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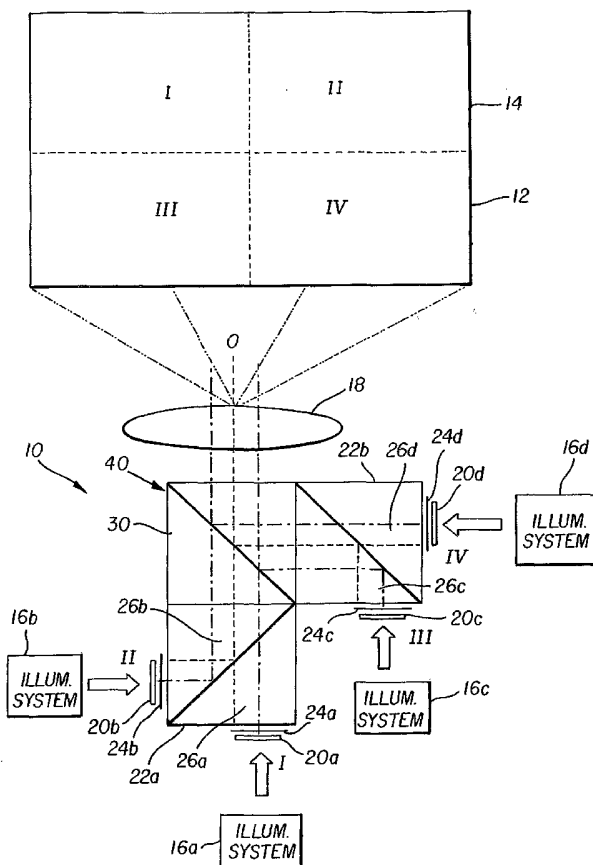
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- (71) Applicant (for all designated States except US): EASTMAN KODAK COMPANY [US/US]; 343 State Street, Rochester, NY 14650-2201 (US).
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): LIANG, Rongguang [CN/US]; 16 Millford Crossing, Penfield, NY 14526 (US).
- (74) Common Representative: EASTMAN KODAK COMPANY; 343 State Street, Rochester, NY 14650-2201 (US).
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(54) Title: TILED PROJECTION DISPLAY USING SPATIAL LIGHT MODULATORS



(57) Abstract: A projection apparatus (10) forms a tiled image (12) on a display surface (14), the tiled image (14) having at least two adjacent image tile segments. The projection apparatus (10) includes an illumination system (16) for providing a first illumination beam having a first polarization state and a second illumination beam having a second polarization state, these illumination beams being substantially non-overlapping. First and second spatial light modulators (20) form first and second modulated light beams from their respective illumination beams. A beam aligner (40) directs these first and second modulated light beams along adjacent parallel paths, in the direction of the optical axis of a projection lens (18). The projection lens (18) directs the first and second modulated beams to the display surface (14) to form the first and second tile segments respectively.

WO 2005/074258 A1



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**TILED PROJECTION DISPLAY USING SPATIAL LIGHT
MODULATORS**

FIELD OF THE INVENTION

This invention generally relates to projection imaging apparatus
5 and more particularly relates to an apparatus and method for tiled projection
display using spatial light modulators.

BACKGROUND OF THE INVENTION

There is a recognized need for wide-screen electronic displays in a
number of fields, with typical uses ranging from desktop computer applications, to
10 visualization and design software, to diagnostic imaging equipment, to still and
motion picture entertainment systems and advertising displays, for example. In a
recent paper entitled "DSHARP – A Wide Screen Multi-Projector Display" by
Gary K. Starkweather in SID Digest 2003, potential advantages of wide-screen
electronic displays for workstation environments are enumerated, including
15 improved productivity and efficiency, minimized "household" chores for desktop
organization, improved adaptability to the human visual system, and improved
task comprehension.

With existing projection display systems, both film-based and
electronic, images can be projected only at limited sizes and aspect ratios. These
20 conventional display sizes are not sufficient to provide large-scale wide-screen
display systems based on a single image-forming component. While there have
been attempts to fabricate large-scale electronic spatial light modulators,
exceeding conventional image frame sizes has proved difficult in practice.
Instead, schemes for tiling multiple display systems have been adapted to
25 overcome size and aspect ratio limitations.

Tiling solutions for conventional projection systems have been
successfully implemented with various configurations. Tiling arrangements using
conventional displays are disclosed in a number of publications, including the
following:

- 30 • "DottyToto: A Measurement Engine for Aligning Multi-projector Display
Systems" by Mark Hereld, Ivan R. Judson, and Rick Stevens in Projection

Displays IX, Proceedings of SPIE-IS&T Electronic Imaging, Ming H. Wu, editor;

- “Immersive Planar Display Using Roughly Aligned Projectors” by Ramesh Raskar, The Office of the Future Group, University of North Carolina at Chapel Hill; and
- “Multi-Projector Displays Using Camera-Based Registration” by Ramesh Raskar et al., Department of Computer Science, University of North Carolina at Chapel Hill.

These and other display tiling solutions operate by attempting precision alignment between projected images from multiple projectors. However, this type of solution is hampered by effects such as slight movement of the display screen, jarring or movement of one or more projection apparatus, expansion due to heat, and imperfections due to projection optics, such as keystone effects, for example. Moreover, slight color changes in adjacent tiled image sections become readily noticeable, detracting from the intended effect of projection image tiling. Among solutions proposed for tiling projection apparatus with minimal visibility of tile borders are those proposed in U.S. Patent No. 6,590,621 (Creek et al.) and U.S. Patent No. 6,513,938 (Kubota et al.)

Tiling has been used for spatial light modulators used in backlighting display applications. For example, U.S. Patent No. 6,262,696 (Seraphim et al.) discloses a large display panel having a number of precisely aligned LCD display modules arranged as tiles over a backlighting surface; U.S. Patent No. 5,626,410 (Chambers et al.) discloses tiling of LCD devices in a backlighting display using a fiber optic array for achieving more uniform brightness; U.S. Patent No. 5,902,030 (Blanchard) discloses a backlighting system using multiple projectors, with a screen outfitted for suitably combining images, such as using Fresnel lens. While these approaches offer some solutions for backlighting systems that form an image on a specially designed, diffusive surface, the apparatus and techniques of these patents are not suitable for front-projection systems.

Tiling approaches have been proposed for printing applications. For example, commonly assigned U.S. Patent No. 6,580,490 (Wong et al.)

discloses the use of multiple tiled LCD spatial light modulators for providing exposure energy to a photosensitive medium over an enlarged two-dimensional area. However, print requirements vary significantly from projection requirements, requiring different solutions for uniformity, resolution, luminous
5 flux, contrast, imaging artifacts, and other image characteristics.

