Sept. 22, 1942. H. W. LEVERENZ 2,296,643

LUMINESCENT LAMP

Filed March 22, 1941 2 Sheets-Sheet 1

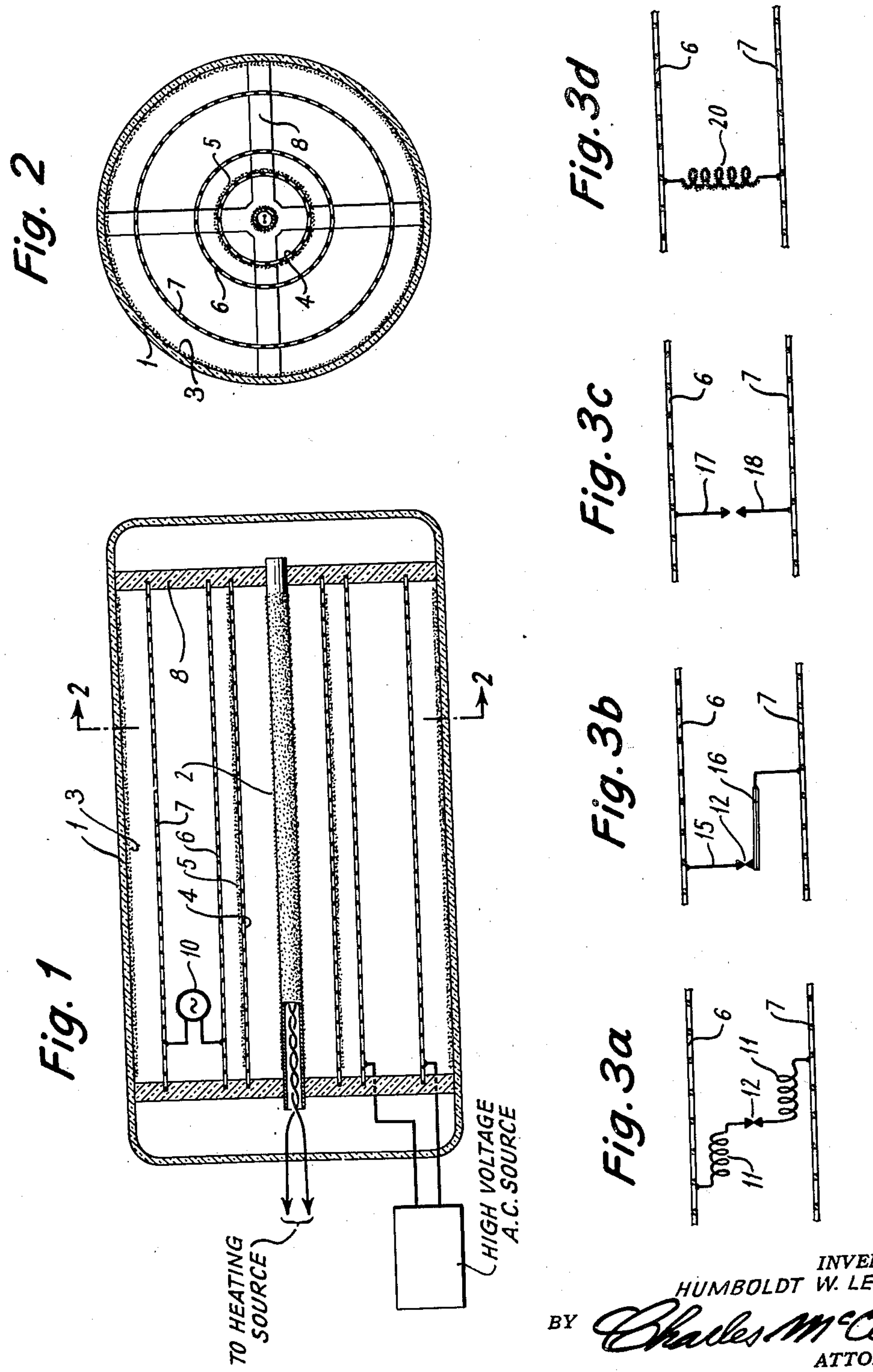

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Fig. 4

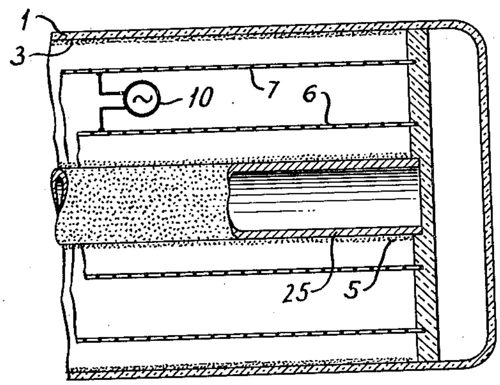
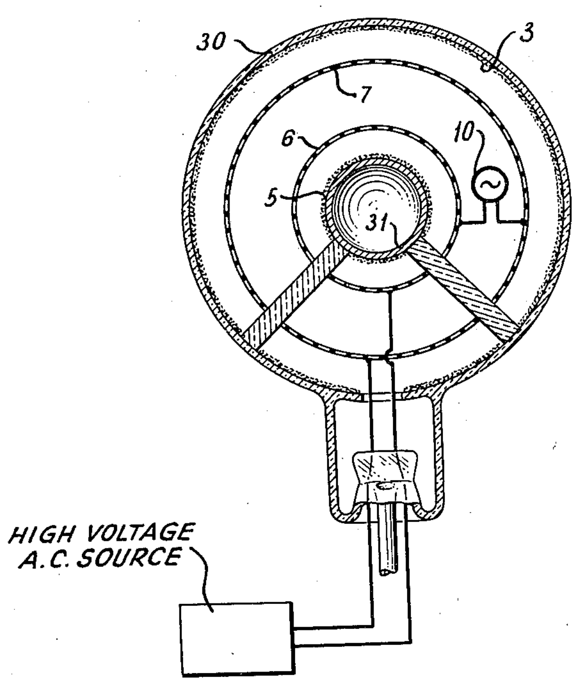


Fig. 5



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LUMINESCENT LAMP

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11 Claims. (Cl. 176—122)

My invention relates to improvements in luminescent lamps and particularly to lamps having luminescent phosphors excitable by corpuscular and radiant energy.

Luminescent lamps are known wherein a finely divided luminescent material or phosphor is provided on the interior surface of an envelope, which material, upon excitation by radiant energy, becomes luminescent and fluoresces with a soft luminescent glow. The luminescent glow is of relatively low intensity and is proportional to the interior surface area of the lamp coated with the phosphor. Many such lamps require the use of starting auxiliaries for each lamp and it is impractical to use a multiple of such lamps from a single power supply without the use of the individually associated auxiliaries.

Objects of my invention include providing luminescent lamps having high levels of light output, lamps of high brilliance having a wide range of colors or band spectrum emissions within the visible portions of the spectrum, and electron discharge lamps of high brilliance capable of utilizing the excitation energy more efficiently. A further object is to provide a lamp of the type described in which regeneration of the exciting medium is used to obtain high intensity of the developed light. A still further object is to provide such lamps which may be used in multiple without recourse to individual auxiliary controls.

In accordance with my invention, I provide a luminescent lamp excited predominantly by corpuscular radiation, such as by an electron discharge, and provide means to regenerate the corpuscular radiation to provide high levels of light output. Further in accordance with my invention, I provide a plurality of luminescent phosphor screens or members which are subjected to corpuscular excitation to develop light, having their band spectrum emissions separated by relatively wide bands, and further excite at least one of the screens or members with radiant excitation developed by the corpuscular excitation, thereby greatly increasing the luminous efficiency of the device. These and other objects, features and advantages of my invention will become apparent to those skilled in the art when considered in view of the following description and the accompanying drawings in which:

Figure 1 is a longitudinal cross-sectional view and schematic circuit of one form of luminescent lamp made in accordance with my invention;

Figure 2 is a cross-section of the device shown in Figure 1 taken along the lines 2—2;

Figures 3*a*, 3*b*, 3*c* and 3*d* are schematic representations of an auxiliary which may be included within the lamps of my invention;

Figure 4 is a view similar to Figure 1 showing a modification of my invention, and

Figure 5 is a cross-sectional view of a further modification of my invention.

