

**LOW-VOLTAGE NON-THERMIONIC BALLAST-FREE
FLUORESCENT LIGHT SYSTEM AND METHOD**



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BACKGROUND AND BRIEF DESCRIPTION OF THE INVENTION

The present invention relates to fluorescent lighting systems and, more particularly, to low-voltage, non-thermionic (no heated filament) ballast-free fluorescent lighting systems which are more efficient, less expensive, substantially free of RF emissions and which preferably use conventional commercial, office and home-grade fluorescent tubes.

In most commercial and home-grade fluorescent lighting systems, the heart of the system is the ballast, which is an inductance or transformer device that boosts the incoming voltage to a higher voltage level to start the fluorescent tubes and then, once the fluorescent tubes are lit or ignited (gas-activated, ionized or "discharged"), reduces the voltage to a level for normal continuous lighting. Moreover, these prior systems often use transformer filament windings to heat the filaments to therefore provide thermionic emission for assisting in the ignition phase. Heated filaments vaporize and form black deposits at the end of each tube and limit tube life. Also, sputtered material traps fill gases and reduces gas pressure. Early ballasted fluorescent lighting systems are shown in Figures 1A and 1B. In Figure 1A the ballast unit



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L is in series with filaments F and switch S, and in Figure 1B, glow switch GS which opens after the filaments are heated to initiate a discharge.

Ballast transformers are often the most expensive part of commercial fluorescent lighting systems. There have been numerous past efforts to provide fluorescent lighting systems which do not use ballast transformers.

Electronic ballasts of the type shown in Figure 1C are common in the art and are disclosed in International Rectifier Publication Application Notes AN-995, "Electronic Ballasts Using the Cost-Saving IR2155 Driver". In this circuit, two power switches Q1, Q2 are connected in a totem pole topology with the tube circuits consisting of an LC series resonant circuit with the lamp across one of the reactances. The switches are power MOSFETS driven to conduct alternately by windings on current transformer T. In this circuit, the primary winding is driven by current to the lamp circuit and operates at the resonant frequency of L and C. A starting pulse is provided by a starting circuit comprised of resistor R1 and capacitor C1 and DIAC D1 connected to one of the gates of one of the power switches. After oscillation is initiated, a high frequency square wave (30-80 kHz) excites the LC resonant circuit. The sinusoidal voltage across the reactance C is magnified by the Q at resonance and develops sufficient amplitude to strike the fluorescent lamp. In this system, the filaments

of the lamp are heated and connected in series with the series resonant circuit.

RF driven fluorescent lamps are known in the art. In Piejak et al U.S. Patent No. 5,325,024, a fluorescent light source includes multiple lamp tubes driven in parallel by a single RF source. External and internal capacitive couplings of the electrodes to the gas filling of the tubes is used to induce the plasma-forming discharge period.

Godyak et al U.S. Patent No. 5,300,860 discloses capacitive coupled fluorescent lamps with RF magnetic enhancement.

Presz et al U.S. Patent No. 4,920,299 discloses a push-pull fluorescent dimming circuit in which high voltage DC pulses are used to ionize the mercury argon vapor lamp. Dual outputs from the digital timing circuit control a pair of switches in the arc voltage power supply for alternately reversing the polarity of the arc voltage supplies.

Kerwin U.S. Patent No. 4,973,885 discloses a low-voltage direct current powered fluorescent lamp in which a stabilized blocking oscillator circuit provides high-voltage alternating current for addition and operation of a lamp as well as power for operating a filament or heaters included in the lamp. In Kerwin, the blocking oscillator circuit incorporates a transformer which steps up the voltage for ignition of the lamps.

In Roberts U.S. Patent No. 5,359,263, a resonant voltage rise in an LRC ballasting circuit is utilized to increase the cyclic crest voltage for lamp ionization.

