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Johnson

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[54] **HIGH INTENSITY LAMP APPARATUS AND METHOD OF OPERATION THEREOF**

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[73] Assignee: **General Electric Company,** New York, N.Y.

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[52] **U.S. Cl.** **313/183,** 313/186, 315/266, 315/199

[51] **Int. Cl.** **H01j 17/20**

[58] **Field of Search** .... 315/97, 105, 266, 315/199, DIG. 2, DIG. 5, DIG. 7; 313/186, 183

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[57] **ABSTRACT**

Describes photochemical and fluorescent lamp apparatus including means for providing a far U.V. ionic radiation emitting discharge, the intensity of which varies as a superlinear function of discharge current, and means for exciting the discharge source with a shaped current waveform. The use of a shaped current waveform permits operation at higher instantaneous currents without increasing average cathode or wall loading and results in greatly increased intensity of lamp output.

7 Claims, 5 Drawing Figures

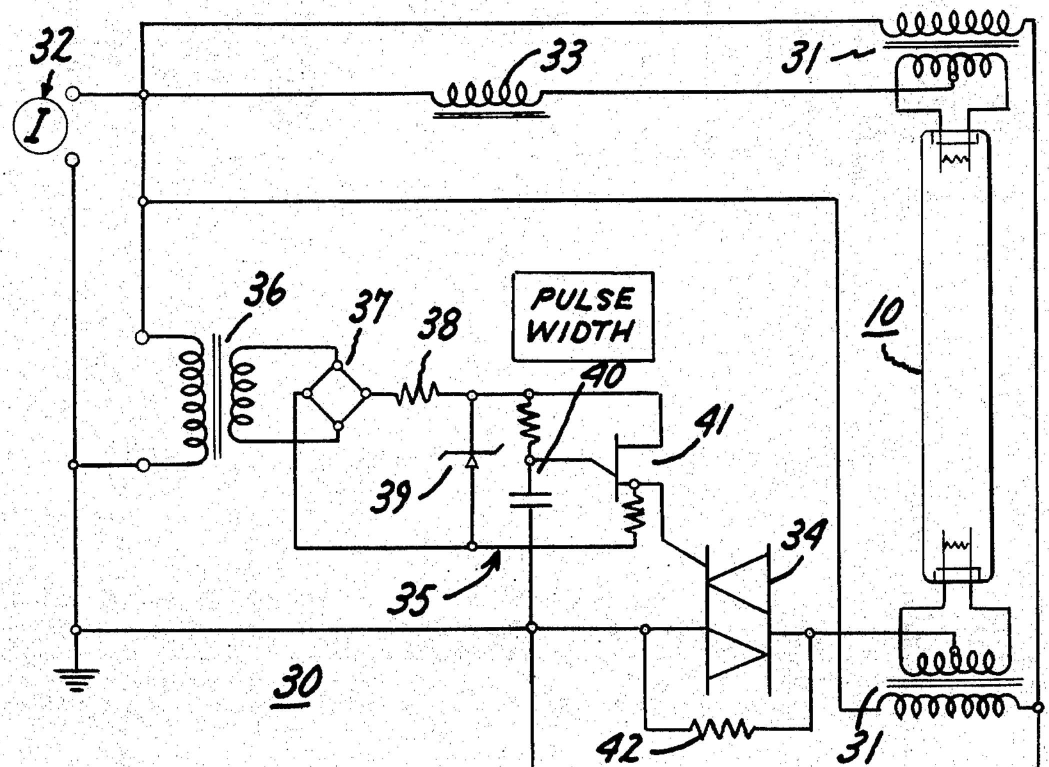

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Fig.1.

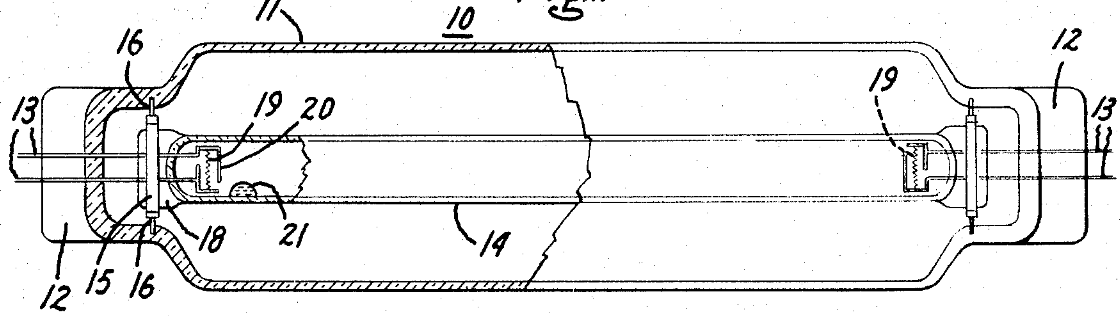


Fig.2.

