

Feb. 26, 1957

P. VIERKÖTTER
SOURCE OF LIGHT

2,783,407

Filed June 25, 1953

3 Sheets-Sheet 1

Fig. 1

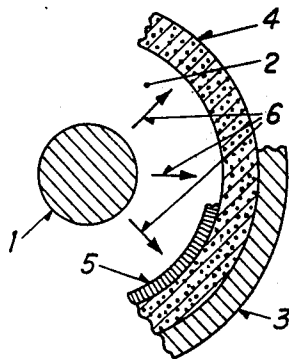


Fig. 4

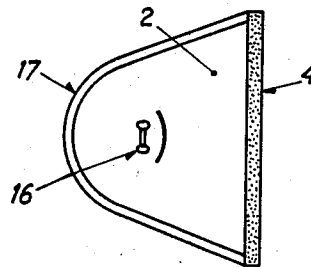


Fig. 5

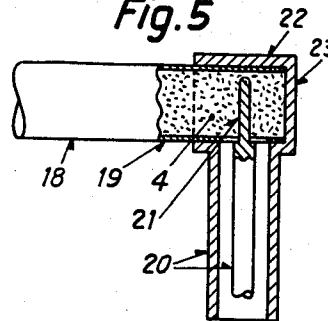
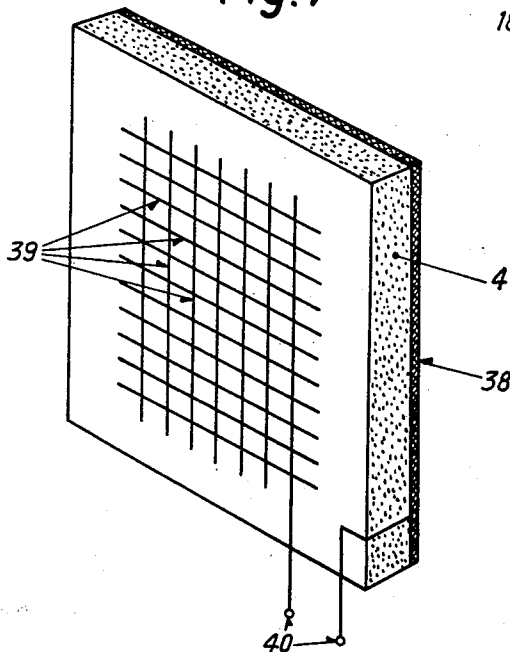


Fig. 7



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Feb. 26, 1957

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3 Sheets-Sheet 2

Fig. 2

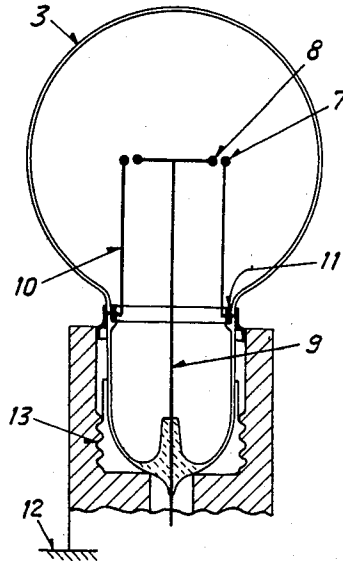
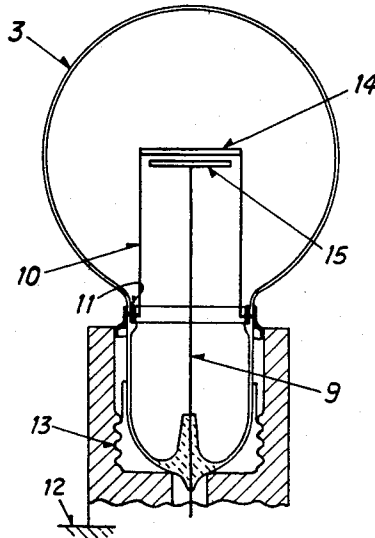