There have been a number of proposed projection systems using multiple spatial light modulators and combining output beams, centered on a single optical axis for projection as a single output beam. For example, commonly-assigned U.S. Patent No. 6,585,378 (Kurtz et al.) discloses a full-color
10 projection system that employs a separate spatial light modulator in each color path, one each for red, green, and blue light modulation. Modulated light beams from these devices are then overlapped, typically using a polarization beam splitter, an x-cube, or other component as a beam combiner to provide the composite color image. Similarly, U.S. Patent No. 5,788,352 (Montroy et al.)
15 discloses the use of two LCD spatial light modulators to form overlapping images, providing increased luminance and resolution and improved response time. However, the arrangements disclosed in U.S. Patent No. 6,585,378 and U.S. Patent No. 5,788,352 are directed to overlapping of images formed on separate spatial light modulators rather than to tiling images adjacently to increase the size
20 of the projected image.

Thus, it can be seen that tiling arrangements using multiple spatial light modulators have been adapted for a small number of backlit display and print imaging applications. However, projection display apparatus employing LCD spatial light modulators present some significant challenges to tiling
25 implementation. For example, polarization states of incident illumination and modulated light must be accounted for in many types of projection apparatus using these devices. Projection optics must be suitable for projecting a tiled display, where tiles are adjacent, rather than overlapping as in the apparatus of U.S. Patent No. 6,585,378 and U.S. Patent No. 5,788,352.

30 **SUMMARY OF THE INVENTION**

It is an object of the present invention to provide a projection apparatus and method for forming a tiled display. With this object in mind, the

present invention provides a projection apparatus for forming a tiled image on a display surface, the tiled image comprising at least a first image tile segment and an adjacent second image tile segment, the projection apparatus comprising:

- 5 (a) an illumination system providing a first illumination beam having a first polarization state and a second illumination beam having a second polarization state, the first and second illumination beams being parallel and substantially non-overlapping;
 - 10 (b) a first spatial light modulator for forming a first modulated light beam from the first illumination beam;
 - (c) a second spatial light modulator for forming a second modulated light beam from the second illumination beam;
 - 15 (d) a beam aligner for directing the first and second modulated light beams along adjacent parallel paths, in the direction of the optical axis of a projection lens; and
- projection lens directing the first modulated beam to the display surface to form the first tile segment and directing the second modulated beam to the display surface to form the second tile segment.

20 It is a feature of the present invention that it provides a light-combining mechanism that directs adjacent modulated image beams toward projection optics along parallel paths, allowing projection optics to project a tiled image having two or more adjacent tiles.

25 It is an advantage of the present invention that it obviates the need to align multiple projectors for obtaining a tiled output image. Instead, the apparatus of the present invention can be aligned for tiling at the time of manufacture.

30 It is a further advantage of the present invention that it allows a number of possible arrangements for illumination systems, including the use of the same illumination system for forming multiple tiled images. This helps to provide more uniform color from one tiled image to the next.

These and other objects, features, and advantages of the present invention will become apparent to those skilled in the art upon a reading of the following detailed description when taken in conjunction with the drawings wherein there is shown and described an illustrative embodiment of the invention.

5

BRIEF DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of the present invention, it is believed that the invention will be better understood from the following description when taken in conjunction with the accompanying drawings, wherein:

10

Figure 1 is a schematic block diagram showing components of a projection apparatus for forming a tiled image on a display surface in a first embodiment of the present invention, using transmissive spatial light modulators;

Figure 2 is a plan view showing components of the projection apparatus of Figure 1;

15

Figure 3 is a schematic block diagram showing a projection apparatus for forming a tiled image in an alternate embodiment using reflective spatial light modulators;

Figure 4 is a schematic block diagram showing a projection apparatus for forming a tiled image in yet another alternate embodiment;

20

Figure 5 is a schematic block diagram showing a projection apparatus for forming a tiled image in an alternate embodiment using two reflective spatial light modulators; and

Figure 6 is a schematic block diagram showing a projection apparatus for forming a tiled image in another alternate embodiment using two transmissive spatial light modulators.

25

DETAILED DESCRIPTION OF THE INVENTION

The present description is directed in particular to elements forming part of, or cooperating more directly with, apparatus in accordance with the invention. It is to be understood that elements not specifically shown or described may take various forms well known to those skilled in the art.

30

In the description that follows, references to components may have part numbers with appended alphabetic characters, where it is useful to describe

specific optical paths, as shown in the accompanying figures. Where the discussion refers to general characteristics of components, rather than to specific optical paths, appended alphabetic characters may be omitted.

First Embodiment

5 Referring to Figure 1, there is shown a projection apparatus 10 for forming a tiled image 12 on a display surface 14. A set of four spatial light modulators 20a, 20b, 20c, and 20d, transmissive liquid crystal devices (LCDs) in a preferred embodiment, is arranged to provide tiled image 12. Each spatial light modulator 20a-20d has a corresponding illumination system 16a, 16b, 16c, and 16d for providing source illumination. Possible configurations for illumination systems 16a-16d are given subsequently. The corresponding segment of tiled image 12 (with tiled segments arranged as four contiguous quadrants numbered I, II, III, and IV) is indicated for each spatial light modulator 20a-20d. An arrangement of polarization beamsplitters 22a and 22b with a beamsplitter 30 is provided as a beam aligner 40 for directing a corresponding modulated light beam 15 26a, 26b, 26c, and 26d from each spatial light modulator 20a, 20b, 20c, and 20d respectively, along a separate path parallel to optical axis O of a projection lens 18. Each spatial light modulator 20a-20d is provided with an analyzer 24a, 24b, 24c, and 24d for improved contrast. (Note that beamsplitter 30 is not a 20 polarization beamsplitter where shown in embodiments disclosed herein.)

Projection lens 18 directs each modulated light beam to a separate tiled segment, as a corresponding one of quadrants I, II, III, or IV. These modulated light beams must be carefully aligned adjacently to minimize gaps, unintended overlaps, or skewing of tiled quadrants I-IV. Figure 1 shows the 25 relative positioning of spatial light modulators 20a-20d and their relative arrangement about beam aligner 40 components from a top view. Figure 2 shows relative positions of spatial light modulators 20a-20d from a side view.

For an understanding of how projection apparatus 10 operates, it is instructive to follow the path of modulated light for each of the four tiled 30 quadrants I-IV in Figure 1, with reference also to the positioning of spatial light modulators 20a-20d from the side view of Figure 2:

5 (i) Modulated light for quadrant I from illumination system 16a is modulated by spatial light modulator 20a to form modulated light beam 26a. Polarization beamsplitter 22a and beamsplitter 30 transmit modulated light beam 26a toward projection lens 18, on a path parallel to optical axis O, for forming tiled quadrant I.

10 (ii) Modulated light for quadrant II from illumination system 16b is modulated by spatial light modulator 20b to form modulated light beam 26b. Polarization beamsplitter 22a reflects modulated light beam 26b and beamsplitter 30 transmits modulated light beam 26b toward projection lens 18, on a path parallel to optical axis O, for forming tiled quadrant II.

