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Schroder

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[54] **SYSTEM FOR GENERATING MULTISTABLE VOLTAGE AND/OR CURRENT STEPS**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **315/352;** 315/326; 315/339; 315/350; 328/125; 328/205; 328/250

[51] **Int. Cl.** **H03k 4/02;** H01j 17/02

[58] **Field of Search** 315/133, 272, 326, 339, 315/350, 352; 307/280, 281, 283; 323/31; 328/121, 125, 142, 168, 172, 205, 241, 250

[56] **References Cited**

UNITED STATES PATENTS

1,465,998	8/1923	Rentschler	315/350 X
2,651,717	9/1953	Uttley et al.	328/205
2,810,072	10/1957	Amatniek	328/205
2,934,657	4/1960	Rack	307/283 X
3,053,998	9/1962	Chynoweth et al.	307/272
3,430,150	2/1969	Sigorsky et al.	307/272 X

FOREIGN PATENTS OR APPLICATIONS

208,351	6/1956	Australia	307/272

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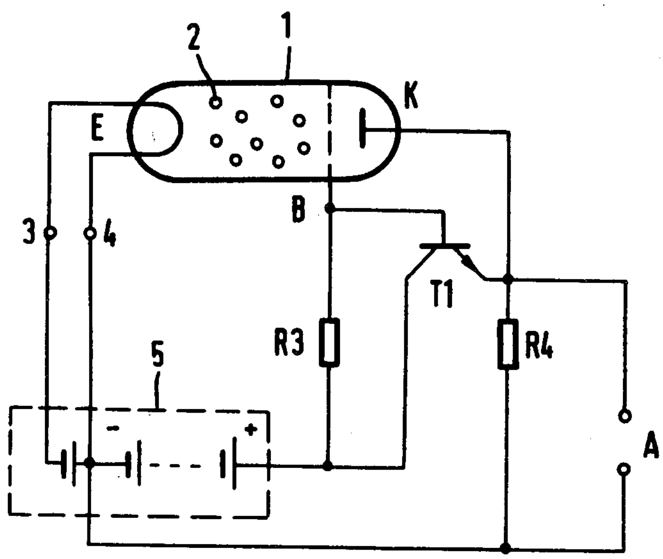
[57] **ABSTRACT**

A multistable device consisting of an emitter, an accelerating electrode and a collector, serving as the controlling element in conjunction with a control circuit, is used e.g. for the remote control of television receivers. The charge carriers as accelerated in the device, serve to supply atoms with excitation energy in the quantum-mechanical way by passing through various minimum and maximum speed values. From this, dynamic characteristics are obtained with multi-stable operating points. A closed control circuit is formed between the collector and the accelerating electrode, for causing stabilization at one of the possible voltage or current steps. Momentary variation of the accelerating voltage will effect the changing to different voltage or current steps.