Fig. 3



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Feb. 26, 1957

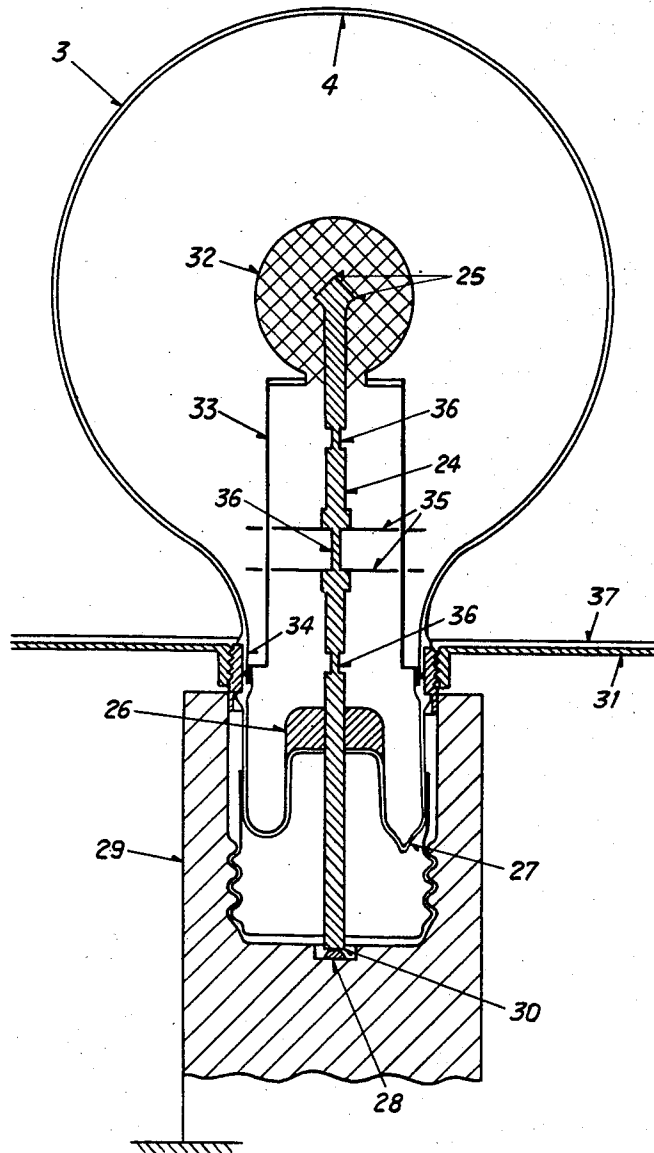
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3 Sheets-Sheet 3

Fig. 6



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SOURCE OF LIGHT

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Claims priority, application Switzerland June 28, 1952

5 Claims. (Cl. 313—109)

The present invention relates to sources of light for general lighting purposes as well as for special application which require a high luminous intensity.

For general lighting purposes two methods of producing light have so far achieved importance and practical success, namely incandescent light radiation and fluorescence radiation generated by electricity. In incandescent light radiators the light is produced by the electrical resistance heating of a metal wire to the temperature of incandescence in a vacuum or a protective gaseous atmosphere. The typical example of incandescent light radiator actuated by electrical resistance heating is the incandescent bulb. In fluorescence radiators vapours or gases which emit invisible ultraviolet light on the passage of the current stimulate the fluorescence of a layer of luminescent substance and consequently the emission of light. The most well-known fluorescence radiator is the neon tube.

Incandescent light radiation and fluorescence radiators have in common the drawback that sources of light with a very great luminous intensity are difficult to make, complicated to install, and uneconomical to operate. On the other hand lamps of very great luminous intensity present an interest of the first magnitude both technically and economically for large or lofty halls, galleries, churches, schools, stairways, theatres, cinemas, public squares, streets, workshops, store-rooms, railway stations, airports, factory yards, search lights, beacons, signalling systems, advertisements, etc.

Apart from this shortcoming which is common to both incandescent light radiators and fluorescence radiators, each of the two methods has its own advantages and drawbacks, which will be briefly pointed out below.

In electric incandescent light radiators based on resistance heating the temperature of the incandescent wire must not exceed 2700° abs. in consideration of its melting point and of the disintegration of the wire which occurs even before the melting point is reached. Higher temperatures substantially shorten the life of the lamp. The light emitted by fluorescence radiators presents the advantage that, like sunlight, it has a continuous spectrum comprising a large number of light waves. On the contrary, the light emitted at this temperature by incandescent light radiators contains only a few green and blue components and therefore does not present the same continuous spectrum as sunlight. Their light is reddish yellow in colour and not white like that of the sun, which is the target aimed at by technicians for general lighting purposes. Another drawback of the electric incandescent light radiator is the low economic efficiency with which the electric power is transformed into visible light. Thus to the advantage of an essentially continuous spectrum the incandescent light radiator opposes the disadvantages of incorrect colouring and deficient economy. Both of these drawbacks would disappear if it were possible to raise the temperature of the incandescent wire to that of the sun, which is of the magnitude of 6000° abs. An incandescent light radiator burning at about 6000° abs.

2

would emit light with a continuous spectrum and the same colouring as the sun. An incandescent light radiator radiating at 6000° abs. would be economical because then, as in the case of the sun, the maximum emission of energy would coincide with the middle of the visible spectrum to which the human eye is most sensitive. However, incandescent wires made of metal or other substances and able to support such temperatures are not known and therefore the problem of producing white light with incandescent light radiators and improving their economic efficiency still remains to be solved.

For fluorescence radiators there exist various fluorescent and phosphorescent substances of a solid, liquid or gaseous character—designated generally as luminescent substances in the present specification—which on excitation emit certain distinct wavelengths in the visible light spectrum. In this process the excitation energy is transformed into the energy of the emitted radiation.

