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(54) **Title:** LASER ILLUMINATION SYSTEM AND PROJECTION SYSTEM INCORPORATING SUCH LASER ILLUMINATION SYSTEM

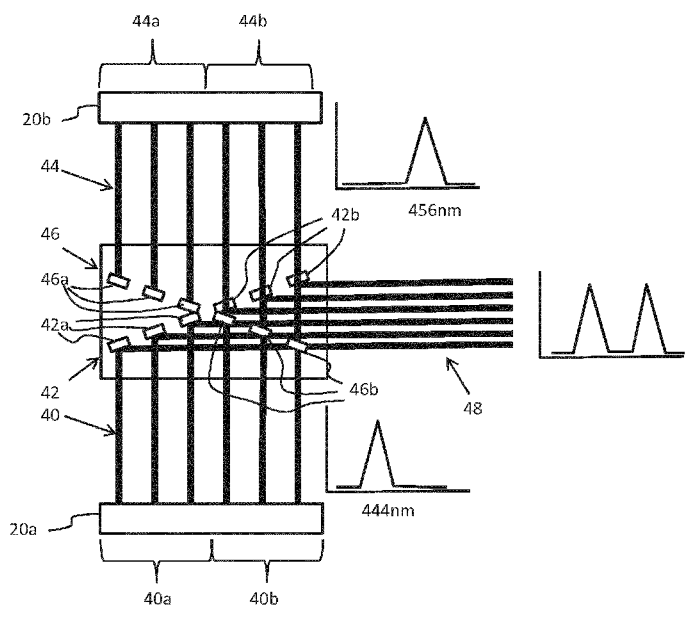

FIG. 4

(57) Abstract: The invention provides a laser illumination system comprising first and second arrays of laser light sources each with an associated array of reflectors. The light sources of the two arrays have a different output wavelength and the output of each laser light source of the first array is combined with the output of a corresponding laser light source of the second array to form a coaxial combined beam. Wavelength-selective ref ectors are used to form thelaser illumination system and projection system incorporating such laser illumination system combined beams.

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Laser illumination system and projection system incorporating such laser illumination system

FIELD OF THE INVENTION

This invention relates to laser illumination systems and to projection systems incorporating such laser illumination systems.

BACKGROUND OF THE INVENTION

As technology develops, sold state image projectors are gaining interest for their high lifetime. At the same time, these solid state image projectors are also becoming less expensive. As a result of these trends, it is expected that there will be a proliferation in both the number of solid state image projectors, and the usage of these devices. For example, an array of lasers may be used to form a high brightness light source, which light source illuminates a miniaturized display panel that is imaged by a projection lens on a screen.

One example of a solid state image projector comprises an array of blue laser light sources, in which light of all lasers is focused on a small spot of a phosphor wheel to convert the laser light into light of the desired color.

Since many lasers are imaged to the same spot of the phosphor wheel, very high brightness can be obtained. The lasers are integrated into a single laser bank, allowing for a well-defined optical and thermal interface.

The number of lasers that may be focused on the phosphor wheel is limited by the practical size of the laser housing and the thermal cooling requirements of the individual lasers.

It would be desirable to be able to stack more laser beams in the same shape of laser envelope, without compromising the packaging of the lasers and without compromising the heat sink facilities of each individual laser.

SUMMARY OF THE INVENTION

The invention is defined by the claims.

According to examples in accordance with an aspect of the invention, there is provided a laser illumination system comprising:

a first array of laser light sources;

a first array of reflectors, wherein the output of each laser light source of the first array is directed to a respective reflector which redirects the laser output to an output direction, wherein the light sources of the first array have a first output wavelength;

a second array of laser light sources;

a second array of reflectors, wherein the output of each laser light source of the second array is directed to a respective reflector which redirects the laser output to the output direction, wherein the light sources of the second array have a second output wavelength different to the first output wavelength;

wherein the output of each laser light source of the first array is combined with the output of a corresponding laser light source of the second array to form a coaxial combined beam;

wherein the first array of reflectors and the second array of reflectors each have a ladder-like structure comprising rungs relative to a plane, the rungs corresponding to the reflectors;

wherein the planes of the first and second arrays cross at a crossing point, and

wherein, relative to the output direction, for each of the first and second arrays the reflectors that are located before the crossing point are non-wavelength-selective reflectors, the reflectors of the first array that are located after the crossing point are wavelength-selective reflectors for reflecting the first wavelength and not the second wavelength, and the reflectors of the second array that are located after the crossing point are wavelength-selective reflectors for reflecting the second wavelength and not the first wavelength.

In this arrangement, two laser banks are used to provide a combined light output. The laser banks have different wavelength, and wavelength-selective reflectors are used to combine laser outputs, so that the overall number of laser spots is the same as if a single laser bank were being used.

By making the two laser banks geometrically overlap, they form a single beam of the same geometrical shape. This result in a larger light flux through the system, while the geometry is not changed. The geometry of the optical system after the reflector arrays can thus be kept the same size.

The outputs of the first array of laser light sources form a first grid, the outputs of the second array of laser light sources form a second grid, and the first and second grids face each other. This provides a compact arrangement but in which the two laser banks are at different locations so that cooling is possible at separate locations.