The lamp shown in Figures 1 and 2 comprises an elongated highly evacuated envelope **1** closed at both ends and provided with a centrally disposed electron source such as the cathode **2**. By "highly evacuated" I mean an envelope substantially devoid of ionizable gas or vapor. The cathode preferably includes a heater and means to liberate electrons such as a coating on the exterior surface of the cathode comprising barium strontium oxides. While I have shown the cathode as being of the indirectly heated type, it will be appreciated that this is merely for purposes of the following description and that various other cathode types or those of the directly heated type may be substituted for the cathode **2**.

In accordance with my invention, I provide on the interior surface of the envelope **1** or on an equivalent foundation adjacent thereto a coating **3** of a phosphor or luminescent material preferably in finely divided form, as well known in the art of manufacturing luminescent lamps, and between the envelope **1** and the cathode **2** an electron permeable foundation **4** likewise provided with a coating **5** of phosphor or luminescent material having a predetermined band spectrum emission with respect to that of the coating **3**. In addition, I provide between the luminescent coatings **3** and **5** means to accelerate electrons liberated from the cathode **2** within the space between the coatings **3** and **5**. More particularly, I provide a first accelerating electrode which may be in the form of an electron permeable wire mesh electrode **6** and a second electron permeable electrode **7** which may likewise be in the form of wire mesh. The foundation member **4** and the wire mesh electrodes **6** and **7** are preferably of cylindrical form and are supported, together with the cathode, from the walls of the envelope **1** preferably at the ends thereof by insulating support members **8** which may be in the form of cross-shaped members.

The phosphor materials comprising the luminescent coatings **3** and **5** as indicated above comprise materials which liberate light under excitation provided by electron bombardment, the light from these coatings having band spectrum emissions which are widely separated one from the other over the visible spectrum. More specifically, the coating 3 may comprise any of the well-known phosphor materials such as manganese activated zinc silicate, zinc beryllium silicate, silver activated zinc sulphide, zinc cadmium sulphide or other materials capable of emitting light of any color or colors within the visible spectrum when subjected to electron bombardment. I prefer to provide the luminescent coating 5 of material having a band spectrum emission under corpuscular radiation, such as electron bombardment, in the violet or ultra violet portions of the spectrum. For example, materials comprising aluminum oxide, copper activated beryllium zirconium silicate, beryllium silicate, or silver activated zinc sulphide, when excited by electron bambardment, produce high intensity violet or ultra violet light which, when incident upon the material of the coating 3, excites further luminescence and produces visible radiation which is cumulative with the light produced on the coating 3 by electron bombardment.