In the fluorescent lamps now in general use electrical energy is preferably transformed in a gaseous or vaporous atmosphere into an ultraviolet radiation of short wavelength and therefore rich in energy. This transformation is very economical and is not greatly prejudiced by the ulterior conversion of the short-wave radiation into long-wave visible light which takes place in the layer of luminescent substance. There exist for instance tubular lamps of glass with a layer of luminescent substance on the inner face of the glass tube and enclosing a source of ultraviolet radiation, whose radiation excites the layer of appropriately chosen luminescent substance to emit light which is projected outwards through the glass walls of the tube.

However, the known sources of light based on luminescent substances have a rather bad balance between the excitation energy supplied and the radiation energy given off in the visible light spectrum, for which reason such sources of light are only rarely utilized for lighting purposes. The uneconomical energy transformation is due less to the properties of the luminescent substances and their capacity for transforming primary energy into secondary lighting power than to the unpractical constitution of the layers of luminescent substance. The usual method hitherto employed is to use as luminescent substances fine-grained powders generally of crystalline structure, which are mixed with an appropriate binder and applied in a layer of the desired thickness on to a transparent base. This technique results in layers of luminescent substance which are as a rule not very pervious to extraneous light and considerably reduce the intensity of the light even when of slight thickness. The same applies to the emission of light derived from the luminescent substance itself, particularly when the reverse face of the layer is activated by the impact of a suitable energy and the light thus generated only radiates outwards after passing through the layer. Even if the excitation energy could penetrate into the layer of luminescent substance and act on the whole layer of luminescent substance—which is usually not the case—it would be impossible to avoid a greater or lesser weakening of all the radiation not originated by the front of the layer. This absorption of light occurs even when the particles of luminescent substance are themselves translucent, for even layers of transparent particles, made for instance of pulverized glass, possess the capacity of considerably weakening the light through dispersion. This weakening of the light emitted by the luminescent substance within the layer of that substance is the chief cause of the unfavorable balance of energy characteristic of the known sources of light based on luminescent substances. The bad balance of energy appears also when layers of luminescent substance are employed as screens in cathodic ray tubes, which are rendered luminous by the impact

of electrons or ions and make the point of impact of these corpuscles visible from without (oscillograph tubes, TV tubes, etc.). The same applies to the screens employed for radioscopy which utilize the secondary light radiated by activated luminescent substances.

The object of the present invention is a novel source of light which delivers a broad spectrum, functions economically, and combines to a great extent the advantages of fluorescence radiators with those of incandescent light radiators, while substantially diminishing the above-mentioned drawbacks hitherto presented by both those sources of light. Characteristic of the source of light according to the invention is at least one primary source of energy, whose energy components can also comprise the emission of wavelengths in the visible light spectrum, and media through which at least part of the energy components must pass. These media allow the energy components situated in the visible light spectrum to pass largely without loss but transform at least part of the other energy components of the primary sources of energy by energy conversion into secondary radiation energy within the range of the visible light spectrum.

The invention is described below as embodied in examples illustrated in Figs. 1-7.

Fig. 1 shows the principle of the process schematically represented in cross-section by a cylindrical or spherical source of light;

Figs. 2 and 3 show two different examples of embodiments of the source of light according to the invention with selective radiators as primary source of energy;

Fig. 4 shows a source of light built after the manner of a search light, represented schematically in longitudinal section;

Fig. 5 shows a cylindrical source of light designed to be excited by high-frequency oscillations, schematically reproduced in elevation and partly in cross-section;

Fig. 6 shows another example of an embodiment of a source of light excited, according to the invention, by particles rich in energy as primary source of energy; and

Fig. 7 shows a perspective view of a plate-shaped source of light designed to be excited by an electric field.

The principle of the source of light according to the present invention is shown in one embodiment by way of example in Fig. 1 as a cross-section through a source of light in the shape of a sphere or elongated tube. The source of primary energy 1 is situated in a suitable gaseous atmosphere or in a vacuum 2 enclosed on all sides by a transparent or translucent wall 3. On the inner face of the wall 3 is applied a layer of a mass of luminescent substance 4 which can if required be separated from the enclosed space 2 by a lining 5. The layer of luminescent substance 4 is excited through the lining 5 by the primary source of energy 1, for instance by a radiation emitted by the latter in the direction of the arrows 6.

According to the invention the mass of luminescent substance 4 consists of particles of luminescent substance such as zinc sulphide (indicated in Fig. 1 by dark dots) embedded in a surrounding medium such as arsenic sulfide which has approximately the same refraction index for visible light. In this embodiment the luminescent particles constitute a solid agglomerate in an equally solid medium. Since the solid medium and the particles of luminescent substance embedded therein have approximately the same refraction index for visible light, and consequently for the visible light spectrum emitted by the particles of luminescent substance, the absorption that usually occurs with a mixture of pulverized substances and a binder is greatly reduced. If the components of the luminescent substance are suitably chosen the mass assumes a "clear glass quality" at least for a predetermined band of the spectrum.

