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EP 0385705 A2 **WO 2016/069631 A1**
WO 2000/017844 A1 **US 20100253916 A1**

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INT CL **G02B, H04N**
Other: **WPI, EPODOC**

(54) Title of the Invention: **Image display screen**
Abstract Title: **Volumetric image display screen comprising optically anisotropic reflective layer**

(57) Image display screen comprising: an image reflecting portion comprising an optically anisotropic layer and configured such that light incident thereon is reflected principally by the optically anisotropic layer. Also disclosed: image reflecting portion comprises a lenticular reflector and a layer of paint. Lenticular array may comprise prisms, cylindrical, hemicylindrical or elliptically cylindrical elongate, mutually parallel lenses with horizontally aligned longitudinal axes. Paint may be pigmented black to absorb light but may contain dispersed reflective particles eg. aluminium. Also disclosed: image reflector may rotate about an axis displaced from its centre. This may generate a volumetric display. Also disclosed: image may be projected on to the screen and may be rotated at the same speed as the screen. Image rotator may be a Dove prism and may be rotated at half the speed of the screen. Anisotropic material may be a holographic diffuser or reflector layer or a lenslet array. Light transmitted through optically anisotropic layer may be attenuated. Image reflector may comprise contrast layer. Longitudinal lens axis may be perpendicular to screen rotation axis. Video may be projected.

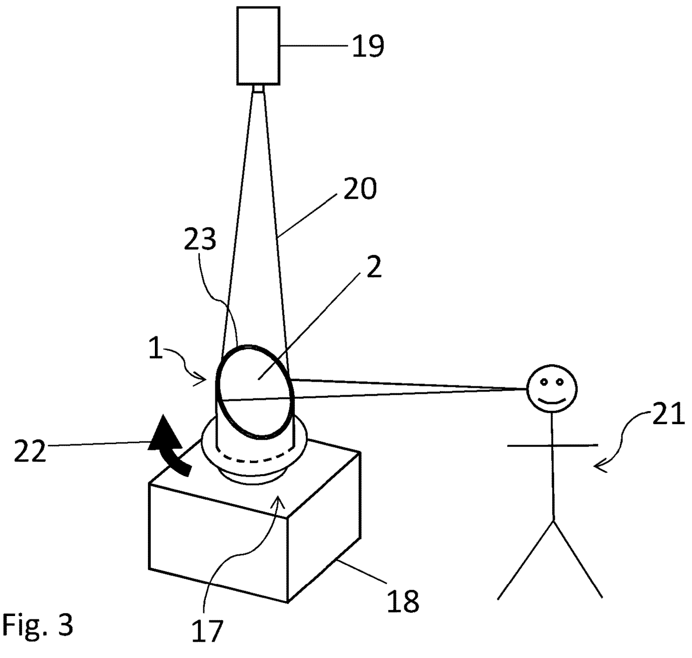

Fig. 3

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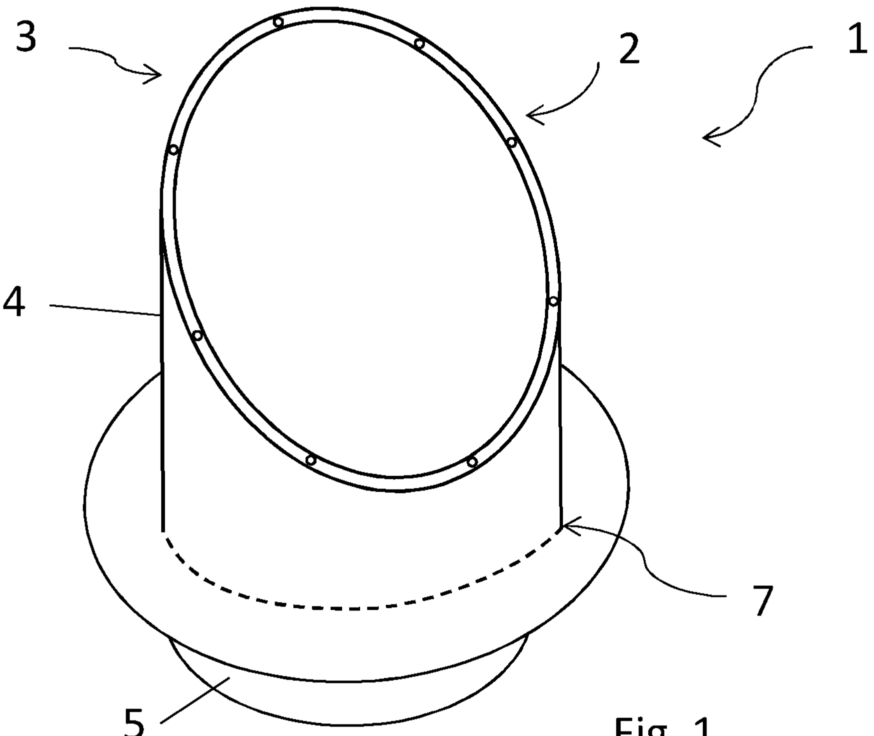