5 Tao et al U.S. Patent No. 5,578,907 discloses a power supply circuit for a fluorescent lamp in which a power supply, such as a high-voltage square wave switching power supply, drives a current regulating inductor and a starting capacitor. The fluorescent tube is connected across the starting capacitor.

10 In Nilssen U.S. Patent No. 5,512,801, a ballast for an instant start parallel connected lamp is provided. In this patent, a half bridge inverter is powered from a DC voltage and provides a 30 kHz square wave like inverter output. As in Figure 1C, the inverter output is applied to a series
15 resonant LC circuit and parallel connected across the capacitor of the LC circuit is a plural series combination which consists of an instant start lamp series connected with a current limiting capacitor. The magnitude of the high current frequency voltage across the tank circuit is
20 controlled by controlling the frequency of the inverter output voltage. Prior to lamp ignition, the magnitude of the high-frequency voltage controlled to a relatively high level to provide for sufficiently forceful lamp ignition.

25 Hirschman Patent No. 4,959,591 discloses a rectifier inverter circuit for operation of fluorescent lamps in which lamp energy is supplied via a resonant LC circuit (as in Figure 1C) which is driven at a frequency of between 10

and 100 kHz and preferably at about 35 kHz from a push-pull oscillator or frequency generator formed by two transistors, each of which have bypass diodes connected to the cross-linked current carrying path thereof. These switching transistors receive control voltage through feedback windings from a feedback transformer having a primary winding serially connected with the lamp. A step-up converter is coupled between a starting capacitor for the push-pull generator, and the fluorescent lamp filaments are connected in series with the LC resonant circuit.

In Williams U.S. Patent No. 5,408,162, the combination of a switching regulator and a high-voltage inverter produces a high sinusoidal ignition voltage of approximately 1400 volts peak-to-peak with low RF emissions.

Fahnrich et al U.S. patent No. 4,808,887 discloses a low-pressure discharge lamp operating at a high frequency with the low induction power network which has a push-pull frequency generator and a series resonant LC circuit (as in Figure 1C) with a harmonic filter connected in series with the lamp so as to assure sinusoidal operation. A similar system for suppressing harmonics is disclosed in Farnrich et al Patent No. 4,782,268.

Williams Patent No. 5,548,189 discloses a DC to AC converter coupled to a switching regulator which converts low DC voltage into higher sinusoidal AC voltage for driving a fluorescent lamp. This reference points out the

geometric nature of the magnetic step-up transformers and seeks to reduce the transformers size by using a special piezoelectric acoustic transformer.

5 Nilssen U.S. Patent No. 5,581,161 uses a voltage multiplying circuit to raise the voltages for operating a fluorescent lamp to 1100 to 1500 volts.

THE PRESENT INVENTION

The basic objective of the present invention is to provide improved fluorescent lighting systems.

10 Another object of the present invention is to provide a more energy-efficient fluorescent lighting system.

Another object of the invention is to provide a more energy-efficient fluorescent lighting system which is low in cost and operates at low voltages.

15 Another object of the invention is to provide a low-voltage (from about 2 to about 85 - 90 volts) fluorescent lighting system having a square wave voltage in the frequency range of about 75 kHz to about 3.5 - 4 MHz.

20 Another objective of this invention is to provide a fluorescent lighting system wherein one or more conventional fluorescent tubes is non-thermionically operated and driven by a low-voltage, high-frequency square wave source.

25 Another objective of this invention is to provide a fluorescent lighting system wherein multiple fluorescent

tubes are electrically connected in series and non-thermionically driven by a low-voltage square wave voltage.

Another object of the invention is to provide a fluorescent lighting system in which the light intensity is variable from low-level illumination to high-level illumination and from high-level illumination to low-level illumination.