In the source of light according to the invention the energy impacting of the mass of luminescent substance can be achieved in various ways, for instance by electromagnetic oscillations, by highly energetic particles, by

thermal energy, by field effects, etc. Obviously the embodiment of the source of light varies according to the method of impacting desired.

Energy impacting by means of electromagnetic oscillation occurs when, for instance, the source of energy 1 in Fig. 1 is a so-called incandescent light radiator, formed for instance by electrically heated wire spirals. Such incandescent light radiators emit a continuous light spectrum whose maximum intensity lies chiefly in the red or chiefly in the blue portion of the spectrum according to the temperature of the heated body, but may also possess a considerable radiant energy in the infrared and ultraviolet bands of the spectrum. The radiant energy outside the visible light spectrum can be utilized for impacting the mass of luminescent substance, thus causing a secondary radiation of the mass of luminescent substance and consequently achieving a transposition of the frequency of the radiant energy. In this case it is particularly advantageous for the mass of luminescent substance 4 in Fig. 1 to be sufficiently pervious to the visible light spectrum so as to permit the visible portion of the rays emitted by the incandescent light radiator to pass without being greatly weakened. In the embodiment shown in Fig. 1 the enclosed space 2 of the source of light is either evacuated or filled with a protective gas.

According to the invention a selectively radiant body is preferably employed as incandescent light radiator. If the material for the selective radiator is suitably chosen the approximate colour of sunlight can be obtained at a temperature well below 6000° abs., and consequently the economic efficiency improved. Appropriate selective emitting bodies with greater resistance to temperature and less tendency to disintegration than metal wires are known. The selective radiator can be a conductor or semiconductor through which the current passes directly or indirectly, or can constitute directly or indirectly the non-conducting envelope of a highly heated carrier, for instance a metal part. The temperature is preferably produced by the impact of highly energetic particles, such as electrons or ions, on the body to be heated. It can also be produced by high-frequency oscillations, by radiant heat, or by any other direct or indirect method of supplying energy. The shape, size and proportions of the body to be heated are not dependent on the voltage of the supply network as occurs in the resistance heating of an incandescent wire. Furthermore, the body to be heated does not require a base nor must it be a conductor. If, for instance, the selectively radiant body is heated as an anode by the impact of accelerated electrons from a relatively negative cathode as the source of electrons, a conducting layer of no more than molecular thickness suffices for the selective radiator, which can even be electrically non-conducting if the anode is grounded and the cathodic voltage rather high. It is also possible, for instance, to render incandescent in a vacuum by electron bombardment the very thin, airtight metal envelope of a sphere, hemisphere, etc. and thus heating an external coating of the envelope made of selectively radiant substance in a gaseous or vaporous atmosphere which counteracts disintegration. The selective radiator can also be constituted by a fine-mesh net of wire coated with the selectively radiant mass, or of wire containing the selectively radiant mass, or of the selectively radiant mass alone presenting a large surface and very small thickness, and be heated like an anode by electron bombardment. The selective radiator can also form a thin layer between two flat or curved fine-mesh nets, or constitute the core or coating of a fine wire coil or spiral, or like a fine, tangled knot of wire, foil or other suitable form surround the cathode at a certain distance and fill the whole lamp. In all these cases practically all the heat radiates from the whole large surface in the form of light. Due to the thinness of the mass heat losses are very small. In the case of a resistance-heated incandescent wire, whose length depends on the voltage of the supply network, the interior of the wire, which for a high luminous intensity

5

must be thick, is also heated to no purpose although only the small surface of the wire radiates light. If the selective radiator is a semi electrical conductor or a non-conductor, it is also a semi conductor of heat so that but little heat is lost by thermal conduction in the substance itself. In a vacuum or a suitable gas the heat lost to the environment is also small.

By using a selective radiator directly or indirectly heated by energy supplied in a suitable form it has been possible to eliminate the drawbacks of incandescent light radiators and create an economical incandescent light radiator with a continuous spectrum of good colour as a source of energy.

Since the mass of luminescent substance 4 in the form of a layer in Fig. 1 is largely pervious without loss to light in the visible spectrum, most of the visible light can be exploited to the full.

Figs. 2 and 3 show two typical embodiments of such selective radiators. The envelope 3 represents, for instance, a self-supporting mass of luminescent substance inserted in the known way in the mount 13. The mass of luminescent substance 1 is largely pervious without loss to light in the visible band of the spectrum. Two rings 7 and 8 of selectively radiant substance are set close together in the envelope 3. The ring 8 is attached to a current lead 9 which issues from the envelope 3 and is connected with a source of current, while the ring 7 is fastened via the current leads 10 to a ring 11 which is grounded at 12.