Fig. 1

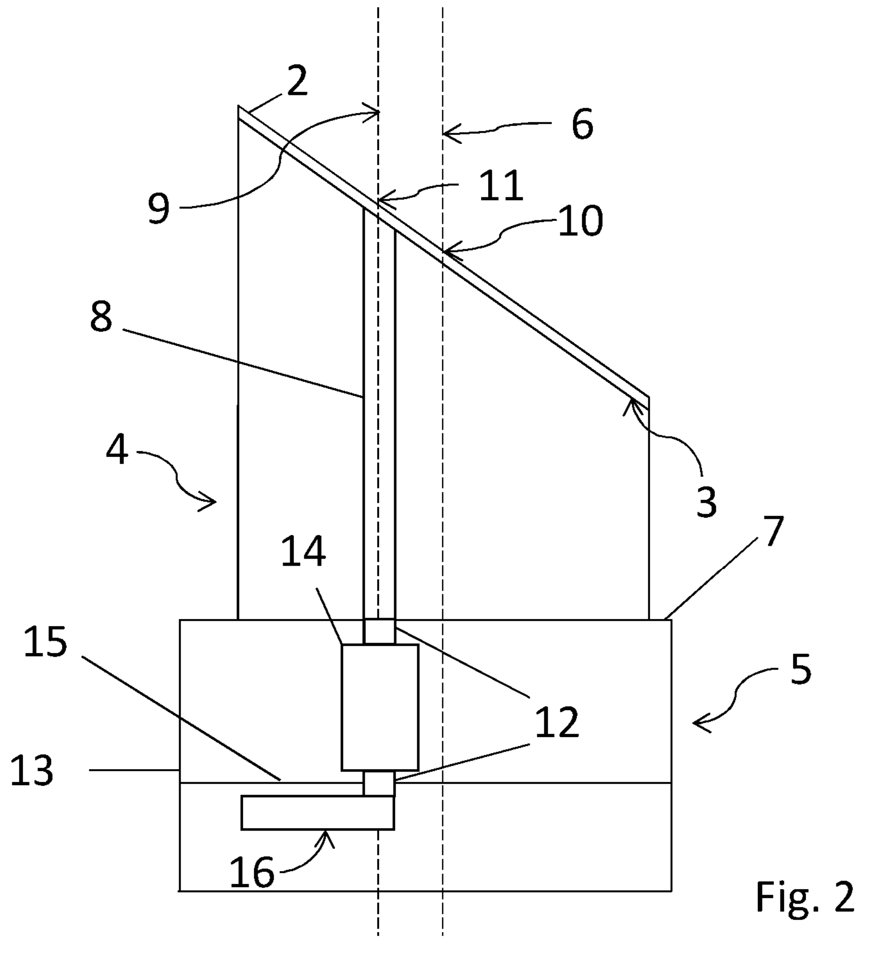

Fig. 2

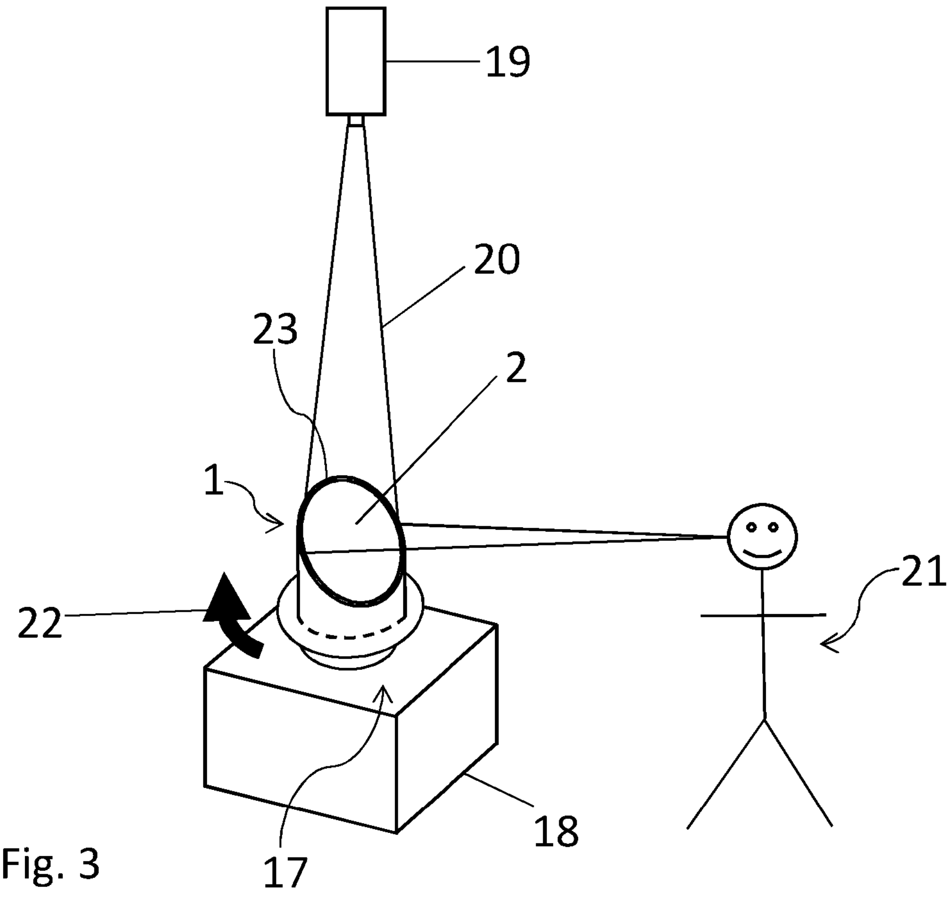

Fig. 3

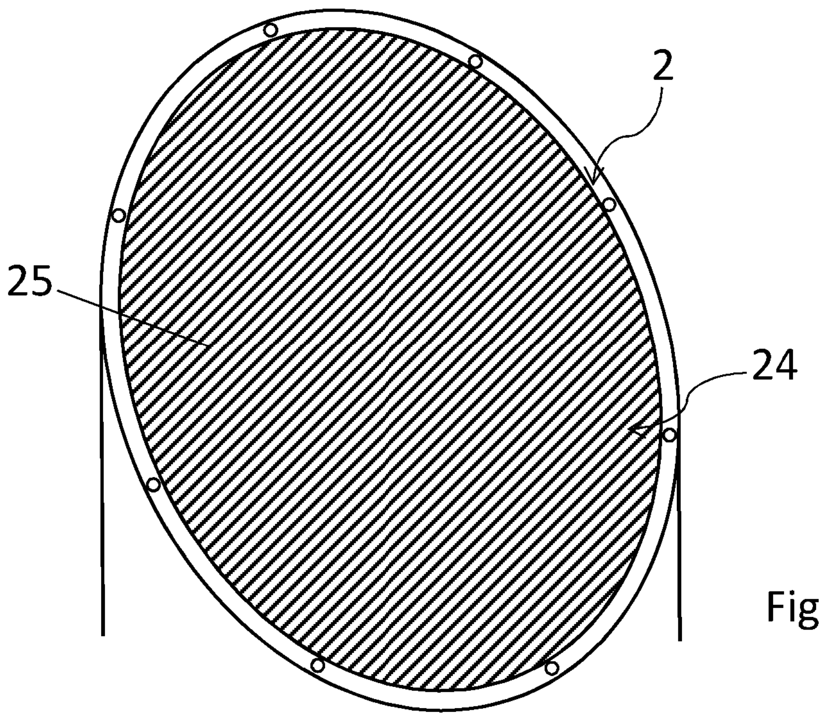

Fig. 4

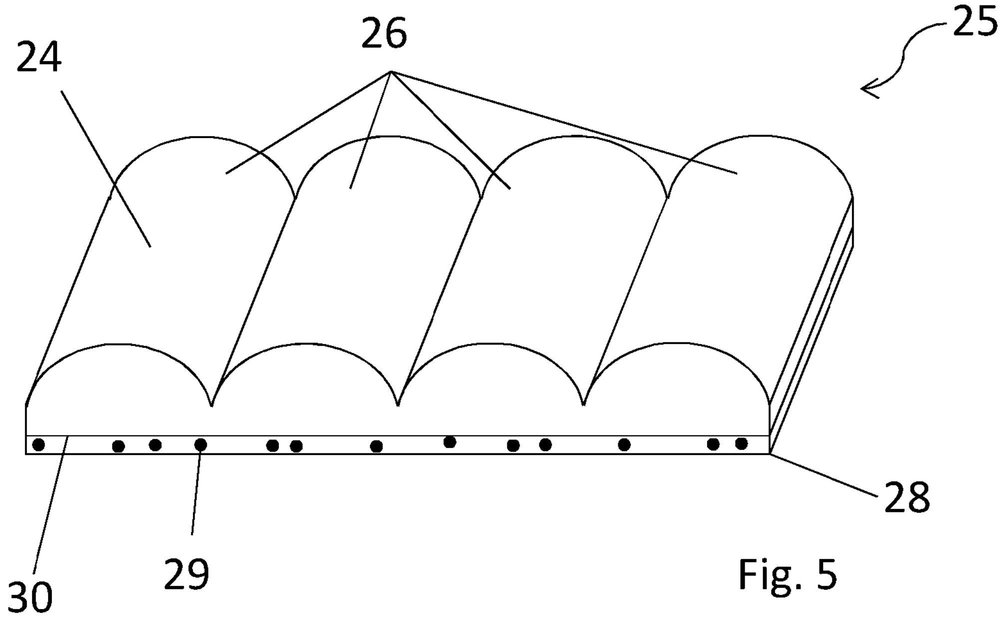

Fig. 5

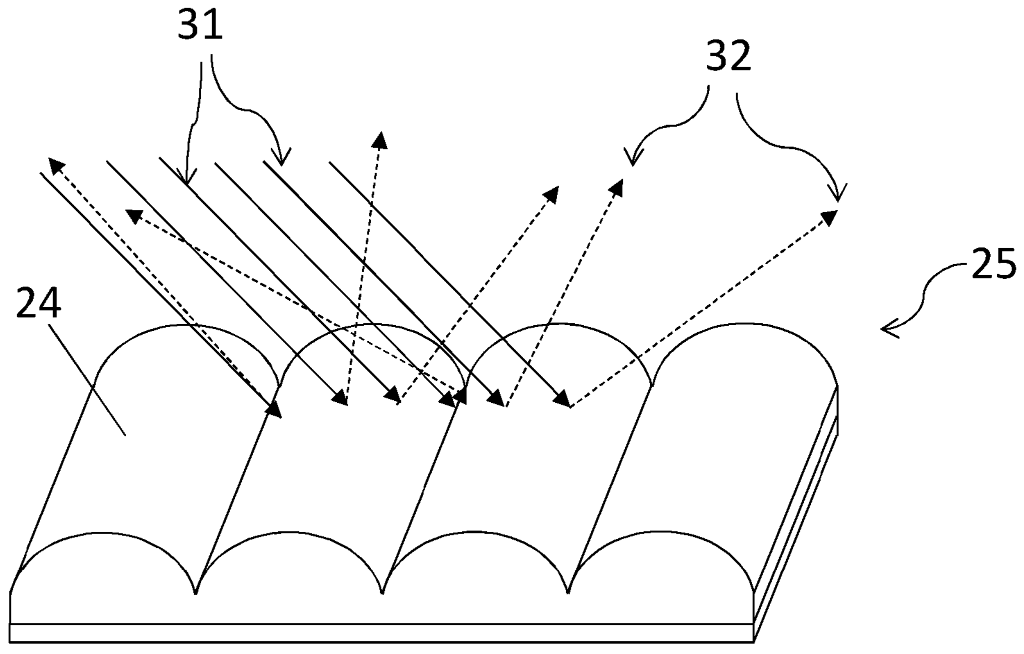

Fig. 6

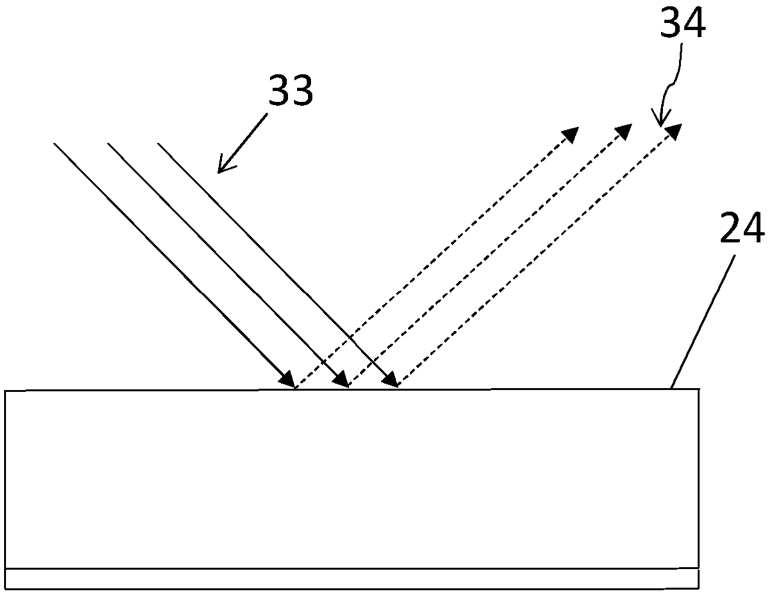

Fig. 7

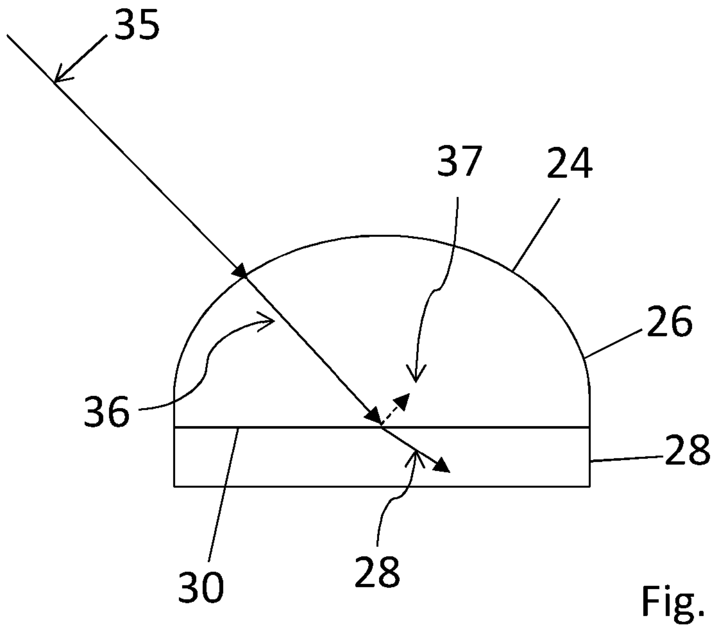

Fig. 8

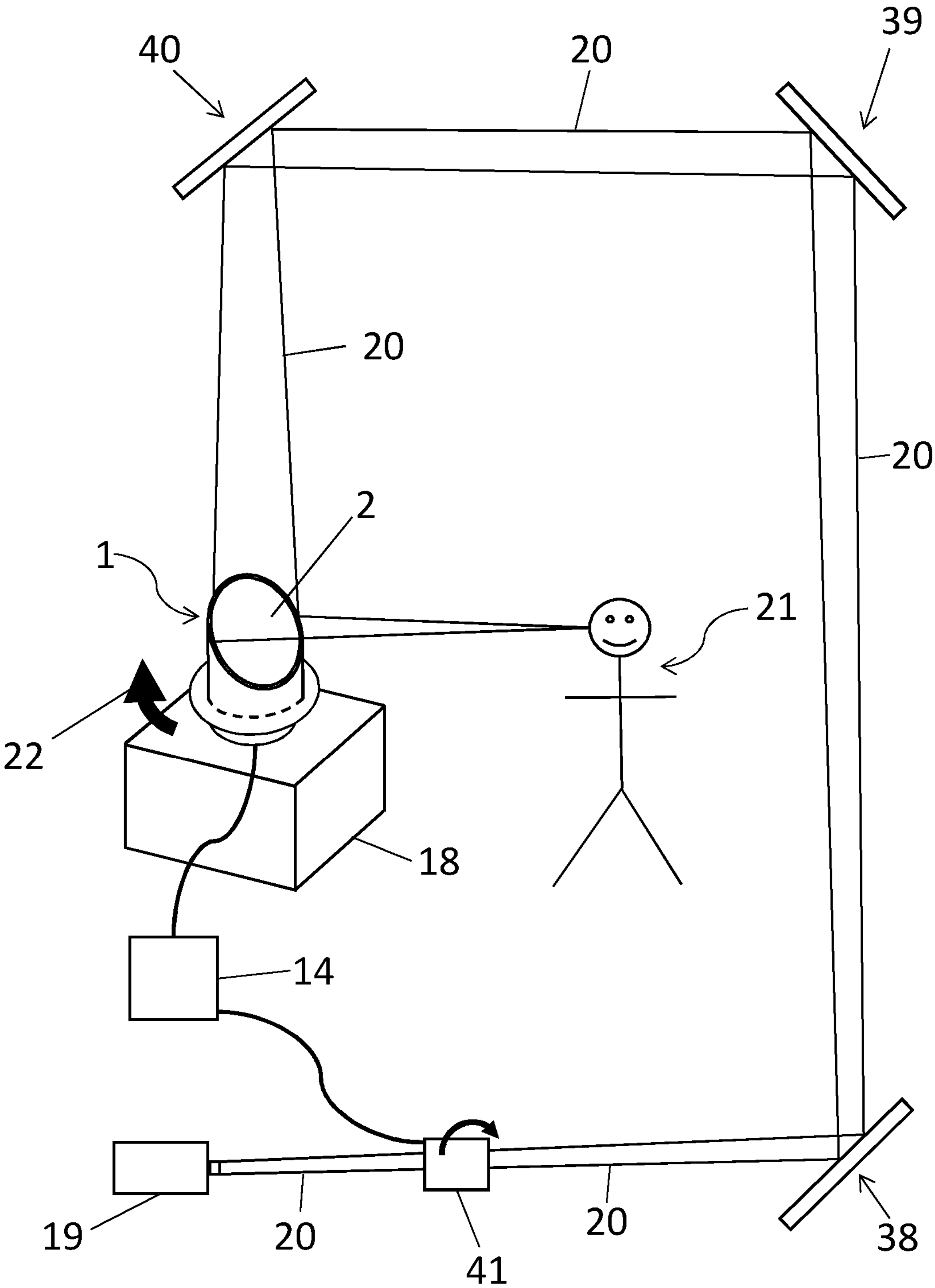

Fig. 9

IMAGE DISPLAY SCREEN

Field of the invention

The invention relates to image display screens and associated image display apparatus.

Background to the invention

Volumetric displays capable of forming a visual representation of an image in three dimensions are generally known and are commercially available. Volumetric displays may be autostereoscopic or automultiscopic, meaning that they can render a three dimensional image visible by the unaided human eye (for example, without requiring use of special eyewear). Some volumetric displays create the illusion of a volumetric image by projecting a two-dimensional image onto a rotating display screen. Such displays typically provide a reflecting surface of the rotating display screen which is inclined with respect to the direction in which the image is projected such that the image is reflected through a wide range of viewing angles as the screen rotates, thereby rendering the image visible from a multitude of viewing positions.