15 (iii) Modulated light for quadrant III from illumination system 16c is modulated by spatial light modulator 20c to form modulated light beam 26c. Polarization beamsplitter 22b reflects modulated light beam 26c and beamsplitter 30 reflects modulated light beam 26c toward projection lens 18, on a path parallel to optical axis O, for forming tiled quadrant III.

20 (iv) Modulated light for quadrant IV from illumination system 16d is modulated by spatial light modulator 20d to form modulated light beam 26d. Polarization beamsplitter 22b transmits modulated light beam 26d and beamsplitter 30 reflects modulated light beam 26d toward projection lens 18, on a path parallel to optical axis O, for forming tiled quadrant IV.

25 Adjacent modulated light beams 26a, 26b, 26c, and 26d are directed toward projection lens 18 in parallel paths to output axis O. Unlike with prior art arrangements, modulated light beams 26a, 26b, 26c, and 26d are not
30 centered onto the same optical axis by beam-combining elements. Instead, modulated light beams 26a, 26b, 26c, and 26d are directed adjacently, in a non-overlapping manner. Certainly, some slight overlap is unavoidable between any

two adjacent modulated light beams 26a, 26b, 26c, and 26d, necessary for providing a suitable join or seam between adjacent image segments of tiled image 12. However, modulated light beams 26a, 26b, 26c, and 26d themselves are directed along separate, parallel axes rather than being centered onto the same optical axis O.

5 Analyzers 24a, 24b, 24c, and 24d are used in this embodiment to improve contrast for each tiled segment. Alternate arrangements for positioning analyzers 24a-24d are shown in subsequent embodiments.

Second Embodiment

10 Referring to Figure 3, there is shown an alternate component arrangement for projection apparatus 10 in a second embodiment, using reflective spatial light modulators 20a-20d and using only two illumination systems 16a and 16b with beam aligner 40 for forming four quadrant tiled image 12 (not shown in Figure 3, but similar to that shown in Figure 1). For the beam-combining arrangement of Figure 3, illumination systems 16a and 16b both provide polarized light along two parallel paths. Along one path, illumination system 16a provides S-polarized light; along the other parallel path, illumination system 16a provides P-polarized light. This light from illumination system 16a provides source illumination to a polarization beamsplitter 28a, a wire-grid polarization beamsplitter in one embodiment. Polarization beamsplitter 28a separates light by its polarization state, directing light of one polarization state to polarization beamsplitter 22a for modulation by reflective spatial light modulator 20a. Output modulated light beam 26a from spatial light modulator 20a is then transmitted through polarization beamsplitter 22a and an analyzer 24a and through polarization beamsplitter 22e and beamsplitter 30 to projection lens 18, in a path parallel to optical axis O, for forming tiled quadrant I. The other polarization state from polarization beamsplitter 28a goes through a half-wave plate 42 to alter its polarization state and is reflected toward reflective spatial light modulator 20b from polarization beamsplitter 22b. Output modulated light beam 26b is then transmitted through polarization beamsplitter 22b and an analyzer 24b, reflected by polarization beamsplitter 22e, and transmitted through beamsplitter 30, in a

path parallel to optical axis O, toward projection lens 18 for forming tiled quadrant II.

Formation of tiled quadrants III and IV is similar. Polarization beamsplitter 28b separates the polarized light along parallel paths from illumination system 16b by its polarization state, directing light of one polarization state to polarization beamsplitter 22c for modulation by reflective spatial-light modulator 20c. Output modulated light beam 26c from spatial light modulator 20c is then transmitted through polarization beamsplitter 22c and through an analyzer 24c and is reflected by polarization beamsplitter 22f and beamsplitter 30, into a path parallel to optical axis O, to projection lens 18 for forming tiled quadrant III. The other polarization state from polarization beamsplitter 28b is transmitted through half-wave plate 42 to alter its polarization state, and toward reflective spatial light modulator 20d from polarization beamsplitter 22d. Output modulated light beam 26d is then transmitted through polarization beamsplitter 22d and an analyzer 24d and through polarization beamsplitter 22f, and is reflected by beamsplitter 30 into a path parallel to optical axis O, toward projection lens 18 for forming tiled quadrant IV.

Third Embodiment

Referring to Figure 4, there is shown a third embodiment of projection apparatus 10 of the present invention, using two separate illumination systems 16a and 16b that, in similar manner to the embodiment shown in Figure 3, provide light having orthogonal polarization states in separate paths, indicated as paths S and P. Polarized illumination system 16a provides light of both polarization states to polarization beamsplitter 22a, which directs the received illumination into separate paths for each polarization state. In the example of Figure 4, light having the S path polarization state is reflected toward reflective spatial light modulator 20a by polarization beamsplitter 22a. Light having the P path polarization state is transmitted toward spatial light modulator 20b. Modulated light beams 26a and 26b are then transmitted through beamsplitter 30, along adjacent paths parallel to optical axis O, toward lens 18 for forming tiled quadrants I and II respectively (as shown in Figure 1). Similarly, polarization beamsplitter 22b directs the received P and S path polarized illumination from

illumination system 16b into separate paths for spatial light modulators 20c and 20d respectively. Modulated light beams 26c and 26d are then directed by polarization beamsplitter 22b and reflected by beamsplitter 30, along adjacent paths parallel to optical axis O, toward projection lens 18 for forming tiled
5 quadrants III and IV respectively (as shown in Figure 1).

Fourth Embodiment

Referring to Figure 5, there is shown an embodiment using two reflective spatial light modulators 20a and 20b for forming tiled image 12 having two tiled sections I and II. Figure 5 also shows an arrangement of illumination
10 system 16 that provides separate paths for S- and P-polarized light, as is needed for the alternative embodiments of Figures 3 and 4. A light source 38, such as a lamp or LED, for example, provides light to a polarization beamsplitter 32, typically through a uniformizer component of some kind, such as a lenslet array or integrator bar (not shown). Polarization beamsplitter 32 separates illumination
15 into its orthogonal polarization states, and, using reflective surface 44 or a prism for redirecting light in the path of one of the polarization states, along spatially separate paths S and P. Lenses 36 direct this light toward a single polarization beamsplitter 22 which serves as beam aligner 40. Light having one polarization state is transmitted directly through polarization beamsplitter 32 along a path S for
20 modulation by spatial light modulator 20a. Light having the orthogonal polarization state is reflected by polarization beamsplitter 22 for modulation by spatial light modulator 20b. Output modulated light is then directed from polarization beamsplitter 22 in the direction of optical axis O toward projection lens 18.

Fifth Embodiment

Referring to Figure 6, there is shown an alternate embodiment for projection using two transmissive spatial light modulators 20a and 20b for forming tiled image 12 having two tiled sections. As in the embodiment of Figure
5, polarization beamsplitter 32 and reflective surface 44 are provided as part of
30 illumination system 16 to separate the illumination into its orthogonal polarization states, along spatially separate paths, P and S. Polarization beamsplitter 28 directs one polarization state to transmissive spatial light modulator 20a, reflected by a

turning mirror 34 in the embodiment of Figure 6. Light having the orthogonal polarization state is directed through polarization beamsplitter 28 and to transmissive spatial light modulator 20b. Polarization beamsplitter 22, acting as beam aligner 40, then directs modulated light from both spatial light modulators 5 20a and 20b along adjacent paths, in the direction of optical axis O, toward projection lens 18.

