Projection television display tube and projection television device comprising at least one such tube.

Priority: 29.05.86 GB 8513558

Date of publication of application: 30.12.86 Bulletin 86/52

Publication of the grant of the patent: 03.10.90 Bulletin 90/40

Designated Contracting States: DE FR GB IT SE

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EP-A-0 170 320
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The invention relates to a projection television display tube comprising in an evacuated envelope a display screen which is provided on the inside of a display window in the wall of the envelope, said display screen comprising a luminescent material, between said luminescent material and the display window a multilayer interference filter being provided, which filter comprises a number of layers which are manufactured alternately from a material having a high refractive index and a material having a low refractive index.

From German Patent Application 23 30 898 laid open to public inspection a display tube is known in which a multilayer interference filter is used between the luminescent material (the phosphor) and the display window. For the thickness of the layers of the filter of a material having a high refractive index an optical thickness smaller than 0.25 λ or between 0.5 λ and 0.75 λ is chosen, wherein λ is the wavelength of the light emitted by the luminescent material. For the layers of the filter of a material having a low refractive index an optical thickness of 0.25 λ is chosen or an odd multiple thereof. The light emission characteristic of the display screen of the tube is varied by the filter in such a manner that the quantity of light emitted within a restricted angular aperture increases by 25% compared with a tube without a filter. The contrast in the produced picture is also increased by a reduction of the background brightness.

A similar display tube is disclosed in British Patent Specification 1,306,335 in which a so-called passband interference filter is provided between the phosphor and the display screen. This filter consists of layers having an optical thickness of 0.25 λ and appears as follows:

S L H L L L L L L L L L L L L L H H L H L L L L L L L L L L L L L H,

wherein S is the display window, L are layers of a material having a low refractive index, and H are layers of a material having a high refractive index. Such a filter may also be represented as follows:

S L H (L)⁹ H L H (L)⁹ H L H (L)⁹ H.

As a result of the presence of the six layers placed against each other and having a low refractive index (L), a Fabry-Perot filter is formed. This filter, with a given choice of the optical layer thickness, has a desired transmission band for band for light rays which enclose an angle smaller than 25° to 40° to the normal on the filter. In addition however, there is a non-desired wide transmission band for light rays which enclose an angle between 55° and 90°. All the light which is passed in this band is lost or contributes to so-called halo and hence to loss of contrast in the displayed picture. This will be explained hereinafter. Moreover, the cryolite layers used in said filter are hygroscopic and remain soft so that damage of the filter can easily occur. The zinc sulphide (ZnS) layers used in said filters easily oxidize during firing the tube at approximately 460°C, so that they are not so suitable for use in display tubes.

In the article "Anti-halo coatings for cathode ray tubes face-plates", J. D. Rancourt, Proceedings of the SID, Vol. 25/1, 1984, an 11-layer edge-filter and an 8-layer pass-band-interference filter for suppressing halo effects is described. It is also suggested to use one of these filters for projection T.V. (page 47, right-hand top). An 11-layer filter, however, for projection T.V. still gives much loss because too much light is passed at large angles.

In projection television display tubes a number of problems occur, for example:

a) The display of a flat display screen on a flat projection screen requires a very complicated system of lenses. In order to reach a "Hi-Fi" (optical) quality, for example, a five or eight element lens is necessary.

b) A luminous decline to approximately 20% occurs from the centre of the projection screen towards the corners, caused by reduction of the acceptance angles of the lens (including vignetting). This decline in brightness becomes the worse according as the focal distance of the lens is smaller. At the moment there is a clear trend towards smaller focal distances so as to reduce the size of the housing of the projection television device.

It is an object of the invention to provide a projection television display tube having a multilayer interference filter in which these problems are lessened.

A projection television display tube of the kind described in the opening paragraph is characterized according to the invention in that the display window on the vacuum side is inwardly curved having an angle of curvature φ, wherein φ is the angle between a line at right angles to the centre of the display window and a line at right angles to the part of the display window farthest remote from the centre, said angle φ being between 5° and 25°.

By providing the projection television display tube with both a curved display screen and with a multilayer interference filter, the above problems are solved for the greater part. The display quality is improved and at the same time the number of required lens elements in a projection television device is reduced. Less light decline towards the corners also occurs.

The light gain in the corners of the display screen has proved to be considerably larger than the sum of the effects of the individual measures, namely the curved display window and the provision of an interference filter, would produce.
Display tubes having inwardly curved display windows are known per se from British Patent Specification 2,091,898.

A preferred embodiment of a projection television display tube, according to the invention, is characterized in that the curved display window is substantially spherical having a radius of curvature between 150 mm and 730 mm, for example, for a 127 mm diagonal display screen.

Further problems that occur are:

c) Projection television display tubes having green phosphors with Terbium as an activator have a less good colour rendition by too great contribution of orange and red spectral lines.

d) In tubes with the green Tb phosphors and with the wide band blue ZnS:Ag-phosphor, chromatic aberration occurs.

e) The brightness on the projection screen generally is on the low side.

f) The contrast also requires some improvement.

A second preferred embodiment of a projection television display tube according to the invention is characterized in that the filter is composed of at least 6 layers each having an optical thickness $nd$, wherein $n$ is the refractive index of the material of the layer and $d$ is the thickness, said optical thickness being between $0.2\lambda$ and $0.3\lambda$, wherein $\lambda_i$ is equal to $p/\lambda$, wherein $\lambda$ is the desired central wavelength which is selected from the spectrum emitted by the luminescent material and $p$ is a number between 1.18 and 1.32. The average optical thickness is $0.25\lambda_i$ and $\lambda_i$ is the central wavelength of the filter. On a frequency scale, $1/\lambda_i$ corresponds to the centre of the reflection band with perpendicular incidence of the light.

By using a suitable multilayer optical interference filter between the phosphor and the display screen:

1) The colour point in the green for the usual Tb-phosphors is improved (solution problem c).