According to the invention, a low voltage (under 85 - 90 volts, preferably in the range of 7 - 12 volts at about 100 kHz), non-thermionic, ballast-free, fluorescent lighting system comprises at least one fluorescent lighting lamp or tube (constituted by UV-responsive phosphor-coated envelope confining a gaseous discharge medium at a predetermined pressure between a pair of electrodes) and a low-voltage square wave power supply. The square wave power supply incorporates a solid state switch which is operated to generate a substantially square wave alternating current wave at the lamp or tube electrodes such that the voltage supplied to the electrodes reverses polarity more rapidly than the pattern of electron and ion density in the tube can shift so that electrons throughout the length of the tube are continually accelerated and will, through several cycles of said square wave, create free electrons and ions throughout the tube's volume, in steady state operation and illuminate the fluorescent lighting lamp.

According to a preferred embodiment of the present invention, a fluorescent lighting system comprises at least one fluorescent tube with electrodes (which may be conventional filaments or not) immersed in a gaseous discharge medium, such as argon gas and mercury vapor; and the fluorescent tubes are non-thermionically driven with a low-voltage, high-frequency square wave voltage. In the preferred embodiment, the fluorescent lamp driver circuit includes an inverter circuit using two solid state switching devices which are connected across a direct current supply. The gate electrode of each switch transistor is connected in circuit with a primary winding for each switch device and a primary winding of the transformer. A starting circuit to start the oscillator is utilized to provide a positive turn-on pulse to the gate electrode of one of the transistor switches. When one of the transistor switches turns on, its voltage is rapidly switched to ground which starts the circuit in oscillation. In the preferred embodiment, the oscillating frequency is set at about 100 kHz, but the range of successful operation runs from about 75 kHz through about 4 MHz. Since there are no high voltages in the driver circuit, safe operation is assured. Illumination or luminosity levels or dimming can be achieved by varying the voltage (or energy level) from the direct current supply. In the preferred embodiment, care is taken to assure that there are no spike voltages due to inductive kick and the like since voltage

spikes are not required for starting or operation and, if present, may reduce operating efficiency. Since the fluorescent lamps are non-thermionically driven, the luminous efficiency is significantly improved. Moreover, at the preferred high frequency, power supply components can be smaller.

The invention has the following further features:

(1) Being Non-Thermionic

You can intermingle tubes of different ratings or configuration, like the new "watt miser" 32 watt or the new 25 watts "energy savers" with the "standard" 40 watts (four footers). The light output essentially remains the same regardless of the tube rating. Today's usual shop lights can only use 40 watt regular tubes due to the shortcomings of the ballast as well as the use of chains to hang them because they can be a fire hazard. Tubes that are "non operative" on standard systems will operate (function).

(2) Being Ballast-Free

The fixture weight and operating temperature are substantially reduced, eliminating the need for chain hanging. The system is not a temperature driven fire hazard.

(3) Since the system is ballast-free, there is no need for a sound rating because the system is silent. The greatly reduced heat and weight will allow the use of a plastic

housing, eliminating the "electric shock hazard" as well as the need for grounding.

(4) Being of Reduced Heat.

The system can be mounted in any orientation and in
5 contact with standard combustible surfaces (wood, wallpaper, etc.).

(5) The fluorescent tubes, if filamented, will keep emitting normal light even in the event that one or both filaments are inoperative.

10 (6) Most fluorescent arrays or multiple tube units consist of identical tubes in parallel. The plural or multiple tube array systems can comprise identical or different rated tubes in series.

15 (7) Standard 1-1/4 and 1-1/2 inch diameter four-feet or long fluorescent tubes filled with conventional mercury vapor and/or argon gases and simple non-filamentary electrodes, and even conventional tubes with non-working or burned out filaments can be successfully used in the practice of this invention.

20 (8) Flexible plastic tubing, such as used in surgical gas transport systems, having UV responsive phosphors incorporated on the walls therein, Lexan™ type hard

plastic, shatter-proof gas retention vessels with simple discharge electrodes in the gas and fluorescent coatings on the walls can be driven in accordance with the invention. In such cases, the darkening of the plastic due to UV bombardment with time can be advantageous, or the darkening can be prevented with a UV blocking coating.

