists of resonant cavities **22** as opposed to a helical slow wave structure **4** in FIG. 3. Input and output terminals **17, 18** in FIG. 4 couple to coupling loops disposed within the cavities **22**.

FIG. 5, as far as the type of deflection means **5** used, is similar in every way to the embodiment of FIG. 2, and

FIG. 6 employs the same type of deflection as shown in connection with the embodiment of FIG. 3. In the externally disposed electrostatic deflection application of FIG. 6, the vacuum envelope should be limited to either glass or ceramic material, so that the beam will not be shielded as it would be if a metallic envelope were used.

The operations of the embodiments of FIGS. 1 through 6 are alike; the only differences being the type of deflection means used and the position of the deflection means **5** with respect to vacuum envelope **6**. Thus, in FIGS. 1 through 6, the grids or modulating anodes **13** of electron discharge devices are energized from a pulse source **16** which is coupled to grids **13**. The potential on grids **13** is pulsed from some negative voltage with respect to the cathode which substantially cuts off the beam current to a value which permits the electrons to enter the tube interaction region where the beam interacts with the radio frequency energy present in the interaction means **3**. FIGS. 1 to 3 operate in a manner well known in the traveling wave tube art and FIGS. 4 to 6 operate in a manner well known in the klystron art in their respective interaction regions. The radio frequency energy is then passed to the output **18** as an amplified pulse of radio frequency energy. At the end of the pulse applied to grid **13** from source **16**, the beam is cut-off and no further action is intended in the interaction means **3** until the start of the next pulse. However, due to the fact that grid **13** does not provide complete cut-off of the electron beam and due to the fact that primary emission due to heating of grid **13** and some secondary emission exists, a residual beam is present during the interpulse interval which can be amplified in the interaction means **3**, if it is allowed to enter interaction means **3**. A potential difference applied from voltage source **11** to deflection means **5** of the various embodiments precludes the above-described action from taking place. By means well known to those skilled in the electronics art, a potential from voltage source **11** is applied, at the end of the pulse from pulsed source **16**, to deflection means **5** to deflect the residual beam away from interaction means **3** and onto first anode **14**. A trigger pulse from pulse source **16** over lead **11'**, for instance, may be used to indicate the instant at which pulse source **16** is de-energized and the instant at which voltage source **11** should be energized.

The action of electrostatic and electromagnetic fields on electrons is well known to those skilled in the electron ballistic art and occurs in each of the above embodiments in this known manner. The magnitude of the deflecting potential is relatively small because the density of the residual beam is small. The residual beam, for the same reason, may be collected on the first anode **14** or the vacuum envelope walls with the generation of only a small amount of heat. The potential from voltage source **11** is removed from deflection means **5** at the beginning of the next pulse from pulsed source **16**. In this manner, therefore, the residual beam is precluded from entering the interaction means and the noise due to the amplification in the interaction means **3** is substantially eliminated.

Referring now to FIG. 7, there is shown therein a preferred embodiment which operates in accordance with the principles of this invention. Since the novelty of this invention resides principally in the region of the electron gun, only the electron gun and the deflection structure are shown. The portions of the traveling wave tube or klystron not shown can be of a design well known to those skilled in the art. Electron gun **23** consists of a cathode **24** for projecting an electron beam along a given path; a heater **25** for energizing cathode **24**, a grid **26** disposed adjacent cathode to apply pulse modulation from pulsed source **16** to the electron beam; a focusing electrode **27** to focus the electron beam to a given cross-sectional area, and a first anode **28** to accelerate the electron beam toward interaction structure shown generally at **29**. Interaction structure **29** may be any slow wave structure used in conventional traveling wave tubes or may be a series of cavities such as used in conventional

klystrons. All of the above-mentioned elements are conventional and operate in the conventional manner with the exception of the focusing electrode **27** which differs from the ordinary electrode both as to structure and function. Structurally, focusing electrode **27** has at least two portions **30**, **31** separated one from the other by a narrow gap **32** and oppositely disposed to act as deflection electrodes during the interpulse interval. The narrow gap **32** has no effect whatsoever on the operation of electrode **27** when it is functioning as a focusing electrode during pulsed operation provided the gap **32** is kept quite narrow. By applying a difference of potential from voltage source **11** between the two portions **30**, **31** of electrode **27**, it is possible to electrostatically deflect the residual electron beam such that it is intercepted by first anode **28** and dissipated as heat thereon. The deflection of the beam may be accomplished, in a practical way, by simply reducing the voltage on existing connections applied to one of the portions **30**, **31** during the interpulse interval from the equal negative voltages with respect to the cathode which exist when the tube is operating as a pulsed amplifier. Focusing electrode **27** may be divided into a plurality of opposed portions any pair of which may be energized to cause deflection of the residual beam without affecting operation of the tube as a pulsed amplifier.

