

(19)



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(11)

EP 0 786 799 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
30.07.1997 Bulletin 1997/31

(51) Int Cl.⁶: **H01K 1/26, F21V 9/02**

(21) Application number: **97300451.8**

(22) Date of filing: **24.01.1997**

(84) Designated Contracting States:
BE DE FR GB NL

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(30) Priority: **24.01.1996 GB 9601402**

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(54) Incandescent reflector lamp with sun-like spectral output

(57) In a reflector lamp having a halogen light source (3), a dichroic filter (5) is applied to the front glass (1) of the lamp in order to produce light having a spectral emission with a single peak which substantially matches the emission spectrum of sunlight, at least over the visible range. The dichroic filter is tuned to the characteristics

of the particular light source used and reduces the transmission of yellow and red light significantly below the theoretical values for a lamp with no reflector in order to take into account of secondary and multiple reflections when a reflector is present. In an alternative embodiment, the dichroic filter is applied directly to the light source (3).

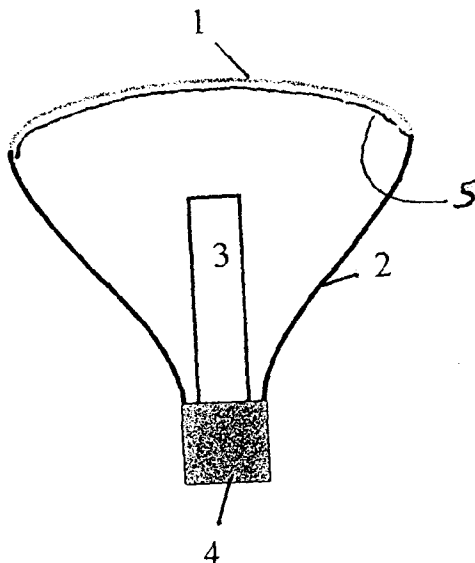


FIG. 1

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Description

The present invention relates to an incandescent reflector lamp which emits light with a spectral output that substantially simulates sunlight, at least over the visible range of the electromagnetic spectrum.

For many years, it has been sought to produce light by artificial means. In the film and TV industry, for example, where daylight hours are precious and a standard amount of light having a particular colour is desirable, there is a need to produce artificial daylight. In response to this need a company by the name of Balzers has developed a "TL60" daylight filter, which when put in front of a halogen lamp, can convert the light output of the lamp to roughly that of daylight.

Artificial daylight is nowadays also sought after for the home and the office to offer a more soothing environment. A number of different approaches are known where particular lamps have been adapted in some way to shift their colour coordinates to values closer to those of the sun.

For example, it is known to provide an incandescent lamp containing the rare earth element Neodymium in or on the glass envelope. This addition has a filtering effect which results in a quite severe absorption in the yellow/orange region of the visual spectrum. Unfortunately, this results in a spectrum which is not particularly smooth and which tends to highlight and enhance other colours of the visual spectrum.

Incandescent daylight lamps having a blue coating are also known. The blue coating results in a partial filtering of the red portion of the spectrum from the light source. Generally, this may cause the colour coordinates in the CIE chromaticity diagram to exhibit a shift towards perfect white, ie. $x = 0.33$ and $y = 0.33$, though it still remains in the yellowish region. However, the spectral output has no real correlation with the spectrum of sunlight.

Another attempt to produce artificial daylight is known from the field of fluorescent lamps. This is achieved by selecting a precise mix of different phosphors in order to match a desired set of colour coordinates, such as those of sunlight. However, a problem with these lamps is that their spectral output comprises a series of discrete sharp spectral peaks, which bears no real correlation to that of sunlight. In addition, the flickering effect of a fluorescent lamp, due to the AC power supply, often has a negative effect on people and may defeat any soothing effect created by the simulated daylight.

Another lamp is known from DE-A-3931950. This lamp uses an incandescent halogen burner as the light source and incorporates a cold light reflector on its parabolic surface behind the light source. The lamp further includes a separate filter, which is preferably a daylight filter made from a dichroic material, which provides a colour temperature of approximately 5600K. Although this lamp is said to produce an agreeable cool light, the filter is just a standard dichroic filter.

A problem with such standard dichroic daylight filters is that they do not take into account secondary or multiple reflectors which occur within reflector lamps.

Reflector lamps are lamps which have an integral coating on the generally parabolic surface located behind the light source, usually a dichroic coating, in order to reflect light back past the light source and through the front glass.