17 Claims, 9 Drawing Figures



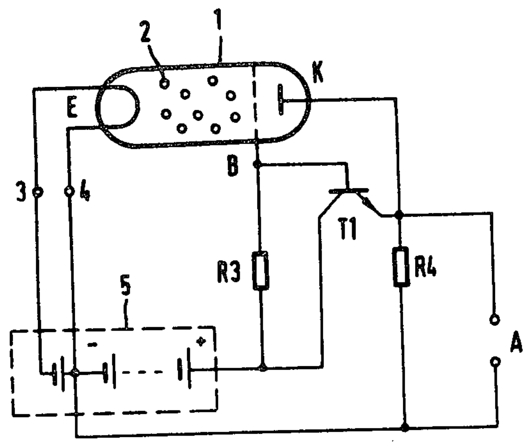


Fig.1

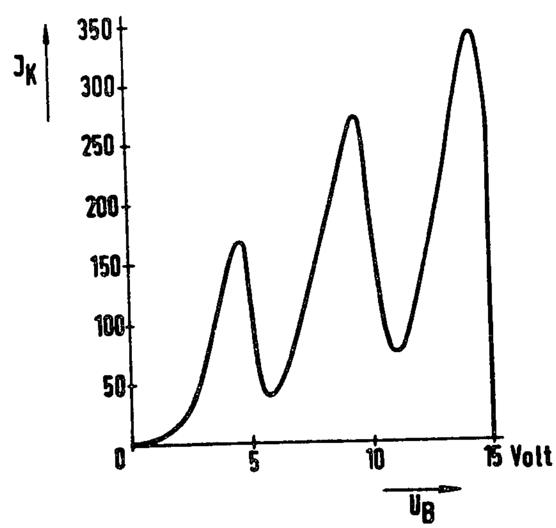


Fig.2

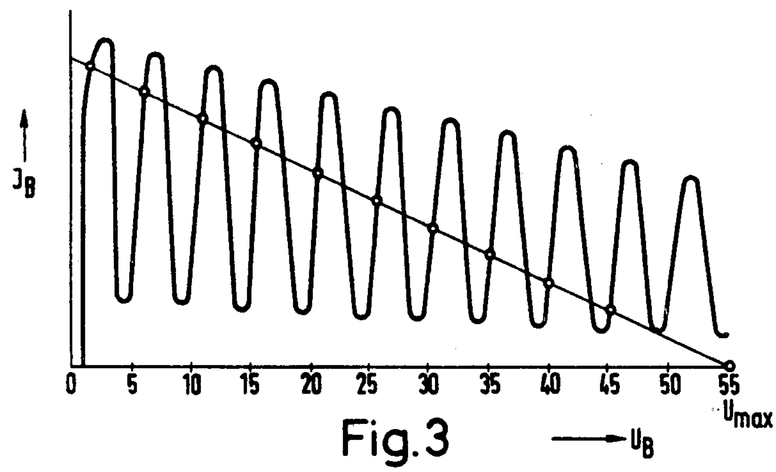


Fig.3

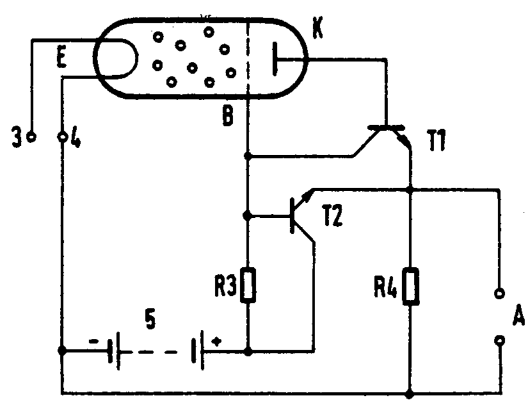


Fig.4

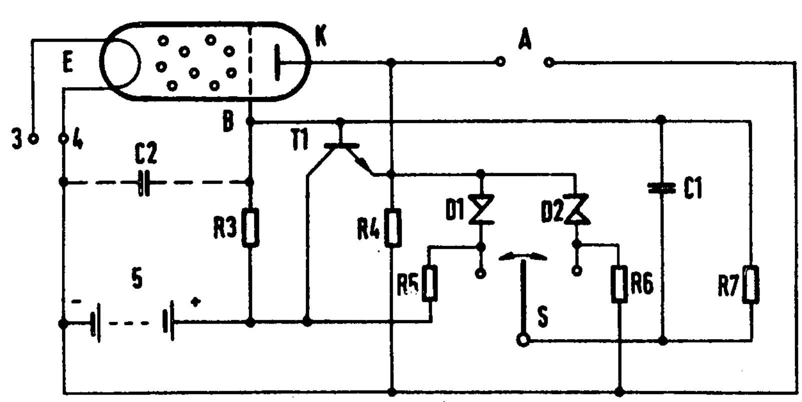


Fig.5

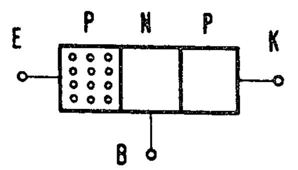


Fig.6a

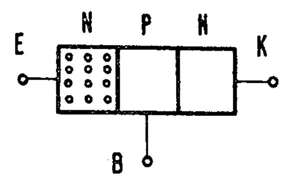


Fig.6b

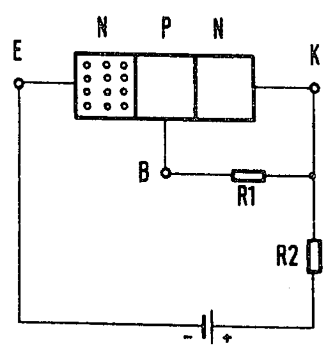


Fig.7

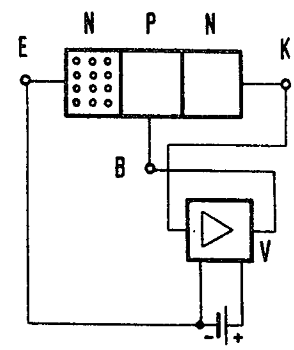


Fig.8

SYSTEM FOR GENERATING MULTISTABLE VOLTAGE AND/OR CURRENT STEPS

The present invention relates to a system for generating multistable voltage and/or current steps.