In the embodiment exemplified in Fig. 3 the two rings 7 and 8 are replaced, for instance, by two plates 14 and 15. Obviously it is also possible to provide more than two rings and also more than two plates. The latter can also be placed at different levels. The envelope 3 is filled in the known way with a gaseous or vaporous atmosphere which causes the selective radiator to be bombarded by particles and consequently to be heated when a voltage is laid on to the terminals 9 and 13. As a rule a transformer is employed as a source of current. If both half-waves of the voltage supplied by the transformer, whether grounded or not, are utilized, this is rendered possible by means of a suitable connection, by designing the cathode for the simultaneous limitation of the emission current and by the characteristic of the source of light. In the embodiment exemplified in Fig. 2 the two rings can be made to heat each other reciprocally and excite each other to emit light. The necessary limitation of the current flow can be achieved by the characteristic of the source of light, which can also be so chosen as to be largely independent of the current and voltage. The selective radiators 7 and 8 or 14 and 15, when suitably excited, already emit largely white light, which can radiate outwards practically unhindered through the envelope 3. Energy components of the radiation emitted by the selective radiators outside the visible light spectrum are converted into visible light by the mass of luminescent substance that constitutes the envelope 3. Compared with the layers of luminescent substance hitherto employed, the mass of luminescent substance according to the invention, which consists of particles of luminescent substance in a medium with approximately the same refraction index for visible light, renders possible a considerable saving of luminescent substance per unit of volume or surface of the mass or layers and an augmentation of the thickness of the layers. The saving of luminescent substance is possible because it is no longer necessary, as formerly, to aim at achieving the greatest possible density of the particles of luminescent substance within the layer and reducing the quantity of binder to a minimum. On the contrary the single particles of luminescent substance should, according to the present invention, be completely surrounded by the medium and form a loosely coherent structure within the medium itself. In a mass of this kind the light yield per unit of weight of luminescent substance is considerably greater than when all the particles

6

of luminescent substance are closely packed together. Obviously a preliminary condition is that the impact of energy on the particles of luminescent substance occurs uniformly throughout the whole mass and that the energy serving for their excitation is only slightly absorbed or damped by the medium in which they are embedded. If, however, this condition is fulfilled, which can be achieved by the use of suitably chosen materials and an appropriate source of energy, the layer of luminescent substance can be made considerably thicker than has hitherto been customary without bringing about any great absorption of the exciting or radiating energy. In this case the layer of luminescent substance 4 in Fig. 1 can be made self-supporting and so formed that it replaces the outer wall 3.

The present invention is not, of course, restricted to the utilization of a solid medium for embedding the particles of luminescent substance. For instance, in the illustration of Fig. 1, the inner lining 5 can also be a self-supporting container pervious to impacting energy, and the mass of luminescent substance 4 placed in the space between the inner container 5 and the outer container 3 can consist of a viscous or fluid medium in which the particles of luminescent substance are suspended. In this case the quantity of luminescent substance contained in the fluid mass must be sufficiently great to prevent the components of the mixture from separating and the particles of luminescent substance from depositing. If so desired, a luminous substance in a state of fluid aggregation can, of course, be mixed with the fluid medium and emulsified therewith in a known way.

Finally, it should also be pointed out that with two concentrically arranged containers 3 and 5 the intermediate space can be filled with a mass of luminescent substance 4 in a state of gaseous aggregation; in this case the particles of luminescent substance consist in the individual molecules of gas or vapor of a preferably gaseous luminescent substance which is mixed with the carrier that serves as a medium.

In every case the inner layer 5, whether it is a coating on the solid layer of luminous substance 4 or a self-supporting container, must be pervious to the energy that serves to excite the particles of luminescent substance in the mass 4 and therefore possess the smallest possible coefficients of absorption for that energy. It must also be pervious largely without loss to any radiant energy that may be produced by the primary source of energy in the visible band of the spectrum. It is advantageous for the limiting surfaces between the layers 5 and 4 to be so formed as to enable the excitation energy to enter the layer of luminescent substance 4 largely without loss while totally reflecting the light spectrum emitted by the particles of luminescent substance, by which means the light yield is further enhanced. For this purpose a semipermeable metal layer of known constitution can, for instance, be employed.

The particles of luminescent substance embedded in the medium and the impacting energy that acts on them from the primary source of energy are so reciprocally adjusted that the particles of luminescent substance largely absorb the quantity of energy supplied per unit of volume or surface of the mass or layer and their atoms are transmuted in the known way into an excited state, from which they return—either immediately after the absorption of the quanta of energy or only after a certain period of time—to their unexcited state while emitting light. The emission of light that accompanies this process consists of separate lines of the spectrum and the colour of the light produced by the mass of luminescent substance can be varied in the known way by choosing appropriate luminescent substances. The emission of a composite light can be achieved by mixing various luminescent substances having different characteristic emission and embedding them in the same medium whose refraction index must of course be approximately the same as that of each of the luminescent components.