FIG. 8 is an alternative to the embodiment of FIG. 7. In the embodiment of FIG. 8, the focusing electrode **27** is no longer split, but appears as a conventional focusing electrode. Like elements in FIG. 8 are numbered the same as in FIG. 7. First anode **28**, however, differs from the anode of FIG. 7 in that it has at least two portions **33**, **34** to which a potential difference is applied from voltage source **11** to cause electrostatic deflection of the residual beam current during the transmitter off-time. Further, each of the portions **33**, **34** has extensions or skirts **35**, **36** which extend in the direction of the electron beam flow to act as collectors for the residual beam current which is deflected by the first anode. The skirts **35**, **36**, of course, could be used in the embodiment of FIG. 7 in the same manner. Since a potential is to be applied to at least one of the two portions **33**, **34** of anode **28**, one of the portions or both may be insulated from the tube shell by a semi-circular insulator **37** disposed between anode **28** and tube shell **38**. In this manner, the deflecting voltage is prevented from shorting to ground. The deflection voltage is applied to anode **28** by means of terminal **39** and lead **40** which is passed through the vacuum envelope by a conventional vacuum seal. The embodiment of FIG. 8, like the embodiment of FIG. 7, may be used with both traveling wave tubes and with klystrons.

Experiments conducted on the above-described deflection technique have produced significant reductions in the noise due to residual beam current during the interpulse interval. The results are significant in that it is possible to provide bulit-in noise reduction means in pulse tubes such as shown in FIGS. 7 and 8 without seriously altering the structure of the electron discharge device.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. An electron discharge device system comprising an electron discharge device, means to project discrete electron beam segments along a given path, said electron beam segments having undesired electrons therebetween, interaction means for deriving energy from said beam segments disposed along said given path, electron deflection means disposed adjacent said beam segment projecting means to deflect said undesired electrons from said path, and means coupled to said electron deflection means to energize said electron deflection means during the interval between each of said beam segments to preclude interaction of said undesired electrons with said interaction means.

2. An electron discharge device system comprising an electron discharge device, means to project discrete electron beam segments along a given path, said electron beam segments having undesired electrons therebetween, interaction means for deriving energy from said beam segments disposed along said given path, electron deflection means disposed adjacent said beam segment projecting means to deflect said undesired electrons from said path, means coupled to said electron deflection means to energize said electron deflection means during the interval between each of said beam segments to preclude interaction of said undesired electrons with said interaction means, and an electron absorption electrode mounted between said interaction means and said electron deflection means for absorbing said undesired electrons during the intervals between each of said beam segments.

3. An electron discharge device system comprising an electron discharge device, a source of pulses, means responsive to said pulses for projecting a plurality of discrete beam segments along a given path, said electron beam segments having undesired electrons therebetween, interaction means for deriving energy from said beam segments disposed along said given path, electron deflection means disposed adjacent said beam segment projecting means to deflect said undesired electrons from said path, means coupled to said electron deflection means and said source of pulses to energize said electron deflection means during the interval between each of said pulses to preclude interaction of said undesired electrons with said interaction means, and an electron absorption electrode mounted between said interaction means and said electron deflection means for absorbing said undesired electrons between each of said pulses.

4. A traveling wave tube system comprising a traveling wave tube, a source of pulses, means responsive to said pulses for projecting a plurality of discrete electron beam segments along a given path, said electron beam segments having undesired electrons therebetween, a slow wave interaction structure for deriving energy from said beam segments disposed along said given path, electron deflection means disposed intermediate said beam segment projecting means and said slow wave structure to deflect said undesired electron from said path, and means coupled to said electron deflection means and said source of pulses to energize said electron deflection means during the interval between each of said pulses to preclude interaction of said undesired electrons with said slow wave structure.

5. A klystron tube system comprising a klystron tube, a source of pulses, means responsive to said pulses for projecting a plurality of discrete electron beam segments along a given path, said electron beam segments having undesired electrons therebetween, radio frequency resonant structure for deriving energy from said beam segments disposed along said given path, electron deflection means disposed intermediate said beam generating means and said resonant structures to deflect said undesired electrons from said path, and means coupled to said electron deflection means and said source of pulses to energize said electron deflection means during the interval between each of said pulses to preclude interaction of said undesired electrons with said resonant structures.

6. An electron discharge device system comprising an electron discharge device having an input means for projecting an electron beam along a given path, means for applying beam switching pulses to said beam projecting means to produce a plurality of discrete beam segments having undesired electrons therebetween, electron deflection means adjacent said beam projecting means and adapted to deflect said undesired electrons from said path,

means coupled to said pulse applying means and said electron deflection means for applying a voltage to said electron deflection means at the end of each of said pulses to deflect said undesired electrons from said path at the end of each of said pulses, an interaction means adjacent said path adapted to be coupled to said beam segments and derive energy therefrom, and a beam absorption electrode connected in the space between said interaction means and said electron deflection means for absorbing said undesired electrons between said beam segments.

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