Arrangements for generating multistable voltage or current steps are used as electric control elements especially in broadcast and television receivers as well as in related equipments, together with remote controls. They may also be used, however, in computers, counters, measuring instruments, as digital-to-analog converters or as electronic storages. Multistable arrangements have also already been referred to as information storages (see e.g. German Patent Nos. 1,272,368, **1,059,508, 1,085,912, 1,063,207**).

Multistable arrangements of the aforementioned kind are set by a signal of corresponding duration or by several short-time, e.g. also encoded signals, to the desired voltage or current step which, thereafter, may be stored for any optionally long period of time.

The longest known arrangement for storing remote-controlled settings is the servomotor, which has also been frequently used in remote-control circuits. The great mechanical investment, the motor noises, the space requirement and the costs, however, have led to other electronic solutions. More recent circuits employ e.g. the variation and storing of a capacitor charge as the servo setting and storing element. In this case, however, difficulties concerning the insulation have proved to be disadvantageous because of not permitting the capacitor charge to be stored for an optionally long period of time and which, moreover, render such an arrangement considerably more expensive. For this reason there are also being used other electronic circuits, such as storage flip-flops, for serving as combined switches for binary resistance combinations of arbitrarily fine stepping or gradation, which are set via the flip-flops connected as binary counters, and capable of being stored for any desired period of time as long as the power supply is not interrupted. As a disadvantage there is considered in this case the complicated arrangement and necessity of having to use additional components, such as the narrower tolerated combination resistances, even when integrated circuits are employed.

It is the object of the invention to avoid the aforementioned disadvantages and to provide an uncomplicated multistable component permitting a more simple setting or adjustment and the storing of voltage or current steps.

This problem is solved according to the invention by the solution as set forth in claim 1. Further embodiments of the invention are characterized in the subclaims.

One test assembly set-up by Franck and Hertz in 1913 for proving the activation of mercury atoms is known, for example, from the book by Wilhelm H. Westphal "Lehrbuch der Physik"Springerverlag Berlin 1941, p. 594. It is the object of the invention, however, to provide a component and to enable the utilization of the effect or the arrangement for generating multistable voltage or current steps respectively. The known test or measuring set-up does likewise not provide for influencing the potential difference between the emitter and the accelerator electrode by the current or voltage variation at the collector electrode.

Examples of embodiment of the invention are shown in the accompanying drawings and will be described in greater detail hereinafter. In the drawings

FIG. 1 shows an inventive type of multistable tube in the inventive application to a functionable circuit,

FIG. 2 shows a diagram of the type known per se, for explaining the activation voltage,

FIG. 3 is an amendment of the diagram shown in FIG. 2, measured with respect to the accelerator electrode,

FIG. 4 shows an enlargement of the circuit employing an amplifier stage in the control circuit at the accelerator electrode,

FIG. 5 shows a modification of the circuit according to FIG. 1,

FIGS. 6*a* and 6*b* show a semiconductor arrangement doped in accordance with the invention, of the PNP- and NPN-type, for being used in accordance with the invention,

FIG. 7 shows a circuit example relating to FIGS. 6*a* and 6*b*, and

FIG. 8 shows the use of the example of embodiment shown in FIGS. 6*a*, 6*b* or 7, in a closed control circuit.

For enabling a better understanding of the terms used in the present specification, some of these terms relating to the fields of quantum physics and the activation and ionization of atoms will now be difined hereinafter.