In accordance with a still further teaching of my invention, I utilize the electron permeable electrodes 6 and 7 to accelerate the electrons in sequentially opposite directions within the space between the two luminescent coatings 3 and 5. To obtain such intensification I connect the electrodes 6 and 7 across a high potential source of alternating current which in operation causes electrons liberated from the cathode 2 to flow through the electron permeable foundation 4 which is preferably maintained at a relatively high positive potential with respect to the cathode 2 and into the space between the coatings 3 and 5. Electrons within this space are alternately accelerated in opposite directions by the potentials applied to the electrodes 6 and 7, the electrons not impinging on the electrode 7 passing through this electrode and impinging on the luminescent coating 3 where secondary electrons are liberated. These secondary electrons are then accelerated by the changing alternating potentials applied between the electrodes 6 and 7 and flow in the direction of the luminescent coating 5; those passing through the interstices of the wire mesh of electrode 6 being incident upon the luminescent coating 5 where additional secondary electrons are liberated. This process is repeated at a frequency determined by the frequency applied to the electrodes 6 and 7 from the alternating current source. The frequency of this source is determined by the spacing between the electrodes 6 and 7, and I prefer to position the electrode 6 relatively close to the luminescent coating 5 and similarly the electrode 7 closely adjacent the luminescent coating 3 so that the secondary electrons liberated by the phosphor coatings may contribute to further secondary emission. Thus the spacing between the electrodes 6 and 7 is preferably greater than the spacing between the respective electrode and its nearest adjacent luminescent coating. In operation, electrons incident upon the luminescent coating 3 liberate light of a lower frequency band than the light liberated by secondary electrons incident on the luminescent coating 5 which is preferably of violet or ultra violet light emitting material. The interstices of the electrodes 6 and 7 are preferably large in comparison with the electrode area to permit light liberated by the luminescent coating 5 to be incident upon the luminescent coating 3. Since the band spectrum emission of the coating 5 is in the ultra violet, its energy may be utilized to liberate visible light from the luminescent coating 3, thereby adding a light component cumulative with the visible light component produced by the corpuscular or electron bombardment. In this manner, a considerable increase in the total light output and light intensity of the device may be obtained.

While I have described the coating 3 as being of phosphor material luminescent in the visible portion of the spectrum and the coating 5 as being excitable to violet or ultra violet, the materials of these coatings may be reversed. I have found that certain phosphors have practically no upper excitation limit for converting light of a higher frequency into light of a lower frequency. Thus materials luminescent under ultra violet light have substantially no saturation effects so that the light output is substantially proportional to the input ultra violet energy, notwithstanding exceptionally high values of incident ultra violet light input. The coating 3, if of ultra violet emitting material, will therefore excite the coating 5, if of longer wavelength emitting material, and since the coating 3 may be made of larger extent and absorbs little, if any, of the visible light from the coating 5, the overall light output of the device is increased.

The lamp shown in Figures 1 and 2 may continue to operate after starting without liberation of electrons from the cathode 2. Means may therefore be included within the heating circuit of the cathode to disconnect the heater from the heating circuit after the lamp is started, depending entirely for operation upon the liberation of secondary electrons from the luminescent coatings 3 and 5. The use of the cathode 2 may be avoided by providing means to develop an initial quantity of primary electrons between the two luminescent coatings. For example, I may provide means such as the starting device 10 shown in Figure 1 connected between and energized by the electrodes 6 and 7. Referring to Figures 3*a*–3*d*, I have shown various modifications of the starting device 10 of Figure 1. The device of Figure 3*a* preferably comprises two helical metal coils 11, each coil being supported from one end and being in electrical contact with the electrodes 6 and 7. The free ends of the coils 11 are in normally closed position at the point 12 to allow an alternating current flow through the coils which become heated and expand, whereupon their ends become separated at the point 12, thereby developing a small arc which serves as a source of primary electrons which immediately begin to oscillate between the luminescent coatings 3 and 5 due to the alternating potentials applied to the electrodes 6 and 7. These electrons cause emission of secondary electrons, the action being cumulative until space charge limitations arise, whereupon the device is in full operation, liberating visible light from the luminescent coating 3 and violet or ultra violet from the luminescent coating 5 which in turn increases the liberation of light from the coating 3. The form of starter shown in Figure 3*b* comprises two contacts 15 and 16, each of which is supported by one of the electrodes 6 and 7 in a normally closed position. The member 16 may be of the bimetallic type which, upon becoming heated by the current flow through the contacts, becomes distorted, opening the circuit between the electrodes 6 and 7 at the point 13 in a manner similar to that shown in Figure 3*a*, thereby developing an arc and generating a cloud of electrons for starting the lamp. The types of starters shown in Figures 3a and 3b are preferably so designed that the heat of operation of the lamp maintains the contacts in an open position during subsequent operation of the lamp. A surge-type started shown in Figure 3c may be used to develop a cloud of electrons between the members 17 and 18 which are similarly supported by the electrodes 6 and 7 in fixed separated relation, the distance between the adjacent ends of the members 17 and 18 being such that a spark occurs during maximum potential differences impressed across the electrodes 6 and 7. Similarly, the members 17 and 18 may be designed to provide increased separation after starting, such as by becoming heated due to the normal operation of the lamp. The starter shown in Figure 3d is of the continuously operative type and comprises an electron emitting filament 20 supported by and in conductive relation with the electrodes 6 and 7 to emit electrons during the operation of the lamp.