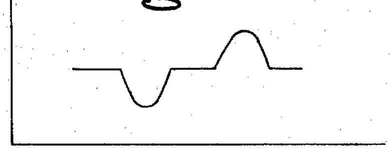


Fig.3.

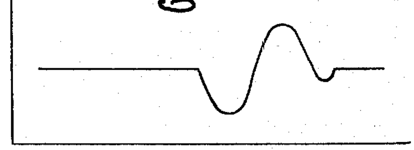


Fig. 4.

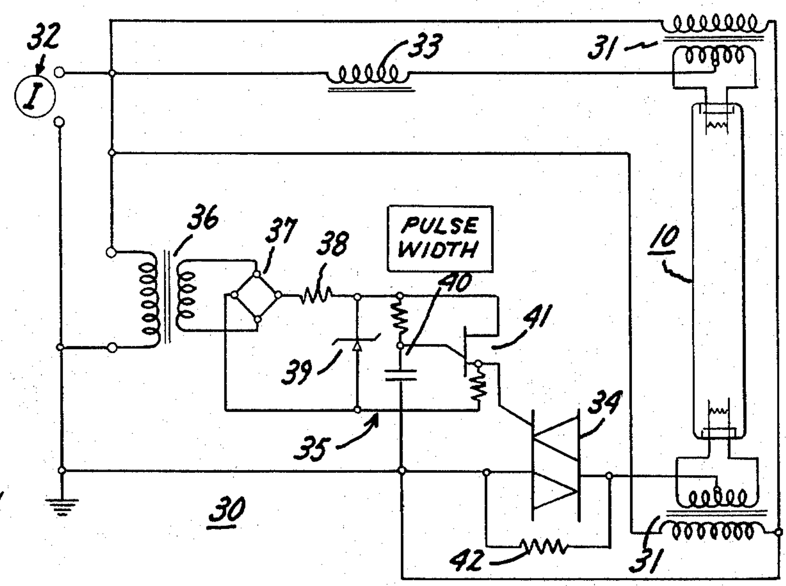
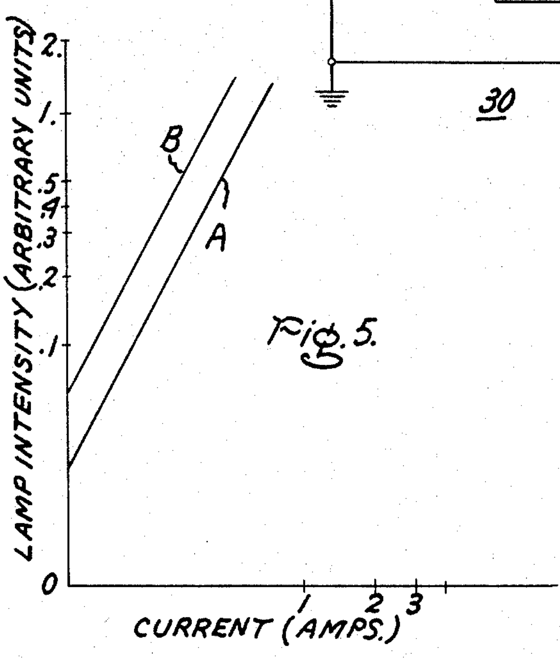


Fig.5.



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HIGH INTENSITY LAMP APPARATUS AND METHOD OF OPERATION THEREOF

This invention relates to high intensity operation of lamps in which the radiant energy output thereof is directly or indirectly the result of ionic excitation of the vaporizable ionizable metal present in a lamp envelope at low pressure by a high current density electric discharge. More particularly, the invention relates to apparatus and methods for the improved operation of such lamps.

This invention is related to the invention set forth in my co-pending applications, Ser. Nos. 50,105, now U.S. Pat. No. 3,657,590 issued Apr. 18, 1972, 50,106, now U.S. Pat. No. 3,679,928, issued July 25, 1972 and 50,203, now U.S. Pat. No. 3,657,591, issued Apr. 18, 1972 all of which were filed on June 26, 1970, and to my currently filed application, Ser. No. 80,901, all of which are assigned to the assignee of this invention.