The known daylight filters generally reduce the proportion of the yellow and red light being transmitted. When these filters are formed as dichroic coatings, they do not absorb but reflect the unwanted radiation back to the parabolic reflector, whereupon the light is reflected back again towards the front glass. These secondary and multiple reflections will increase the relative amount of yellow and red light hitting the dichroic coating of the filter, which also increases the amount of yellow and red light being transmitted. To correct this, the transmission of yellow and red light must be significantly lower than the theoretical value.

Thus, viewed from a first aspect, the present invention provides a reflector lamp having a halogen light source and a front glass through which light is transmitted, the front glass having a dichroic filter to convert the light from the light source to light having colour coordinates approximately those of sunlight, characterised in that the transmission properties of the dichroic filter have been tuned to take account of secondary and multiple reflections from the reflector so that the lamp has a spectral emission substantially the same as sunlight, at least over the visible range.

Thus the lamp allows a reflector to be used whilst producing a light that more closely resembles sunlight. In a preferred embodiment, the spectral emission has a coefficient of correlation with the spectrum of sunlight over the visible region of between 0.7 and 1.0, preferably between 0.8 and 1.0, and most preferably between 0.85 and 1.0. In existing products, generally no correlation exists and in many cases the opposite tendency is found producing negative values for the correlation coefficient.

Preferably, the transmission of light through the filter of the front glass between the range of 400 and 480nm is higher, and between 580 and 700nm is lower, than the predicted values for a lamp not having a reflector. This therefore reduces the relative amount of yellow and red light being emitted and produces light from a reflector lamp whose spectral emission is closer to that of sunlight.

In one preferred embodiment, the transmission of light through the front glass of the lamp over the range 400 to 480nm is greater than 90%. In particular, preferably the filter produces a transmission curve that has a single broad peak with no minima between 400 and 580 nm, most preferably between 400 and 480nm. Preferably the transmission

of light over the range 580 to 760nm is below 25%.

Viewed from another aspect, the present invention provides a reflector lamp having a halogen light source and a front glass through which light is transmitted, the front glass having a dichroic filter to convert the light from the light source to light having colour coordinates approximately those of sunlight, characterised in that the transmission curve of the dichroic filter has a single broad peak which extends between 400 and 480 nm.

With the known standard daylight filters, which do not take account of secondary and multiple reflections, the transmission curve exhibits a minimum between 400 and 480nm, usually at around 430nm.

A further difference between the known filters and that of the present invention can be seen when the average transmittance in the 580-760 nm region is subtracted from the average transmittance in the 400-480 nm region. In existing daylight filters such as those supplied by Balzers and Schott the difference is about 60%, whereas in the present invention the difference between the two regions is greater than 70%.

In addition to resembling the sunlight spectrum, the lamp also has colour coordinates which substantially match those of the sun. In a preferred embodiment, the colour coordinates were measured as approximately $x = 0.32$ and $y = 0.33$. Preferably the colour coordinates are between $0.310 < x < 0.350$ and $0.320 < y < 0.360$.

Although the spectral emission curve of the lamp closely resembles that of sunlight over the visible region having a single peak in the region between 430 and 530nm, preferably the width of the peak is narrower than that of the sunlight spectrum. Medical tests have shown that the human eye can focus more easily on single peaked spectral light distributions, resulting in better vision for contrast and detail. By decreasing the width of the single peak, this effect can be increased whilst maintaining a good colour rendering index (CRI).

Preferably the lamp has a CRI of greater than 90%. Preferably the CRI is greater than 93% and in a most preferred embodiment the CRI is equal to or greater than 95%. A preferred range for the CRI is between 93 and 97%.

Viewed from a further aspect, the present invention provides a reflector lamp having a halogen light source and a front glass through which light is transmitted, the front glass having a dichroic filter to convert the light from the light source to light having colour coordinates approximately those of sunlight, characterised in that the lamp produces an emission spectrum having a single peaked curve, the peak laying between 450 and 580 nm.

Preferably the peak is at 480 nm as this correlates well with the peak of the sunlight spectrum. However, just having a single peaked spectrum provides advantages in its own right, because of the increase in ease with which the eye can focus.

In a preferred embodiment, the dichroic filter comprises alternating layers of ZnS and SiO₂. Preferably the filter consists of the following 8 layers:

- layer 1 - ZnS of 76.73nm thickness;
- layer 2 - SiO₂ of 110.74nm thickness;
- layer 3 - ZnS of 65.04nm thickness;
- layer 4 - SiO₂ of 103.86nm thickness;
- layer 5 - ZnS of 71.59nm thickness;
- layer 6 - SiO₂ of 118.81nm thickness;
- layer 7 - ZnS of 102.94nm thickness; and
- layer 8 - SiO₂ of 80.38nm thickness.