That the use of a separate and distinct electron source in the form of the cathode 2 is unnecessary may be noted from the type of lamp shown in Figure 4 which utilizes no cathode axially supported with respect to the various members.

The structure of Figure 4 comprises an envelope 1 preferably supporting on its inner surface the luminescent phosphor coating 3. Oppositely disposed from the coating 3 I provide a second phosphor coating 5 supported on an inner foundation 25 which is preferably cylindrical in form and concentric with the envelope 1. The electron permeable electrodes 6 and 7 are similar to and perform a similar function as those of the corresponding electrodes of Figure 1. The phosphor screens 3 and 5 are chosen as indicated above with respect to their spectral emission characteristics. Thus the coating 5 may be of a material excitable to ultra violet when subjected to electron bombardment, and the coating 3 excitable to the emission of visible light under electron bombardment so that the resulting light from the lamp results not only from the bombardment of the two phosphor coatings but also from the light liberated from coating 3 when subjected to ultra violet radiation from the coating 5. Obviously, the materials of these coating may be reversed as described above in connection with the device of Figures 1 and 2.

For starting the device of Figure 4 a starter of any of the types shown in Figures 3a–3d may be used, connected as shown at 10 in Figure 4, between the electrodes 6 and 7. Following the starting of the device the operation is continuous due to the liberation of secondary electrons from the two phosphor coatings.

In Figure 5 I have shown a further modification of the structure of Figure 4 wherein the envelope 30 is of spherical form coated on the inner surface with the visible light emitting phosphor 3 and provided with an inner foundation 31, likewise of spherical shape, forming a concentric envelope and bearing the luminescent coating 5. Likewise the electrodes 6 and 7 are similar to those of Figures 1 and 4 and may be provided with a starting device 10 connected thereto for purposes of initiating the operation.

I have described my invention in connection with devices for developing light in the visible portion of the spectrum, but it will be obvious in view of my teachings that the device may be used as a source of infra red or ultra violet light. The coatings 3 and 5 may be chosen from materials excitable to luminescence of different frequencies within the ultra violet portion of the spectrum. Thus one coating may develop light around 2000 Å. while the other coating develops light of longer wavelength, such as around 2950 Å., making my device very effective for erythemal treatments.

While I have indicated the preferred embodiments of my invention and have indicated the use as directed to luminescent lamps, it will be appreciated that my invention is not limited to the modifications described or the uses herein set forth but that many variations may be made in the particular structure described without departing from the scope of the appended claims.

I claim:

1. A luminescent lamp comprising an envelope, a pair of oppositely disposed luminescent phosphor screens having differing spectral emission properties whereby luminescence developed by one of said screens, develops luminescence in the other of said screens, means to develop electrons within said envelope and dual electrode means including an electrode adjacent each of said screens adapted when energized with alternating current potentials to oscillate electrons between said screens to render said screens luminescent.

2. A luminescent lamp comprising an evacuated envelope, a luminescent phosphor screen adjacent the wall of said envelope of material luminescent under electron excitation in the visible portion of the spectrum, a second luminescent phosphor screen oppositely disposed from said first screen of material luminescent at a shorter wavelength than the material of said first phosphor screen, means within said envelope to develop electrons and means including two separated electrodes coextensive with and between said screens which when energized with alternating current potentials cause electrons to oscillate therebetween and render said screens luminescent.

3. A luminescent lamp comprising an envelope, a pair of phosphor screens within said envelope adapted to luminesce at different wavelengths of light under electron bombardment the screen adapted to luminesce at the shorter wavelength being positioned within the other of said screens, means within said envelope to develop a cloud of electrons between said screens and a pair of electron permeable electrodes between said screens adapted when energized by alternating current potentials to oscillate electrons of said cloud between said screens to render said screens luminescent.