2) The chromatic aberration, in particular in the green, is reduced (solution problem d).

3) The brightness for all central colours is increased (solution problem e).

4) The contrast is improved (solution problem f).

The filter in the projection tube according to the second preferred embodiment hence consists exclusively or substantially exclusively of layers having an optical thickness of approximately $0.25\lambda_i$.

Herefrom the filter derives the special property of the very wide reflection band (no transmission) for light rays which enclose an angle between approximately 30° and 80° to 90° to the normal on the filter.

For example, in 0.75 $\lambda_i$ and 1.25 $\lambda_i$ filters the width of the reflection band is reduced by factors 3 and 5, respectively, and undesired transmission occurs at large angles. As a result of this the gain in luminous efficiency with such filters in the forward direction, hence for light rays which enclose small angles to the normal on the filter, as described in German Patent Application 2,330,898 is restricted to 25%. There is also less gain in contrast. The Fabry-Perot filter according to British Patent Specification 1,306,335 comprises three 1.5 $\lambda$ layers (each consisting of six 0.25 $\lambda$ layers of a material having a low refractive index) and also has an undesired wide transmission band for light rays which enclose large angles to the normal on the filter.

In the above article “Proceedings of the SID”, Vol. 25/1, 1984 filters for halo-suppression have been described as already mentioned above. Even absorbing filters are suggested. Due to their small number of layers said filters are less critical as regards the angle within which the reflection strongly decreases (the acceptance angle). Characteristic of the second preferred embodiment present invention is that the position of the “edge” of the filter (hence $p$ and $\lambda_i$ in $\lambda_i=p\lambda$) is exactly defined and the acceptance angle is comparatively small. This leads to a great gain in brightness at small angles. As a result of this the filter is very sensitive to losses at large angles and therefore filters having many layers (≥14) are desired.

The layer thicknesses in the filter are hence chosen to be so that at a desired wavelength the reflection begins to increase considerably for light rays of a luminescent material which enclose an angle exceeding 18° to 30° to the normal on the filter. The wide reflection band ensures that light rays having angles exceeding 25° to 35° are reflected as much as possible and after scattering in the luminescent material again obtain a chance to emanate from the tube within an angle of 18° to 30° to the normal on the filter. As a result of this a maximum luminous efficiency in the forward direction occurs and at small angles which for the central wavelength $\lambda$ of the phosphor is at least 50% larger than without the use of the filter. Moreover, the wide reflection band ensures a strongly reduced halo effect and a reduced emanation of light at large angles. The optical thickness $nd$ of the layers of the filter preferably is not equal for all layers but varies between 0.2 $\lambda_i$ and 0.3 $\lambda_i$, and preferably between 0.23 $\lambda_i$ and 0.27 $\lambda_i$ as will be explained in greater detail with reference to an embodiment. As a result of this variation of the thickness a flatter transmission characteristic of the filter is obtained. Because the transmission characteristic of the filter is dependent on the wavelength, it is possible by a combination of a phosphor and an adapted filter to improve the colour point of the light rays which pass through the filter within an angle of 20° to 30° to the normal.

The value of the numeral $p$ is between 1.18 and 1.32 dependent on the reflective indices of the layers used and on the width of the selected wavelength range, which will be explained inter alia with reference to the embodiments. For a TiO$_2$—SiO$_2$ filter $p=\lambda_0/\lambda$ is between 1.21 and 1.32 screen.

A third preferred embodiment of a projection television display tube according to the invention is characterized in that the filter is composed substantially of 14 to 30 layers.

A fourth preferred embodiment of a tube according to the invention is characterized in that the said optical thicknesses $nd$ are between 0.23 $\lambda_i$ and 0.27 $\lambda_i$. 

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A fifth preferred embodiment is characterized in that the layers of the filter having a high refractive index consist of titanium oxide (TiO₂) or tantalum oxide (Ta₂O₅) and the layers having a low refractive index consist of silicon oxide (SiO₂) or magnesium fluoride (MgF₂). The optimum p values for a Ta₂O₅—SiO₂ filter are approximately 0.04 to 0.05 lower than for a TiO₂—SiO₂ filter. In this case the reflection band is less wide. Furthermore, the magnesium fluoride is preferably provided at approximately 300°C to thus obtain a sufficiently hard layer.

A sixth preferred embodiment is characterized in that the luminescent material comprises a terbium-activated substantially green-luminescing phosphor and λ = 545 nm and p is a number between 1.21 and 1.25 for a TiO₂—SiO₂ filter. Terbium-activated substantially green-luminescing phosphors are, for example, yttrium aluminium garnet-terbium (YAG: Tb), yttrium-silicate-terbium (Y₃SiO₅: Tb), lanthanum oxyxobromide-terbium (LaOBr: Tb), lanthanum oxychloride-terbium (LaOCl: Tb), and indium borate-terbium (InBO₃: Tb). For all these Tb-activated green phosphors the central wavelength is λ = 545 nm. By choosing for the filter according to the invention p to be between 1.21 and 1.25, hence λ, between 660 nm and 680 nm, a filter is obtained having a high transmission (exceeding 90%) for light rays which enclose an angle smaller than 20°—30° to the normal on the filter. For light rays which enclose an angle greater than 25° to 35° to the normal on the filter the transmission rapidly reduces and reflection occurs up to 80°—90°. This filter has a particularly good operation for these Tb-activated phosphors which have emission lines in the blue, green, orange-red and red. By using the filter a gain occurs in the green, a much smaller gain in the blue and a substantially complete reduction of the quantity of light emitted by the tube occurs in the red, which is favourable for the colour point. All this provides a gain in luminous efficiency, colour improvement (closer to the EBU-standards) and gain in contrast. In an optimum filter the overall gain in luminous efficiency for all colours together in these Tb-activated phosphors is 30—60%. The gain in the green is 80 to 120%. The coordinates x and y in the CIE colour triangle are then 0.26 to 0.30 and 0.60 to 0.64, respectively. Without a filter these coordinates are x = 0.33 to 0.36 and y = 0.54 to 0.59, respectively. The gain in contrast is approximately a factor 2. For optical display with lenses, as in the case of projection television, this presents considerable advantages, much less chromatic aberration (little or no red and proportionally less blue with respect to the green).