DESCRIPTION OF THE DRAWINGS

The above and other objects, advantages and features of the invention will become more apparent when considered with the following specification and accompanying drawings wherein:

Figure 1A is a circuit diagram of prior art transformer ballasted fluorescent lighting systems, Figure 1B is prior art ballasted fluorescent lighting systems with a glow switch starter, Figure 1C is a circuit diagram of an electronic ballasted fluorescent lighting system,

Figure 2A is a general block diagram of the fluorescent lighting system incorporating the invention and Figure 2B illustrates the various shapes of fluorescent tubes or fluorescent gas discharge devices to which the invention is applicable,

Figure 3 is a general block diagram of a fluorescent lighting system incorporating a preferred embodiment of the invention,

Figure 4 is a general block diagram of a fluorescent lighting system showing the same driver system driving at least three fluorescent lamps in series,

5 Figure 5 is a detailed circuit diagram of a preferred embodiment of the invention,

Figure 6 is a circuit diagram illustrating a further preferred embodiment of the invention, and

10 Figure 7 is a diagrammatic illustration of a further embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is based on the discovery that using a rapidly repetitive low-voltage square wave alternating voltage, ignition may take place in fluorescent gas discharge tubes gradually at lower voltages and power. Since the half-cycle period of the square wave alternating voltage power according to the invention is very short (of the order of 5 microseconds for 100 kHz), there is very little opportunity for decay of the plasma between half-cycles. At start-up, ambient free electrons in the gas increase in energy in a half-cycle more than they lose energy due to collision processes. According to the invention, during one half-cycle, an electron will move in a roughly constant electric field. During each interval between collisions with neutral atoms, or ions, its kinetic energy will increase if its previous collision left it

traveling with a component of velocity in the direction of the acceleration produced by the electric field. It will decrease if its previous collision left it moving without a component of velocity opposed to the field's acceleration. According to the invention, the square wave alternating supply voltage serves principally to raise the effective electron energy (or temperature). The current flowing consists of electrons flowing to the instantaneous anode and positive ions flowing to the instantaneous cathode where they recombine with electrons and are released as neutral atoms. Total gas pressure in the tube is sufficient to make the mean free path considerably less than the tube diameter and much less than its length. Most electrons and ions separate and recombine, in a small fraction of the overall length of the tube, rather than flowing as continuous streams along its axis. The important thing for ionization of the light emitting gas atoms is that the electron energy continues to increase even though the field reverses periodically.

The operation of RF discharged at such low field strengths that the electrons cannot accelerate to ionization energy level in one-half cycle demonstrates that the process is cumulative over many half cycles.

The biggest problem in 60-Hz lamps is that ion and electron densities essentially virtually go to zero at the end of each half-cycle. To achieve light output again after a few milliseconds requires an active supply of

electrons (the filament) with high heating power for that filament. But, then, if the lamp system of the present invention starts at voltage levels far below that usually associated with plasma "breakdown", why does an equally low voltage applied constantly across a single tube not result in the same glowing plasma?

This can be explained in terms of the natural tendency of particles of a plasma subject to a static external field to move so as to create a space charge pattern and field that counteracts the applied field. The result of applying a voltage between two electrodes is to induce positive charge on the positive electrode and negative charge on the negative electrode, the absolute amount of charge depending on course on the capacitance between the two.

If free electrons and ions fill the space between these electrodes, the electrons are pulled toward the anode, and the positive ions toward the cathode, until in the space between there is no longer a field and therefore no means to cause further movement of the particles; a voltage drop, that is, region of high field, will exist very close to each of the two electrodes. The electrons (and ions) in the main part of the tube will not be further affected by the field; when electrons reach the high field region near the anode, they will probably be accelerated to half the applied voltage within less than one mean free path of the anode's surface and hence will be unlikely to produce ionization.

In the fluorescent lamp system of this invention, the applied square wave voltage is alternated rapidly enough that the charged particles cannot move enough to accumulate near cathode and anode during a half-cycle of the applied voltage. Thus, the field remains almost continuously active in accelerating electrons within the main body of the tube.

