May 3, 1966 F. E. WELKER ETAL 3,249,793

CONTROLLED ELECTRON BUNCHER

Filed April 2, 1964 3 Sheets-Sheet 1

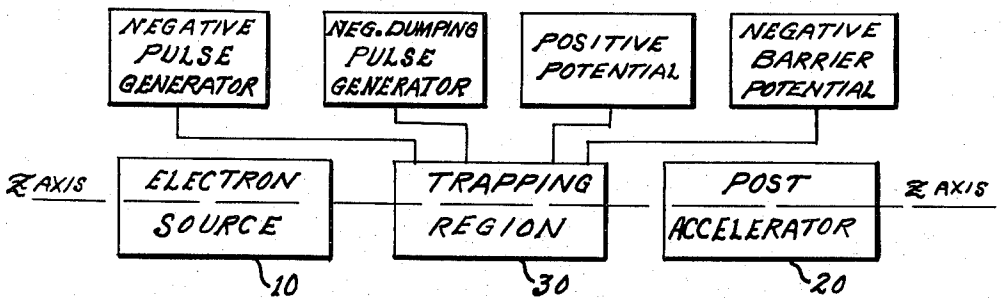


FIG. 1

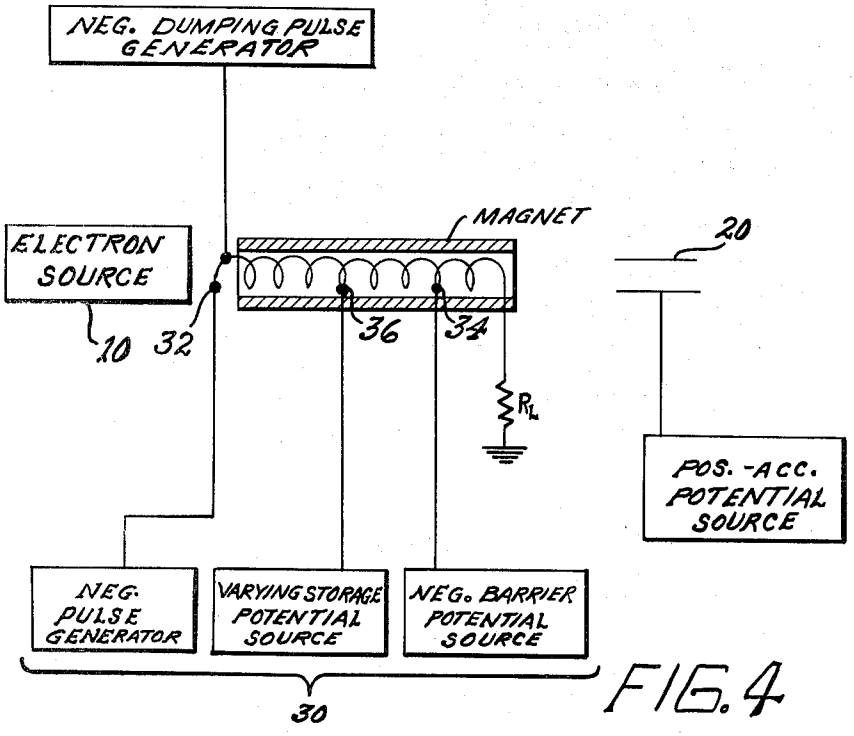