The first and second arrays of reflectors each have a ladder-like structure comprising rungs relative to a plane, the rungs corresponding to the reflectors, wherein the planes of the first and second arrays cross at a crossing point. Again, this means the arrangement is compact.

The reflectors in each ladder-like structure that are located, relative to the output direction, before the first and second arrays cross at the crossing point are non-wavelength-selective reflectors and the reflectors that are located, relative to the output direction, after the first and second arrays cross at the crossing point are wavelength-selective reflectors. Thus, not all reflectors need to be wavelength-selective, only those where light from one laser bank needs to pass through before reflection by the other reflector array or those where light from one laser bank needs to pass through to form the output.

The wavelength-selective reflectors of the first array and the wavelenght-selective reflectors of the second array may comprise dichroic mirrors.

Each reflector may reflect the incoming laser light beam by 90 degrees. This provides an easy to configure system.

The system may further comprise a phosphor wheel and a lens system for focusing the outputs onto the phosphor wheel. The phosphor wheel is used to generate a light output of a desired color. It may be one color of a multiple color system. A drive arrangement is then provided for rotating the phosphor wheel. This provides intermittent use of any particular area of a phosphor layer of the phosphor wheel and will provide better cooling of the illuminated phosphor area on the phosphor wheel.

The phosphor wheel may comprise a phosphor layer and a reflector behind the phosphor layer, wherein the lens system redirects the reflected phosphor-converted light to a wavelength-dependent reflector which creates the light output. In this way, wavelength-converted light is reflected from the phosphor wheel and optically processed to form the optical output of the system towards the display panel to be illuminated.

The invention also provides a laser system, comprising:

a phosphor wheel;

a first laser illumination system as defined above on one side of the phosphor wheel;

a first lens system for focusing the outputs of the first laser projection system onto the phosphor wheel;

a second laser illumination system as defined above on the other side of the phosphor wheel; and a second lens system for focusing the outputs of the second laser projection system onto the phosphor wheel,

wherein the phosphor wheel comprises a phosphor layer facing the one side, and a wavelength-selective reflector behind the phosphor layer for reflecting the phosphor-converted light.

This arrangement has two laser systems on opposite sides of a phosphor wheel. One side is reflected by the phosphor wheel and the other side is transmitted through the phosphor wheel.

The first lens system for example redirects the reflected phosphor-converted light from the one side and the transmitted phosphor-converted light from the other side to a wavelength-dependent reflector which creates the light output. A drive arrangement is preferably provided for rotating the phosphor wheel.

In one example, a spot light illuminating device makes use of the system as defined above (with one or two pairs of laser banks).

In another example, an image projection system makes use of the system as defined above (with one or two pairs of laser banks). The image projection system comprises a display panel and the illumination system for illuminating the display panel for projecting a display image.

The display panel for example comprises an LCD display device or a digital micromirror device (DMD).

BRIEF DESCRIPTION OF THE DRAWINGS

Examples of the invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 shows a known laser projection system;

Figure 2 shows an array of lasers;

Figure 3 shows a known way to combine the laser outputs from one laser bank to create a smaller area set of output beams;

Figure 4 shows an example of how to combine the laser outputs from two laser banks to create the same smaller area set of output beams as in Figure 3;

Figure 5 shows a first example of a laser projection system; and

Figure 6 shows a second example of a laser projection system.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The invention provides a laser illumination system comprising first and second arrays of laser light sources each with an associated array of reflectors. The light sources of the two arrays have a different output wavelength and the output of each laser light source of the first array is combined with the output of a corresponding laser light source of the second array to form a coaxial combined beam. Wavelength-selective reflectors are used to form the combined beams.

The invention may be applied to a single color lighting system such as a spot light or illumination system, or to a single color image projection system, or to a multi-color image projection system.

By way of example, Figure 1 shows a known solid state image projection system in which a display panel 2 is time sequentially illuminated by a red, a green and a blue solid state light source 4 and the display panel output is projected onto a display surface 6. In a color image, each pixel has its own brightness and color, usually represented as a triple of red, green and blue (RGB) intensities.

High power blue solid state lasers are available, however high power green and high power red lasers lack sufficient efficiencies to be successfully applied in high lumen output solid state laser based projection systems. Typically, a phosphor conversion layer is used to convert blue laser light to green and/or red light of the desired color.

For a single color system, a single phosphor may be used to generate the desired output color. For a multi-color system, separate phosphor systems may be used to generate for example the red and green colors, which together with the blue lasers form a RGB color image. The color image is then formed by combing the different colors within an overall optical system, making use of wavelength-selective reflectors and transmitters.

Figure 2 shows an example of a laser bank 20 comprising a two dimensional grid of individual lasers 22; in this example there is an 8x3 grid. Each laser emits an almost perfect parallel beam of light so that the beam envelope of the laser array is determined by the height and width of the grid. The distance between the individual lasers 22 is determined by the size of their package and the amount of surrounding metal required to flow the heat from each individual laser via a heat sink of the laser bank to the environment.

These requirements set a limitation of the number of laser outputs that may be focused onto a single spot, such as the same spot of a phosphor wheel. It also means that the beam illuminating the phosphor wheel consists of a set of beams having relatively large gaps between the individual beams.