Existing volumetric displays comprising rotating, inclined display screens typically produce images which are blurred, smeared or otherwise affected by image distortions or aberrations. For example, some such volumetric displays produce volumetric representations in which two or more overlayed images are visible, rendering the perceived representation less realistic. It would therefore be beneficial to provide a volumetric display which renders a clearer volumetric image in which multiple overlayed images are less visible or eliminated.

Summary of the invention

A first aspect of the invention provides an image display screen comprising an image reflecting portion, the image reflecting portion comprising an optically anisotropic layer, the image reflecting portion configured such that light incident thereon is reflected principally by the optically anisotropic layer. The image reflecting portion is typically configured such that light incident thereon is reflected away from said image reflecting portion principally by said optically anisotropic layer.

The image display screen is typically a projection screen, that is to say that the image display screen is typically configured to display an image which is projected thereon. The image reflecting portion of the image display screen is typically configured to reflect an image projected thereon. The image reflecting portion therefore typically reflects light (i.e. visible light typically having a wavelength between 390 nm and 700 nm) which is shone onto said image reflecting portion from an image projector, the image reflecting portion typically thereby reflecting an image projected by the image projector onto said image reflecting portion. Because the image reflecting portion comprises an optically anisotropic layer, reflection of incident light from the image reflecting portion typically differs in different directions, for example in different reflection planes. For example, the image reflecting portion (i.e. the optically anisotropic layer) may be configured to reflect incident light through a first range of reflection angles within a first reflection plane and through a second range of reflection angles within a second reflection plane inclined with respect to (e.g. substantially perpendicular to) said first reflection plane. It may be that said first range of reflection angles is broader than said second range of reflection angles. The optically anisotropic layer may therefore, through reflection, modify an image projected thereon. Additionally and/or alternatively, the optically anisotropic layer may determine a range of viewing angles (e.g. a range of viewing angles in each of said first and/or second reflection planes) through which an image (projected onto and reflected by said optically anisotropic layer) is typically visible by an observer. The optically anisotropic layer may be configured to achieve more than one such optical effect. The structure and/or composition of the optically anisotropic layer is typically selected (i.e. configured) for one or more chosen optical effects.