FIG. 4

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CONTROLLED ELECTRON BUNCHER

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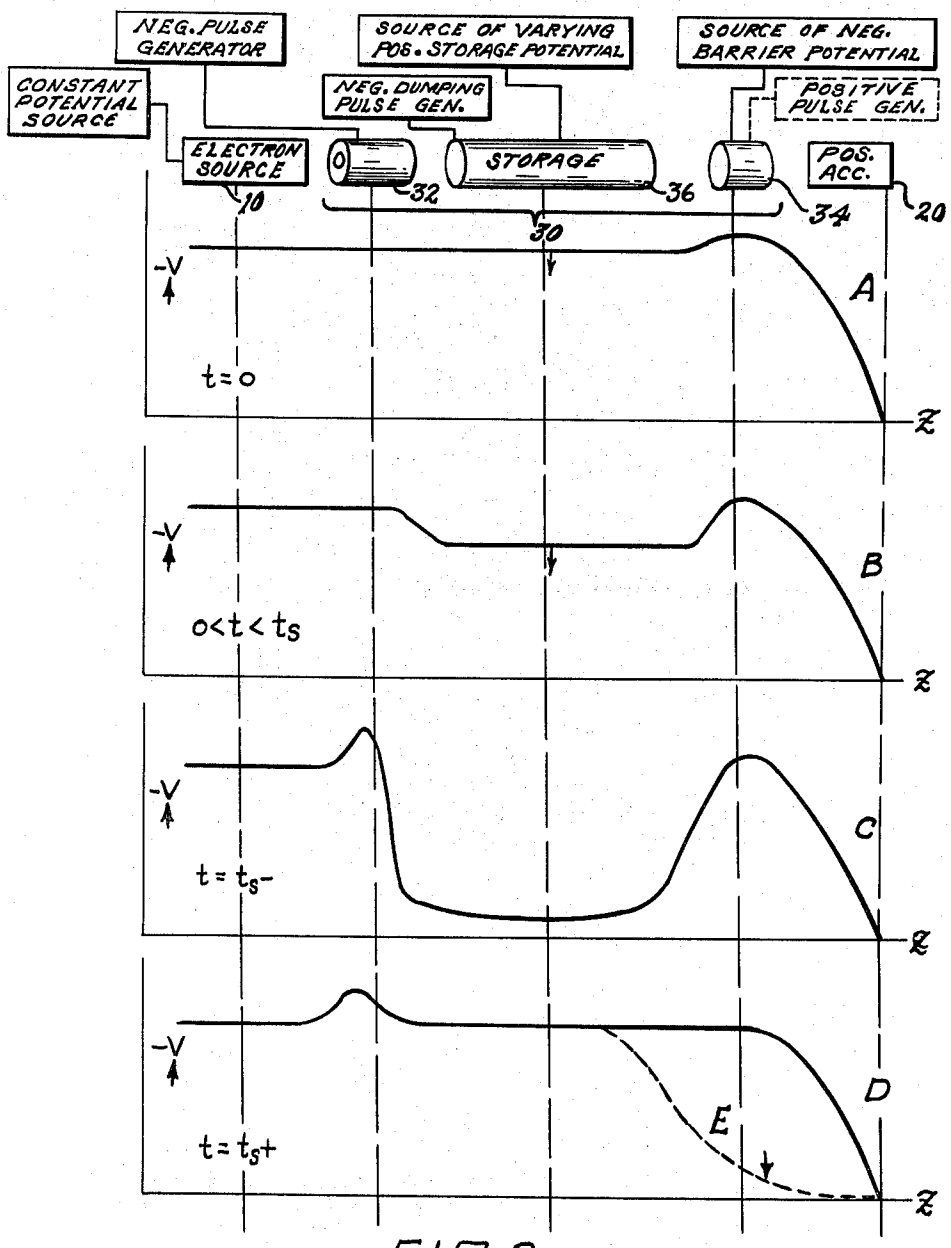