In the aforementioned applications, briefly stated, I have disclosed and claimed electric discharge lamp devices which produce far ultraviolet radiation which is achieved by utilizing a fused quartz, high density alumina, or sapphire, for example, far U.V. light transmissive discharge envelope containing a pair of suitable discharge electrodes adapted to carry a relatively high current density discharge and maintaining within the discharge envelope a quantity or charge of a vaporizable ionizable metal which may be mercury, cadmium or zinc together with a suitable noble gas which may be any one of the gases including helium, argon, neon, krypton and xenon. The operating parameters of the far U.V. stimulating discharge are controlled so as to cause a current density in excess of 1 ampere per square centimeter and as high as 25 amperes per square centimeter to be established between the discharge electrodes. The metal charge is present within the discharge envelope in a quantity sufficient for the generation, at the operating temperature of the discharge, of a pressure thereof within the range of 10^{-4} of 1 torr of vaporized metal. The pressure of the inert gas is maintained at a value of approximately 1–20 but preferably approximately 2–5 torr.

Under these conditions of operation and specifically of vaporized metallic pressure and discharge current density, the metallic specie are excited to both atomic and ionic radiation in the far ultraviolet region of the electromagnetic spectrum.

In accord with the improvement set forth in my co-pending concurrently filed application, Ser. No. 80,901, I have discovered that the far ultraviolet excitation produced by the far U.V. discharge means described in my previously described co-pending applications, may be coupled with a suitable far U.V. sensitive and visible light emitting luminescent phosphor to produce fluorescent lamps having an intensity which is greatly improved over the fluorescent lamps of the prior art due to the sensitivity and efficacy of the far ultraviolet radiation as a phosphor exciting means.

Although the invention set forth in the previous and co-pending applications as described hereinbefore, are of great utility in increasing and making more effective the light emitting characteristics of electric discharge and fluorescent lamps, it is desirable that such lamps be operated with excitation apparatus and in such a fashion as to derive the maximum amount of light therefrom.

Accordingly, it is an object of the present invention to provide electric lamp apparatus having improved operating excitation means.

Still another object of the present invention is to provide a new and improved method for operating electric discharge lamps which utilize far ultraviolet radiation as an excitation for light emitting means.

Yet another object of the present invention is to provide improved means for utilizing the ionic, far ultraviolet radiation of electric discharge lamps.

Briefly stated, in accord with one embodiment of the present invention, I provide electric discharge lamps utilizing the passage of a high current density electric discharge through a low pressure of vaporizable ionizable metallic radiating specie operative to provide strong ionic emission radiation. Means are provided associated with the discharge electrodes to supply thereto an exciting current waveform which is shaped to as to provide a current value sufficient to cause the emission of far U.V. ionic radiation for a portion of the total excitation time which is a maximum of 40 percent thereof and for providing to the lamp electrodes for the remaining portion of the excitation time, a current which is sufficient only to maintain the vaporized and ionized state of the radiating specie and insufficient to cause emission therefrom.

The novel features believed to be characteristic of the present invention are set forth in the appended claims. The invention itself, together with further objects and advantages thereof, may best be understood with reference to the following detailed description taken in connection with the appended drawing in which,

FIG. 1 is a schematic vertical cross-sectional view of a lamp utilized in accord with the present invention,

FIGS. 2 and 3 are representative waveforms of suitable shaped current waveforms for utilization in the excitation of lamps in accord with the invention,

FIG. 4 is a schematic diagram of one representative suitable electronic circuit adapted to provide a shaped current waveform for excitation of lamps in accord with the present invention and,

FIG. 5 is a logarithmic plot of the intensity of lamps operated in accord with the present invention as compared with the intensity of similar lamps operated in accord with prior art teachings.

In FIG. 1 of the drawing, a typical lamp constructed in accord with the present invention is represented generally at **10**. Lamp **10** includes an evacuated hermetically sealed envelope **11**, having a pinch seal **12** at either end thereof and accommodating inleads **13** therethrough. Interior of envelope **11**, a second inner envelope **14** having an elongated tubular shape is supported within envelope **11** by a pair of saddle clamps **15** suspended upon support members **16**. The ends of envelope **14** terminate in a pair of pinch seals **18**. Inleads **13** pass through pinch seals **18** and are terminated in a pair of filaments or discharge electrodes **19**. Discharge electrodes **19** as illustrated herein, may be conventional fluorescent type lamp electrodes and include a thermionic filament connected across inleads **13** and having associated therewith a pair of anode members **20** which function on alternate portions of an alternating current cycle with an oppositely disposed filament operating as cathode. Alternatively, a thermionic hollow cathode may be used for the attainment of higher discharge currents to optimize the invention.