Figure 3 shows a method to combine the beams of six columns of lasers into a smaller beam using a reflector arrangement 30 that comprises a set of reflectors 32. The reflector arrangement 30 has a ladder-like structure wherein the reflectors 32 correspond to the rungs of the ladder-like structure. Each of the reflectors 32 can be considered to be connected to a plane that passes through the center of the reflector 32. Such a reflector arrangement is sometimes also referred to as a Jacob's Ladder mirror arrangement. Only six reflectors 32 are shown in order to simplify the diagram, but there may of course be eight, for the grid design of Figure 2, or more. Each reflector 32 is for one column of lasers of the two dimensional grid. This approach is well known and is used in commercially available products.

The rectangular shape of the grid as shown in Figure 2 is in this way converted into a more square shape (i.e. with unity aspect ratio). It means the array of beams is more easily optically processed (for example with circular lenses) and the beams are closer together (at least in one dimension) so that more beams may be provided within a given geometry of the further optical system.

A laser typically has an emission spectrum in the form of a narrow emission band centered on the output wavelength (for simplicity illustrated in Figure 4 as triangle spectra).

The phosphor of a phosphor wheel may be excited by a wider spectrum than is emitted by a particular laser. As a result, it is possible to use two laser banks each having a slightly different wavelength, and the outputs may then be combined using wavelength-selective reflectors such as dichroic mirrors.

Figure 4 shows a first example of an optical arrangement for combining laser beams, for use in a laser illumination system, such as a laser light source or a laser projection system. The system may be used to provide a high brightness light source to be applied for general illumination like blanket illumination or a narrow angle spot light, or it may be used for projecting an image in a projection system.

A first array of laser light sources 20a generate a first set 40 of output beams and these are each directed to a respective reflector 42 which redirects the laser output to from a corresponding one of the set 48 of output beams. The laser light sources of the first array have a first output wavelength which in the example shown is 444 nm.

A second array 20b of laser light sources generate a second set 44 of output beams and these are each directed to a respective reflector 46 which redirects the laser output to from a corresponding one of the set 48 of output beams. The laser light sources of the second array have a second output wavelength which in the example shown is 456 nm.

The two laser light source arrays thus generate beams with closely spaced wavelengths, which in this example are both generally blue. The output wavelengths are sufficiently closely spaced that they both fall within the absorption band of a shared phosphor conversion layer used later in the system (and shown in Figures 5 and 6).

The output of each laser light source of the first array is combined with the output of a corresponding laser light source of the second array to form a coaxial combined beam. Thus, each output beam of the set 48 comprises the superposition of one output from the first array of laser light sources and one output from the second array of laser light sources. As shown in Figure 4, each output beam of the set 48 comprises intensity peaks at the two different wavelengths.

Combining the individual beams of the two laser banks using such dichroic mirrors has the advantage that the geometry of the output beam 48 is identical to the geometry of the beams 40 and 44, such that the acceptance of the further optical systems does not need to be increased after the laser beams of the individual banks are combined. This issue of maintaining the same acceptance of the optical system will now be discussed.

The geometry of a beam that may pass through an optical sub-system is defined by the open apertures of the sub-system. For example, in a two lens system, the open, circular shapes, of the lens holders of the two individual lenses, and the distance between these two lenses determines the open apertures. In particular, the angular acceptance ($\Omega\iota$) of the light that may pass both the aperture (Ai) of the first lens and the aperture (A_2) of the second lens lens depends on the distance between the two apertures, and the size of the apertures.

The etendue (also known as the acceptance or optical throughput) is defined as:

$$E = A\,i * \Omega\iota = JJ \cos(0>)\, dA\, d\Omega \cdot$$

For an optical system that consists of more than two lenses, the optical throughput of the entire system is limited by the maximum acceptance between two sequential lenses in the system.

For an LED illumination system, the LED light source emits a certain amount of light within a certain etendue of the source, where the maximum etendue of this source equals $E_{source} = \pi * A_{source}$-

If the system etendue is less than the source etendue, not all the light emitted by the LED source can be accepted by the further optical system, resulting in light loss from the light emitted by the LED source.

By overlapping the lasers, the source etendue is not changed so that the required system etendue does not need to be increased to accept the light of the additional laser bank.

In order to combine the beams, the first and second arrays of reflectors make use of wavelength-selective reflectors. However, only the reflectors which have both wavelengths at their output need to be formed as wavelength-selective reflectors.

For example, a first subset 40a of the first set 40 of output beams may each be associated with a normal specular reflector 42a. A second subset 40b of the first set 40 of output beams may each be associated with a wavelength-selective reflector 42b. These reflectors 42b reflect the first wavelength (444nm in this example) and transmit the second wavelength (456nm in this example).

A first subset 44a of the second set 44 of output beams may each be associated with a normal specular reflector 46a. A second subset 44b of the second set 44 of output beams may each be associated with a wavelength-selective reflector 46b. These reflectors 46b reflect the second wavelength (456nm in this example) and transmit the first wavelength (444nm in this example).

In this example, the outputs of the first and second sets 40 and 44 are directed towards each other and rotated by 90 degrees by the reflection. The outputs of the first array of laser light sources form a first grid, the outputs of the second array of laser light sources form a second grid, and the first and second grids face each other. The reflectors each reflect a set of beams so that they extend into or out of Figure 4. Each reflector is for a column of the laser source outputs of the bank, as shown in Figure 2.