It is known that strong sources of energy for ultra-

violet light exist and can be employed to advantage for the source of light according to the invention. This can occur, for instance, in an arrangement according to Fig. 4 in which the source of ultraviolet rays 16 is arranged in the focal point of an interiorly specular reflector 17. The mouth of the reflector 17, which is advantageously symmetrical in relation to its axis of rotation, is closed by the mass of luminescent substance 4 which, as already explained in connection with Fig. 1, can be designed in many different ways. Needless to say, the source of light that functions with ultraviolet radiators as primary source of energy is not limited to the structural principle shown in Fig. 4, but can also be of the type illustrated in Fig. 1 or have any number of other shapes.

High frequency electromagnetic oscillations can also be utilized as a source of energy, as by way of example the embodiment shown in Fig. 5. In this case the luminescent substance and the medium in which it is embedded constitute an elongated body of cylindrical or irregular section. This body can be either a self-supporting, homogenous structure, if the luminescent substance and embedding medium are solids, or a hollow container whose wall 19 is pervious to the light emitted by the luminescent substance and whose inner space holds the medium 4 and the particles of luminescent substance embedded therein. An elongated body 18 of this type can be employed in the known way as a conductor for high-frequency oscillations in the centimetre wavelength band, which effect can be exploited for the source of light according to the present invention, inasmuch as a luminescent substance is utilized which strongly absorbs the high-frequency oscillations and is excited thereby to emit light. These particles of luminescent substance are embedded in a medium that has approximately the same refraction index for the emitted light as the particles of luminescent substance, and on the other hand possesses high-frequency dielectric properties which ensure that the high-frequency oscillations are conducted largely without loss inside the body 18. The supply of high-frequency energy for the excitation of high-frequency oscillations in the body 18 can occur in the known way via a concentric energy conductor 20 and the coupling pin 21 inside the metal reflector 22, 23. Depending on the length of the body 18 its shape and opposite face (not shown in the drawing) are so designed that owing to their incomplete absorption by the particles of luminescent substance any high-frequency oscillation energy reaching that point is prevented from emerging into the open space outside the body 18 and reflected.

Electromagnetic oscillations in the frequency band of ordinary X-rays can also be employed for the excitation of the particles of luminescent substance, for instance in the embodiment of the source of light according to the invention illustrated in Fig. 1. The source of energy 1 is in this case any source of X-rays whose radiation impinges on the mass of luminescent substance 4 in the direction of the arrows 6 through a thin metal coating 5, and excites the particles of luminescent substance inside the layer 4.

Finally, it should also be pointed out that the gamma rays emitted by natural and artificial radioactive substances can constitute the primary energy for the source of light according to the invention. This can occur, for instance, in an embodiment according to Fig. 1, in which case the radioactive substance occupies the whole enclosed space 2 up to the lining 5, for example as a liquid or gas the emits gamma rays, or is appropriately combined with the lining 5 or applied to the latter.

Besides electromagnetic oscillating energy, the energy impacting by the primary source of energy in the source of light according to the invention can also occur through the intermediary of highly energetic particles such as electrons, ions or neutrons. For this purpose, for example in the embodiment shown in Fig. 4, as source of energy 16 is employed a projector of electrons or ions of

known type, which as far as possible impacts the whole interior of the mass of luminescent substance 4 uniformly with electrons or ions through the enclosed space 2 which is preferably evacuated. The thickness of the mass of luminescent substance 4 is adjusted to the depth of penetration, that is, to the kind and energy of the impacting particles, the medium enclosing the luminescent substance of the mass of luminescent substance 4 being appropriately chosen to ensure the greatest possible depth of penetration while at the same time largely preventing the highly energetic particles from emerging into the open space outside the layer 4. Here too, of course, the medium of the mass 4 must satisfy the condition that its refraction index for the light emitted by the particles of luminescent substance is at least approximately the same as that of the particles of luminescent substance themselves. For excitation by a source of neutrons it is advantageous to employ a source of light based on a luminescent substance like the embodiment shown in Fig. 1.

The utilization of highly energetic particles as primary source of energy is not restricted, however, according to the invention to the case where the particles, as described above, directly provide the excitation of the mass of luminescent substance. According to the present invention the highly energetic, accelerated particles are utilized to produce radiant energy by momentary braking at their impact on a body which in heated state constitutes an incandescent light or selective radiator. The emission of radiant energy by the passage of such particles, particularly electrons and ions, through rarified gases or residual gases is also utilized.