Because the image reflecting portion of the image display screen is configured such that light incident thereon is reflected principally by the optically anisotropic layer, there are typically fewer distortions or aberrations visible in an image reflected by said image reflecting portion. For example, light incident on image reflecting portions of existing image display screens comprising one or more optically anisotropic layers is typically reflected significantly by more than one surface, interface or structure in said image reflecting portions. When an image is reflected significantly by more than one surface, interface or structure in said image reflecting portions, the reflected image visible by the observer is typically distorted (for example, the image may be blurry or smeared, or a double image or multiple superimposed or partially displaced images may be visible). This degradation in the visible reflected image is typically most problematic when the image display screen forms part of a volumetric display apparatus (for example when said image display screen is a rotatable image display screen configured to rotate about an axis such that a projected image is reflected and therefore visible through a range of viewing angles, e.g. through a 360° viewing angle), the clarity of volumetric images reflected from such volumetric displays typically depending on careful calibration of the optically anisotropic layer(s). By ensuring that incident light is reflected principally by the optically anisotropic layer, the image display screen of the present invention is therefore more suited for use in such volumetric displays where reflection of a clear, sharp image is vital to achieve a realistic volumetric effect.

In use, the image display screen is typically positioned and oriented relative to an image projector such that the image reflecting portion at least partially faces the image projector. The image display screen is typically positioned and oriented such that (a substantial proportion of) light emitted by the image projector (in a principal projection direction) is incident on the image reflecting portion such that said incident light may be reflected by said image reflecting portion. The image display screen therefore typically comprises an outward facing surface (i.e. a forward facing surface) which is a surface of said image display screen which typically (at least partially) faces towards the image projector when in use. The outward facing surface of the image display screen may be a surface of said image display screen which is (on average) closest to the image projector when in use. Similarly, the image reflecting portion typically comprises an outward facing surface (i.e. a forward facing surface) which is a surface of said image reflecting portion which typically (at least partially) faces towards the image projector when in use. The outward facing surface of the image reflecting portion may be a surface of said image reflecting portion which is (on average) closest to the image projector when in use. Light emitted by the image projector and incident on said image reflecting portion is typically first incident on the outward facing surface of said image reflecting portion. The outward facing surface of the image reflecting portion is typically an external surface of said image reflecting portion. Additionally and/or alternatively, the optically anisotropic layer typically comprises an outward facing surface (i.e. a forward facing surface) which is a surface of said optically anisotropic layer which typically (at least partially) faces towards the image projector when in use. The outward facing surface of the optically anisotropic layer may be a surface of said optically anisotropic layer which is (on average) closest to the image projector when in use. Light emitted by the image projector and incident on said optically anisotropic layer is typically first incident on the outward facing surface of the optically anisotropic layer.

It may be that the external surface of the image reflecting portion is formed by the outward facing (i.e. forward facing) surface of the optically anisotropic layer. Said outward facing (i.e. forward facing) surface of the optically anisotropic layer forming the external surface of the image reflecting portion may therefore be an external surface of said optically anisotropic layer. Nevertheless, it may be that one or more additional layers are provided on (e.g. on top of) the outward facing (i.e. forward facing) surface of the optically anisotropic layer such that said outward facing surface is not an external surface of said optically anisotropic layer or of the image reflecting portion.

The image reflecting portion (e.g. the outward facing surface of the image reflecting portion) typically extends across (e.g. forms) a substantial area of the image display screen (e.g. across a substantial area of the outward facing surface of the image display screen). It may be that the image reflecting portion (e.g. the outward facing surface of the image reflecting portion) extends across (e.g. forms) a majority of (e.g. 90% of the area of) the image display screen (e.g. across a majority of (e.g. 90% of the area of) the outward facing surface of the image display screen). It may be that the image reflecting portion (e.g. the outward facing surface of the image reflecting portion) extends across (e.g. forms) the entirety of the image display screen (e.g. across the entirety of the outward facing surface of the image display screen).

The optically anisotropic layer (e.g. the outward facing surface of the optically anisotropic layer) typically extends across (e.g. forms) a substantial area of the image reflecting portion (e.g. across a substantial area of the outward facing surface of the image reflecting portion). It may be that the optically anisotropic layer (e.g. the outward facing surface of the optically anisotropic layer) extends across (e.g. forms) a majority of (e.g. 90% of the area of) the image reflecting portion (e.g. across a majority of (e.g. 90% of the area of) the outward facing surface of the image reflecting portion). It may be that the optically anisotropic layer (e.g. the outward facing surface of the optically anisotropic layer) extends across (e.g. forms) the entirety of the image reflecting portion (e.g. across the entirety of the outward facing surface of the image reflecting portion).

The optically anisotropic layer (e.g. the outward facing surface of the optically anisotropic layer) typically extends across (e.g. forms) a substantial area of the image display screen (e.g. across a substantial area of the outward facing surface of the image display screen). It may be that the optically anisotropic layer (e.g. the outward facing surface of the optically anisotropic layer) extends across (e.g. forms) a majority of (e.g. 90% of the area of) the image display screen (e.g. across a majority of (e.g. 90% of the area of) the outward facing surface of the image display screen). It may be that the optically anisotropic layer (e.g. the outward facing surface of the optically anisotropic layer) extends across (e.g. forms) the entirety of the image display screen (e.g. across the entirety of the outward facing surface of the image display screen).

It may be that the image reflecting portion is further configured to attenuate reflection of light transmitted through said optically anisotropic layer. That is to say the image reflecting portion may be further configured to attenuate secondary reflections of light transmitted through said optically anisotropic layer, wherein primary reflections of light comprise reflections of light by the optically anisotropic layer and wherein secondary reflections of light comprise reflections of light (which has been transmitted through the optically anisotropic layer) by another (different) layer of the image reflecting portion or by an interface between the optically anisotropic layer and said another (different) layer of the image reflecting portion.

It may be that the image reflecting portion is configured such that light incident thereon is reflected (in a forwards direction, i.e. away from the image reflecting portion) principally by a reflecting surface of the optically anisotropic layer. The reflecting surface of the optically anisotropic layer may be the outwards facing (i.e. forwards facing) surface of the optically anisotropic layer. The reflecting surface of the optically anisotropic layer may be the external surface of the image reflecting portion (i.e. the external surface of the optically anisotropic layer forming said external surface of the image reflecting portion).

The reflecting surface of the optically anisotropic layer may be a rearwards facing surface of the optically anisotropic layer. The rearwards facing surface of said optically anisotropic layer is typically a surface of said optically anisotropic layer opposite said outward facing surface of said optically anisotropic layer and is typically provided further away from the image projector than the outward facing surface of said optically anisotropic layer when in use. When the reflecting surface of the optically anisotropic layer is the rearwards facing surface of said optically anisotropic layer, the image reflecting portion is typically configured such that light incident thereon is initially transmitted through the forwards facing surface of the optically anisotropic layer and is subsequently reflected principally by the rearwards facing surface of said optically anisotropic layer.