The first and second arrays of reflectors in this way each have a ladder-like structure, individually similar to the known arrangement of Figure 3. Each individual reflector may be considered to be a rung of the ladder-like structure and it is for a column of laser sources. Of course, there may instead be an individual reflector for each laser beam without changing the function at all. However, the first and second arrays of reflectors cross.

The reflectors 42a and 46a that are located in each ladder-like structure before the first and second arrays cross may be the non-wavelength-selective reflectors. These are the reflectors on the left half of the reflector arrangement. This is because these reflectors only receive incident light from one of the banks of laser light sources. The reflectors 42b and 46b located after the first and second arrays cross comprise the wavelength-selective reflectors. These are the reflectors on the right half of the reflector arrangement. This is because these reflectors receive incident light from both arrays of laser light sources.

Thus, not all reflectors need to be wavelength-selective, only those where light from one reflector bank needs to pass through before reflection by the other reflector bank or to pass through to form an output beam.

The wavelength-selective reflectors are for example implemented as dichroic mirrors.

Figure 5 shows a first implementation of the reflector arrangement of Figure 4 in a laser projection system.

The system comprises the reflector arrangement 50 as shown in Figure 4. The set 48 of output beams is provided to a lens system 52 which focuses the set of beams onto a single spot on a phosphor wheel 54. The phosphor wheel 54 comprises a phosphor layer 56 and an aluminum reflecting backing disc 58.

The incident blue light is converted by the phosphor wheel to a desired output color, such as green. The wavelength-converted green light is reflected by the backing disc 58 of the phosphor wheel. A wavelength-dependent reflector in the form of a dichroic mirror 60 is transmissive to the incident blue light and reflective to the incident green light. The green light beams are then directed to a desired output direction by the mirror 60.

The output light is then used to illuminate a display panel 61 from which light is then projected onto a screen 6. The display panel 61 for example comprises an LCD display device or a digital micromirror (DMD) device.

A digital micromirror device is for example used in a digital light processing (DLP) projector. The (or each) digital micromirror device (DMD) functions as a light valve. A single DMD may be used which is flashed in time sequential manner with Red, Green and Blue light flashes. The sequence of Red, Green and Blue flashes may be obtained using a phosphor wheel that is split into segments, each segment coated with a different phosphor and/or a segment having no phosphor and synchronizing the video data to the DMD display with the phosphor wheel. The phosphor wheel may consist of 3 segments, the first segment coated with a green phosphor, the second segment coated with a red segment and the third segment having no phosphor, such that the blue laser light incident on this segment may be used to flash the DMD panel with blue light. The phosphor wheel may consist of more than 3 segments such as Red, Green, Blue (blank), Red, Green, Blue (blank). The phosphor wheel may also include other color segments, such as a Yellow or Cyan phosphor, such that the DMD panel is flashed with Red, Green, Blue Yellow, Cyan, Purple flashes. Other segmentations of the phosphor wheel may be used as is well known to those skilled in this art.

A drive arrangement 62 is provided for rotating the phosphor wheel 54. This improves the cooling of the phosphor of the phosphor wheel, and provides intermittent use of any particular area of the phosphor layer thus allowing a high intensity light output without overheating.

Figure 5 shows a system which makes use of illumination of the phosphor wheel 54 from one side of the phosphor wheel only.

Figure 6 shows a system in which the phosphor wheel 54 is illuminated from both sides.

On each side of the phosphor wheel 54 is a reflector arrangement 50a, 50b as shown in Figure 4.

The phosphor wheel 54 comprises the phosphor layer 56 facing the first reflector arrangement 50a, but instead of a reflective backing disc, a wavelength-dependent reflector, again in the form of a dichroic mirror 70, is behind the phosphor layer. This mirror 70 reflects the phosphor-converted light (green in this example) but transmits blue light, in particular both blue wavelengths of the two types of laser light source array.

A lens arrangement 52a, 52b is on each side of the phosphor wheel, but only one side needs the dichroic output reflector 60.

Light from the first reflector arrangement 50a which has been phosphor-converted is reflected and output in the same way as explained with reference to Figure 5. Light from the second reflector arrangement 50b is transmitted through the mirror 70, is then phosphor-converted by the phosphor layer 56 before being output in the same way as explained with reference to Figure 5. Figure 6 also shows a transparent carrier 72.

This arrangement has two laser systems on opposite sides of the phosphor wheel. One operates in a reflective mode and the other operates in a transmission mode.

The phosphor layer has a thickness such that all the original (blue) light is converted in the phosphor layer. Since the dichroic layer in the phosphor wheel reflects the phosphor-converted (green) light, all the converted light leaves the phosphor wheel at the same side, while the light originating from the opposite side will be transmitted by the dichroic layer in the phosphor wheel, and as such will enter the phosphor layer, further increasing the brightness of the illuminated spot on the phosphor wheel.

In this design, four laser banks illuminate the same spot on the phosphor wheel.

Since all the laser light is focused onto a small spot on the phosphor wheel, a high heat dissipation on that spot will occur, but the temperature of the phosphor layer needs to be kept sufficiently low. Lower temperatures are achieved by rotating the phosphor wheel and providing a cooling mechanism to the phosphor wheel.

Improved cooling may be obtained by increasing the diameter of the phosphor wheel, by applying a forced cooling system, such as blowing cold air on the phosphor wheel or rotating the phosphor wheel in a cooling liquid. Any additional active cooling provisions may be provided for further cooling of the air (or cooling liquid) provided to cool the phosphor wheel.