The production and intensity of ultraviolet light and the intensity of X-ray radiation of still shorter wavelength and greater energy due to the braking of particles depend exclusively on the magnitude of the voltage that accelerates the particles and the atomic number of the anodic material. The braking of electrons emitted by an incandescent, oxide, photo or cold cathode, released by ionization and accelerated by voltage, gives rise to a braking spectrum and simultaneously to a characteristic line or band spectrum determined by the anodic material. The wavelength of the various lines of the line spectrum depends on the element that constitutes the anode or on the elements contained in the anode, if more than one, whether gaseous, liquid or solid. The braking spectrum is penetrated by and subject to the line spectrum, so that any desired type of oscillations for exciting the mass of luminescent particles, ranging from visible light to X-rays, can be generated by a great many different ways. An appropriate choice of the accelerating voltage, of the anodic material and of the discharge characteristic permits of generating in the most favorable manner the radiation in the braking and line spectrum for which the conversion of shortwave radiation into visible light in the luminescent substance, whether solid, liquid or gaseous, is achieved with the highest degree of efficiency.

The combination of an incandescent light radiator of this type with a luminescent substance radiator satisfies exacting requirements in respect of spectrum, light colour, and operative economy. The selective incandescent light radiator produces under electron bombardment an approximately white light with a continuous spectrum while at the same time the selective radiator at white heat emits by electron braking both ultraviolet rays and X-rays, which cause the mass of luminescent substance to produce coloured light which has a line spectrum and is non-dazzling if the surface of the luminescent substance is large. The two spectra are superimposed on one another and offer the eye a composite light whose colour varies with the type of light emitted by the luminescent substance, and can therefore even be white. Thus, in addition to economy and freedom from dazzle, the combination of selective and fluorescence radiators ac-

cording to the invention renders possible the production of white light if desired.

Fig. 6 shows an embodiment by way of example of such a source of composite light with electron bombardment and selective radiator as primary source of energy. The container 3 pervious to light but preferably impervious to ultraviolet rays and X-rays encloses the cathode 24. This cathode consists of a more or less conducting peg of a material with high melting point provided with acuminate tips 25. The cathode 24 is fixed by a vacuum-tight seal in the container 3 via a foot 26. The container 3 can be evacuated through the pump connection 27. The tips 25 of the cathode 24 under the action of the negative half-wave of the voltage supplied to the cathode 24 via the contact 30 of the insulated lamp base 31 by a terminal 28 of the transformer 29, one of whose sides is grounded, emit electrons which are accelerated by field emission. During this process the positive half-wave must be prevented from intervening. The electrons impinge on the fine-mesh inner surface of the hollow, spherical, shell-like, very thin-walled selective radiator 32 made of tungsten, carbon, zirconium oxide, cerium oxide and thorium oxide, and penetrate subject to braking into the radiator. The selective radiator is maintained by supports 33 which in turn are fastened to the metal ring 34 inserted in the hollow container with a vacuum-tight seal. The layer of luminescent substance 4, the metal ring and the transformer casing are grounded. The selective mass is momentarily heated to white heat by the impacting and penetrating electrons and at the same time emits ultraviolet rays, X-rays or both together. The visible light penetrates largely without loss to the exterior through the thin layer of a mass of luminescent substance 4 which is pervious to visible light and covers the inner surface of the container 3. The invisible shortwave radiation emitted by the selective radiator and any ions or electrons that may be accelerated by the meshes of the selective radiator are absorbed in the mass of luminescent substance 4 and excite the particles of luminescent substance contained therein to emit a bright light. The numeral 35 represents reflecting fluorescent protective screens which reduce the losses in the neck of the bulb and protect it and the foot 26 from errant particles and from heating. For the latter purpose the peg 24 is also made thinner at several points 36. With a view to guiding the light preferably in any desired direction, it can be made to fall on the reflecting surface 37 of the support 31. The reflecting layer 37 itself can if desired contain a luminescent substance which is excited by the presence of shortwave radiations penetrating through the container 3. The screen 37 and the support 31 can also be transparent, and the reverse of the support 31 can also be coated with a luminescent substance if the penetrating power of the radiation is sufficiently great. Moreover, the whole support can consist of fluorescent glass. Several planes of the above-described type can be employed either parallel or at a slant, or can be arranged around the whole lamp in a circle or polygon. If both half-waves of the voltage supplied by the transformer, whether grounded or not, are to be utilized, this is rendered possible by an appropriate circuit, by suitably designing the cathode for the simultaneous limitation of the emission current, and by the characteristic of the tube. If, when the selective body 32 is incandescent, the positive half-wave is laid on to the cathode 24, the selective body 32 itself emits electrons. They impinge subject to braking on the cathode. The latter, designed as a selective body as described above or of any other appropriate shape or type, then also emits shortwave rays and white light. In this case the tips 25 are no longer necessary, or only serve for momentarily instituting the discharge.