The reflecting surface of the optically anisotropic layer may be an anisotropic surface. The reflecting surface of the optically anisotropic layer is typically an anisotropically reflecting surface. For example, a structural and/or compositional variation of said reflecting surface of said optically anisotropic layer may be configured such that said reflecting surface is an anisotropically reflecting surface. The anisotropically reflecting surface is typically configured such that a first light ray incident at a first position on said anisotropically reflective surface in a first direction at first angle of incidence will be reflected differently from a different second light ray incident at a second position on said anisotropically reflective surface in a second direction at second angle of incidence. For example, said first ray may be reflected diffusely (i.e. over a relatively broad range of reflection angles) and said second ray may be reflected specularly (i.e. through a relatively narrow range of reflection angles, preferably through one reflection angle equal to said second angle of incidence). Alternatively, it may be that while the anisotropically reflective surface (e.g. the (scale of the) structure of the anisotropically reflective surface) is configured such that each individual light ray incident thereon is reflected specularly, said anisotropically reflective surface may be further configured such that a first incident light ray and an adjacent second incident light ray, said first and second light rays being parallel, are reflected through different angles of reflection.

When the distance between adjacent parallel light rays, which are reflected individually specularly through different angles of reflection, is less than a characteristic dimension of each image pixel projected by the image projector onto the image reflection portion, each image pixel will be effectively reflected diffusely by the image reflection portion.

It may be that the image reflecting portion comprises a reflection attenuating layer. Said reflection attenuating layer may be a secondary reflection attenuating layer configured to attenuate secondary reflections of light transmitted through (i.e. which has been previously transmitted through) the optically anisotropic layer. The reflection attenuating layer may extend across a substantial area (e.g. a majority of, such as at least 90% of the area of, for example the entirety of) the image reflecting portion of the image display screen. The reflection attenuating layer typically extends across the image reflection portion of the image display screen below (i.e. rearwards of) the optically anisotropic layer. It may be that the reflection attenuating layer is configured to attenuate reflections of light at an interface between said reflection attenuating layer and said optically anisotropic layer. Additionally or alternatively, it may be that said reflection attenuating layer is configured to attenuate reflection of light at an interface between the reflection attenuating layer and another, different layer (i.e. a third layer different from both said reflection attenuating layer and said optically anisotropic layer). It may be that the reflection attenuating layer is configured to attenuate reflection of light transmitted through the optically anisotropic layer and transmitted (at least partially, for example at least part of the way) through the reflection attenuating layer. It may be that the reflection attenuating layer is pigmented such that said reflection attenuating layer typically absorbs a substantial percentage (e.g. more than 30%, typically more than 50%, even more typically more than 70%) of light incident on the image reflecting portion of the image display which is transmitted to (i.e. reaches) said reflection attenuating layer, thereby preventing reflection of the absorbed light. By reducing secondary reflection of light, the reflection attenuating layer typically results, in use, in a clearer image formed principally by primary reflection of light by the optically anisotropic layer and visible by an observer.

It may be that the image reflecting portion comprises a contrast layer (different from said optically anisotropic layer). The contrast layer typically extends across a substantial area of (e.g. across the majority of, for example across at least 90% of the area of, such as across the entirety of) the image reflecting portion of the image display screen. The contrast layer typically extends across the image reflecting portion of the image display screen below (i.e. rearwards of) the optically anisotropic layer. The contrast layer, in use, typically provides optical contrast for the image reflected by the image reflecting portion of the image display screen and visible by an observer. For example, the contrast layer may comprise one or more pigments (i.e. the contrast layer may be at least partially pigmented)). The contrast layer may be darkly pigmented (i.e. the contrast layer may appear substantially grey or black). The pigmented (e.g. coloured) contrast layer may provide an image background colour visible by an observer. When an image recorded against a background similar in colour to (i.e. the same colour as) the image background colour (produced by the contrast layer) is projected onto the image reflecting portion of said image display screen comprising said contrast layer, the reflected image perceived by an observer typically appears of higher contrast, allowing the observer to perceive fine detail in the reflected image. This perceived contrast effect results in the observer finding the reflected image to be more ‘realistic’, i.e. more similar to viewing a real world object, for example, than an artificial image of said object.

It may be that the image reflecting portion comprises a diffusely reflective layer (different from said optically anisotropic layer). The diffusely reflective layer typically extends across a substantial area of (e.g. across the majority of, for example across at least 90% of the area of, such as across the entirety of) the image reflecting portion of the image display screen. The diffusely reflective layer typically extends across the image reflecting portion of the image display screen below (i.e. rearwards of) the optically anisotropic layer. The diffusely reflective layer is typically configured to reflect incident light diffusely, that is to say over a relatively wide range of reflection angles (i.e. over a range of angles of width typically greater than 10°, more typically greater than 20° or even more typically greater than 30°). In use, the diffusely reflective layer typically reduces specular secondary reflection of light from the image reflecting portion of the image display screen, reducing any double- (or multiple-) image effects which can be produced by specular (i.e. mirror-like) reflection of light rays forming the image not reflected by the optically anisotropic layer.

It may be that the optically anisotropic layer is provided (directly) on top of (i.e. forwards of) a backing. It may be that the optically anisotropic layer is formed (directly) on top of (i.e. forwards of) said backing. It may be that the optically anisotropic layer is integrally formed with said backing. The backing typically extends across a substantial area of (e.g. across the majority of, for example across at least 90% of the area of, such as across the entirety of) the image reflecting portion of the image display screen. The backing further typically extends below (i.e. rearwards of) a substantial area of (e.g. below the majority of, for example below at least 90% of the area of, such as below the entirety of) the optically anisotropic layer.

It may be that the backing is configured to attenuate reflection of light transmitted through the optically anisotropic layer. It may be that the backing comprises (e.g. consists of) the reflection attenuating layer. Additionally or alternatively, it may be that the backing comprises (e.g. consists of) the contrast layer. It may be that the backing is diffusely reflective. Additionally or alternatively, it may be that the backing comprises (e.g. consists of) the diffusely reflective layer.

The image reflecting portion may comprise one or more pigments (i.e. the image reflecting portion may be (at least partially) pigmented). The backing may comprise one or more pigments (i.e. the backing may be (at least partially) pigmented). The backing may be darkly pigmented (i.e. the backing may appear substantially grey or black). The optically anisotropic layer may comprise one or more pigments (i.e. the optically anisotropic layer may be (at least partially) pigmented). The optically anisotropic layer may be darkly pigmented (i.e. the optically anisotropic layer may appear substantially grey or black). Pigmentation of the image reflecting portion, such as pigmentation of the backing and/or the optically anisotropic layer, typically results, in use, in an improved perceived contrast in the reflected image.