Figure 2A is a schematic block diagram of a fluorescent lighting system incorporating the invention. A direct current (DC) power supply 200 is protected by a fast-acting fuse 201 and/or a crowbar circuit 202 which provides fast-acting protection of the circuit in the event of a fault. The DC voltage is applied to square wave inverter circuit 203 which converts the DC voltage to a low-voltage (between about 3 to about 20 volts RMS), AC square wave voltage having a high-frequency (between about 75 kHz and about 4 MHz) which is applied to electrodes 204 and 205 of a fluorescent gas discharge device 208. The current is very low so in comparison with light output equivalent to a conventional 60 Hz, thermionically operated fluorescent tube or lamp, the luminous efficiency is significantly improved. Moreover, the fluorescent lamp or tube can be straight, folded or looped as indicated in Figure 2B. A rheostat 200R can be used to adjust or vary the voltage or energy level from the source 203 to gas discharge device 208 and thereby dim or vary the level of luminosity from the lamp. Since the system does not depend

on a large ignition voltage level, the luminosity can be varied from low to high and back to low. In contrast, most conventional dimming circuits for fluorescent lamps require starting with a relatively high luminosity or level of illumination and then reducing the level to a desired point.

Figure 3 is a schematic block diagram illustrating two fluorescent tubes 301 and 302 driven by low-voltage, high-frequency square wave inverter circuit 303. Note that the tubes 301 and 302 are connected in series so that while the square wave inverter circuit 303 can be of the same capacity as the square wave inverter circuit 202, if tubes 301 and 302 have the same length and diameter as fluorescent gas discharge device 206, the volume of gas is essentially doubled. Note that the devices 301 and 302 are non-thermionically driven, even though the tubes may incorporate conventional filaments (not shown).

Figure 4 is a schematic block diagram illustrating three or more fluorescent tubes 401, 402...40N driven by a low-voltage, high-frequency, square wave inverter circuit 404. In this case, the serially connected fluorescent tubes 401, 402...40N, the middle tubes 402...are not directly connected to the output terminals of the inverter circuit 404. The total volume of gas driven is the sum of the volumes of gas in the individual of fluorescent gas discharge devices, none of which is thermionically energized or excited. If all of the fluorescent tubes are

batteries, solar cells, etc., may be used to provide operating energy.

The fluorescent lamp driver comprises an oscillator circuit using two solid state switching devices or transistors Q3 and Q4 (HEXFET'S, IRF624). The switching transistors Q3 and Q4 are connected in totem-pole-fashion across the direct current supply lines 17 (+) and 18 (- or ground). The gate electrode G circuit of each switch driver Q3 and Q4 is connected in circuit with a primary winding PW1 (twenty-five turns) for switch device Q3 and primary winding PW2 (twenty-five turns) for switch device Q4.

Resistor 20 and capacitor 21, with DIAC 22 form a starting circuit for the lower transistor switch Q3. In this embodiment, when the DIAC 22 reaches about 35 volts, a positive turn on pulse is applied to gate G1 of the lower switch device Q3. When switch Q3 switches on, the drain voltage is rapidly switched to ground which starts circuit oscillation. Current flowing through the two turn primary winding PW3 provides gate drive voltages for switching the switch devices Q3 and Q4. This causes the circuit to oscillate at about 100 kHz. Primary winding PW3 speeds up switching of the switches Q3 and Q4 by an order of magnitude. This is caused by a feedback switching action speeding up the switching operation of switches Q3 and Q4.

Figure 6 illustrates a low-voltage square wave inverter circuit requiring a minimum of five components

identical or essentially the same they all illuminate with equal intensity. However, tubes of different lengths, diameter and gas pressures have been successfully operated in series.