Preferably the dichroic filter is a coating which is integral with the front glass of the lamp, preferably coated on the inside of the front glass.

Viewed from yet another aspect, the present invention provides a reflector lamp having a halogen light source and a front glass through which light is transmitted, the front glass having a dichroic filter to convert the light from the light source to light having colour coordinates approximately those of sunlight, characterised in that the dichroic filter is a coating applied to the inside surface of the front glass and in that it consists of alternating layers of ZnS and SiO₂.

This coating is preferably applied by the molybdenum boat thermal evaporation process using ZnS and SiO as evaporation materials. The SiO is evaporated in a partial oxygen atmosphere to form SiO₂ layers. This method is advantageous because it is considerably cheaper to use than other evaporation processes, such as the electron beam gun evaporation process, with SiO₂ and TiO₂ as evaporation materials, used by Balzers in the production of their above mentioned "TL60" filter.

In order to produce the correct spectral emission for the lamp, it is important to tune the lamp's filter to the particular burner or light source being used and also to the reflector.

The reflector may be a standard reflector material which reflects substantially all of the visible light incident on it back into the lamp, or it may be designed to reflect only selected wavelengths, for example, a cold light reflector which may allow infrared light to pass through.

The preferred light source is an incandescent halogen capsule or burner with a colour temperature of between 2700 and 3200K, for example, a 100W high volt halogen lamp or at least a 50W low volt lamp. The higher the colour temperature of the light source, the better the result will be because less filtering has to be applied.

It is preferred for the emission from the lamp itself to have a colour temperature higher than 5000K, while maintaining the smallest possible deviation from the black body locus of a chromaticity diagram. In the most preferred embodiments, the lamp has an emission with a colour temperature of greater than 6000K, preferably as high as 6500K, since this provides a person using the light with better conditions for reading due to improved contrast and vision.

However, to an extent many of the advantages provided by the invention, for example, the soothing properties and the improved contrast and vision can be achieved by the single peaked distribution without having such a high colour temperature, for example, 4000K. Such a colour temperature may be produced by a high volt 50W lamp, which may be more appropriate for existing desk top fixtures which usually only allow up to a maximum of 60W. In a lamp of this type, the single peak of the emission curve would be at approximately 580 nm, rather than 480 nm for the 6500K version.

According to yet another preferred aspect of the invention, a dichroic filter is coated directly onto the light source capsule itself.

Thus, viewed from another aspect, the present invention provides an incandescent halogen light source for a lamp wherein the light source is coated with a dichroic filter to emit light having colour coordinates and a spectral emission substantially the same as sunlight.

Preferably the light source is incorporated in a reflector lamp.

The preferred illuminance level for the lamp is between 1100 and 1700 lx, preferably between 1200 and 1650 lx, and most preferably at 1350 lx. A homogeneous illumination of the work space by the lamp is important, especially if the lamp is to maximise its soothing and its improved contrast and vision properties. The reflector should therefore have a large beam angle, for example, 50° or more, preferably 60° or greater for desk top applications, in order to spread the beam of desired illuminance over a reasonable area, rather than just a small spot.

Some preferred embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

FIG. 1 is a side sectional elevation through the central axis of a preferred reflector lamp;

FIG. 2 is a graph showing the spectral outputs of various lamps from the prior art compared to that of the sun;

FIG. 3 is a graph showing the spectral outputs of a preferred embodiment of the lamp of the present invention in comparison with spectral outputs from the sun and a standard incandescent halogen lamp;

FIG. 4 is a graph showing the transmission properties of the Balzers' "TL60" daylight filter;

FIG. 5 is a graph showing the transmission properties of the Schott No. 512 filter used in DE-A-3931950; and

FIG. 6 is a graph showing the transmission properties of a preferred dichroic front glass coating, in accordance with the present invention.

In Figure 1, there is shown an embodiment of a preferred reflector lamp. The lamp comprises a front glass 1, a reflector 2, an incandescent light source 3, often referred to as a "burner", and a socket 4.

In the most preferred embodiment, the lamp has a dichroic filter 5 coated on the inside of the front glass 1.