4. A luminescent lamp including an envelope, a pair of oppositely disposed and spaced luminescent phosphor screens, the phosphor of one screen being of material having a shorter wavelength spectral emission than the material of the other screen and means between said screens to excite said screens to luminescence whereby the excitation of the material of shorter wavelength spectral emission supplements the excitation of said other screen.

5. A luminescent lamp comprising an envelope, a pair of oppositely disposed luminescent screens within said envelope, a pair of electron permeable electrodes, each of which is coextensive with the area of said screens between said screens, and means connected between said electrodes to develop a cloud of electrons within said envelope to initiate an alternating electron flow between said screens when a potential difference is applied between said electron permeable electrodes.

6. A luminescent lamp comprising an envelope, a pair of oppositely disposed luminescent screens within said envelope, each of said screens having different spectral emission characteristics, a pair of mesh-like electrodes, each of which is coextensive with the area of said screens between said screens, and means connected between said electrodes and adapted to be energized from said electrodes to develop a cloud of electrons within said envelope upon energization of said electrodes to initiate an electron flow between said screens.

7. A luminescent lamp comprising a cylindrical envelope, a pair of cylindrical luminescent phosphor screens substantially concentrically disposed and spaced from each other within said envelope, a pair of concentric cylindrical electron permeable electrodes spaced from each other and from said screens, means comprising a conductor to each of said electrodes to apply an alternating current therebetween, and means connected between said electrodes to initiate a cloud of electrons which are periodically accelerated toward said screens in alternating succession under alternating potentials applied between said electrodes.

8. A luminescent lamp comprising a cylindrical envelope, a pair of cylindrical luminescent phosphor screens spaced one within the other and substantially concentric with said envelope, the phosphor of the inner screen being excitable to luminescence under electron excitation over a spectral range of higher frequency than the other, a pair of concentric cylindrical electron permeable electrodes spaced from each other and from said screens, means comprising a conductor to each of said electrodes to apply an alternating current therebetween, and means connected between said electrodes to initiate a cloud of electrons which are periodically accelerated toward said screens in alternating succession under alternating potentials applied between said electrodes to develop luminescence of said screens.

9. A luminescent lamp comprising a highly evacuated cylindrical envelope, a cylindrical luminescent phosphor screen of material luminescent under electron excitation in the visible portion of the spectrum adjacent the wall of said envelope, a second luminescent phosphor screen positioned within and spaced from the screen adjacent said envelope of material luminescent under an electron discharge in the violet portion of the spectrum, means within said envelope to develop electrons and dual electrode means within said envelope and adjacent each of said screens which when energized with alternating current potentials cause electrons to oscillate therebetween to develop luminescence on said screens.

10. A luminescent lamp comprising a highly evacuated envelope, a luminescent screen within and adjacent the wall of said envelope adapted to luminesce in the visible portion of the spectrum under electron bombardment, means within said envelope to develop a cloud of electrons, an electron permeable luminescent screen of material luminescent in the ultra violet portion of the spectrum positioned between said means and said first-mentioned screen, and a pair of electron permeable electrodes between said screens to oscillate electrons of said cloud between said screens when said electrodes are energized with alternating current potentials to develop luminescent light on said screens.

11. A luminescent lamp comprising an evacuated envelope, a luminescent screen foundation within said envelope, said foundation being reflective to light, a coating of a luminescent phosphor on said foundation, said phosphor being of material luminescent in the ultra violet portion of the spectrum when excited by an electron discharge, a second coating of a luminescent phosphor on the wall of said envelope, said second coating being of material luminescent in the visible portion of the spectrum when excited by an electron discharge, a pair of electrodes each coextensive with and each positioned respectively adjacent one of said coatings adapted to be energized by alternating current, means connected between said electrodes which, upon being heated, produce a cloud of electrons, thereby initiating luminescence in said coatings.

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