The normal state of an atom, as the quantum state of smallest energy, is hereinafter referred to as its ground state. From any other higher quantum state it may automatically reach the ground state by the release of energy (e.g. the emission of light). An atom not in the ground state, is referred to as an activated (stimulated) atom. The energy required for its activation, may be supplied to an atom in different ways, e.g. by the absorption of a light quantum, by mechanical energy (collisions of the molecules at a sufficiently high temperature), moreover by electronic impact, i.e. by the collision of an electron with the atom. Ionization voltage or potential refers to the energy which is necessary for effecting the expulsion of an electron from the atom. Relative thereto, it is of interest to know at what voltage values an activation or ionization of the atoms commences. It has been able to prove (for example by the well-known experiments by Franck and Hertz) that the collisions of the electrons as emitted by an emission electrode, with e.g. mercury atoms at a small applied voltage, hence at a low electron speed, are first of all performed completely elastic, without any loss of energy, and that the electron stream first of all increases as the voltage increases. From a certain voltage value onwards, however, it suddenly becomes very much smaller. The electrons have suffered a loss of energy and their collisions with the mercury atoms have suddenly become completely unelastic. This voltage is referred to as the excitation voltage. As the voltage increases, also the current increases again, for dropping off again at double the voltage value. The activation voltage provides the colliding electrons with the necessary energy for lifting the atom from its ground state to the next higher step of energy. In order that it can excite again in response to a further impact, the same energy must be supplied to it again. The same is repeated when the applied voltage has become an integral multiple of the activation voltage. When sufficiently increasing the applied voltage, there will thus be obtained that particular electron energy which is sufficient for effecting the ionization of the atom (ionization voltage or energy necessary for effecting the expulsion of an electron from the atom respectively).

FIG. 1 illustrates the realization of the inventive system with the aid of an inventive multistable tube. Since also in this case, the multistable voltage steps are controlled by quantum-mechanical processes, the tube will hereinafter be briefly referred to as the "quantum tube".

The quantum tube consists of the evacuated bulb or envelope **1** filled with the gas or the vapor of suitable atoms **2** (e.g. mercury) under corresponding pressure. The emitter electrode E is a filament comprising the terminals **3** and **4,** for emitting the electrons as soon as it is heated from the source of supply voltage **5.** The grid-like accelerating electrode B is connected across the resistor R3 to the positive pole of the source of supply voltage **5,** thus causing the electrons which, during their emission, very often collide with the gas atoms elastically without causing any loss of energy but, in the case of unelastic collisions, lose some of their activation energy (about 5 V in the case of mercury), to be attached by suction. If, after one or more such unelastic collisions, the remaining accelerating voltage is insufficient for causing further such activation processes then, quite depending on the amount of this residual voltage, the collector electrode K is either reached or not reached, because K is at a lower potential than the accelerating electrode B. Electrons no longer capable of reaching K, are taken up by B.

When varying the accelarating voltage (U_B in FIG. 2) between E and B, directly after multiples of the activation voltage of the atoms (after multiples of each time about 5 V in the case of mercury), a current minimum is registered at the collector electrode K. Upon increasing accelerating accelerting voltage, the current at the collector electrode increases until the reaching of a further multiple of the activation voltage together with the loss of electron velocity (speed of electrons), will again cause a current minimum.

This periodic dependence of the current I_K of the collector electrode K upon the voltage U_B at the accelerating electrode B, which is already known from the measurements carried out by Franck and Hertz, is shown in FIG. 2 and is supplemented by an enlarged representation of the dependence of the current I_B of the accelerating electrode B in FIG. **3,** in which case the minimum and maximum values corresponding to the current distribution between the two electrodes may be expected to be constant or decreasing. With the aid of the I_B/U_B-characteristic of the quantum tube, and extending from the maximum supply voltage U_{max}, it is possible to construct a load line with the aid of the series resistor R3 which, in the known manner, forms intersecting points with the characteristic. But only those of the operating points are stable which, in the intersecting point with the load line, form an angle less than 90° in relation to the abscissa. In the example shown in FIG. **3** it is possible to form eight stable operating points. The voltage values to be read off at these intersecting points, correspond to the stable voltage or current steps capable of being achieved with the aid of this arrangement. The number of steps can be further increased by correspondingly increasing the maximum supply voltage U_{max}.