The example above of Figure 2 shows a laser bank as an array of 3x8 lasers. Of course, this is purely by way of example. In general, a laser bank may comprise between 4 and 60 lasers. Each laser for example has an output power in the range 1 to 10W. The separation between individual lasers is for example in the mm to cm range.

One example has been given based on the use of blue lasers, with two different wavelengths. Of course, other wavelength lasers may be used. The invention is not intended to be limited to any particular laser technology, but relates instead to the optical arrangement for combining laser outputs.

The example above makes use of 90 degree reflection at the reflectors. However, while this gives a compact arrangement, with the two laser banks on each side of the reflector arrangement (and therefore a simple configuration to implement), this is not essential.

As mentioned above, the invention may be used for high intensity illumination, for example within a spot light of general illumination system, or as part of an image projection system.

In the case of an image projection system, the display image is created from the light output from the system in conventional manner, using a projection system with light modulation based on a transmissive or reflective system.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A laser illumination system comprising:

a first array (20a) of laser light sources;

a first array (42) of reflectors (42a, 42b), wherein the output of each laser light source of the first array (20a) is directed to a respective reflector (42a, 42b) which redirects the laser output to an output direction, wherein the light sources of the first array (20a) have a first output wavelength;

a second array (20b) of laser light sources;

a second array (46) of reflectors (46a, 46b), wherein the output of each laser light source of the second array (20b) is directed to a respective reflector (46a, 46b) which redirects the laser output to the output direction, wherein the light sources of the second array (20b) have a second output wavelength different to the first output wavelength;

wherein the output of each laser light source of the first array (20a) is combined with the output of a corresponding laser light source of the second array (20b) to form a coaxial combined beam,

wherein the first array (42) of reflectors (42a, 42b) and the second array (46) of reflectors (46a, 46b) each have a ladder-like structure comprising rungs relative to a plane, the rungs corresponding to the reflectors (42a, 42b, 46a, 46b),

wherein the planes of the first and second arrays (42, 46) cross at a crossing point, and

wherein, relative to the output direction, for each of the first and second arrays (42, 46) the reflectors (42a, 46a) that are located before the crossing point are non-wavelength-selective reflectors, the reflectors (42b) of the first array (42) that are located after the crossing point are wavelength-selective reflectors for reflecting the first wavelength and not the second wavelength, and the reflectors (46b) of the second array (46) that are located after the crossing point are wavelength-selective reflectors for reflecting the second wavelength and not the first wavelength.

2. A system as claimed in claim 1, wherein the outputs of the first array (20a) of laser light sources form a first grid, the outputs of the second array (20b) of laser light sources form a second grid, and the first and second grids face each other.

3. A system as claimed in any preceding claim, wherein the wavelength-selective reflectors (42b, 46b) of the first and second arrays (42, 46) comprise dichroic mirrors.

4. A system as claimed in any preceding claim, wherein each reflector reflects the incoming laser light beam by 90 degrees.

5. A system as claimed in any preceding claim, further comprising a phosphor wheel (54) and a lens system (52) for focusing the reflected outputs of the laser beams onto the phosphor wheel.

6. A system as claimed in claim 5, further comprising a drive arrangement (56) for rotating the phosphor wheel (54).

7. A system as claimed in claim 5 or 6, wherein the phosphor wheel comprises a phosphor layer (56) and a reflector (58) behind the phosphor layer, wherein the lens system (52) redirects the reflected phosphor-converted light to a wavelength-dependent reflector which creates the light output.

8. A laser system, comprising:

a phosphor wheel (54);

a first laser illumination system (50a) as claimed in any one of claims 1 to 4 on one side of the phosphor wheel;

a first lens system (52a) for focusing the outputs of the first laser projection system onto the phosphor wheel;

a second laser illumination system (50b) as claimed in any one of claims 1 to 4 on the other side of the phosphor wheel; and

a second lens system (52b) for focusing the outputs of the second laser projection system onto the phosphor wheel,

wherein the phosphor wheel comprises a phosphor layer (56) facing the one side, and a wavelength-selective reflector (70) behind the phosphor layer for reflecting the phosphor-converted light.

9. A system as claimed in claim 8, wherein the first lens system (52a) redirects the reflected phosphor-converted light from the one side and the transmitted phosphor-converted light from the other side to a wavelength-dependent reflector (60) which creates the light output.

10. A system as claimed in claim 8 or 9, further comprising a drive arrangement (62) for rotating the phosphor wheel (54).

11. A spot light illuminating device comprising a system according to any one of claims 1 to 10.

12. An image projection system comprising a display panel (61) and a system according to any one of claims 1 to 10 for illuminating the display panel (61) for projecting a display image.

13. An image projection system according to claim 12 wherein the display panel (61) comprises an LCD device or a digital micromirror device.