A charge **21** of a quantity of an ionizable vaporizable metal, such as mercury, cadmium or zinc, together with a partial pressure of a suitable noble gas such as helium, neon, argon, krypton or xenon is located within inner envelope **14** to provide for a far U.V. emitting lamp **10** suitable for use in accord with the present invention. The quantity of metal is such as to insure a partial pressure of approximately 10^{-4} to 10^{-1} torr of vaporized metal at operating temperature and current.

If desired, in the instance in which the lamp is to be utilized in the mode of operation wherein the far U.V. light excites a fluorescent phosphor to emission of visible light, a fluroescent phosphor adapted to emit visible and near ultraviolet light when irradiated by far ultraviolet light is disposed over substantially all of the inner portion of the bulbous portion of outer envelope **11.** Alternatively, in the instance on which the direct radiant emission of the discharge providing far ultraviolet light is to be utilized, then the outer envelope **11,** if present, is clear but must be constructed of a material such as fused quartz, high density alumina or sapphire which is transparent to far ultraviolet radiation. In all instances, inner envelope **14** must likewise be fabricated of an ultraviolet transmissive material as is recited above. In instances in which very low currents are to be utilized for the operation of a discharge between electrodes **19,** it is not essential that a double walled envelope structure be utilized. This is also particularly true in the instance in which a mercury discharge, which may be maintained within the desirable operating pressure at a temperature of from 25°–125°C and there is no great necessity for providing means for maintaining high temperature within the inner envelope, and likewise the outer envelope may be dispensed with. Alternatively, in the instance in which zinc or cadmium are utilized as the radiating specie and it is necessary to maintain the temperature within the envelope **14** at a value of 200°–400°C, then it is a necessary condition that thermal buffering means may be provided to maintain the coldest portion of envelope wall **14** at the elevated temperature and the double envelope structure is utilized. In such instances, it is desirable that the inter-envelope space be evacuated in order to prevent dissipation of heat from the inner envelope.

In accord with the present invention, I have discovered that unlike the ultraviolet light sources of the prior art which generally utilized mercury discharges at such values of current and pressure of the mercury such that the primary emission of the mercury spectrum was of the 2537 A.U. atomic mercury line, the ultraviolet light sources in accord with the present invention utilizing high currents and low pressures radiate ionic radiation that is within the range of 1,600–2,300 A.U. Thus, for example, when mercury is the radiating specie, the emission is the 1650 and 1942 ionic lines. When the radiating specie is cadmium, the emission is from the 2,144 A.U. and 2,265 A.U. ionic lines. When zinc is the radiating specie, the radiation is the 2,026 A.U. and 2,062 A.U. ionic lines.

I have further discovered that although the emission of atomic radiation in lamps in accord with the prior art generally varies as a direct function of the discharge current, the emission of the ionic lines varies according to a relationship which may be stated by the formula,

$$I = ci^n,$$

where i is the current density, c is a constant and n equals 1.75 for the Hg-A discharge and n equals 2.0 for the Hg-Kr discharge. Thus, it follows that the emission of the ionic lines varies superlinearly and almost by the square of the discharge current.

Accordingly, rather than utilizing a direct current or sine wave alternating current excitation (or even a pulsed current excitation wherein the average current supplied to the radiating specie is a major fraction, i.e., 50 percent of the peak current supplied to the radiating specie,) I provide lamp apparatus wherein a high current, low pressure radiating specie type discharge is excited with a shaped current waveform wherein a sufficient value of current to excite the radiating specie to ultraviolet emission is provided for only a small fraction of the total excitation period. This fraction has a maximum of approximately 40 percent of the excitation period and may vary as low as 5 percent for alternating positive and negative going peaks of the pulsed waveform and as low as 1 percent of the total period when pulsed unidirectional voltages are utilized. Thus, for example, for discharge tubes as illustrated in FIG. **1** having an I.d. of the inner envelope of 14 mm. and an interelectrode spacing of 22 cm., a peak current of 5–50 amperes is applied for from 5 to 40 percent of the time and a "keep alive" current of several hundred milliamperes is supplied for the remaining time.