When the optically anisotropic layer is provided directly on top of (i.e. forward of), or is formed directly on top of (i.e. forwards of), or is integrally formed with, the backing, an (direct) interface is typically provided between said optically anisotropic layer and said backing. In such embodiments, the backing typically has an (optical) refractive index (in the visible spectrum) of greater than 1, or more typically greater than 1.000277. The (optical) refractive index (in the visible spectrum) of the backing is therefore typically greater than the (optical) refractive index (in the visible spectrum) of vacuum, or more typically greater than the (optical) refractive index (in the visible spectrum) of air (at standard temperature and pressure). The (optical) refractive index (in the visible spectrum) of the backing is typically greater than the (optical) refractive index (in the visible spectrum) of air at the temperature and pressure at which the image display screen is typically used. Preferably, the (optical) refractive index (in the visible spectrum) of the backing is typically similar to (e.g. (approximately) equal to) the (optical) refractive index (in the visible spectrum) of the optically anisotropic layer. Because the refractive index of the backing is typically at least greater than the refractive index of air, total internal reflection of light transmitted through the optically anisotropic layer and incident on the interface between said optically anisotropic layer and the backing is typically reduced (in comparison to embodiments in which the rearwards surface of the optically anisotropic layer is an internal surface, e.g. in which an air gap is provided between the optically anisotropic layer and any other layers (including the backing)). By reducing total internal reflection of light at the interface between the optically anisotropic layer and the backing, secondary reflections of light are reduced, resulting, in use, in fewer double- or multiple-images perceived by an observer. The closer the refractive index of the backing to the refractive index of the optically anisotropic layer, the typically greater the reduction in total internal reflection of light at the interface. If the refractive index of the backing is in fact greater than the refractive index of the optically anisotropic layer, total internal reflection of light at said interface is typically essentially eliminated.

It may be that the optically anisotropic layer comprises at least one of the following: a lenticular diffuser and/or reflector, a lenslet array diffuser and/or reflector, a holographic diffuser and/or reflector. For example, the optically anisotropic layer may be a layer of lenticular diffuser and/or reflector. The optically anisotropic layer may be a layer of a lenslet array diffuser and/or reflector. The optically anisotropic layer may be a layer of a holographic diffuser and/or reflector.

The lenticular diffuser and/or reflector typically comprises an array of aligned elongate lenses. The lenslet array diffuser and/or reflector typically comprises an (regular, i.e. periodic) array of lenses. The holographic diffuser and/or reflector typically has a regular (i.e. periodic) variation in structure (e.g. surface structure) and/or refractive index and/or composition.

It may be that the optically anisotropic layer comprises an array of aligned, elongate lenses. Said elongate lenses may be substantially prismatic. Said elongate lenses may be substantially cylindrical. Said elongate lenses may each be formed in the shape of a portion of a cylinder. Said elongate lenses may each be formed in the shape of a portion of an elliptical cylinder. Said elongate lenses may be formed in the shape of a portion of a polygonal prism such as a triangular prism, a square prism, a rectangular prism or a pentagonal prism. It may be that the optically anisotropic layer comprises an array of aligned, rounded rods.

It may be that the surface of each elongate lens is substantially curved in a first direction substantially perpendicular to the longitudinal axis of said elongate lens. It may be that the surface of each elongate lens is substantially flat (i.e. not curved) in a second direction substantially parallel to the longitudinal axis of said elongate lens. The profile of the reflecting surface of the optically anisotropic layer in cross section through a plane substantially perpendicular to the longitudinal axis of each elongate lens typically varies along a direction in said plane parallel to said reflecting surface (i.e. the profile is not flat).

It may be that the optically anisotropic layer (e.g. the lenticular diffuser and/or reflector) comprises an array of aligned, (substantially) hemicylindrical lenses. Said (substantially) hemicylindrical lenses are typically mutually parallel. Each said (substantially) hemicylindrical lens is typically elongate and comprises a longitudinal axis. The (substantially) hemicylindrical lenses are typically aligned such that the longitudinal axis of each said lens is parallel to the longitudinal axis of each other adjacent (substantially) hemicylindrical lens.

It may be that the hemicylindrical lenses are aligned such that a longitudinal axis of each said lens is substantially horizontal. For example, it may be that the image display screen is mounted (e.g. on a mount) configured such that image display screen is rotatable (with said mount) about a substantially vertical axis and that the hemicylindrical lenses are aligned such that the longitudinal axis of each said lens is substantially horizontal (i.e. perpendicular to the substantially vertical axis of rotation).

The optically anisotropic layer is typically configured to reflect incident light (substantially) diffusely within a first reflection plane and (substantially) specularly within a second reflection plane inclined with respect to (e.g. substantially perpendicular to) said first reflection plane. In embodiments in which the optically anisotropic layer comprises an array of aligned, (substantially) hemicylindrical lenses, light incident on said optically anisotropic layer is typically reflected (substantially) specularly within a first reflection plane (substantially) perpendicular to the reflecting surface of the optically anisotropic layer and (substantially) perpendicular to the longitudinal axis of each said (substantially) hemicylindrical lens, and (substantially) diffusely within a second reflection plane (substantially) perpendicular to the reflecting surface of the optically anisotropic layer and (substantially) perpendicular to said first reflection plane.

It may be that a rearward facing (e.g. internal) surface of the optically anisotropic layer is (directly) coated with paint (e.g. acrylic paint). A (direct) interface is therefore typically provided between said optically anisotropic layer and said paint. The paint may comprise one or more pigments (i.e. the paint may be (at least partially) pigmented). The paint may be darkly pigmented (i.e. the paint may appear substantially grey or black). The paint may comprise a plurality of reflective particles such as a plurality of metal (e.g. aluminium) particles.

A second aspect of the invention provides image display apparatus comprising the image display screen according to the first aspect of the invention. The image display screen may be rotatable. It may be that the image display screen is rotatable about a rotation axis which extends through said image display screen. It may be that the rotation axis about which the image display screen is rotatable intersects the image reflecting portion of the image display screen at an oblique angle. It may be that said rotation axis which intersects the image reflecting portion of the image display screen at an oblique angle intersects said image reflecting portion at a point of intersection displaced from the centre of said image reflecting portion. The centre of the image reflecting portion may be, for example, the centroid (i.e. the geometric centre) of the image reflecting portion, that is to say the centre of the image reflecting portion may be the arithmetic mean position of all points forming the image reflecting portion. The centre of the image reflecting portion may be a point on said image reflecting portion equidistant from each point on a peripheral edge (e.g. perimeter) of said image reflecting portion. For example, the image reflecting portion may be elliptical in shape (i.e. the peripheral edge (perimeter) of the image reflecting portion may form an ellipse), and the centre of the image reflecting portion may be the centre of said ellipse, i.e. the point of intersection of the major and minor axes of said ellipse. The centre of said elliptical image reflecting portion may therefore be also the midpoint between first and second foci defining the elliptical shape.

The image display screen may be rotatably coupled to one or more bearings such that said image display screen is rotatable about said rotation axis. The image display screen may be coupled to rotation means (i.e. a rotation mechanism such as a motor) configured to rotate, in use, the image display screen on said bearings about said rotation axis.

The image display apparatus may comprise an image projector configured to project an image in a principal projection direction onto the image display screen. The image display screen may be oriented such that light emitted by the projector and forming the projected image is incident on the image reflecting portion of the image display screen at an (acute) angle of between 35° and 55°.