5 A preferred embodiment of the system for driving two FT40 fluorescent tubes in series is illustrated in Figure 5. The component values and component types are merely exemplary. This produces a square wave voltage at about 100 kHz with sharp transitions such that the voltage
10 supplied to the lamp L1 electrode LE1 and lamp L2 electrode LE2 reverses polarity more rapidly than the pattern of electron and ion density in the gaseous volume can shift so that electrons throughout the length of the tube are continually oscillated and will, through several cycles of
15 the square wave, create ions throughout the tubes, gaseous volume, in steady state operation.

 In this embodiment of the invention, alternating current (120 VAC for example) is applied through a fast-acting fuse 10 to terminals 11 and 12 of full wave bridge
20 rectifier 13 which provides DC voltage which is filtered by an electrolytic capacitor 15. In this embodiment fast-acting fuse 10 or a crowbar circuit at the output is required to prevent damage to the circuit if the lamp is removed from the circuit. High-frequency filter capacitor
25 16 is connected across the AC input to the bridge rectifier 13. Other sources of direct current voltage, such as

S4 are closed simultaneously or at the same time (preferably by the same signal from controller CONT, the positive terminal (+) is connected to electrode 8-1 and the negative terminal (-) is connected directly to electrode 8-2. When the switches S1 and S2 are simultaneously closed (and switches S3 and S4 are open) by controller CONT, the positive terminal (+) is connected directly to lamp electrode 8-2 and the negative terminal (-) is connected to fluorescent lamp electrode 8-1. Controller CONT can operate the switches in the range of about 75 kHz to about 3.9 MHz and preferably operates the switches to cause the square wave applied to lamp electrodes 8-1 and 8-2 to be at a frequency of about 100 kHz.

In this invention, the magnitude of the alternating voltage at the electrodes is of small significance in initiating the discharge reaction, allowing the capability to start the production of visible light at a low or high intensity -- since the light generated is in direct proportion to the total energy input. (There is no need for a large "starting strike" voltage to ionize the gas.)

Experiments with a transparent Phillips mercury vapor electric discharge lamp model H39KB-175 (175 watts) connected to the 1.2 watt driver (shown in Figure 6) shows the same behavior and characteristics of the fluorescent application. It is believed that the reaction starts at one end of the tube and rapidly extends to the other or far end and then gets stable. Experiments connecting only one

(the electrolytic filter capacitor C1 is deemed to be a part of the DC power source or supply). Switch 57 couples DC voltage (7.2 volts for example) from a battery to the low-voltage square wave inverter drive circuit 701 via dimmer resistor 702 and filter capacitor 701. This driver circuit includes an oscillation transformer 702 having a center tapped primary winding 704 having primary winding 705 and 706 with the center tap 707 connected to gate electrode 708 of oscillating diode transistor 709. The opposing ends of oscillating diode D1 are connected to the upper and lower ends of the primary windings 705 and 706. A capacitor shunts the oscillating transistor/diode 709. The exemplary circuit components are as follow:

Fluorescent tube	FT6
Resistor R1	1500 Ohms
Capacitor C1	47UF 10V Electrolytic
Transistor diode 709	5609/6BC/ECB
Capacitor 711	2A562K
Capacitor 712	2A22K

The output to the fluorescent tube is about 1.4 volts RMS at 3.9 MHz open circuit and 1.7 MHz, square wave at the tube. Thus, the system has no ballast transformer, no thermionic heating of filaments, no starter circuit, and produces light in a more energy-efficient way.

Figure 7 diagrammatically illustrates a transformerless square wave inverter circuit. Here, the positive (+) and negative (-) terminals of a direct current source are alternately connected to opposing electrodes of the fluorescent lamp(s). In this case, when switches S3 and

WHAT IS CLAIMED IS:

1. A low-voltage, non-thermionic, ballast-free fluorescent lighting system comprising at least one fluorescent tube with electrodes spaced in said fluorescent tube, a UV responsive phosphor and a light transmissive envelope confining a gaseous discharge medium at a predetermined pressure between said electrodes, and a power supply, said power supply having a transformer with primary and secondary windings, a direct current source, a solid state switch means connected between said primary winding and said source of direct current and means connecting said secondary winding to said electrodes, said switch means and said transformer primary winding being operated to generate a substantially square wave alternating current wave at said electrodes so that the voltage supplied to said electrodes reverses polarity more rapidly than the pattern of electron and ion density in the tube can shift and electrons throughout the length of the tube are continually accelerated and will, through several cycles of said square wave create ions throughout the tube's volume, in steady state operation.