A seventh preferred embodiment of a tube according to the invention is characterized in that the luminescent material comprises a terbium-activated blue-luminescing phosphor and λ = 490 nm and p is a number between 1.21 and 1.25 for a TiO₂—SiO₂ filter. By using for the doping a small quantity of Tb a predominantly blue-luminescing phosphor is obtained with λ = 490 nm. By choosing p to be between 1.21 and 1.25, hence λ, between 590 nm and 615 nm, a filter is obtained in which the reflection increases comparatively steeply for light rays which enclose an angle greater than 25°—35° to the normal on the filter. Then there is a gain in contrast of 70 to 100% and a gain in luminous efficiency in the blue of 60—100%. In the case a considerable improvement of the colour point occurs because the green spectral lines are filtered out by the multilayer filter.

An eighth preferred embodiment of a tube in accordance with the invention is characterized in that the luminescent material is europium-activated yttrium oxide (Y₂O₃: Eu) and λ = 612 nm and p is a number between 1.21 and 1.25 for a TiO₂—SiO₂ filter. As a result of this choice of p between 1.21 and 1.25, hence λ, between 740 nm and 765 nm, the reflection of the filter for light rays which enclose an angle greater than 25° to 35° to the normal on the filter increases considerably. Now there is a gain of 60 to 120% in total luminous efficiency. The gain in contrast is approximately 100%. In this case there is a small colour point improvement. The red components in the spectrum of the generated light are as a matter of fact more strongly intensified than the components of shorter wavelength.

The invention may also be used in wide-band phosphors, for example willemite (Zn₃SiO₄: Mn), zinc sulphide silver (Zn₁₋ₓAgₓS) and strontium aluminate-europium (SrAl₂O₄: Eu) with central wavelengths λ of 530 nm, 460 nm and 460 nm, respectively. The value of p is now chosen to be between 1.21 and 1.32.

As a result of this choice of p between 1.24 and 1.32, hence λ, between 570 nm and 610 nm, the reflection of the filter for light rays which enclose an angle greater than 25° to 35° to the normal on the filter increases considerably. Now there is a gain of 30 to 80% in the luminous efficiency for wavelengths between approximately 440 nm and 500 nm. The gain in contrast is 80 to 100%. In this case the longwave (green) part of the Zn₁₋ₓAgₓS spectrum is filtered out.

Chromatic aberration caused by the displaying lens is hence reduced.

An ninth preferred embodiment of a tube in accordance with the invention is characterized in that the luminescent material comprises a terbium-activated substantially green-luminescing phosphor and λ = 545 nm and p is a number between 1.18 and 1.22 for a Ta₂O₅—SiO₂ filter.

A tenth preferred embodiment of a tube in accordance with the invention is characterized in that the luminescent material comprises a terbium-activated blue-luminescing phosphor and λ = 490 nm and p is a number between 1.18 and 1.22 for a Ta₂O₅—SiO₂ filter.

An eleventh preferred embodiment of a tube in accordance with the invention is characterized in that the luminescent material comprises a terbium-activated blue-luminescing phosphor and λ = 490 nm and p is a number between 1.18 and 1.22 for a Ta₂O₅—SiO₂ filter.
A thirteenth preferred embodiment of a tube in accordance with the invention is characterized in that the luminescent material is zinc sulphide-silver (ZnS:Ag) and \( \lambda = 460 \) nm and \( p \) is a number between 1.21 and 1.28 for a \( \text{Ta}_2\text{O}_5-\text{SiO}_2 \) filter.

For a \( \text{Ta}_2\text{O}_5-\text{SiO}_2 \) filter the optimum \( p \) values are approximately 0.04 to 0.05 lower than for a \( \text{TiO}_2-\text{SiO}_2 \) filter. The reflection band in this case is less wide.

A fourteenth preferred embodiment of a display tube in accordance with the invention is characterized in that the outermost approximately 0.25 \( \lambda \) thick layer of the filter which faces the luminescent material consists of a material having a high refractive index and is covered with a terminating layer having an optical thickness of approximately 0.125 \( \lambda \) of a material having a low refractive index, on which terminating layer the luminescent material is provided.

A fifteenth preferred embodiment of a display tube in accordance with the invention is characterized in that the outermost approximately 0.25 \( \lambda \) thick layer of the filter facing the display window consists of a material having a high refractive index and is covered with an intermediate layer having an optical thickness of approximately 0.125 \( \lambda \) of a material having a lower refractive index. By providing a terminating layer and/or intermediate layer having an optical thickness of approximately 0.125 \( \lambda \) on the phosphor side and/or the display window side, respectively, the transmission in the forward direction for light rays which enclose small angles to the normal is increased and the oscillations in the transmissions are reduced. The transmission characteristic becomes flatter.

A sixteenth preferred embodiment of a display tube in accordance with the invention is characterized in that the outermost approximately 0.25 \( \lambda \) thick layer of the filter facing the luminescent material is composed of a mixture of metal oxide, said mixture comprising titanium oxide (\( \text{TiO}_2 \)) and a metal oxide from the group beryllium oxide (\( \text{BeO} \)), magnesium oxide (\( \text{MgO} \)) and calcium oxide (\( \text{CaO} \)), in which mixture the quantity of titanium oxide is 70 to 90% by weight.

By using such an extra smooth hence less porous coating layer on the phosphor side of the filter the optical contact with the phosphor is reduced so that the gain in contrast and luminous efficiency are extra increased.

Tubes according to the invention are preferably coupled optically via liquid to a system of lenses or are provided with liquid cooling in which the likewise curved cover glass is provided on its outside with an anti-reflection layer. Said cover glass may also serve as the first lens element (the so-called “field-flattener”).