FIG. 2

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CONTROLLED ELECTRON BUNCHER

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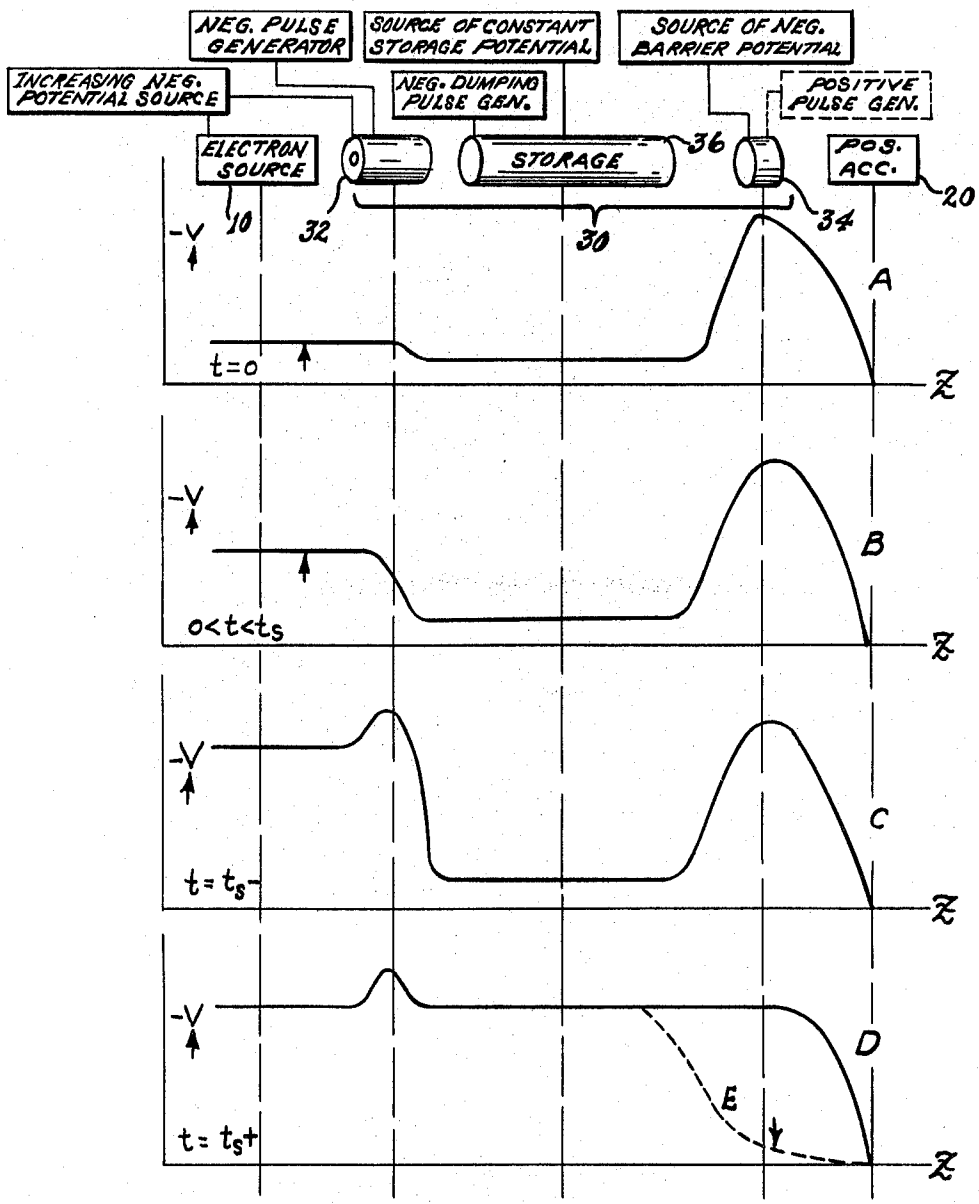


FIG. 3

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3,249,793

CONTROLLED ELECTRON BUNCHER

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Filed Apr. 2, 1964, Ser. No. 356,994
8 Claims. (Cl. 315—5)

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to us of any royalty thereon.

This invention relates, in general, to electron tubes, and in particular, to a controlled electron buncher capable of producing an output of extremely short pulses.

Extremely short pulses, of nanosecond duration, are required for future development of high resolution radar systems. Now, it is well known that the conventional technique of applying a video pulse to an electron gun becomes increasingly more difficult as the pulse width is shortened. At nanosecond pulse widths, lead inductance and interelectrode capacity present very difficult, in most cases insurmountable, obstacles. The invention herein, all but eliminates the effects of lead inductance and interelectrode capacity by forming and isolating electron bunches prior to pulsing.

Therefore, it is an object of this invention to provide a controlled electron buncher for a vacuum tube.

It is another object of this invention to provide an electron buncher device capable of producing an output of nanosecond pulse widths.

A further object is the formation and isolation of electron bunches in a trapping region and a subsequent dumping thereof by application of a suitable signal to produce an output of nanosecond pulse width.

It is still another object of the invention to provide a controlled electron buncher which is economical to produce and which utilizes conventional, currently available components that lend themselves to standard mass production manufacturing techniques.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic representation of the invented device;

FIGURE 2 is a schematic representation of the invention's electrode configuration with a series of electric potential distribution curves directly therebelow;

FIGURE 3 is an alternate operation for the schematic representation of FIGURE 2; and

FIGURE 4 is a schematic representation of an alternate electrode geometry.

With reference to the figures, wherein like numerals refer to like parts, the electron source **10**, the post-accelerator **20**, and the trapping region **30**, are the three major regions of the device which are generally arranged along an axis Z as shown in FIGURE 1. It is understood, of course, that the electrode geometry may take many alternate forms, however, the underlying principles of operation will, in all cases, be the same.

The electron source **10** may be any cathode or other suitable electron supplier which is capable of supplying the desired current level to the trapping region. A conventional electron gun of the cathode ray type may be utilized to provide a suitable and well defined beam of electrons.