2. A low-voltage, non-thermionic, ballast-free fluorescent lighting system comprising at least one gas filled tube with electrodes spaced in said gas filled

electrode supports this theory. This is why several lamps in series can be used, because the field reversal is achieved before the original distal reaction in the tube collapses.

- 5 While preferred embodiments of the invention have been described and illustrated, it will be appreciated that other embodiments, adaptations and modifications of the invention will be readily apparent to those skilled in the art.

10 alternating current wave at said electrodes so that the
voltage supplied to said electrodes reverses polarity more
rapidly than the pattern of electron and ion density in the
tube can shift and electrons throughout the length of each
of the tubes are continually accelerated and will, through
15 several cycles of said square wave create ions throughout
the tube's volume, in steady state operation.

4. A fluorescent lighting system comprising in
combination a fluorescent gas discharge lamp means, a
source of a low-voltage, high-frequency square wave voltage
having a pair of output terminals and a substantially LC
5 free circuit connecting said low-voltage, high-frequency
square wave voltage to said fluorescent gas discharge means
to non-thermionically excite and illuminate said
fluorescent gas discharge lamp means.

5. The fluorescent lighting system defined in Claim
4 wherein said low-voltage, high-frequency square wave
voltage is in the frequency range of about 75 kHz to about
3.5 MHz.

6. The fluorescent lighting system defined in Claim
4 wherein said low-voltage, high-frequency square wave
voltage has a frequency of about 100 kHz.

phosphor coated tube, a light transmissive envelope,
confining a gaseous discharge medium at a predetermined
pressure between said electrodes, UV phosphor material on
the internal walls of said envelope, and a power supply,
said power supply having a transformer with primary and
secondary windings, a direct current source, a switch means
connected between said primary winding and said source of
direct current and means connecting said secondary winding
to said electrodes, said switch means and said transformer
primary winding being operated to generate a substantially
square wave alternating current wave at said electrodes so
that the voltage supplied to said electrodes reverses
polarity more rapidly than the pattern of electron and ion
density in the tube can shift and electrons throughout the
length of the tube are continually accelerated and will
create ions throughout the tube's volume, in steady state
operation.

3. A low-voltage fluorescent lighting system
comprising at least three fluorescent tubes, each tube
having spaced electrodes in a light transmissive envelope
confining a gaseous discharge medium at a predetermined
pressure between said electrodes, and a power supply,
means connecting a direct current source, a solid state
switch means connected between said electrodes and said
source and said electrodes, said switch means being
operated to generate a substantially square wave

high-frequency, square wave voltage from an open circuit at said pair of output terminals.

13. The fluorescent lighting system defined in Claim 12 wherein said means to protect includes a fast-acting fuse.

14. The fluorescent lighting system defined in Claim 12 wherein said means to protect includes a crowbar circuit connected across said output terminals.

15. The fluorescent lighting system defined in Claim 10 wherein said low voltage is from about 2 volts to about 90 volts and the frequency is from about 75 kHz to about 3.5 MHz.

16. The fluorescent lighting system defined in Claim 11 wherein said low voltage is from about 2 volts to about 90 volts and the frequency is from about 75 kHz to about 3.5 MHz.

17. The fluorescent lighting system defined in Claim 4 wherein said low voltage is about 7 - 12 volts and said frequency is about 100 kHz.

7. The fluorescent lighting system defined in Claim 4 wherein said low voltage is in the range of about 2 volts to about 90 volts.