The embodiments described hereinabove perform image tiling by alignment of modulated light beams 26a, 26b for forming adjacent image tiles, where this alignment is performed within the imaging subsystem of projection 10 apparatus 10 itself, rather than requiring separate projection optics for each modulated light beam 26a, 26b, as with conventional tiling arrangements. Alignment of multiple spatial light modulators 20 need only be performed at the time of manufacture, thereby simplifying the setup and use of projection apparatus 10 when compared with conventional techniques for alignment of individual 15 projectors to achieve tiling.

Projection lens 18 is a lens assembly that typically comprises a plurality of lens elements, rather than a single lens component as is represented in Figures 1, 3, and 4. Beam aligner 40, in the various embodiments of Figures 1-6, may use a number of alternative arrangements of beamsplitters 30 and/or 20 polarization beamsplitters 22, 28. It is instructive to observe again that beam aligner 40 provides a separate path for modulated light from each spatial light modulator 20, with respective paths substantially non-overlapping.

Illumination system 16 may derive polarized light from a xenon lamp, an LED, or other suitable component for providing illumination. 25 Alternately, illumination system 16 may direct light through an optical fiber or other light-guiding component. Methods for providing polarized light could employ polarization beamsplitter 32 in combination with reflective surface 44, as was shown in Figures 5 and 6, or other suitable components. The apparatus of the present invention could be employed for either monochrome or full-color 30 imaging, using temporal sequencing of red, green, and blue light, each light provided separately to spatial light modulator 20, or some other method for providing a modulated color beam along the optical paths shown in Figures 1-6.

Temporal sequencing could be provided using a color filter wheel or using other techniques well known in the electronic image projection arts.

In the simplest embodiment, using only two tiled image segments, beam aligner 40 is a single component, polarization beamsplitter 22 as shown in
5 Figures 5 and 6. For more complex embodiments used for projecting three or more tiled image segments, beam aligner 40 is formed as a more complex arrangement of polarizing and conventional beamsplitters, with any number of suitable dichroic support elements, mirrors, and polarizing components, as shown
10 in the embodiments of Figures 1, 3, and 4. It is instructive to note that the relative spatial positioning of spatial light modulators 20 is important, relative to the arrangement of beam aligner 40, for obtaining tiled image 12 with its separate tiled segments properly placed and aligned.

Suitable polarization states and polarization components in the imaging path would be chosen for compatibility and performance, using
15 techniques well known in the imaging arts. Different types of polarization beamsplitters could be used as components of beam aligner 40, including conventional MacNeille polarization beamsplitters, as disclosed in U.S. Patent No. 2,403,731, (MacNeille) and wire-grid polarization beamsplitters, as disclosed in U.S. Patent No. 6,122,103 (Perkins et al.), for example.

20 Thus, what is provided is an apparatus and method for tiled projection display using spatial light modulators.

PARTS LIST

10	projection apparatus
12	tiled image
14	display surface
16	illumination system
16a	illumination system
16b	illumination system
16c	illumination system
16d	illumination system
18	projection lens
20	spatial light modulator
20a	spatial light modulator
20b	spatial light modulator
20c	spatial light modulator
20d	spatial light modulator
22	polarization beamsplitter
22a	polarization beamsplitter
22b	polarization beamsplitter
22c	polarization beamsplitter
22d	polarization beamsplitter
22e	polarization beamsplitter
22f	polarization beamsplitter
24a	analyzer
24b	analyzer
24c	analyzer
24d	analyzer
26a	modulated light beam
26b	modulated light beam
26c	modulated light beam
26d	modulated light beam
28	polarization beamsplitter
28a	polarization beamsplitter

- 28b polarization beamsplitter
- 30 beamsplitter
- 32 polarization beamsplitter
- 34 mirror
- 36 lens
- 38 light source
- 40 beam aligner
- 42 half-wave plate
- 44 reflective surface

CLAIMS:

1. A projection apparatus for forming a tiled image on a display surface, said tiled image comprising at least a first, second, third, and fourth image tile segments the projection apparatus comprising:
 - 5 (a) an illumination system providing a first illumination beam having a first polarization state and a second illumination beam having a second polarization state, said first and second illumination beams being spatially separated;
 - (b) a first spatial light modulator for forming a first
10 modulated light beam from said first illumination beam;
 - (c) a second spatial light modulator for forming a second modulated light beam from said second illumination beam;
 - (d) a first beam aligner for directing said first and second
15 modulated light beams along adjacent parallel paths, the first and second modulated light beams being substantially non-overlapping and parallel to an optical axis of a projection lens;
 - (e) said illumination system providing a third illumination beam having a first polarization state and a fourth illumination beam having a second polarization state, said third and fourth illumination beams being spatially
20 separated;
 - (f) a third spatial light modulator for forming a third modulated light beam from said third illumination beam;
 - (g) a fourth spatial light modulator for forming a fourth modulated light beam from said fourth illumination beam;
 - 25 (h) a second beam aligner for directing said third and fourth modulated light beams along adjacent parallel paths, the third and fourth modulated light beams being substantially non-overlapping;
 - (i) a beamsplitter which redirects said third and fourth modulated light beams parallel to said optical axis of said projection lens and
30 transmits said first and second modulated light beams; and

said projection lens directing said first, second, third, and fourth modulated beams to said display surface to form the first, second, third, and fourth tile segments.

- 5 2. A projection apparatus according to claim 1 wherein said first beam aligner comprises a polarization beamsplitter.
3. A projection apparatus according to claim 1 wherein said first spatial light modulator is a transmissive LCD.
- 10 4. A projection apparatus according to claim 1 wherein said first spatial light modulator is a reflective LCD.
5. A projection apparatus according to claim 1 further
- 15 comprising an analyzer in the path of said first modulated beam.
6. A projection apparatus according to claim 1 wherein said illumination system comprises a polarization beamsplitter.
- 20 7. A projection apparatus according to claim 1 wherein said illumination system comprises a light source selected from the group consisting of a lamp and an LED.
8. A projection apparatus according to claim 1 wherein said
- 25 illumination system sequentially provides light having a first color, followed by light having a second color, followed by light having a third color.
9. A projection apparatus according to claim 1 further comprising a half-wave plate in the path of said first modulated beam.