Display tubes according to the invention can advantageously be used in projection television devices. The very bright picture transmitted in the forward direction is received substantially without losses by a system of lenses having a limited acceptance angle of, for example, 25——30°. As a result of this a brighter picture with more contrast and an improved colour rendition is obtained.

The invention will now be described in greater detail, by way of example, with reference to a drawing, in which:

- Figure 1 is an elevation of a projection television display tube partly broken away having an inwardly curved display window,
- Figure 2 is a partial sectional view of the curved display screen, the filter and the curved display window,
- Figure 3 shows diagrammatically the composition of a filter as used in a display tube according to the invention,
- Figure 4 shows a spectrum of \( \text{LaOCl:Ti} \),
- Figure 5 shows the transmission \( T \) as a function of the angle \( \alpha \) with respect to the normal for light rays through a filter as shown in Figure 3 for a display tube according to the invention,
- Figure 6 shows the transmission \( T \) for perpendicularly incident light rays (0°) as a function of the spectral wavelength \( \lambda \) for the Figure 3 filter,
- Figure 7 shows the angular distribution of the emitted quantity of light \( dp/da \) as a function of the angle \( \alpha \), measured at a projection television display tube, and
- Figure 8 shows the brightness on the projection screen as a function of the distance to the centre.

Figure 2 is a diagrammatic partial sectional view of the curved display window 2 and of a part of said curved display window 2, the multilayer interference filter 12, and the curved display screen 7. The display screen 7 consists of a layer of luminescent material (phosphor) 13 and a thin aluminium film 14 (the so-called “aluminium-backing”). The display window has an angle of curvature 4 and is preferably spherical having a radius of curvature \( r \).

Figure 3 shows diagrammatically a 20-layer filter 12 between a display screen 7, consisting of a layer of phosphor 13 (Ph) and an aluminium film 14, and the display window 2 (S). Said diagrammatic representation is flat. Of course, the filter in the tube is curved just like the display window and the display screen. The filter consists of layers of \( \text{SiO}_2 \) indicated by a letter L and \( L' \) (refractive index \( n = 1.47 \)) and layers
of TiO₂ (n=2.35) indicated by a letter H. The layers have a thickness of approximately 0.25 λᵣ. The last approximately 0.25 λᵣ thick layer 15 on the side of the display screen 7 is covered by an approximately 0.125 λᵣ thick terminating layer 16 (L). The phosphor 13 is a Tb-phosphor with λᵣ=545 nm. At p=1.22, λᵣ becomes equal to 665 nm. The composition of the filter with this λᵣ is indicated in the table hereinafter.

<table>
<thead>
<tr>
<th>Layer No.</th>
<th>Phosphor</th>
<th>n</th>
<th>n.d/λᵣ</th>
</tr>
</thead>
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<tr>
<td>10</td>
<td></td>
<td>L</td>
<td>0.131</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>L</td>
<td>0.260</td>
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<tr>
<td>15</td>
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<td>L</td>
<td>0.264</td>
</tr>
<tr>
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<td>L</td>
<td>0.261</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>L</td>
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</tr>
<tr>
<td>15</td>
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<td>0.247</td>
</tr>
<tr>
<td>15</td>
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<td>L</td>
<td>0.246</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>L</td>
<td>0.245</td>
</tr>
<tr>
<td>15</td>
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</tr>
<tr>
<td>15</td>
<td></td>
<td>L</td>
<td>0.260</td>
</tr>
</tbody>
</table>

Figure 4 shows the spectrum (the intensity standardized at the highest peak (I₀) in % as a function of λᵣ) of lanthanumoxychlorideterbium. This spectrum is representative of all green terbium phosphors, such as yttrium-aluminium garnet-terbium (YAG:Tb) yttrium-silicate-terbium (Y₂SiO₅:Tb) lanthanum oxybromide-terbium (LaOBr:Tb) and indium borate-terbium (InBO₂:Tb).

Figure 5 shows the transmission T (the solid line) of the filter shown in Figure 3 as a function of the angle α with respect to the normal on the filter for λᵣ=545 nm. The angle α₀ in which the transmission of the filter has decreased to 50% is approximately 24°. For comparison, this figure shows the transmission (the broken line) as a function of the angle α for the Fabry-Perot filter according to the said British Patent Specification 1,306,335. In order to make this filter comparable to the filter shown according to the invention, α₀ for this filter has also been chosen to be 24°. Moreover, the materials have been chosen to be equal, namely TiO₂ and SiO₂. Due to the different character of the filter, p=0.99 hence λᵣ=0.99×545=540 nm. A great disadvantage of this filter is the wide transmission band between 55° and 90°. All the light which is transmitted in said transmission band is lost or after reflection contributes to halo and thus gives loss of contrast. This disadvantage also applies to 0.75 λᵣ and 1.25 λᵣ filters.

Figure 6 shows the transmission T for light rays which are incident perpendicular on the filter (0°) as a function of the wavelength λᵣ for the Figure 3 filter. The low-pass character of the filter (shortwave-pass filter) and also the wide reflection band between 565 nm and 780 nm are obvious.

Figure 7 shows the light flux ϕ as a function of the angle (dϕ/dd) in arbitrary units as measured at a projection television display tube having a 20-layer filter as shown in Figures 3, 5 and 6. For a smaller than 24° there is a clear gain in luminous efficiency (curve I) as compared with a projection television display tube without a filter (curve II).

Figure 8 shows the brightness L (in arbitrary units) on the projection screen as a function of the distance r (in cm) to the centre

a) for a flat display screen without a filter (the solid line A),
b) for a curved display screen without a filter (the dot-and-dash line B),
c) for a flat display screen with filter (the dash line C),
d) for the same curved display window with the same filter (the dot line D).