The coating may be applied by any suitable technique, the preferred technique being a standard molybdenum boat thermal evaporation process using ZnS and SiO₂ as evaporation materials. In the process, the SiO₂ is evaporated in an oxygen enriched atmosphere to form SiO₂ layers. Other techniques, such as electron beam gun evaporation, may also be used although tend to be more expensive. As discussed above, in accordance with the first aspect of the invention, the transmission properties of the dichroic filter are tuned so that the spectral emission of the lamp is substantially the same as sunlight.

As an example of a preferred lamp, the lamp consists of a high voltage hard glass incandescent halogen burner 3, focused inside a parabolic reflector 2 with a rim diameter of 95mm. The reflector consists of a moulded parabolic glass portion of the lamp envelope inside which a standard semi durable cold light mirror material is coated. The coating reflects visible light but is transparent to infrared. A front glass 1 is glued to the reflector 2 to prevent dust and other pollutants from entering the lamp, as well as providing protection in the event of the burner 3 exploding and a UV-stop filter. The front glass 1 has a coating 5 applied to its inside surface which converts the light emitted from the high voltage burner into a single peaked spectrum with a colour temperature of at least 6000K. The coating 5 consists of 8 layers of alternating ZnS and SiO₂ with the following thicknesses:

Layer Nr.	Material	Thickness (nm)
1	ZnS	76.73
2	SiO ₂	110.74

(continued)

Layer Nr.	Material	Thickness (nm)
3	ZnS	65.04
4	SiO ₂	103.86
5	ZnS	71.59
6	SiO ₂	118.81
7	ZnS	102.94
8	SiO ₂	80.38

The transmission properties of this coating 5 are shown in Figure 6. The coating 5 in this example achieves a colour temperature conversion of 2800K to between 6000 to 6500K when used with a 100W, high volt light source or at least a 50W low volt light source.

The spectral outputs of the sun, various prior art lamps and a preferred embodiment of the present invention are compared in Figures 2 and 3. In the figures, the spectral outputs are normalised to 100% in order to allow for comparison.

The spectral outputs of the different curves when compared to that of the sun correlate as follows:

light source	correlation coefficient
sun	1.00
preferred embodiment of the present invention	0.86
halogen lamp	-0.51
neodymium containing lamp	-0.42
blue coated incandescent daylight lamp	-0.53
fluorescent daylight lamp	0.40

Figure 3, in addition to clearly showing that the single peaked spectral emission of the preferred lamp closely matches that of sunlight, also shows that there is improved kurtosis, ie. sharpness of the peak. This allows for easier focusing of the human eye whilst maintaining the high colour rendering index.

As can be seen from the transmission curves of Figure 4 and 5 of the prior art, the filters exhibit transmission minima between approximately 420 to 430nm. In contrast to this, the preferred filter has a transmission curve that exhibits a single broad peak in the blue region that spans between about 400 and 500nm. The preferred filter also shows lower transmission in the yellow and red region of the spectrum compared to the Balzer's "TL60" daylight filter shown in Figure 4.

The reflector 2 may be of any type, eg. smooth, faceted etc, and its transmission properties may be dictated by the heat resisting properties of the socket 4 and/or the light fitting (not shown). The lamp may, for example, be a 75W lamp with a 25° spread angle for ceiling mount applications, or perhaps a 50W lamp with a 50° spread angle or a 50mm diameter, 50W lamp with a 60° spread angle for desk lamp applications. In all these cases, it may be necessary to adjust the coating or filter in order to compensate for the different colour temperatures of the burners and for the different secondary and multiple reflections of the various reflector types.

Thus there has been described a lamp which does not require a complex construction or extra parts to hold a filter; which in its most preferred embodiment has improved daylight reproducing abilities; and which can provide a soothing light that enables optimal contrast and homogeneous illumination of a reading surface.

Claims

1. A reflector lamp comprising a front glass (1), a reflector (2), a halogen light source (3) and a dichroic filter (5) to convert light from the light source to light having colour coordinates approximately those of sunlight, characterised in that the lamp produces an emission spectrum having a single peaked curve, the peak laying between 450 and 580 nm.
2. A lamp as claimed in claim 1, wherein the dichroic filter (5) is applied to the front glass (1) of the lamp.
3. A lamp as claimed in claim 1, wherein the dichroic filter (5) is applied to the light source (3).