The post-accelerator **20** may be any appropriate conventional electrode or electrodes which upon application of suitable voltage will accelerate electrons to a desired translational energy, for example, a flat disk, or a more complicated wide band coaxial interaction structure.

The acceleration electrode **20** is maintained at a high positive potential.

The trapping region **30** is the heart of the invented device wherein electron bunches are formed, isolated and then dumped to the post-accelerator **20**. During the trapping interval, the potential distribution along the trapping region is such that it prevents electrons entering therein from either advancing to the post-accelerator **20**, or returning to the source **10**. Advancement to the post-accelerator **20** is prevented by establishing a negative potential, with respect to the midportion **36** of trapping region **30**, at a portion **34** thereof proximate to accelerator **20**. This potential difference must be greater than the combined kinetic and potential energies of the trapped electrons throughout the interval. Return to the electron source **10** is prevented by continually increasing the potential difference between the electron source **10** and midpoint **36** of the trapping region **30**, throughout the trapping interval. In this manner, electrons leaving source **10** and entering trapping region **30** will always encounter a greater potential difference if they attempt to return to source **10** at some later time. Essentially, the aforedescribed trapping technique may be considered at a time varying potential well for electrons. Radial confinement of electrons may be accomplished by a magnetic field parallel to the Z axis by any conventional means such as by a solenoid or permanent magnet as illustrated in FIGURE 4. The electric potential distribution may be established by conventional electron tube techniques, well known in the art.

Isolation of an electron bunch in the trapping region **30** may be accomplished by applying a pinch-off pulse at the portion **32** of trapping region **30** which is proximate to source **10**. The pinch-off pulse establishes a negative potential with respect to source **10** for an instantaneous isolation of an electron bunch from source **10**.

Dumping of the trapped and isolated electron bunch may then be easily accomplished by changing the potential distribution in trapping region **30** so the electron bunch therein are forced out toward the accelerator **20**.

The different portions of trapping region **30** may be defined by individual electrodes, as illustrated in FIGURES 2 and 3. Pinch-off electrode **32** may be a short cylindrical can with a small axial hole therethrough. As shown, pinch-off electrode **32** is mounted proximate the cathode gun **10**. A barrier electrode **34** is provided proximate the accelerator electrode **20**. Barrier electrode **34** may be a short open cylinder. A storage electrode **36** formed by an open cylinder, is provided between the pinch-off electrode **32** and barrier electrode **34**, as shown.

FIGURE 4 illustrates an alternate electrode configuration which gives the same electric potential distribution of FIGURES 2 and 3 for the trapping region **30**. A helix of resistive wire which is tapped at appropriate points may be utilized as a single trapping region electrode. In this instance, pinch-off, storage, and barrier taps **32**, **36**, **34** are provided in place of the pinch-off, storage, and barrier electrodes **32**, **36**, **34**, respectively. The helix configuration is of special interest because the helix may be utilized as a slow wave matched transmission line as shown in FIGURE 4 with a termination R_L. Thus, during dumping, the trapped electron bunch in the potential well **36** of trapping region **30** would be forced by the pulse leading edge toward the acceleration electrode **20**.

Operation of the device may be better understood by reference to the potential distribution curves of FIGURES 2 and 3. The curves A, B, C, D, indicate potential distribution along the Z axis at time intervals throughout the trapping, isolating and dumping procedures. Notice that the potential axis has been inverted in order that the "barriers" and "wells" will appear as such in the gravita-

tional sense for the negative electron. The trapping interval or storage cycle begins with the potential distribution shown in curve A of FIGURE 2. At curves B and C the potential well deepens through the application of a positive ramp to the storage electrode **36**, which technique, explained beforehand, prevents electrons therein from advancing or returning. At curve C a pluse is applied to the pinch-off electrode **32** establishing it with a highly negative potential with respect to the cathode gun **10** at the instant that electron bunch formation is halted. This accomplishes an instantaneous isolation of the completely formed potential well from the cathode **10**. At curve D the storage electrode **36** has been pulsed negatively, changing the potential distribution to dump the electron bunch towards the acceleration electrode **20**. Dumping may be facilitated by a positive pulsing (dashed line) of the barrier electrode **34** simultaneous with the negative pulsing of storage electrode **36**, as represented by the dashed curve E.