For the curves shown in Figure 8 holds a p-value of the twenty-layer filter is 1.25 (p=1.25), i.e. a transmission of 50% for an angle of 32°, an angle of curvature p=10.5° in a spherical display window and screen having a 127 mm diagonal and a 350 mm radius of curvature ρp=350 mm, with a numerical aperture of the lens equal to 0.375 and a focal distance of 95 mm. From comparison of these curves it
follows that the sum of the effects as a result of curvature and filters (curve D) gives a much larger gain in the corners and at the edge of the display screen than the sum of the effects individually. As a matter of fact there is a small gain in curve B and even loss in curve C.

Finally the table below gives a number of different embodiments and their results. Column 1 gives the type of phosphor which is used for the display screen, column 2 shows the central wavelength of said phosphor, column 3 gives a few values of \( p \), column 4 gives the value of \( \alpha \) for which the transmission \( T=50\% \). Column 5 shows the number of layers of the filter used.

<table>
<thead>
<tr>
<th>Type of phosphor</th>
<th>( \lambda ) (nm)</th>
<th>( p )</th>
<th>( \alpha ) (50%) (in degrees)</th>
<th>Number of layers filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue-Tb</td>
<td>490</td>
<td>1.21</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>1.22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.25</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>1.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<tr>
<td>( \text{Y}_2\text{O}_3:Eu )</td>
<td>612</td>
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<td></td>
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<tr>
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<td>612</td>
<td>1.25</td>
<td>31</td>
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Upon vapour-depositing interference filters on in particular strongly curved display windows a small thickness variation may occur in which the layers become slightly thinner towards the corners and the edge of the display screen. This variation in thickness, i.e. the variation in \( p \) and \( \lambda \), values, however, always falls within the range claimed in this Application. Such a small thickness variation may even have a favourable effect on the light decline towards the corners and the edge of the display screen.

Claims

1. A projection television display tube comprising in an evacuated envelope a display screen (7) which is provided on the inside of a display window (2) in the wall of the envelope, said display screen comprising a luminescent material (13), between said luminescent material and the display window a multilayer interference filter (12) being provided, which filter comprises a number of layers which are manufactured alternately from a material having a high refractive index and a material having a low refractive index, characterized in that the display window on the vacuum side is inwardly curved having an angle of curvature \( \varphi \), wherein \( \varphi \) is the angle between a line at right angles to the centre of the display window and a line at right angles to the part of the display window farthest remote from the centre, said angle \( \varphi \) being between 5° and 25°.

2. A display tube as claimed in Claim 1, characterized in that the inwardly curved display window is substantially spherical and has a radius of curvature \( p \) between 150 mm and 730 mm.

3. A display tube as claimed in Claim 1 or 2, characterized in that the filter is composed of at least 6 layers each having an optical thickness \( nd \), wherein \( n \) is the refractive index of the material of the layer and \( d \) is the thickness, said optical thickness being between 0.2 \( \lambda \) and 0.3 \( \lambda \) is equal to \( p \times \lambda \), wherein \( \lambda \) is the desired central wavelength which is selected from the spectrum emitted by the luminescent material and \( p \) is a number between 1.16 and 1.32.

4. A display tube as claimed in Claim 3, characterized in that the filter is composed substantially of 14 to 30 layers.

5. A display tube as claimed in Claim 3 or 4, characterized in that the optical thickness \( nd \) is between 0.23 \( \lambda \) and 0.27 \( \lambda \).

6. A display tube as claimed in any of the Claims 3, 4 or 5, characterized in that the layers of the filter having a high refractive index consist of titanium oxide \( \text{TiO}_2 \) or tantalum oxide \( \text{Ta}_2\text{O}_5 \) and the layers having a low refractive index consist of silicon oxide \( \text{SiO}_2 \) or magnesium fluoride \( \text{MgF}_2 \).

7. A display tube as claimed in Claim 6, characterized in that the magnesium fluoride is provided at approximately 300°C.
8. A display tube as claimed in any of the Claims 3—6, characterized in that the luminescent material comprises a terbium-activated substantially green-luminescing phosphor and $\lambda = 545$ nm and $p$ is a number between $1.21$ and $1.25$ for a TiO$_2$—SiO$_2$ filter.

9. A display tube as claimed in any of the Claims 3 to 6, characterized in that the luminescent material comprises terbium-activated blue-luminescing phosphor and $\lambda = 490$ nm and $p$ is a number between $1.21$ and $1.25$ for a TiO$_2$—SiO$_2$ filter.

10. A display tube as claimed in any of the Claims 3—6, characterized in that the luminescent material is europium-activated yttrium oxide Y$_2$O$_3$:Eu and $\lambda = 612$ nm and $p$ is a number between $1.21$ and $1.25$ for a TiO$_2$—SiO$_2$ filter.

11. A display tube as claimed in any of the Claims 3 to 6, characterized in that the luminescent material is zinc sulphide—silver ZnS:Ag and $\lambda = 460$ nm and $p$ is a number between $1.21$ and $1.32$ for a TiO$_2$—SiO$_2$ filter.

12. A display tube as claimed in any of the Claims 3 to 6, characterized in that the luminescent material comprises a terbium-activated substantially green-luminescing phosphor and $\lambda = 545$ nm and $p$ is a number between $1.18$ and $1.22$ for a Ta$_2$O$_5$—SiO$_2$ filter.

13. A display tube as claimed in any of the Claims 3 to 6, characterized in that the luminescent material comprises a terbium-activated blue-luminescing phosphor and $\lambda = 490$ nm and $p$ is a number between $1.18$ and $1.22$ for a Ta$_2$O$_5$—SiO$_2$ filter.

14. A display tube as claimed in any of the Claims 3 to 6, characterized in that the luminescent material is europium-activated yttrium oxide Y$_2$O$_3$:Eu and $\lambda = 612$ nm and $p$ is a number between $1.18$ and $1.22$ for a Ta$_2$O$_5$—SiO$_2$ filter.

15. A display tube as claimed in any of the Claims 3 to 6, characterized in that the luminescent material is zinc sulphide—silver ZnS:Ag and $\lambda = 460$ nm and $p$ is a number between $1.21$ and $1.28$ for a Ta$_2$O$_5$—SiO$_2$ filter.