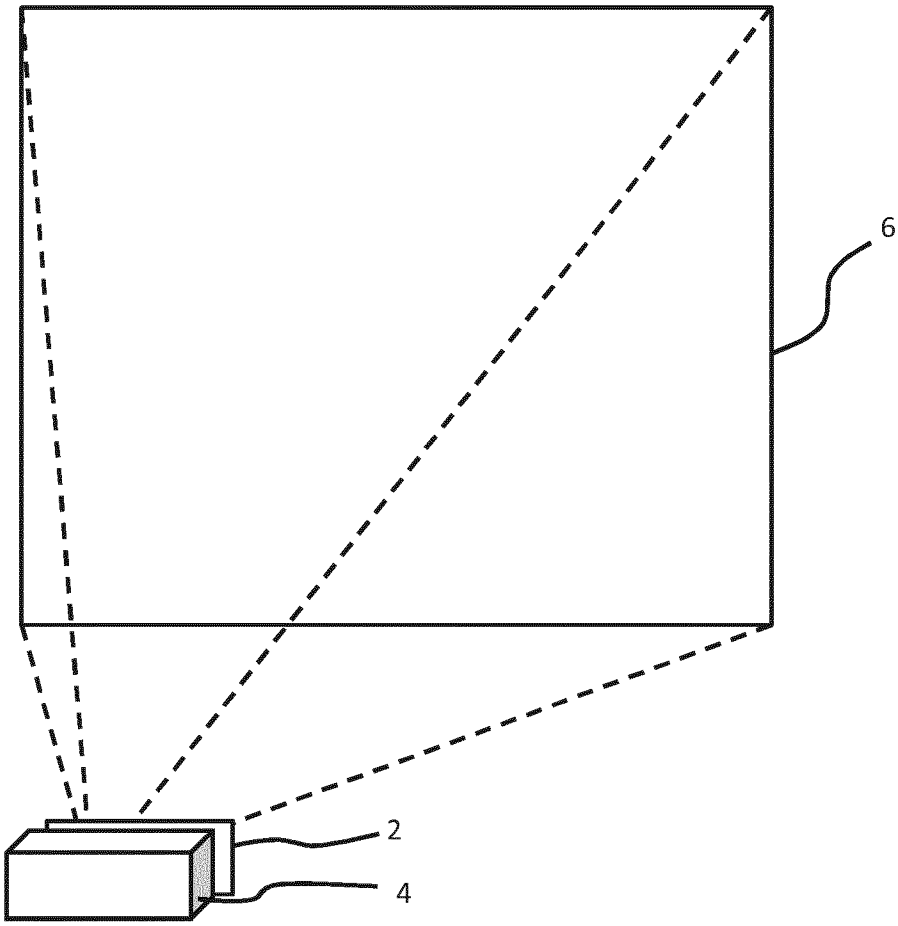

FIG. 1

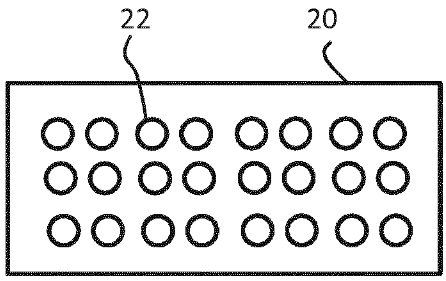

FIG. 2

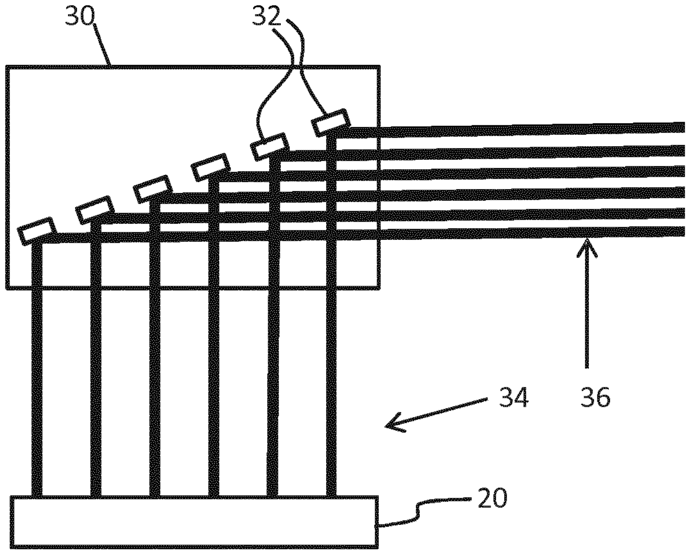

FIG. 3

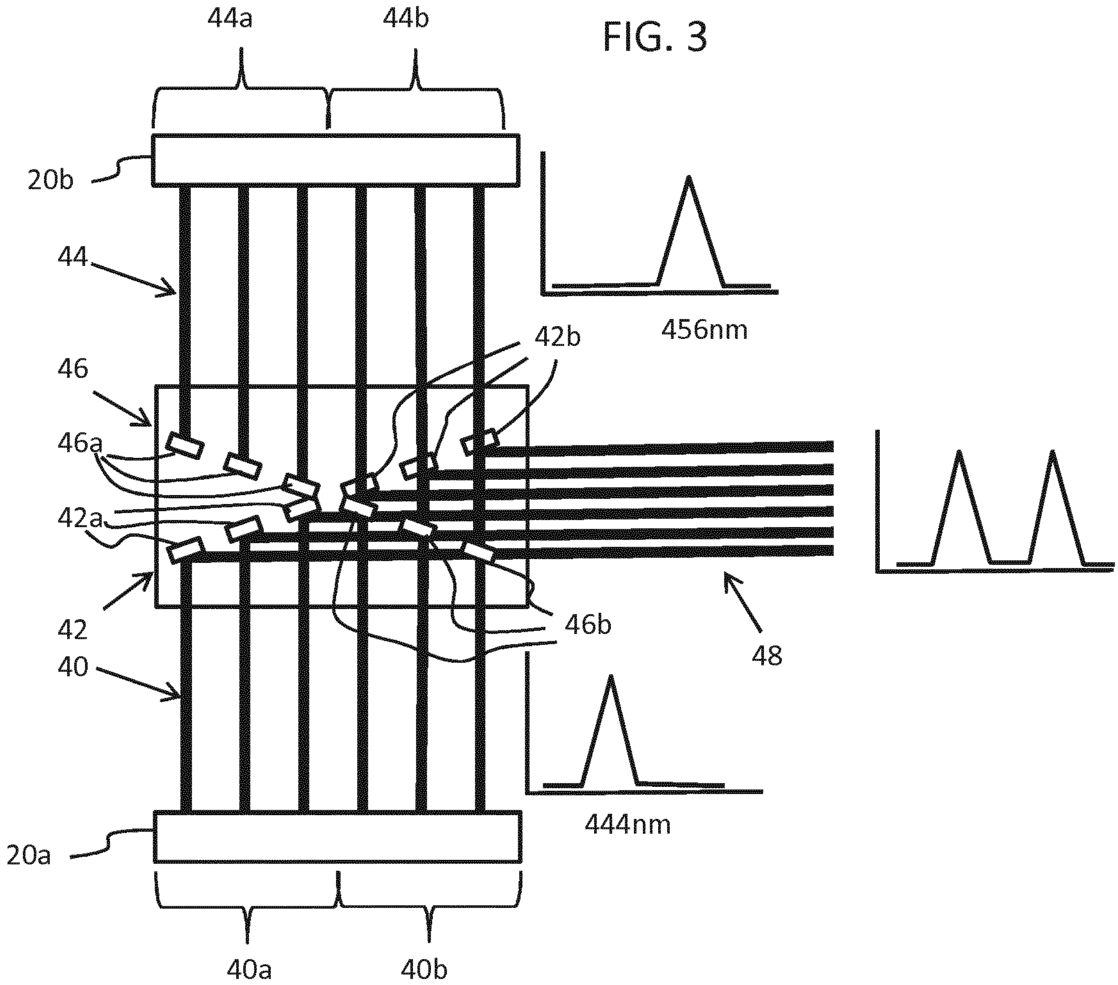

FIG. 4

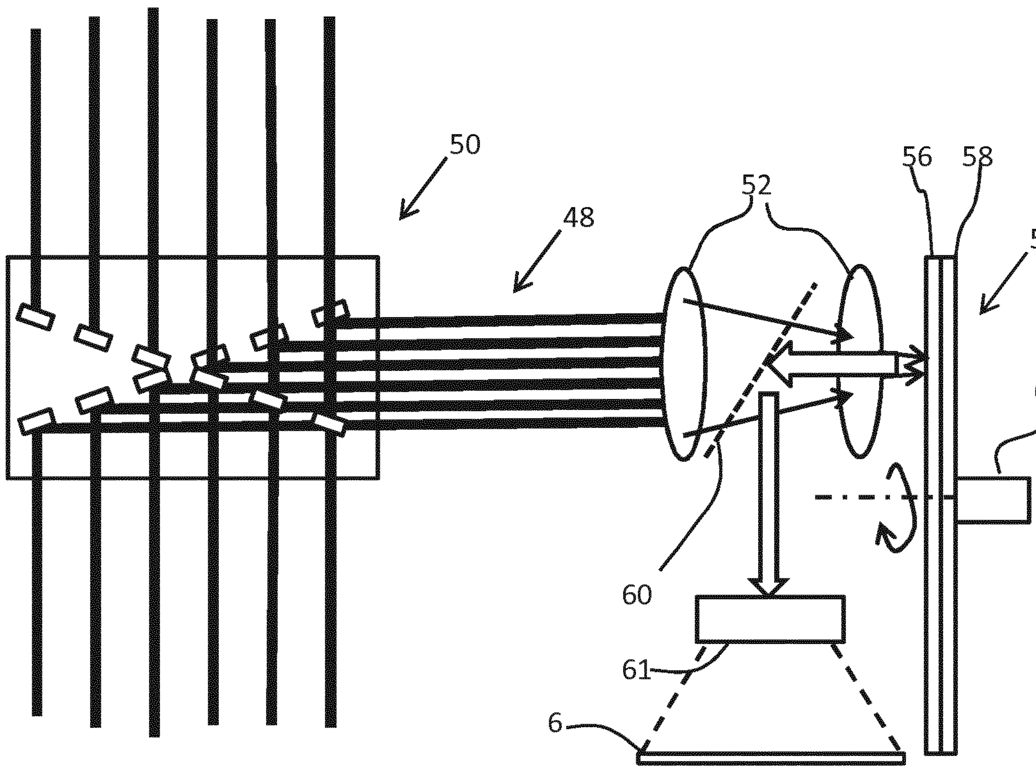

FIG. 5

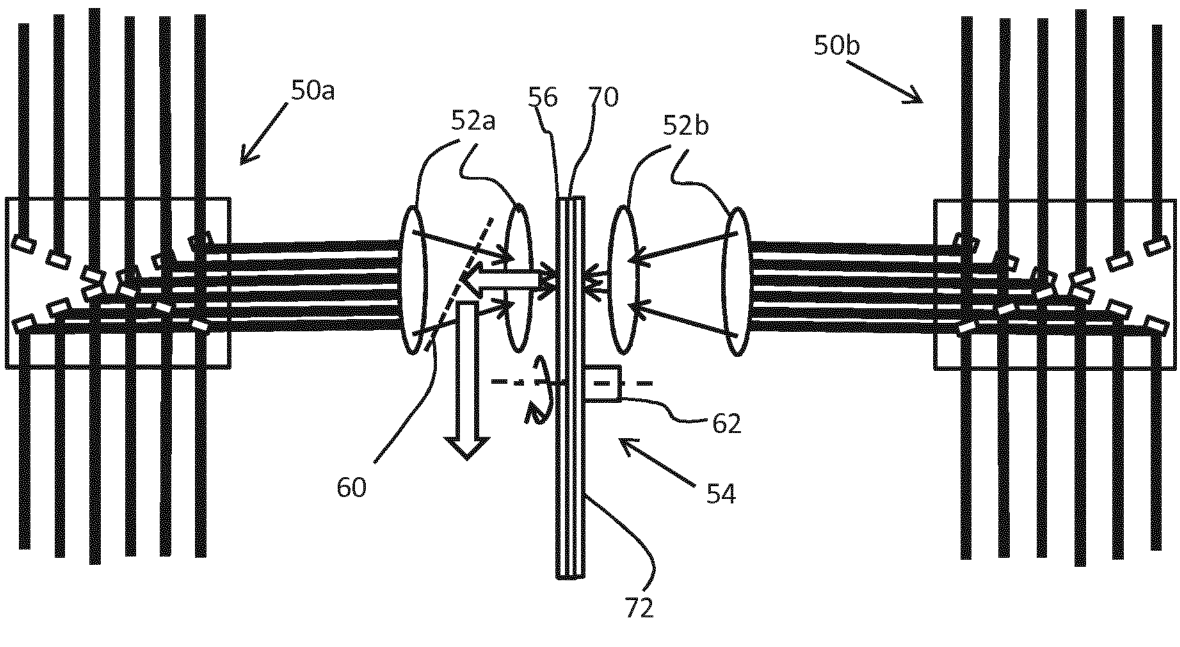

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/051081

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01S5/40 H01S5/00 F21K9/64 H04N9/31 G02B27/14
G03B21/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
HOIS F21K H04N G02B G03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2012/194787 Al (SAWAI YASUMASA [JP]) 2 August 2012 (2012-08-02) paragraphs [0087] , [0089] ; figures 6,10,11	1-13
A	US 2014/354956 Al (YAMADA AKIHIR0 [JP] ET AL) 4 December 2014 (2014-12-04) paragraphs [0323] - [0446] ; figures 16,27 ,31-33	1-13