10. A projection apparatus for forming a tiled image on a display surface, said tiled image comprising at least four contiguous image tile segments, the projection apparatus comprising:

- 5 (a) an illumination system providing a first illumination beam having a first polarization state and a second illumination beam having a second polarization state, said first and second illumination beams being spatially separated;
- (b) a first spatial light modulator for forming a first modulated light beam from said first illumination beam;
- 10 (c) a second spatial light modulator for forming a second modulated light beam from said first illumination beam;
- (d) a third spatial light modulator for forming a third modulated light beam from said second illumination beam;
- 15 (e) a fourth spatial light modulator for forming a fourth modulated light beam from said second illumination beam;
- (f) a beam aligner for directing said first, second, third, and fourth modulated light beams along adjacent parallel paths, in the direction of the optical axis of a projection lens, said first, second, third, and fourth modulated light beams being substantially non-overlapping; and
- 20 (g) said projection lens directing each said modulated beam to the display surface to form each of said at least four contiguous image tile segments.

11. A method for forming a tiled image on a display surface, said tiled image comprising at least a first, second, third, and fourth image tile segments, the method comprising:

- 25 (a) providing a first illumination beam having a first polarization state and a second illumination beam having the orthogonal polarization state, wherein the first and second illumination beams are spatially separated;
- 30 (b) forming a first modulated light beam from said first illumination beam;

(c) forming a second modulated light beam from said second illumination beam;

(d) aligning said first and second modulated light beams along separate, adjacent parallel paths, in the direction of the optical axis of a projection lens;

(e) providing a third illumination beam having a first polarization state and a fourth illumination beam having the orthogonal polarization state, wherein the third and fourth illumination beams are spatially separated;

(f) forming a third modulated light beam from said third illumination beam;

(g) forming a fourth modulated light beam from said fourth illumination beam;

(h) aligning said third and fourth modulated light beams along separate, adjacent parallel paths;

(i) redirecting said third and fourth modulated light beams parallel to the optical axis of the projection lens; and

(j) projecting at least said first, second, third, and fourth modulated beams to said display surface, in a substantially non-overlapping manner, to form the first, second, third, and fourth tile segments.

12. A method for forming a tiled image according to claim 11 wherein the step of forming said first modulated light beam comprises the step of directing said first illumination beam to a reflective spatial light modulator.

13. A method for forming a tiled image according to claim 11 wherein the step of forming said first modulated light beam comprises the step of directing said first illumination beam to a transmissive spatial light modulator.

14. A method for forming a tiled image according to claim 11 wherein the step of providing said first illumination beam comprises the step of providing a beam having a repeating sequence of different colors.

15. A projection apparatus for forming a tiled image on a display surface, said tiled image comprising at least a first, second, third, and fourth image tile segments, the projection apparatus comprising:
- 5 (a) an illumination system providing a first illumination beam having a first polarization state and a second illumination beam having an orthogonal polarization state, said first and second illumination beams being spatially separated;
- (b) a projection lens having a projection lens optical axis;
- 10 (c) a first beam aligner for receiving a first modulated light beam from a first spatial light modulator disposed at a first position, for receiving a second modulated light beam from a second spatial light modulator disposed at a second position and for directing the first modulated light beam and second modulated light beams in parallel to said projection lens optical axis, said first and
- 15 second modulated light beams being substantially non-overlapping;
- (d) wherein the illumination system further provides a third illumination beam having said first polarization state and a fourth illumination beam having said orthogonal polarization state, said third and fourth illumination beams being spatially separated;
- 20 (e) a second beam aligner for receiving said third modulated light beam from a third spatial light modulator disposed at a third position, for receiving said fourth modulated light beam from a fourth spatial light modulator disposed at a fourth position and for directing the third modulated light beam and fourth modulated light beams in parallel with respect to each other and
- 25 substantially perpendicular to said projection lens optical axis, said third and fourth modulated light beams being substantially non-overlapping; and
- (f) a beamsplitter for transmitting said first and second modulated light beams parallel to said projection lens optical axis and for redirecting said third and fourth modulated light beams parallel to said projection
- 30 lens optical axis, thereby directing said first, second, third, and fourth modulated light beams in parallel to said projection lens optical axis and wherein said first, second, third, and fourth modulated light beams are substantially non-overlapping.