For permanently keeping the potential of the collector electrode K by a predetermined amount below the accelerating potential of the accelerating electrode B, the NPN-transistor T1 is controlled as an emitter follower at its base by the accelerating voltage at B. When using a silicon transistor there will appear at its emitter resistor **R4** a voltage which is by about 0.6 V lower than the one at the accelerating electrode B. Therefore, the collector electrode K is connected to the emitter of T1 while the resistor **R4,** on the other hand, is applied to the reference potential of the emitter electrode of the quantum tube. At the output A, the multistable voltage steps are available in low-ohmic fashion.

The example of embodiment shown in FIG. **4** illustrates how both the stability and the accuracy of the voltage steps can be multiplied by means of an additional amplifier. In this case, for example, the transistor T2 has been inserted with its base-emitter path into the current path of the collector electrode K. With its collector current the transistor T2 acts upon the accelerating voltage at the resistor R3; a rising collector current causes a dropping of the accelerating voltage at B. The output voltage is taken off at A.

The switchover of a multistable element to other voltage steps is permitted by the circuit according to FIG. **5,** which is the circuit according to FIG. **1** supplemented by some additional elements.

The zener diodes D1 and D2 are applied on one hand to the variable voltage at the output of the emitter follower T1 and, on the other hand, across the series resistors R5 and **R6,** to the minus and the plus pole of the supply voltage **5** respectively. The zener voltages are chosen thus that they at least exceed the activation voltage and, consequently, one voltage step. With the aid of the switch S these zener voltages can be either added to the voltage at the accelerating electrode B or may be subtracted therefrom respectively. With the aid of the capacitor C1 the time duration of the voltage application is dosed in order thus to release each time only one voltage step variation. The resistor R7 serves to discharge the capacitor C1 during the switching intervals. The switch S may also be replaced by electronic elements, especially for the use in remote-control circuits. In this particular case it may also be appropriate to provide for the capacitor C2 as indicated by the dashline in the drawing, as well as to bridge the capacitor C1, and to remove the Zener diodes **D1** and **D2.** When closing the switch S in direction towards **R5,** the capacitor C2 is charged in accordance with the time constant to more positive values (full battery voltage across **R5** to the base of T1), for remaining at the reached voltage step when interrupting the switch S. When actuating the switch S in direction towards **R6,** the voltage will drop to lower values (battery voltage via B, **R6** to (−) or mass (ground respectively)), for remaining at the reached voltage step when the switch S is interrupted. Also in this case the switch S may be replaced by electronic elements.

FIG. **6***a*, in a way equivalent to the described tube arrangement, shows the inventive system of a semiconductor arrangement with an extrinsic conduction, which is e.g. of the PNP-conductivity type. Between the two barrier layers there is arranged the N-doped base layer with the terminal B, here also designated as the accelerating electrode. The N-doped emitter area which is provided with the emitter contact E, is additionally doped with the atoms or groups or atoms to be activated, if necessary also in a layer-wise manner, with the layers extending vertically in relation to the direction of movement of the charge carriers. The diffusion length in the base layer is adapted in such a way that the charge carriers as injected by the emitter will possibly only reach the collector barrier layer and, consequently, the collector terminal K, provided that they, prior thereto and during the activation work, have not lost so much of their energy to the atoms that they recombine already prior thereto. In this way there is obtained a transistor controlled by energy quantum which, hereinafter, is briefly referred to as a "quantum transistor".

For the sake of completeness there is shown in FIG. **6***b* an NPN-doped design of otherwise the same mode of operation.

FIG. **7** shows a practically employed circuit comprising the quantum transistor wherein the resistor **R1** as applied to the load resistance **R2** of the collector electrode K serves to transfer the voltage variations to the accelerating electrode B. In cases where the voltage between E and B amounts to a certain multiple of the activation voltage, the current at K is at a minimum, and the voltage at R2 increases and is transferred across R1 to the base. The multistable voltage steps may be taken off across the resistor **R2. R1** and V may also be integrated into the semiconductor arrangement in accordance with the known monolithic IC technique.

In the embodiment according to FIG. **8** the amplifier or inverter V is inserted into the control circuit between the collector electrode and the accelerating electrode. The emitter potential of the multistable arrangement serves as the reference potential.