8. The fluorescent lighting system defined in Claim 4 wherein said low voltage is in the range of about 2 to about 90 volts and has a frequency in the range of about 75 kHz to about 3.5 MHz.

9. The fluorescent lighting system defined in Claim 4 wherein said voltage is about 2 volts and said frequency is about 3.5 MHz.

10. The fluorescent lighting system defined in Claim 4 wherein said fluorescent gas discharge lamp means includes at least two conventional fluorescent tubes and means connecting said tubes in series across said pair of output terminals.

11. The fluorescent lighting system defined in Claim 4 wherein said fluorescent gas discharge lamp means includes at least three fluorescent tubes and means connecting said at least three fluorescent tubes in electrical series across said pair of output terminals.

12. The fluorescent lighting system defined in Claim 4 including means to protect said source of low-voltage,

23. The fluorescent lighting system defined in Claim 20 wherein there are at least three fluorescent gas discharge lamps connected in series across said pair of terminals.

24. The fluorescent lighting system defined in Claim 20 wherein said voltage is in the range of about 2 volts to about 90 volts.

25. The fluorescent lighting system defined in Claim 20 wherein said voltage is about 2 volts RMS.

26. The fluorescent lighting system defined in Claim 20 wherein said voltage is about 2-4 volts RMS and said frequency is about 3.5 MHz.

27. The fluorescent lighting system defined in Claim 20 wherein the frequency of said square wave voltage is about 100 kHz.

28. The fluorescent lighting system defined in Claim 27 including means to protect said source of a low-voltage, high-frequency, square wave voltage from an open circuit at said pair of output terminals.

18. The fluorescent lighting system defined in Claim 4 wherein said source includes one or more switching transistors and an oscillation transformer.

19. The fluorescent lighting system defined in Claim 18 wherein said voltage is in the range of 2 - 90 volts and said frequency is in the range of about 75 kHz to about 3.9 kHz.

20. A fluorescent lighting system comprising two or more fluorescent gas discharge lamp devices, a source of low-voltage, high-frequency, square wave voltage having a pair of output terminals and means connecting said two or more fluorescent gas discharge lamp devices in series across said pair of output terminals to non-thermionically excite and illuminate said pair of gas discharge lamp devices.

21. The fluorescent lighting system defined in Claim 20 wherein said low-voltage, high-frequency, square wave voltage source operates in the range of about 75 kHz to about 3.5 MHz.

22. The fluorescent lighting system defined in Claim 20 wherein said low-voltage, high-frequency, square wave voltage source operates at about 100 kHz.

33. The method defined in Claim 32 wherein said voltage is in the range of about 2 volts RMS to about 85 volts RMS.

34. The method defined in Claim 32 wherein said frequency is about 3.5 MHz and said voltage is about 2 volts.

35. The method defined in Claim 32 wherein said frequency is about 100 kHz and said voltage is about 16 volts.

36. The method defined in Claim 32 including the step of varying the energy level from said source to said lamp to vary the level of luminosity emitted by said fluorescent lamp.

29. The fluorescent lighting system defined in Claim 29 wherein said means to protect includes a fast-acting fuse.

30. The fluorescent lighting system defined in Claim 28 wherein said means to protect includes a crowbar circuit connected across said output terminals.

31. The fluorescent lighting system defined in Claim 20 including means to vary the energy level delivered from said source to said lamp devices to vary the level of luminosity emitted by said lamp devices.

32. A method of igniting a fluorescent lamp having spaced electrodes immersed in a gas at voltages far below the required starter ignition voltage for conventional fluorescent lamps with cold cathodes comprising:

5 providing a low-voltage square wave alternating voltage source of between about 2 - 85 volts and between about 75 kHz and 4 MHz,

10 and applying a low-voltage square wave alternating current from said source directly to said fluorescent lamp so that the voltage on said lamp electrodes reverses its polarity more rapidly than the pattern of electron and ion density in the gas can shift.