FIGURE 3 is an alternate operation, wherein the storage electrode **36**, and barrier electrode **34** sustain fixed potentials throughout the trapping interval. At A and B, FIGURE 3, the cathode gun **10** and pinch-off electrode **32** are made progressively negative throughout the trapping interval. At C, an instant before the cathode **10** reaches the potential of barrier electrode **34**, the pinch-off electrode **32** is pulsed to a high negative potential to isolate the cathode **10** from the trapping region **30**. At D, dumping proceeds in the same manner as explained in FIGURE 2.

Although the invention has been described with reference to a particular embodiment, it will be understood to those skilled in the art that the invention is capable of a variety of alternative embodiments within the spirit and scope of the appended claims.

We claim:

1. A vacuum tube device for forming, isolating, and accelerating controlled electron bunches, comprising: an electron source; an electron post-accelerator having a high positive potential with respect to said source; an electron trapping region disposed between said source and accelerator; means for applying a potential distribution along said trapping region which prevents electrons entering therein from advancing and returning, respectively, to said accelerator and source, thereby forming an electron bunch therein; means to apply a pinch-off pulse at a portion of said trapping region proximate said source, said pulse establishing a negative potential with respect to said source for an instantaneous isolation therefrom of said electron bunch; and means to apply a dumping pulse subsequent to said isolation, said dumping pulse changing said potential distribution along said trapping region to force said electron bunch toward said post-accelerator for acceleration therefrom producing a pulsed output.

2. A vacuum tube device for forming, isolating, and accelerating controlled electron bunches, comprising: an electron source; an electron post-accelerator having a high positive potential, with respect to said source, which is suitable to accelerate electrons to a desired translational energy; an electron trapping region disposed between said source and accelerator; means for applying a potential distribution along said trapping region which has, in respect to midportion thereof, a negative potential proximate said accelerator and a continually increasing potential difference from said source, said distribution, respectively, preventing electrons entering therein from advancing and returning to said accelerator and source, thereby forming an electron bunch therein; means to apply a pinch-off pulse at a portion of said trapping region proximate said source, said pulse establishing a negative potential with respect to said source for an instantaneous isolation therefrom of said electron bunch; and means to apply a dumping pulse to said region, subsequent to said isolation, said dumping pulse changing said potential distribution along said trapping region to force said electron bunch toward said post-accelerator for acceleration therefrom producing a pulsed output.

3. A vacuum tube device for forming, isolating, and accelerating controlled electron bunches, comprising: an electron source; an electron post-accelerator having a high positive potential, with respect to said source, which is suitable to accelerate electrons to a desired translational energy; an electron trapping region disposed between said source and accelerator, said trapping region including a pinch-off portion proximate said source, a storage portion midway therealong, and a barrier portion proximate said accelerator; means for applying a potential distribution along said trapping region which has, in respect to said storage portion, a negative potential at said barrier portion and a continually increasing potential difference from said source, said distribution, respectively, preventing electrons entering therein from advancing and returning to said accelerator and source, thereby forming an electron bunch therein; means to apply a pulse at said pinch-off portion, said pulse establishing a negative potential with respect to said source for an instantaneous isolation therefrom of said electron bunch; and means to apply a dumping pulse at said storage portion subsequent to said isolation, said dumping pulse changing said potential distribution along said trapping region to force said electron bunch toward said post-accelerator for acceleration therefrom producing a pulsed output.

4. A vacuum tube device for forming, isolating, and accelerating controlled electron bunches, comprising: an electron source; an electron post-accelerator having a high positive potential, with respect to said source, which is suitable to accelerate electrons to a desired translational energy; an electron trapping region disposed between said source and accelerator, said trapping region including a pinch-off portion proximate said source, a storage portion midway therealong, and a barrier portion proximate said accelerator; means for applying a potential distribution along said trapping region which has, in respect to said storage portion, a negative potential at said barrier portion and a continually increasing potential difference from said source, said distribution, respectively, preventing electrons entering therein from advancing and returning to said accelerator and source, thereby forming an electron bunch therein; means to apply a pulse at said pinch-off portion, said pulse establishing a negative potential with respect to said source for an instantaneous isolation therefrom of said electron bunch; means to apply a negative dumping pulse at said storage portion subsequent to said isolation; and means to apply a positive pulse at said barrier portion simultaneously with said dumping pulse thereby changing said potential distribution along said trapping region to force said electron bunch toward said post-accelerator for acceleration therefrom producing a pulsed output.