1/6

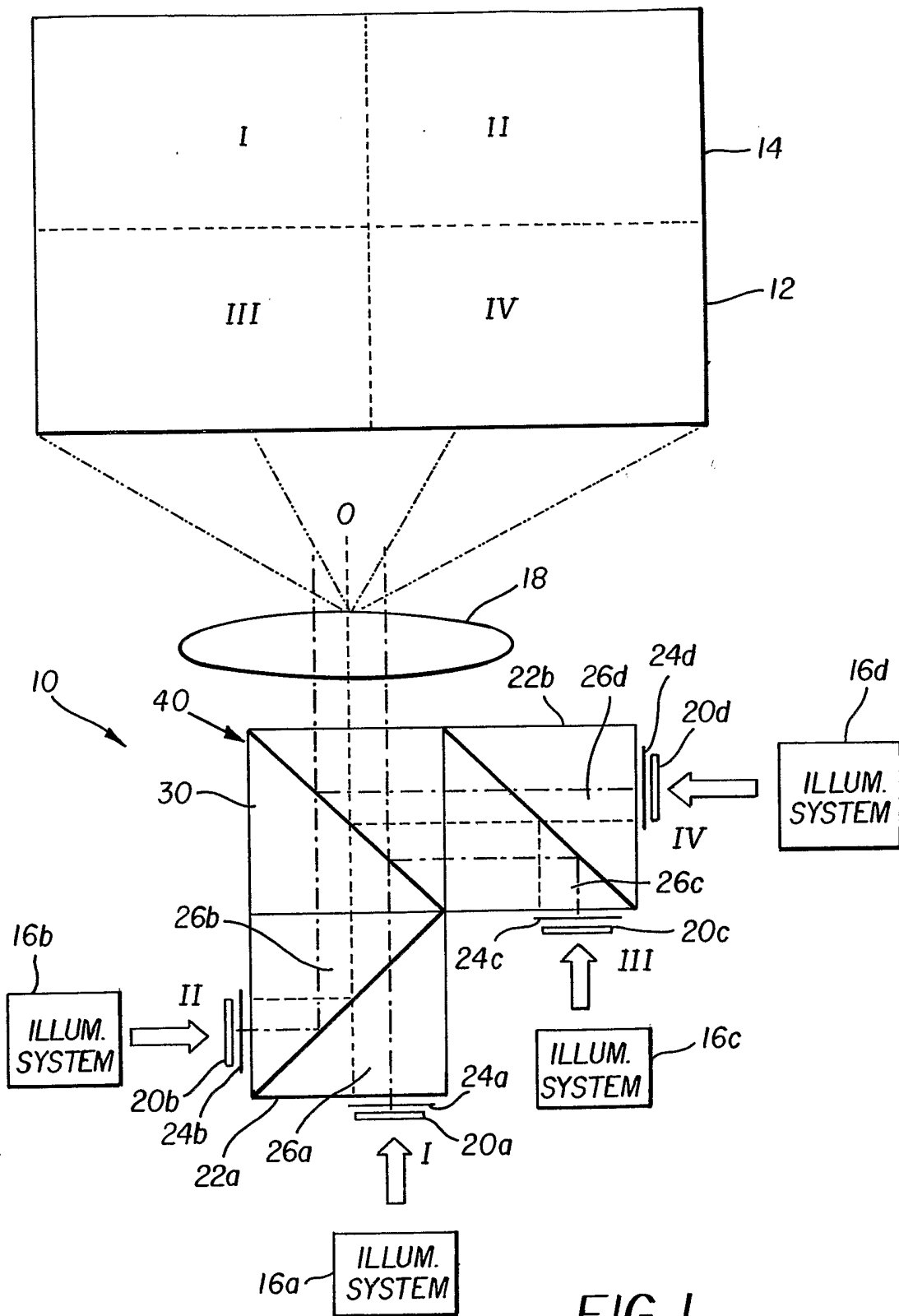


FIG. 1

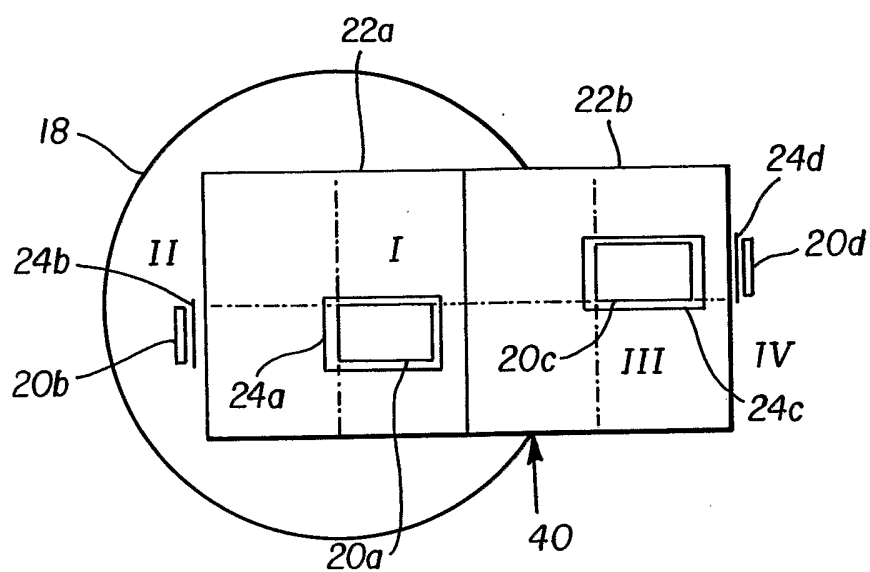


FIG. 2

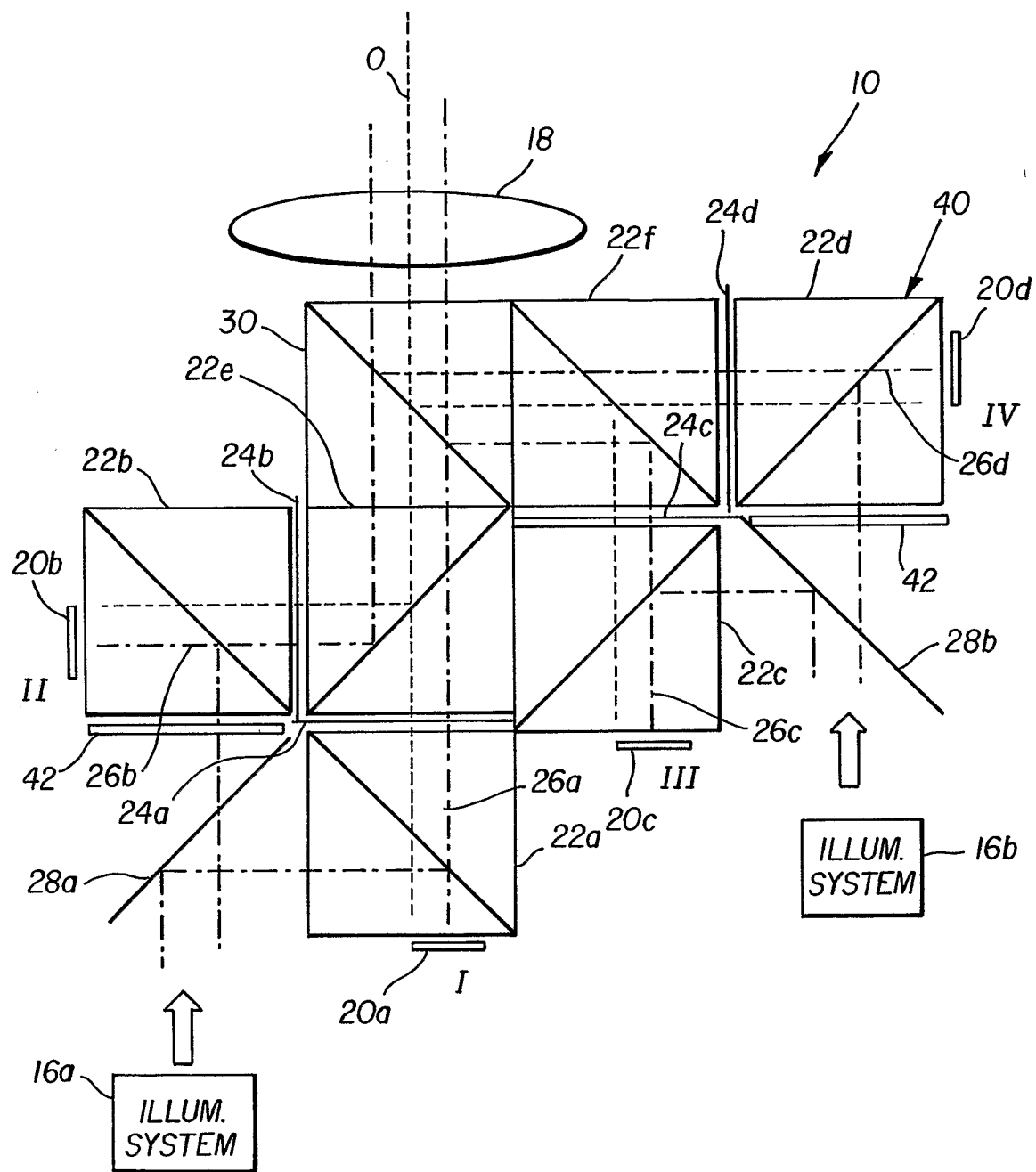


FIG. 3

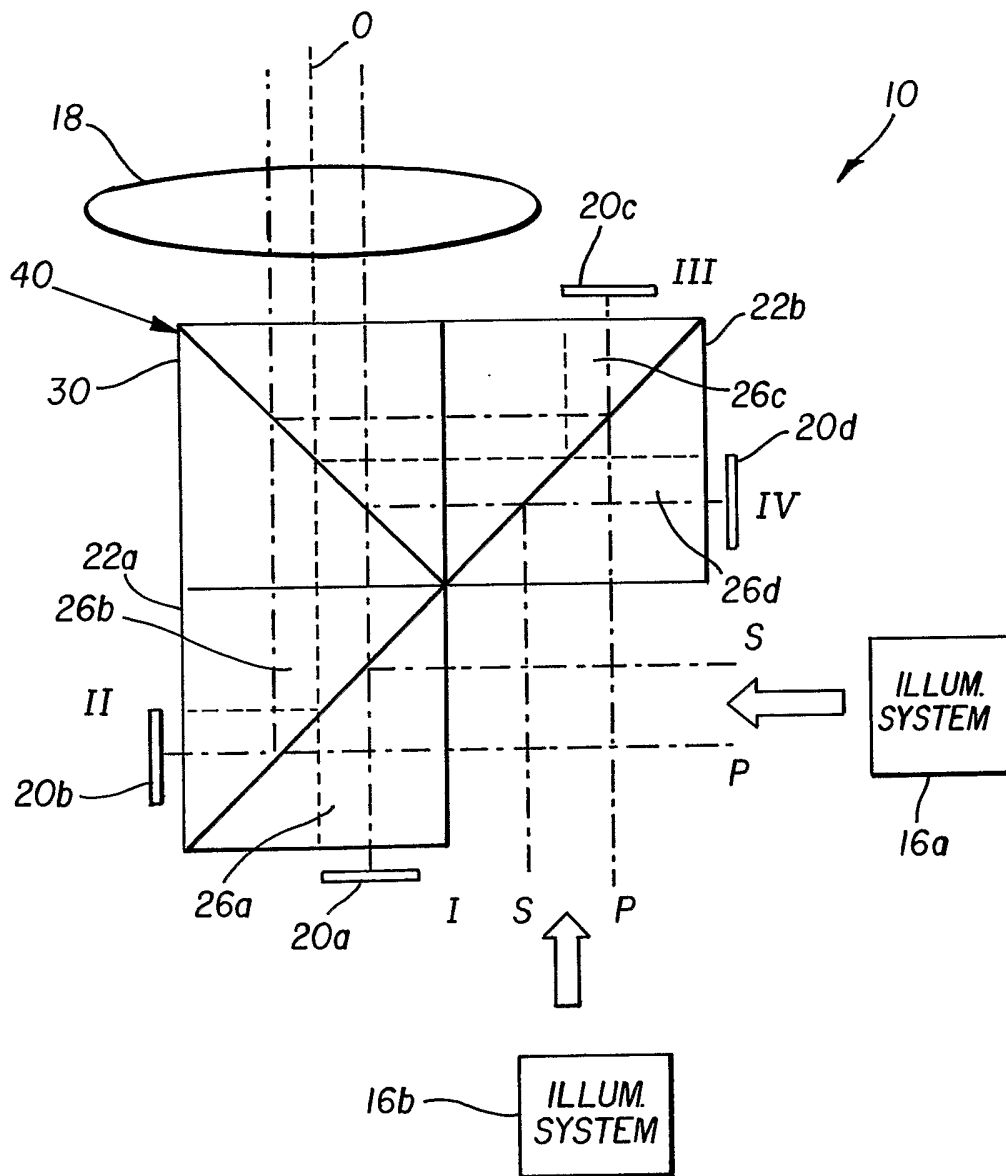


FIG. 4

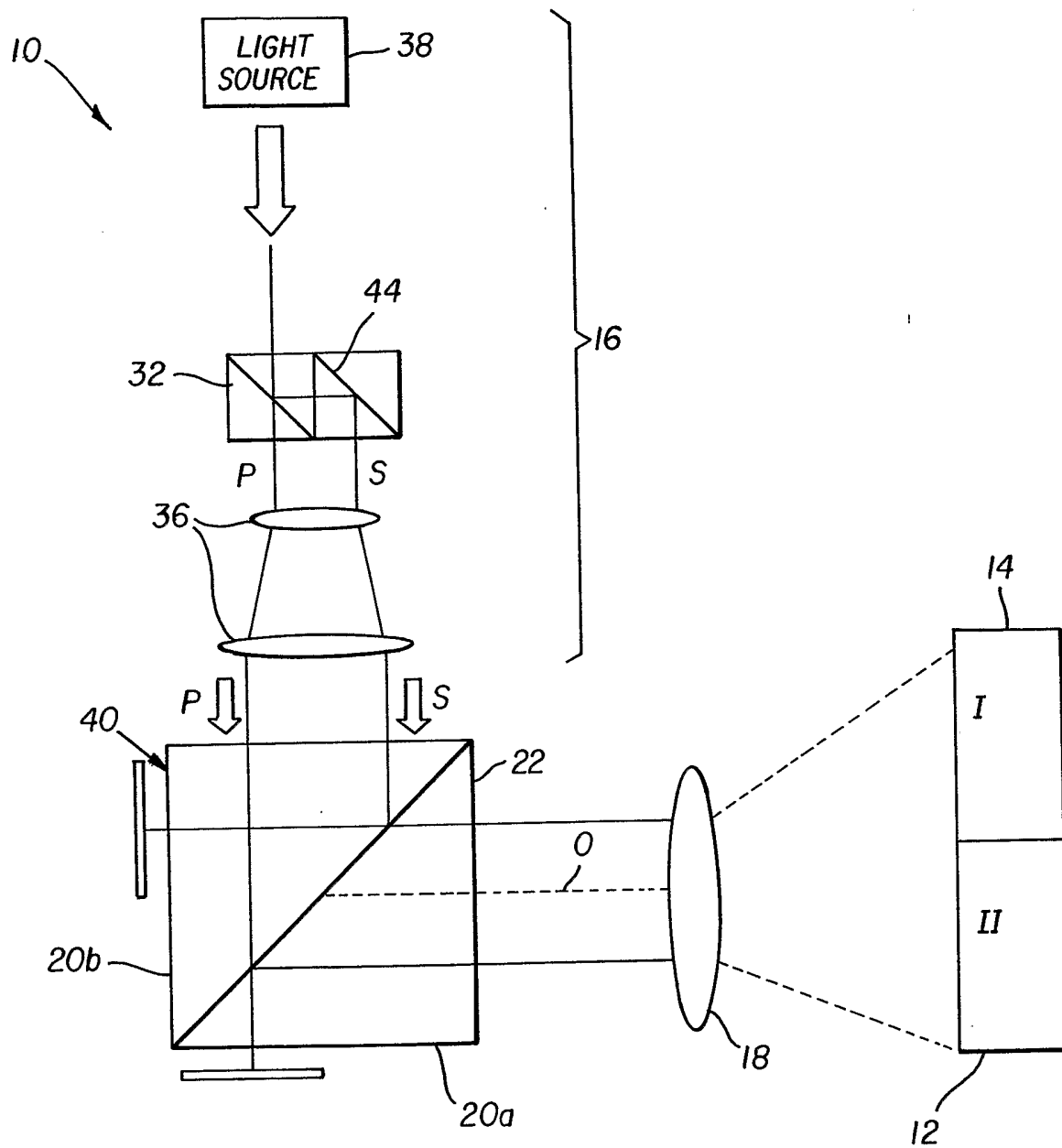


FIG. 5

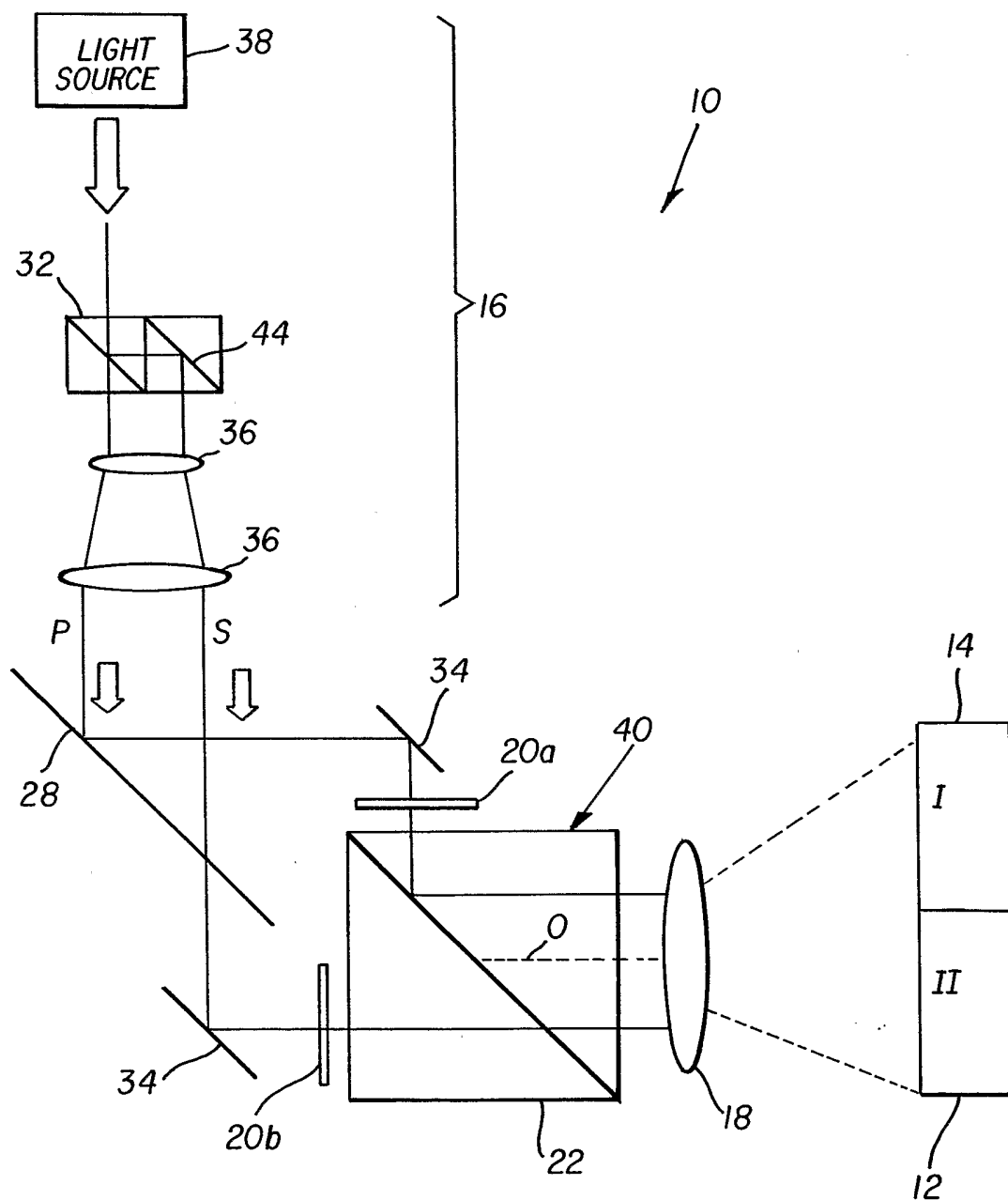


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US2005/000254

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04N5/262 H04N5/74

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)
IPC 7 H04N

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 practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 134 610 A (OLYMPUS CORPORATION; OLYMPUS OPTICAL CO., LTD) 19 September 2001 (2001-09-19) abstract paragraph [0007] - paragraph [0012] figures 1-14	1-9, 11-15
A	----- US 2003/063226 A1 (GIBBON MICHAEL A ET AL) 3 April 2003 (2003-04-03) abstract paragraph [0012] - paragraph [0018] paragraph [0040]; figure 2 ----- -/--	1-9, 11-15

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

° Special categories of cited documents :

- | | |
|---|---|
| "A" document defining the general state of the art which is not considered to be of particular relevance | "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention |
| "E" earlier document but published on or after the international filing date | "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone |
| "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) | "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. |
| "O" document referring to an oral disclosure, use, exhibition or other means | "&" document member of the same patent family |
| "P" document published prior to the international filing date but later than the priority date claimed | |

Date of the actual completion of the international search

18 March 2005

Date of mailing of the international search report

30.05.2005

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Schreib, F

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US2005/000254

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>HERELD, M.; JUDSON, I.R.; STEVENS, R.L: "Introduction to building projection-based tiled display systems" COMPUTER GRAPHICS AND APPLICATIONS, vol. 20, no. 4, August 2000 (2000-08), pages 22-28, XP002321636 page 22 - page 25 figures 1-4</p>	<p>1-9, 11-15</p>
A	<p>----- GARY K STARKWEATHER: "DSHARP?a wide-screen multi-projector display" JOURNAL OF OPTICS A PURE AND APPLIED OPTICS, [Online] 22 October 2003 (2003-10-22), pages 136-139, XP002321637 Retrieved from the Internet: URL:http://ej.iop.org/links/q07/A7ajqNre+7 johBNZKYMZw/oa3554.pdf> [retrieved on 2005-03-16] * section 1Introduction * * section 2: The DSHARP Design * figures 1-6</p> <p>-----</p>	<p>1-9, 11-15</p>

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2005/000254

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-9,11-15

Remark on Protest

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-9,11-15

Projection apparatus for forming a tiled image using 4 illumination beams

2. claim: 10

Projection apparatus for forming a tiled image using 2 illumination beams

INTERNATIONAL SEARCH REPORT
 information on patent family members

International Application No
 PCT/US2005/000254

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1134610	A	19-09-2001	JP 2001268476 A	28-09-2001
			EP 1134610 A2	19-09-2001
			US 2001022651 A1	20-09-2001

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			EP 1210649 A2	05-06-2002
			JP 2004503809 T	05-02-2004
			WO 0196907 A2	20-12-2001