16. A display tube as claimed in any of the Claims 3 to 15, characterized in that the outermost approximately $0.25 \lambda$-thick layer of the filter which faces the luminescent material consists of a material having a high refractive index and is covered with a terminating layer having an optical thickness of approximately $0.125 \lambda$ of a material having a lower refractive index on which terminating layer the luminescent material is provided.

17. A display tube as claimed in any of the Claims 3 to 16, characterized in that the outermost approximately $0.25 \lambda$-thick layer of the filter facing the display window consists of a material having a high refractive index and is covered with an intermediate layer having an optical thickness of approximately $0.125 \lambda$ of a material having a lower refractive index.

18. A display tube as claimed in any of the Claims 3 to 6 and 8 to 10, characterized in that the outermost approximately $0.25 \lambda$-thick layer of the filter facing the luminescent material is composed of a mixture of metal oxides, which mixture comprises titanium oxide TiO$_2$ and a metal oxide from the group beryllium oxide BeO, magnesium oxide MgO and calcium oxide CaO, in which mixture the quantity of titanium oxide is 70—89% by weight.

19. A projection television device comprising at least a display tube as claimed in any of the preceding Claims.

20. A projection television device as claimed in Claim 19, characterized in that it comprises a display tube as claimed in Claim 8, a display tube as claimed in Claim 9, and a display tube as claimed in Claim 10.

21. A projection television device as claimed in Claim 19, characterized in that it comprises a display tube as claimed in Claim 8, a display tube as claimed in Claim 10, and a display tube as claimed in Claim 11.

22. A curved display window for use in a display tube as claimed in any of the Claims 1—18, said window comprising a multilayer interference filter and a display screen having the features as described in said claims.

Patentansprüche

1. Projektionsfernsehwiedergabegeräte, die in einer evakuerten Hülle einen Wiedergabesicht (7) aufweist, der auf der Innenseite eines Wiedergabefensters (2) in der Wand der Hülle vorgesehen ist, wobei dieser Wiedergabesicht einen Leuchtstoff (13) aufweist, wobei zwischen diesem Leuchtstoff und dem Wiedergabefenster ein Mehrfachschichtinterferenzfilter (13) vorgesehen ist, das eine Anzahl Schichten aufweist, die abwechselnd aus einem Werkstoff mit einer hohen Brechzahl und einem Werkstoff mit einer niedrigen Brechzahl hergestellt sind, dadurch gekennzeichnet, daß das Wiedergabefenster auf der Vakuumsseite einwärts gekrümmt ist mit einem Krümmungswinkel $\varphi$, wobei $\varphi$ den Winkel bildet zwischen einer Linie senkrecht zu der Mitte des Wiedergabefensters und einer Linie senkrecht zu demjenigen Teil des Wiedergabefensters, der am weitesten von der Mitte entfernt ist, wobei der Winkel $\varphi$ einen Wert zwischen 5° und 25° aufweist.

2. Wiedergabegeräte nach Anspruch 1, dadurch gekennzeichnet, daß das einwärts gekrümmt Wiedergabefenster im wesentlichen sphärisch ist und einen Krümmungsradius $p$ zwischen 150 mm und 730 mm aufweist.

3. Wiedergabegeräte nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß das Filter aus wenigstens 6
Schichten aufgebaut ist mit je einer optischen Dicke $nd$, wobei $n$ die Brechzahl des Werkstoffes der Schicht und $d$ die Dicke ist, wobei diese optische Dicke zwischen 0,2 $\lambda$ und 0,3 $\lambda$ liegt, wobei $\lambda$ gleich $p \times \lambda$ ist, wobei $\lambda$ die gewünschte zentrale Wellenlänge ist, die aus dem von dem Leuchtstoff ausgestrahlten Spektrum selektiert worden ist, und wobei $p$ eine Zahl zwischen 1,18 und 1,32 ist.

4. Wiedergaberröhre nach Anspruch 3, dadurch gekennzeichnet, daß das Filter im wesentlichen aus 14 bis 30 Schichten aufgebaut ist.

5. Wiedergaberröhre nach Anspruch 3 oder 4, dadurch gekennzeichnet, daß die optische Dicke $nd$ zwischen 0,23 $\lambda$ und 0,27 $\lambda$ liegt.

6. Wiedergaberröhre nach einem der Ansprüche 3, 4 oder 5, dadurch gekennzeichnet, daß die Schichten des Filters mit einer hohen Brechzahl aus Titanoxid $TiO_2$ oder Tantaloxid $Ta_2O_5$ bestehen und die Schichten mit einer niedrigen Brechzahl aus Siliziumoxid $SiO_2$ oder Magnesiumfluorid $MgF_2$ bestehen.

7. Wiedergaberröhre nach Anspruch 6, dadurch gekennzeichnet, daß das Magnesiumfluorid bei etwa 300°C angebracht wird.

8. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß der Leuchtstoff einen terbiumaktivierten im wesentlichen grünleuchtenden Phosphor aufweist und $\lambda=545$ nm ist und $p$ eine Zahl zwischen 1,21 und 1,25 für ein $TiO_2-SiO_2$-Filter ist.

9. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß der Leuchtstoff terbiumaktivierten blauleuchtenden Phosphor aufweist und $\lambda=490$ nm ist und $p$ eine Zahl zwischen 1,21 und 1,25 für ein $TiO_2-SiO_2$-Filter ist.

10. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß der Leuchtstoff europiumaktiviertes Yttriumoxid $Y_2O_3$ ist und $\lambda=612$ nm ist und $p$ eine Zahl zwischen 1,21 und 1,25 für ein $TiO_2-SiO_2$-Filter ist.

11. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß der Leuchtstoff Zinksulfidsilber $ZnS$ : Ag ist und $\lambda=460$ nm ist und $p$ eine Zahl zwischen 1,24 und 1,32 für ein $TiO_2-SiO_2$-Filter ist.

12. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß der Leuchtstoff einen terbiumaktivierten im wesentlichen grünleuchtenden Phosphor aufweist und $\lambda=545$ nm ist und $p$ eine Zahl zwischen 1,18 und 1,22 für ein $Ta_2O_5-SiO_2$-Filter ist.

13. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß der Leuchtstoff einen terbiumaktivierten blauleuchtenden Phosphor aufweist und $\lambda=490$ nm ist und $p$ eine Zahl zwischen 1,18 und 1,22 für ein $Ta_2O_5-SiO_2$-Filter ist.

14. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß der Leuchtstoff ein europiumaktiviertes Yttriumoxid $Y_2O_3$ : Eu ist und $\lambda=612$ nm ist und $p$ eine Zahl zwischen 1,18 und 1,22 für ein $Ta_2O_5-SiO_2$-Filter ist.

15. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß der Leuchtstoff ein Zinksulfidsilber $ZnS$ : Ag aufweist und $\lambda=460$ nm ist und $p$ eine Zahl zwischen 1,21 und 1,28 für ein $Ta_2O_5-SiO_2$-Filter ist.

16. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß die dem Leuchtstoff zugewandte etwa 0,25 $\lambda$ dicke Außenschicht des Filters aus einem Werkstoff mit einer hohen Brechzahl besteht und bedeckt ist mit einer Deckschicht mit einer optischen Dicke von etwa 0,125 $\lambda$ eines Werkstoffes mit einer niedrigen Brechzahl, wobei auf dieser Deckschicht der Leuchtstoff vorgesehen ist.

17. Wiedergaberröhre nach einem der Ansprüche 3 bis 6, dadurch gekennzeichnet, daß die dem Wiedergabefenster zugewandte etwa 0,25 $\lambda$ dicke Außenschicht des Filters aus einem Werkstoff mit einer hohen Brechzahl besteht und bedeckt ist mit einer Zwischenschicht mit einer optischen Dicke von etwa 0,125 $\lambda$ aus einem Werkstoff mit einer niedrigen Brechzahl.

18. Wiedergaberröhre nach einem der Ansprüche 3 bis 6 und 8 bis 10, dadurch gekennzeichnet, daß die dem Leuchtstoff zugewandte etwa 0,25 $\lambda$ dicke Außenschicht des Filters aus einem Gemisch aus Metallioxididen besteht, das Titanoxid $TiO_2$ und ein Metalloxid der Gruppe Berylliumoxid $BeO$, Magnesiumoxid $MgO$ und Kalziumoxid $CaO$ aufweist, wobei in diesem Gemisch die Menge des Titanoxids 70—99 Gew.-% beträgt.


20. Projektionsfernsehanordnung nach Anspruch 19, dadurch gekennzeichnet, daß sie eine Wiedergaberröhre nach Anspruch 8, eine Wiedergaberröhre nach Anspruch 9 und eine Wiedergaberröhre nach Anspruch 10 aufweist.

21. Projektionsfernsehanordnung nach Anspruch 19, dadurch gekennzeichnet, daß sie eine Wiedergaberröhre nach Anspruch 8, eine Wiedergaberröhre nach Anspruch 10 und eine Wiedergaberröhre nach Anspruch 11 aufweist.

22. Gekrömmtes Wiedergabefenster zum Gebrauch in einer Wiedergaberröhre nach einem der Ansprüche 1 bis 18, wobei dieses Fenster ein Mehrfachschichtinterferenzfilter und einen Wiedergabeschirm mit den in den genannten Ansprüchen beschriebenen Eigenschaften aufweist.
d'image prévu à l'intérieur d'une fenêtre d'image (2) dans la paroi de l'enveloppe, le film écran d'image comportant un matériau luminescent (13), un filtre d'interférence (12) à couches multiples étant prévu entre ledit matériau luminescent et la fenêtre d'image, lequel filtre comporte un certain nombre de couches qui sont fabriquées alternativement d'un matériau ayant un indice de réfraction élevé et d'un matériau ayant un indice de réfraction faible, caractérisé en ce que la fenêtre d'image est courbée vers l'intérieur du cotés mis sous vide, l'angle de courbure étant $\phi$, et $\psi$ étant l'angle compris entre une ligne perpendiculaire au centre de la fenêtre d'image et une ligne perpendiculaire à la partie de la fenêtre d'image, située le plus à l'écart du centre, ledit angle $\phi$ étant compris entre $5^\circ$ et $25^\circ$.

2. Tube image selon la revendication 1, caractérisé en ce que la fenêtre d'image courbée vers l'intérieur est sensiblement sphérique et présente un rayon de courbure $p$ compris entre 150 mm et 730 mm.

3. Tube image selon la revendication 1 ou 2, caractérisé en ce que le filtre est composé d'au moins six couches ayant chacune une épaisseur optique $nd$, $n$ étant l'indice de réfraction du matériau de la couche et $d$ étant l'épaisseur, ladite épaisseur optique étant comprise entre $0,2 \lambda$ et $0,3 \lambda$, où $\lambda$ est égal à $\pi \times \lambda$, $\lambda$ est la longueur d'onde centrale souhaitée qui est sélectionnée dans un spectre émis par le matériau luminescent et $P$ un nombre compris entre 1,18 et 1,32.

4. Tube image selon la revendication 3, caractérisé en ce que le filtre est composé sensiblement de 14 à 30 couches.

5. Tube image selon la revendication 3 ou 4, caractérisé en ce que l'épaisseur optique $nd$ est compris entre 0,23 $\lambda$ et 0,27 $\lambda$.

6. Tube image selon l'une quelconque des revendications 3, 4 ou 5, caractérisé en ce que les couches du filtre ayant un indice de réfraction élevé sont constituées d'oxyde de titane $\text{TiO}_2$ ou d'oxyde de tantale $\text{Ta}_2\text{O}_5$ et en ce que les couches ayant un indice de réfraction faible sont constituées d'oxyde de silicium $\text{SiO}_2$ ou de fluorure de magnésium $\text{MgF}_2$.