What is claimed is:

1. An apparatus exhibiting a plurality of stable voltage or current levels, comprising:

- a closed envelope;
- a gas disposed in said envelope, said gas being of the type having atoms that may be activated to different stable energy levels;
- an emitter electrode disposed in said envelope for emitting electrons;
- a collector electrode disposed in said envelope and spaced from said emitter electrode for collecting the electrons;
- electron accelerating electrode disposed between said emitter and collector electrodes and spaced therefrom;
- means associated with said emitter electrode for causing electrons to be emitted therefrom; and
- means for applying potential differences between the emitter and the accelerating electrodes whereby the emitted electrons are accelerated through the gas towards said accelerating and collector electrodes said potential difference being correlated with the spaces between the electrodes and the pressure of said gas to prevent ionization of the atoms, so that at potential differences corresponding to the stable energy levels of the atoms the atoms absorb energy from collisions with the accelerated electrons and as a result undergo a quantized energy jump while the colliding electrons undergo a deceleration so that a reduced number of electrons reach the collector electrode thereby reducing the collector current and causing the electrons to be taken up by the accelerating electrode, whereby stable voltage and current levels are exhibited at the potential differences corresponding to the stable energy levels of the atoms.

2. An apparatus as described in claim **1**, additionally comprising feedback means responsive to the increased electron flow through the accelerating electrode for controlling the potential difference applied between the emitter and accelerating electrodes.

3. An apparatus as described in claim **1**, wherein the stable voltage output is developed across an emitter follower circuit.

4. An apparatus as described in claim **1**, additionally comprising:

- a closed control circuit means responsive to collector current for stablizing the potential at the accelerating electrode; and
- means for maintaining the potential of the collector electrode at a level below the potential of the accelerating electrode.

5. An apparatus as described in claim **4**, wherein the closed control circuit comprises an amplifier having an input connected to the collector electrode and an output connected to the accelerating electrode so that the output voltage of said amplifier varies in accordance with the current or voltage at the input.

6. An apparatus as described in claim **4**, wherein the means for applying potential difference between the emitter electrode and the accelerating electrode, comprises:

- a supply voltage source;
- a resistor disposed between said supply voltage source and said accelerating electrode; and
- the closed control circuit comprises an amplifier having an input connected to the collector electrode and an output connected to the accelerating electrode so that the output current flows across said resistor.

7. An apparatus as described in claim **4**, wherein the means for applying potential differences between the emitter and accelerating electrodes, comprises:

- a supply voltage source; and
- a resistor disposed between said supply voltage source and said accelerating electrode for further stablizing the apparatus at multistable operating levels in response to current flowing through the accelerating electrode.

8. An apparatus as described in claim **7**, wherein the means for maintaining the potential of the collector electrode below the accelerating electrode, comprises:

- a transistor having an emitter connected to the collector electrode, a base connected to the accelerating electrode and a collector connected to a positive terminal of the supply voltage source; and
- a resistor connected between said emitter and a negative terminal of the supply voltage source.

9. An apparatus as described in claim **7**, additionally comprising a capacitor connected between the emitter and accelerating electrodes for delaying potential difference variations.

10. An apparatus as described in claim **7**, additionally comprising:

- a capacitor connected on one side to the accelerating electrode; and
- switch means for selectively connecting the other side of the capacitor to one of the positive and negative terminals of the supply voltage source in accordance with the desired change in voltage level.

11. An apparatus as described in claim **10**, wherein the closed control circuit between the collector electrode and the accelerating electrode is interrupted as a result of the positive or negative voltage applied by the switch means.

12. An apparatus as described in claim **10,** additionally comprising a capacitor connected between the emitter and accelerating electrodes for delaying potential difference variations.

13. An apparatus as described in claim **10,** wherein the capacitor is connected in series with the supply voltage source.

14. An apparatus as described in claim **10,** additionally comprising resistors arranged to be connected in series with said capacitor by said switching means.

15. An apparatus as described in claim **14,** wherein the resistors and capacitors are selected to have values that form a time constant during which a dosed voltage variation will be applied across the accelerating and emitting electrodes.

16. An apparatus as described in claim **15,** wherein the dosed voltage variation is temporarily superimposed across the emitter and accelerating electrodes, additionally comprising means for limiting the dosed voltage variation to a level higher than the excitation voltage of the atom but lower than double the value of the excitation voltage.

17. An apparatus as described in claim **16,** wherein the means for limiting the additional voltage comprises zenor diodes.

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