5. A vacuum tube device for forming, isolating, and accelerating controlled electron bunches, comprising: an electron gun of the cathode ray type providing a well defined beam of electrons; a post-acceleration electrode having a high positive potential with respect to said gun, which is suitable to accelerate electrons to a desired translational energy; an electron trapping region disposed between said gun and acceleration electrode, said region defined by a pinch-off electrode proximate said gun, a barrier electrode proximate said accelerator electrode, with a storage electrode therebetween; means for applying a potential distribution along said trapping region which has, in respect to said storage electrode, a negative potential at said barrier electrode and a continually increasing potential difference from said gun, said distribution, respectively, preventing electrons entering therein from advancing and returning to said accelerator electrode and gun, thereby forming an electron bunch therein; means to apply a pulse at said pinch-off electrode, said pulse establishing a negative potential with respect to said gun for an instantaneous isolation therefrom of said electron bunch; and means to apply a negative dumping pulse at said stor-

age electrode subsequent to said isolation, said dumping pulse changing said potential distribution along said trapping region to force said electron bunch toward said post-accelerator electrode for acceleration therefrom producing a pulsed output.

6. A vacuum tube device for forming, isolating, and accelerating controlled electron bunches by application of a suitable signal to produce an output of nanosecond pulse width capabilities, comprising: an electron gun of the cathode ray type providing a well defined beam of electrons; a post-acceleration electrode having a wide band coaxial interaction structure at a high positive potential with respect to said gun, and which is suitable to accelerate electrons to a desired translational energy; an electron trapping region disposed between said gun and acceleration electrode, said region having, proximate said gun a pinch-off electrode formed of a short cylindrical can with an axial hole therethrough, proximate said acceleration electrode a short open cylindrical barrier electrode, and an open cylindrical storage electrode between said pinch-off and barrier electrodes; means for applying a potential distribution along said trapping region which has, in respect to said storage electrode, a negative potential at said barrier electrode, and a continually increasing potential difference from said gun, said distribution, respectively, preventing electrons entering therein from advancing and returning to said accelerator electrode and gun, thereby forming an electron bunch therein; means to provide a strong magnetic field paralleling said beam of electrons to accomplish radial confinement thereof; means to apply a pulse at said pinch-off electrode, said pulse establishing a negative potential with respect to said gun for an instantaneous isolation therefrom of said electron bunch; means to apply a negative dumping pulse at said storage electrode subsequent to said isolation; and means to apply a positive pulse at said barrier portion simultaneously with said dumping pulse thereby changing said potential distribution along said trapping region to force said electron bunch toward said post-accelerator for acceleration therefrom, said bunches being suitable to produce an output of nanosecond pulse width.

7. A combination as claimed in claim 6 wherein said storage electrode comprises a helix wound wire, said helix affording a slow wave, matched transmission line wherein

the advancing edge of the dumping pulse forces the electron bunch past the barrier electrode.

8. A vacuum tube device for forming, isolating, and accelerating controlled electron bunches by application of a suitable signal to produce an output of nanosecond pulse width capabilities, comprising: an electron gun of the cathode ray type providing a well defined beam of electrons; a post-acceleration electrode having a wide band coaxial interaction structure at a high positive potential with respect to said gun, and which is suitable to accelerate electrons to a desired translational energy; an electron trapping region disposed between said gun and acceleration electrode, said region defined by a helix of resistive wire, with a pinch-off tap proximate said gun, a barrier tap proximate said acceleration electrode, a storage tap midway therebetween, and a dumping tap between said pinch-off and storage taps; means for applying a potential distribution along said trapping region which has, in respect to said storage tap, a negative potential at said barrier tap, and a continually increasing potential difference from said gun, said distribution respectively, preventing electrons entering therein from advancing and returning to said acceleration electrode and gun, thereby forming an electron bunch therein; means to provide a strong magnetic field paralleling said beam of electrons to accomplish radial confinement thereof; means to apply a pulse at said pinch-off tap, said pulse establishing a negative potential with respect to said gun for an instantaneous isolation therefrom of said electron bunch; and means to apply a negative dumping pulse at said dumping tap subsequent to said isolation, said helix affording a slow wave matched transmission line with an advancing edge of said dumping pulse forcing said electron bunch toward said post-acceleration electrode for acceleration therefrom, said bunches being suitable to produce an output of nanosecond pulse width.

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