7. Tube image selon la revendication 6, caractérisé en ce que le fluorure de magnésium est déposé à environ $300^\circ\text{C}$.

8. Tube image selon l'une quelconque des revendications 3 à 6, caractérisé en ce que le matériau luminescent comporte un phosphore activé au terbium à luminescence sensiblement verte et en ce que $\lambda=545$ nm et en ce que $p$ est un nombre compris entre 1,21 et 1,25 pour un filtre au $\text{TiO}_2$—$\text{SiO}_2$.

9. Tube image selon l'une quelconque des revendications 3 à 6, caractérisé en ce que le matériau luminescent comporte un phosphore activé au terbium à luminescence bleue et en ce que $\lambda=490$ nm et en ce que $p$ est un nombre compris entre 1,21 et 1,25 pour un filtre au $\text{TiO}_2$—$\text{SiO}_2$.

10. Tube image selon l'une quelconque des revendications 3 à 6, caractérisé en ce que le matériau luminescent est un oxyde d'yttrium activé à l'europium ($\text{Y}_2\text{O}_3$:Eu) et en ce que $\lambda=612$ nm et en ce que $p$ est un nombre compris entre 1,21 et 1,25 pour un filtre au $\text{TiO}_2$—$\text{SiO}_2$.

11. Tube image selon l'une quelconque des revendications 3 à 6, caractérisé en ce que le matériau luminescent est du sulfate de zinc à l'argent ($\text{ZnS}:\text{Ag}$) et en ce que $\lambda=460$ nm et en ce que $p$ est un nombre compris entre 1,24 et 1,32 pour un filtre au $\text{Ta}_2\text{O}_5$—$\text{SiO}_2$.

12. Tube image selon l'une quelconque des revendications 3 à 6, caractérisé en ce que le matériau luminescent comporte un phosphore à luminescence sensiblement verte activé au terbium et en ce que $\lambda=545$ nm et en ce que $p$ est un nombre compris entre 1,18 et 1,22 pour un filtre au $\text{Ta}_2\text{O}_5$—$\text{SiO}_2$.

13. Tube image selon l'une quelconque des revendications 3 à 6, caractérisé en ce que le matériau luminescent comporte un phosphore à luminescence bleue activé au terbium et en ce que $\lambda=490$ nm et en ce que $p$ est un nombre compris entre 1,18 et 1,22 pour un filtre au $\text{Ta}_2\text{O}_5$—$\text{SiO}_2$.

14. Tube image selon l'une quelconque des revendications 3 à 6, caractérisé en ce que le matériau luminescent est de l'oxyde d'yttrium activé à l'europium ($\text{Y}_2\text{O}_3$:Eu) et en ce que $\lambda=612$ nm et en ce que $p$ est un nombre compris entre 1,18 et 1,22 pour un filtre au $\text{Ta}_2\text{O}_5$—$\text{SiO}_2$.

15. Tube image selon l'une quelconque des revendications 3 à 6, caractérisé en ce que le matériau luminescent est du sulfate de zinc à l'argent ($\text{ZnS}:\text{Ag}$) et en ce que $\lambda=460$ nm et en ce que $p$ est un nombre compris entre 1,21 et 1,28 pour un filtre au $\text{Ta}_2\text{O}_5$—$\text{SiO}_2$.

16. Tube image selon l'une quelconque des revendications 3 à 15, caractérisé en ce que la couche extérieure du filtre, couche qui a une épaisseur optique d'environ 0,25 $\lambda$ et qui est située vis-à-vis du matériau luminescent, est constituée d'un matériau ayant un indice de réfraction élevé et est recouverte d'une couche finale ayant une épaisseur optique d'environ 0,125 $\lambda$ et constituée d'un matériau ayant un indice de réfraction faible, couche finale sur laquelle est prévu le matériau luminescent.

17. Tube image selon l'une quelconque des revendications 3 à 16, caractérisé en ce que la couche extérieure du filtre, couche qui a une épaisseur optique d'environ 0,25 $\lambda$ et qui est situé vis-à-vis de la fenêtre d'image, est constituée d'un matériau ayant un indice de réfraction élevé et est recouverte d'une couche intermédiaire ayant une épaisseur optique d'environ 0,125 $\lambda$ et constituée d'un matériau ayant un indice de réfraction plus faible.

18. Tube image selon l'une quelconque des revendications 3 à 6 et 8 à 10, caractérisé en ce que la couche extérieure du filtre, couche qui a une épaisseur optique d'environ 0,25 $\lambda$ et qui est située vis-à-vis du matériau luminescent est composé d'un mélange d'oxydes métaux, lequel mélange comporte de l'oxyde de titane ($\text{TiO}_2$) et un oxyde métallique du groupe d'oxyde de beryllium ($\text{BeO}$), d'oxyde de magnésium ($\text{MgO}$) et d'oxyde de calcium ($\text{CaO}$), mélange dans lequel la quantité d'oxyde de titane est de 70 à 99% en poids.
19. Dispositif pour télévision à projection comportant au moins un tube image selon l'une quelconque des revendications précédentes.

20. Dispositif pour télévision à projection selon la revendication 19, caractérisé en ce que celui-ci comporte un tube image selon la revendication 8, un tube image selon la revendication 9 et un tube image selon la revendication 10.

21. Dispositif pour télévision à projection selon la revendication 19, caractérisé en ce que celui-ci comporte un tube image selon la revendication 8, un tube image selon la revendication 10 et un tube image selon la revendication 11.

22. Fenêtre d'image courbée destinée à être utilisée dans un tube image selon l'une quelconque des revendications 1 à 18, ladite fenêtre comportant un filtre d'interférence à couches multiples et un écran ayant les caractéristiques comme décrites dans lesdites revendications.