4. A lamp as claimed in claim 1, 2 or 3, wherein the lamp has a colour temperature of greater than 5000K.
5. A lamp as claimed in claim 4, wherein the lamp has a colour temperature of greater than 6000K.
- 5 6. A lamp as claimed in any preceding claim, wherein the peak of the emission spectrum is at 480 nm.
7. A lamp as claimed in any of claims 1 to 3, wherein the lamp has a colour temperature of 4000K and the peak of the emission spectrum is at 580 nm.
- 10 8. A lamp as claimed in any preceding claim, wherein the transmission of light through the dichroic filter (5) over the range 400 to 480 nm is not less than 90%.
9. A lamp as claimed in any preceding claim, wherein the transmission of light through the dichroic filter (5) over the range 580 to 760 nm is not more than 25%.
- 15 10. A lamp as claimed in any preceding claim, wherein the dichroic filter (5) produces a transmission curve that has a single broad peak, with no minima present between the range of 400 to 580 nm.
11. A lamp as claimed in claim 10, wherein the peak of the transmission curve extends between 400 and 480 nm.
- 20 12. A lamp as claimed in any preceding claim, wherein the colour coordinates of the lamp are between $0.310 < x < 0.350$ and $0.320 < y < 0.360$.
13. A lamp as claimed in any preceding claim, wherein the lamp has a Colour Rendering Index of greater than 90%.
- 25 14. A lamp as claimed in claim 13, wherein the Colour Rendering Index is not less than 95%.
15. A lamp as claimed in any preceding claim wherein the dichroic filter (5) comprises alternating layers of ZnS and SiO₂ layers.
- 30 16. A lamp as claimed in claim 15, wherein the dichroic filter (5) comprises 8 or more layers.
17. A lamp as claimed in claim 8, wherein the dichroic filter (5) consists of the following 8 layers:
 - 35 layer 1 - ZnS of 76.73nm thickness;
 - layer 2 - SiO₂ of 110.74nm thickness;
 - layer 3 - ZnS of 65.04nm thickness;
 - layer 4 - SiO₂ of 103.86nm thickness;
 - layer 5 - ZnS of 71.59nm thickness;
 - 40 layer 6 - SiO₂ of 118.81nm thickness;
 - layer 7 - ZnS of 102.94nm thickness; and
 - layer 8 - SiO₂ of 80.38nm thickness.
18. A reflector lamp comprising a front glass (1), a reflector (2) and a dichroic filter (5) to convert light from the light source to light having colour coordinates approximately those of sunlight, characterised in that the transmission properties of the dichroic filter (5) have been tuned to take account of secondary and multiple reflections from the reflector (2) so that the lamp has a spectral emission substantially the same as sunlight, at least over the visible range.
- 45 19. A reflector lamp comprising a front glass (1), a reflector (2), a halogen light source (3) and a dichroic filter (5) to convert light from the light source to light having colour coordinates approximately those of sunlight, characterised in that the transmission curve of the dichroic filter has a single broad peak which extends between 400 and 480 nm.
- 50 20. A reflector lamp comprising a front glass (1), a reflector (2), a halogen light source (3) and a dichroic filter (5) to convert light from the light source to light having colour coordinates approximately those of sunlight, characterised in that the dichroic filter is a coating applied to the inside surface of the front glass and in that it consists of alternating layers of ZnS and SiO₂.
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21. An incandescent halogen light source (3) for a lamp wherein the light source is coated with a dichroic filter to emit light having colour coordinates and a spectral emission substantially the same as sunlight.

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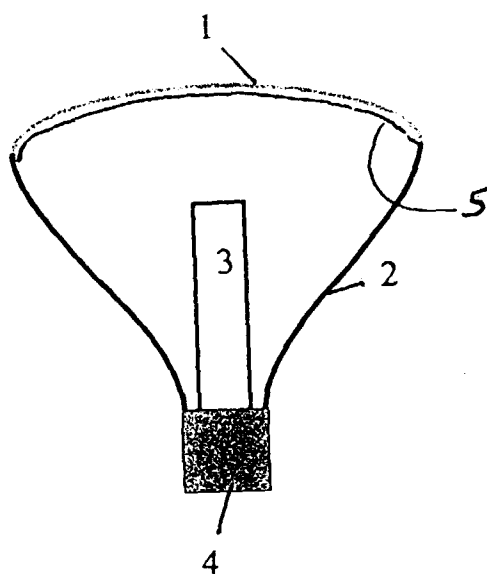