FIG. **2** of the drawing illustrates a pulsed waveform which is a simple shaped 60 Hz alternating positive going and negative going pulse wave having a value sufficient to cause excitation for approximately less than 40 percent of the total excitation period. Actually, the initial and final parts of the positive going and negative going pulses do not supply sufficient current to provide for far U.V. excitation of the discharge in accord with the invention and only the peak of the positive and negative going pulses satisfies this criteria, so that by varying the absolute value of the peak current and its duration, the waveform may be adjusted for any desirable excitation percentage.

FIG. **3** of the drawing illustrates an alternate pulse shaped waveform which is basically a 15 Khz shaped wave having alternate positive and negative going pulses in which the period of current sufficient to excite the specie to far U.V. radiation is a maximum of 40 percent. Such a wave may, as described hereinbefore, by adjustment of the effective width of the positive and negative going pulses, be adjusted to any desirable percentage of the total period of excitation which is effective to cause far U.V. radiation from the lamps of the invention. I find, due to the relaxation times of the radiating species involved, that for alternating shaped waveforms, as illustrated, frequencies of from approximately 10 Hz to 50 Khz are suitable.

FIG. **4** of the drawing is a schematic illustration of a suitable power supply **30,** effective to produce the shaped waveform of FIG. **3** connected to a schematically illustrated far U.V. emitting lamp in accord with the invention. In the circuit of FIG. **4,** lamp **10** having discharge electrodes **12** is connected between a pair of center-tapped filament transformers **31** which are connected across a line voltage source **32.** The current circuit through the lamps passes through a current limiting choke **33** and a solid state switching means **34.** Switching means **34** is supplied with a phase-delayed trigger pulse from a pulse width generating means 35 connected to line voltage through a step down transformer 36. Pulse width generating means 34 includes a full wave rectifier 37, a limiting resistance, a zener diode 39, an RC circuit 40 and a grounded emitter transistor 41, suitable for producing a phase delay which appropriately regulates, in accord with the values thereof, the portion along the total excitation time that the solid state switch 34 is operative to allow the flow of full excitation current to the lamp. Solid state switch 34 is bypassed with a several hundred ohm resistance 42 in order that a current, sufficient to keep the radiating specie ionized, is allowed to flow through the lamp electrode circuit in the inactive portion of the time period.

FIG. 5 is a logarithmic plot of lamp intensity, in arbitrary units, as a function of total lamp current. Curve A is a plot of the intensity from a lamp utilizing mercury and krypton, and emitting principally 1942 A.U. ionic radiation with some 1650 A.U. ionic radiation, operated by a 60 Hz sine wave current. Curve B, on the other hand, is a plot of lamp intensity, in the same units, as a function of discharge current for a similar lamp utilizing a shaped waveform, in accord with this invention. The waveforms of FIGS. 2 and 3 were both plotted and both follow Curve B to an extent that they cannot be distinguished from one another. Comparison of Curves A and B shows a substantial increase in lamp intensity for shaped current waveform excitation.

From the foregoing, it may readily be seen that the intensity of lamps in accord with the present invention clearly increases as a superlinear function of current due to the greater than unity exponential function of the dependence of the intensity upon the current for the shaped waveform mode of operation and the apparatus for providing the same. The data obtained and plotted on FIG. 5 are taken from a lamp utilizing a conventional fluorescent lamp cathode. In accord with the present invention, it is preferable that high current cathodes be utilized as for example, thermionic or hybrid hollow cathodes such as the type cathodes as set forth in the co-pending application, Ser. No. 886,824, filed Dec. 22, 1969, of Harald Witting. Briefly, such hybrid hollow cathodes include a split hollow cathode member including a pair of symmetrically disposed curved surfaces, which may for example, be semi-cylindrical, semi-conical, hemispherical or other appropriate configurations are disposed so as to form a hollow cathode cavity with the thermionic filament disposed therebetween. When the cathode is energized, the thermionic filaments immediately causes the establishment of a discharge and accelerates establishment of a hollow cathode mode discharge which carries very high currents. Lamps utilizing hollow thermionic cathodes as is described hereinbefore, clearly are capable of improved operation more nearly approach the theoretical limit of improvement of the shaped waveform mode of operation due to the increased dependence of the ionic radiation upon peaked current.

By the foregoing, I have disclosed apparatus for providing high intensity luminous output which may be emission in the far ultraviolet caused by the direct operation of a low pressure, high current, vaporizable, ionizable metallic vapor discharge emitting in the far ultraviolet and useful in photochemical and other such non-illuminating purposes.