A	US 2009/034284 Al (LI YI [US] ET AL) 5 February 2009 (2009-02-05) paragraph [0044] ; figures 1,7,15a	5-10

-/-

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 April 2017	17/05/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Moskowitz, Pamela

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/302514 A1 (SILVERSTEIN BARRY D [US] ET AL) 2 December 2010 (2010-12-02) abstract paragraphs [0002], [0075]; figures 7,8,13,15,17	1-13
A	US 2014/078476 A1 (MASUDA HIROKI [JP]) 20 March 2014 (2014-03-20) abstract; figures 4,5	1-13
A	US 2015/270682 A1 (DANIELS MARTIN [DE] ET AL) 24 September 2015 (2015-09-24) abstract paragraphs [0003], [0004], [0006], [0038], [0072] - [0074]; figures 13,15,16	1-13

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/051081

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2012194787	A1	02-08-2012	JP	5678693	B2	04-03-2015
			JP	2012159556	A	23-08-2012
			US	2012194787	A1	02-08-2012
US 2014354956	A1	04-12-2014	CN	103207509	A	17-07-2013
			CN	104040425	A	10-09-2014
			DE	112013000548	T5	30-10-2014
			JP	5634624	B2	03-12-2014
			JP	W02013105546	A1	11-05-2015
			TW	201348847	A	01-12-2013
			US	2014354956	A1	04-12-2014
			WO	2013105546	A1	18-07-2013
US 2009034284	A1	05-02-2009	CN	101836160	A	15-09-2010
			EP	2181358	A1	05-05-2010
			KR	20100037646	A	09-04-2010
			KR	20120105567	A	25-09-2012
			US	2009034284	A1	05-02-2009
			WO	2009017992	A1	05-02-2009
US 2010302514	A1	02-12-2010	CN	102449532	A	09-05-2012
			EP	2435876	A1	04-04-2012
			JP	2012528356	A	12-11-2012
			US	2010302514	A1	02-12-2010
			WO	2010138190	A1	02-12-2010
US 2014078476	A1	20-03-2014	JP	2014062952	A	10-04-2014
			US	2014078476	A1	20-03-2014
US 2015270682	A1	24-09-2015	CN	104949000	A	30-09-2015
			DE	102014205450	A1	24-09-2015
			US	2015270682	A1	24-09-2015