FIG. 1

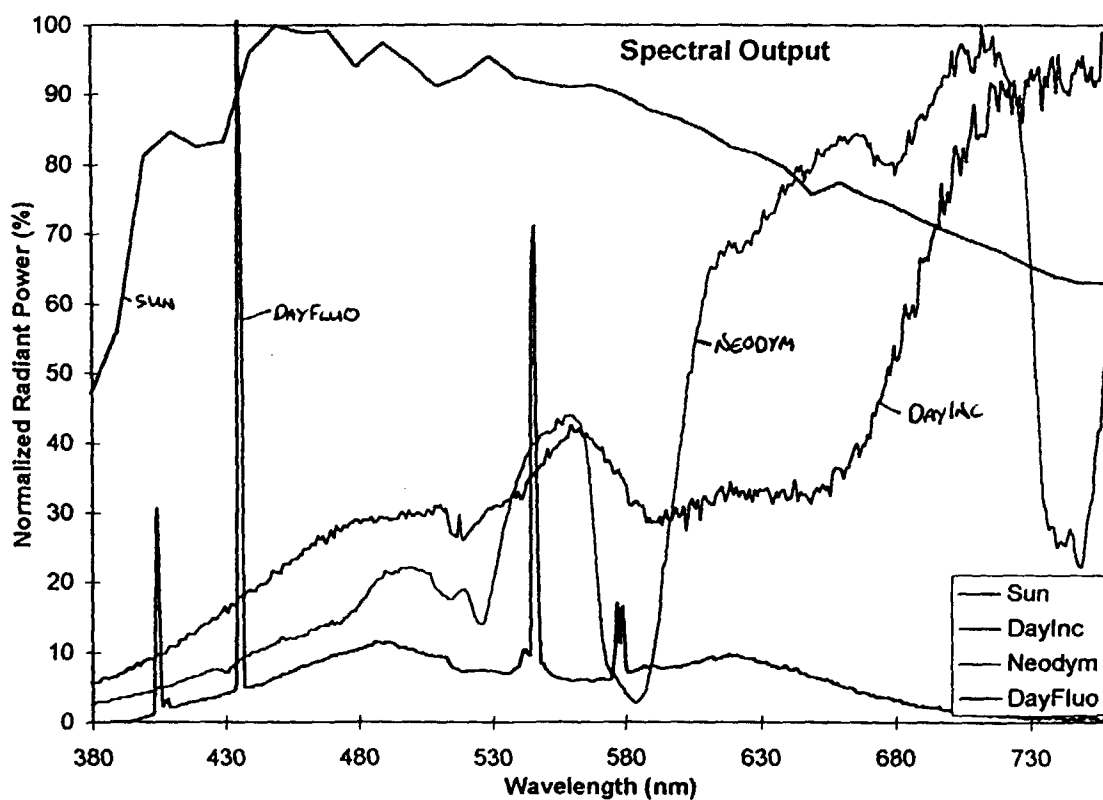


FIG. 2

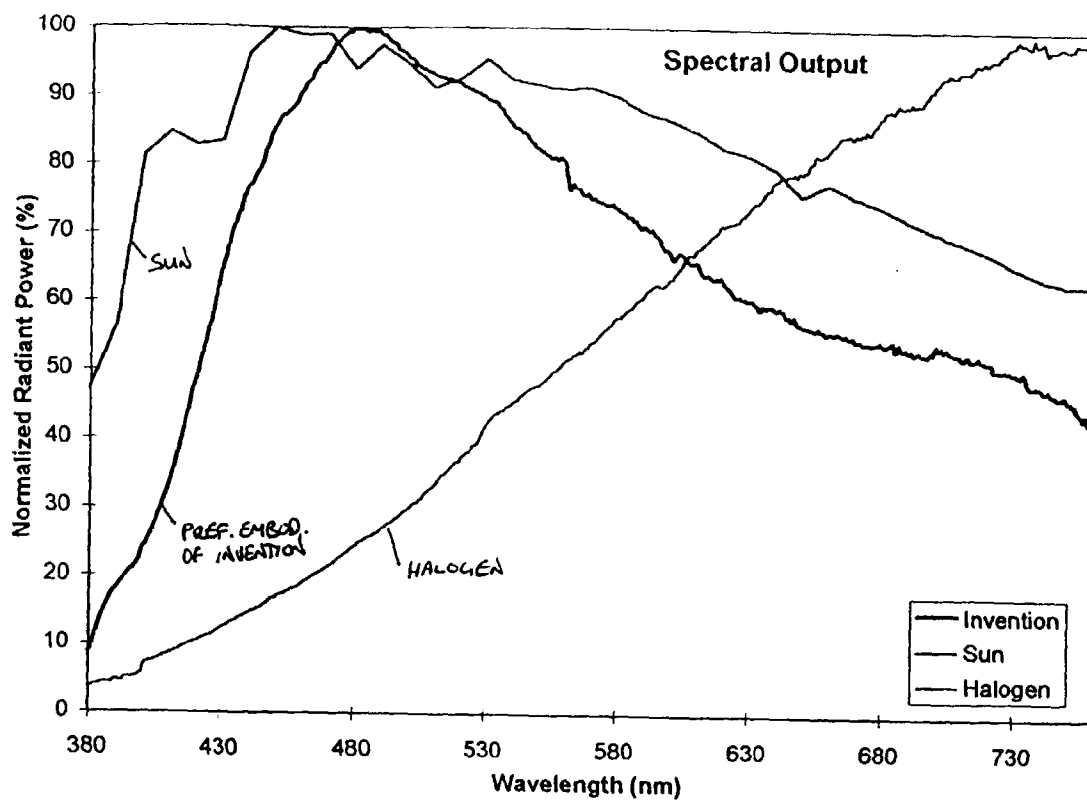


FIG. 3

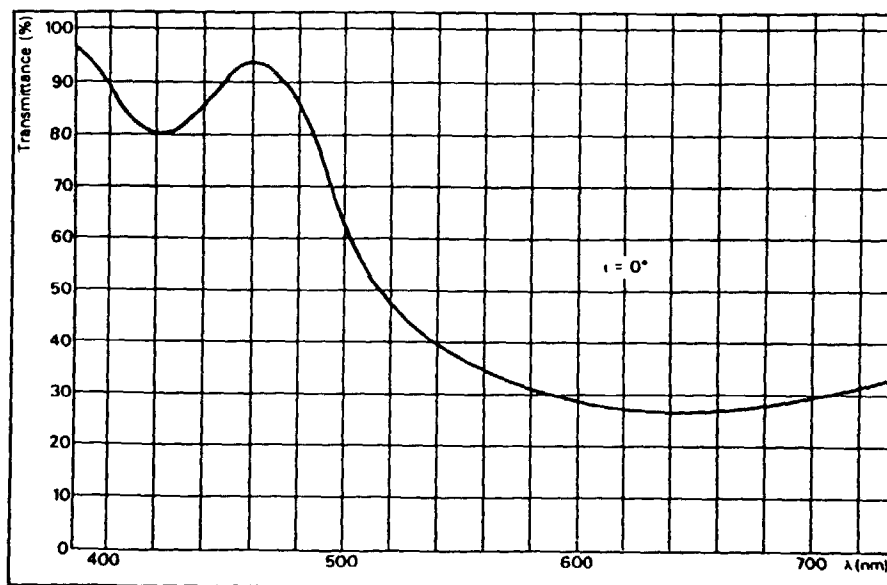


FIG. 4

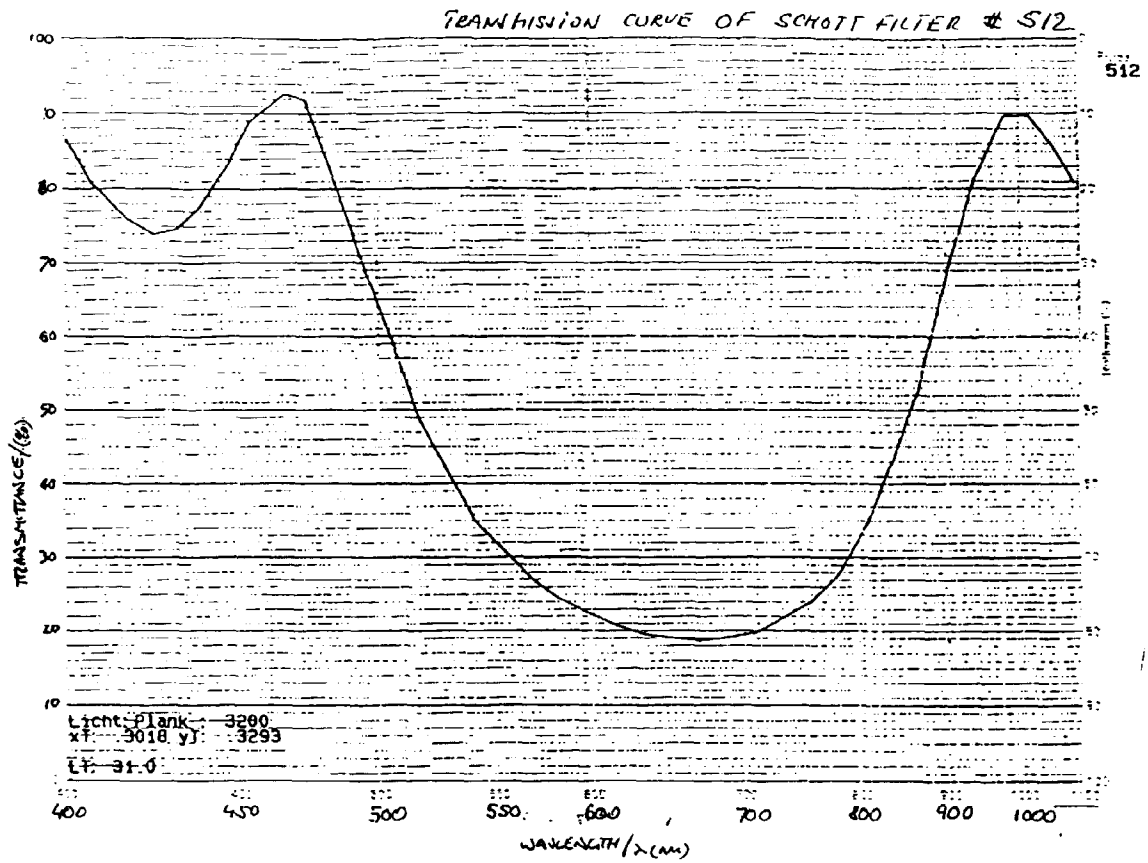


FIG. 5

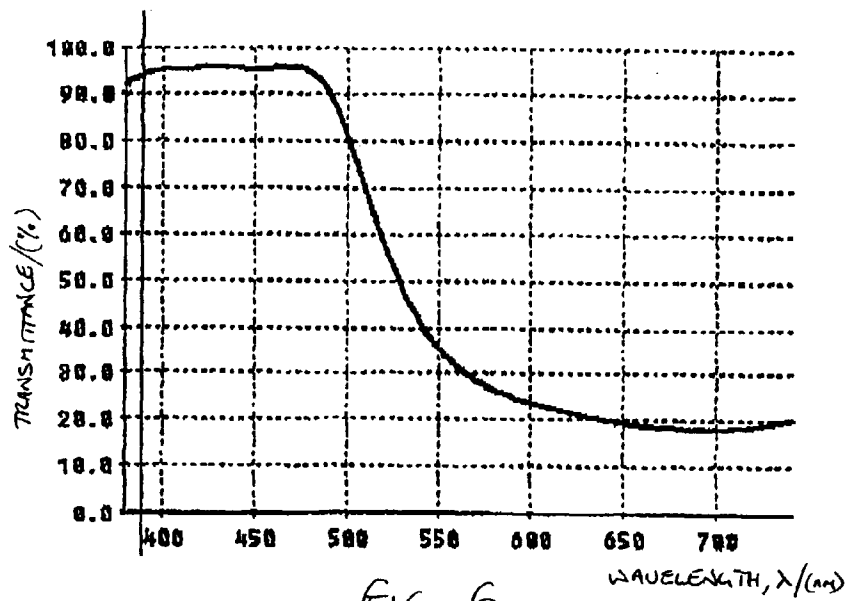


FIG. 6



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 97 30 0451

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	PATENT ABSTRACTS OF JAPAN vol. 096, no. 005, 31 May 1996 & JP 08 021785 A (MITSUBISHI HEAVY IND LTD; OTHERS: 01), 23 January 1996, * abstract; figures 1-3,6-10 *	1,6,7, 10,19,21	H01K1/26 F21V9/02
D,A	DE 39 31 950 A (KAISER ALEXANDER) 4 April 1991 * claims 1-3; figure *	1,2	
A	US 4 125 775 A (CHODAK JAN B) 14 November 1978 * claim 1; figure *	1	
A	US 2 831 966 A (PORTEOUS) * column 1, line 49 - line 55 * * column 2, line 54 - column 3, line 12 * * column 5, line 11 - line 29; figures 3,4 *	1,4-7, 10,11, 15,19-21	
A	DATABASE WPI Section Ch, Week 8406 Derwent Publications Ltd., London, GB; Class L01, AN 84-035659 XP002029718 & SU 1 008 170 A (GLASS RES INST) , 30 March 1983 * abstract *	1,20,21	H01K F21V
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
Place of search THE HAGUE		Date of completion of the search 18 April 1997	Examiner Deroubaix, P
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