There are also luminescent substances that can be excited to emit light by electric or magnetic fields of con-

stant or variable intensity. Luminescent substances of this kind can also be utilized for the source of light according to the invention. An embodiment of such a source of light in which the mass of luminescent substance is excited by an electric field is shown by way of example in Fig. 7, in which the electric field is formed between the rear plate electrode 38 and the front grid electrode 39 as soon as an appropriate voltage is laid on to the pair of terminals 40. In the field of action of the electric field, which in this case is largely at right angles to the surfaces of the electrodes, there is a mass of luminescent substance 4, which here too consists of particles of luminescent substance in a medium, the refraction index of the medium and of the particles of luminescent substance having at least approximately the same value for the light emitted by the latter. Furthermore, the medium is so chosen that owing to its dielectric properties it causes no loss of energy in the electric field. The field energy is utilized exclusively to excite the particles of luminescent substance; the light emitted by the latter escapes forwards through the grid electrode without being noticeably absorbed in the medium of the layer of luminescent substance 4. The light yield is still further increased by rendering specular the limiting surface between the plate electrode 38 and the mass of luminescent substance 4. Needless to say, the grid electrode 39 can also be replaced by a metal layer of suitable thinness and transparency and, if desired, the two electrodes 38 and 39 can be made transparent in order to permit the source of light to radiate on both sides. Here too the mass of luminescent substance 4 itself can constitute a self supporting lining on one or both electrodes, if it is composed of a solid medium with embedded particles of luminescent substance, or the medium together with the particles of luminescent substance can be enclosed in a container pervious at least on portions of its walls to the emitted light and arranged inside the electric field between the electrodes 38 and 39. In this case liquid and gaseous masses of luminescent substance can also be employed. The flat electrodes 38 and 39 can also be replaced by structures of different design, thus enabling the shape of the source of light according to the invention to be varied at will.

Finally, certain luminescent substances can be excited by the impact of thermal energy to emit light and thus be employed for the source of light according to the invention, in which case a source of thermal energy is provided. The energy impacting of the mass of luminescent substance is then obtained mainly by heat conductivity, but heat radiation can also be utilized. The predetermined temperature of the primary source of energy can be produced in many different ways, for instance by means of an electric current or other electrical effect, by fire heating, by chemical reaction, etc. In this embodiment of the source of light, as exemplified in Fig. 1, care must be taken that the transmission of heat between the source of energy 1 and the mass of luminescent substance 4 is as far as possible free from loss, and therefore that the enclosed space 2 and the lining 5 are as good heat conductors as possible. The source of energy 1 can fill the enclosed space 2 completely or can be applied to the lining 5 in the form of a stratified source of energy, e. g. a coil of heating wire. Needless to say, the mass of luminescent substance must stand up to the predetermined temperature, and the medium in which the particles of luminescent substance are embedded should, in contrast to the latter, be as good a heat conductor as possible. By an appropriate choice of the external envelope 3 the leakage of heat to the exterior is largely avoided, while the light emitted by the particles of luminescent substance passes through the wall 3 as far as possible without loss.

Various changes and modifications may be made without departing from the spirit and scope of the present

11

invention and it is intended that such obvious changes and modifications be embraced by the annexed claims.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent, is:

1. In a source of light having at least one primary energy source capable of emitting a first type of radiation having wavelengths in the visible light spectrum and a second type of radiation having wavelengths outside of the visible light spectrum, and a light-enhancing medium positioned adjacent said energy source and in the path of both said types of radiation when the same are emitted by said energy source; said light-enhancing medium comprising a mass of a carrier substance capable of transmitting said first type of radiation substantially without losses due to absorption, and a plurality of particles of luminescent material embedded in and dispersed throughout said carrier substance, said luminescent particles absorbing only said second type of radiation so as to become raised thereby to an excited state and so as to emit, upon return to a non-excited state, additional visible light joining said first type of radiation, said luminescent particles further having an index of refraction for said additional visible light approximately equal to the index of refraction of said carrier substance for said additional visible light.

2. In a source of light according to claim 1; intermediate means interposed between said energy source and said medium and defining a surface facing away from said energy source and capable of reflecting said additional visible light emitted by said luminescent particles; said intermediate means transmitting both said types of radiation substantially without losses due to absorption, and said medium being located on said surface of said intermediate means.

12

3. In a source of light according to claim 1; an evacuated hollow envelope surrounding said primary energy source, said medium being disposed as a layer on the surface of said envelope, and a cathode for the emission of electrons disposed within said envelope, said energy source including a flat plate arranged at least partly around said cathode.

4. In a source of light according to claim 1; said second type of radiation comprising at least partly electromagnetic radiation having wavelengths shorter than the wavelengths of the blue end of said visible light spectrum.

5. In a source of light according to claim 1; said second type of radiation comprising electromagnetic radiations having wavelengths corresponding to wavelengths of radio waves in the band of decimeter and centimeter waves.

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