Alternatively, the invention is operable to utilize far ultraviolet radiation which excites luminescent phosphors which are sensitive to far ultraviolet radiation to produce high luminous intensity in the visible range. The improved intensity of lamps in accord with the present invention results from the coupling therewith of means for providing a current waveform to the electrodes of the far ultraviolet emitting discharge to cause the current through the discharge to exhibit a first value which is effective to cause far ultraviolet emission from the vaporized and ionized metallic specie therein for a period which is a minor fraction of the total period of excitation of the lamp. For the remainder of the total period of excitation of the lamp, the waveform exhibits a second value which is insufficient to cause far ultraviolet emission, but sufficient to maintain the lamp in a state of vaporization and ionization so as readily to return to the emitting state. Due to this shaped current waveform excitation, the average power supplied to the lamp during operation is a relatively small fraction of the peak power supplied thereto. Thus, it is possible with the same average current input, greatly to increase the instantaneous current input to the lamp to cause an increased light output which increased output causes a superlinear variation and increase in the intensity of the emitter light.

While the invention has been disclosed herein with respect to certain specific and preferred embodiments thereof, many modifications and changes will readily occur to those skilled in the art. Accordingly, I intend by the appended claims to cover all such modifications and changes as fall within the true spirit and scope of the present invention, and its specific disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. High intensity lamp apparatus comprising:

a. a far U.V. emitting discharge means including:

a_1. an evacuable hermetically sealed U.V. transmissive envelope,

a_2. a pair of discharge electrodes disposed within said U.V. transmissive envelope and sustaining in operation an electric discharge in excess of 1 A/cm^2,

a_3. a quantity of a vaporizable ionizable metal within said envelope sufficient to produce a partial pressure thereof of approximately 10^{-4} to 1 torr under lamp operating conditions,

a_3^1. said metal emitting far U.V. ionic radiation at wavelengths of from 1,650 to 2,300 A.U. under excitation by discharge current densities of in excess of 1 A/cm^2 at said pressure, and

b. Current waveform shaping means operatively connected with said discharge electrodes and receiving normal fluorescent operating current input to control and modify said input current to provide a shaped current waveform during each period of operation having a value of current in excess of the maximum value of said input current and being sufficient to excite said metal to ionic radiant emission during a portion of each period of approximately 5 to 40% of the period thereof and a minimal ionizing value insufficient to cause ionic emission for the remainder of said period while maintaining substantially the same average current input during said period.

2. The apparatus of claim 1 wherein said far U.V. emitting discharge means includes a vaporizable ioniz-

able metal selected from the group consisting of mercury, cadmium and zinc and a noble gas selected from the group consisting of helium, argon, neon, xenon and krypton.

3. The apparatus of claim 2 wherein said metal is mercury and said gas is argon.

4. The apparatus of claim 2 wherein said metal is mercury and said gas is krypton.

5. The apparatus of claim 1 wherein the value of said shaped current waveform in excess of the maximum value of said input current is in excess of one ampere per square centimeter current density and the value of said minimal ionizing value of current is 10-200 milliamperes.

6. The method of stimulating a lamp having a radiation species emitting ionic radiation selected from the group consisting of mercury, cadmium, and zinc enclosed between a pair of discharge electrodes and mixed with a partial pressure of a few torr of a noble gas with controlled current excitation which method comprises: (a) supplying a current waveform having a predetermined excitation period to said discharge electrodes; (b) electronically controlling the current supplied to said discharge electrodes during a portion of approximately 5 to 40% of each said excitation period of operation to shape the current waveform during said portion to have a value in excess of the normal maximum operating current of said lamp and sufficient to raise excited vapors of said metal to a state at which far UV ionic radiation exponentially dependent upon current value is emitted; (c) further electronically controlling the current supplied to said discharge electrodes during the remaining portion of each said excitation period of opeation to further shape the current waveform during said remaining portion to have a current valve insufficient to stimulate excited vapors of said metal to said ionic emission but sufficient to maintain vapors of said metal in a vaporized and ionized state; (d) said values of current supplied to said discharge electrodes during the UV ionic radiation emitting portion of said excitation period and the remainder of said excitation period being of such magnitude that the average current input to said discharge electrodes during said excitation period maintains the same average value of current input thereto as is supplied under normal current waveform operation during said excitation period; (e) said lamp emitting ionic radiation due to said controlled current excitation which is greater in intensity than that achievable under normal waveform excitation at the same value of average current.

7. The method of claim 6 wherein said shaped current waveform is a pulsed unidirectional current and said portion of said excitation period wherein the current value is in excess of normal maximum operating current is approximately 1 to 10% thereof instead of 5 to 40%.

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