It may be that the anisotropic layer of the image reflecting portion of the image display screen comprises an array of aligned, (substantially) hemicylindrical lenses, said (substantially) hemicylindrical lenses being aligned such that a longitudinal axis of each said lens is substantially perpendicular to the rotation axis about which the image display screen is rotatable. It may be that the (substantially) hemicylindrical lenses are aligned such that the longitudinal axis of each said lens is substantially perpendicular to the principal projection direction.

It may be that the image projector is a video projector configured to project a video output. By video we refer to moving visual images. The images may be interactive. The image display apparatus may comprise a user input interface to receive control instructions from a user and a controller (comprising one or more processors in electronic communication with memory which stores a computer program executed in use by the one or more processors) which controls the images displayed by the image projector responsive to control instructions received from a user through the user input interface. The user input interface may for example comprise a keyboard, computer mouse, proximity server, position sensor, movement sensor, gesture sensor (for example a Microsoft ® Kinect ® or Leap Motion TM sensor (available from Microsoft, Redmond and Leap Motion, San Francisco respectively)), worn or hand-held controller (which may comprise a position sensor, one or more accelerometers etc.) For example, the image display apparatus may display an object and the displayed view of the object may be rotated responsive to control instructions received through the user input interface. It may be that the image projector is a digital video projector configured to project a digital video output. The images which are projected may be of objects.

A third aspect of the invention provides an image display screen comprising an image reflecting portion comprising a lenticular reflector (e.g. a lenticular diffuser such as a lenticular lens (array)) and a layer of paint. An outward surface of the lenticular reflector typically forms a substantial portion (e.g. a majority, such as an entirety) of an external surface of the image reflecting portion. The layer of paint typically extends directly beneath a substantial portion (e.g. a majority, such as an entirety) of a rearwards (e.g. internal) surface of the lenticular reflector, a direct interface being thereby provided between the lenticular reflector and the layer of paint. The lenticular reflector is typically provided (directly) on top of the layer of paint.

A fourth aspect of the invention provides image display apparatus comprising a rotatable image display screen comprising an image reflecting surface, the rotatable image display screen being rotatable about a rotation axis which extends through said rotatable image display screen and intersects the image reflecting surface at an oblique angle at a point of intersection displaced from the centre of said image reflecting surface.

During a rotation cycle of the rotatable image display screen about said rotation axis, different points on a peripheral edge of said image reflecting surface (i.e. on a perimeter of said image reflecting surface) typically trace (non-intersecting) paths of differing lengths (e.g. typically circles or portions of circles of differing circumferential path lengths) in space because the image reflecting surface is oriented at said oblique angle to the rotation axis whose point of intersection with said image reflecting surface is displaced from the centre of said image reflecting surface. A three-dimensional surface traced in space by the peripheral edge (e.g. the perimeter) of the image reflecting surface, as the image display screen rotates about said rotation axis, typically forms the shape of a cone. The rotatable image display screen is therefore typically suitable for use with an image projector configured to project a cone of light. In use, the rotatable image display screen is typically positioned relative to the image projector such that, as the image display screen rotates about its rotation axis, a majority (preferably an entirety) of the image reflecting surface is illuminated by the cone of light emitted by the image projector. The majority (preferably the entirety) of said image reflecting surface is typically illuminated by said cone of light emitted by the image projector for a complete rotation cycle of the image display screen about said rotation axis. As the image display screen rotates about the rotation axis, the image (typically the majority of the image, preferably the entirety of the image) projected by the image projector onto said image display screen is typically visible from a range of positions (i.e. through a range of angles) around the image display screen.

The rotation axis typically intersects the image reflecting surface at an oblique angle (e.g. an acute angle) greater than 0° and less than 90°. For example, the rotation axis typically intersects the image reflecting surface at an (acute) angle of between 25° and 65°, or more typically between 35° and 55°, or even more typically between

40° and 50°. It may be that said rotation axis intersects the image reflecting surface at an (acute) angle of (approximately) 45°.

The point of intersection at which the rotation axis intersects the image reflecting surface is typically a point on said surface displaced from the centre of said image reflecting surface, that is to say said point of intersection does not typically lie at the centre of said image reflecting surface. The centre of the image reflecting surface may be, for example, the centroid (i.e. the geometric centre) of the image reflecting surface, that is to say the centre of the image reflecting surface may be the arithmetic mean position of all points on the image reflecting surface. The centre of the image reflecting surface may be a point on said image reflecting surface equidistant from each point on the peripheral edge (e.g. perimeter) of said image reflecting surface. For example, if the peripheral edge (perimeter) of the image reflecting surface is an ellipse, the centre of the image reflecting surface is typically the centre of said ellipse, i.e. the point of intersection of the major and minor axes of said ellipse. The centre of said elliptical image reflecting surface is therefore also typically the midpoint between first and second foci defining the ellipse.

It may be that the rotatable image display screen is rotatably coupled to one or more bearings such that said rotatable image display screen is rotatable about said rotation axis. It may be that the rotatable image display screen is (rotatably) mounted on said one or more bearings. It may be that the one or more bearings define the orientation of the rotation axis about which the image display screen is rotatable.

It may be that the rotatable image display screen is supported by (e.g. attached to) a mount. Said mount and said rotatable image display screen are typically rotatable together about said rotation axis. It may be that said mount is rotatably coupled to one or more bearings. It may be that said mount is (rotatably) mounted on said one or more bearings.

It may be that said rotatable image display screen is rotatably supported by (e.g. mounted on or attached to) a shaft. The shaft and the rotatable image display screen are typically rotatable together about said rotation axis. It may be that said shaft extends longitudinally parallel to said rotation axis. It may be that said shaft extends longitudinally along said rotation axis. It may be that said shaft is rotatably coupled to said one or more bearings. It may be that said shaft is (rotatably) mounted on said one or more bearings, it may be that said shaft extends longitudinally in a substantially vertical direction. It may be that said shaft is mounted on one or more substantially horizontal bearings, the shaft extending longitudinally in a substantially vertical direction perpendicular to said one or more horizontal bearing.

It may be that the image display apparatus further comprises rotation means (e.g. a rotation mechanism) configured to rotate the rotatable image display screen about said rotation axis. It may be that said rotation means (e.g. rotation mechanism) is configured to drive rotation of said image display screen on the bearing to which it is coupled (e.g. mounted) about said rotation axis. It may be that said rotation means (e.g. rotation mechanism) is configured to rotate said image display screen and said mount about said rotation axis. It may be that said rotation means (e.g. rotation mechanism) is configured to rotate said image display screen and said shaft about said rotation axis.

It may be that said rotation means (rotation mechanism) comprises a motor configured to drive rotation of said rotatable image display screen about said rotation axis. It may be that said motor is configured to drive rotation of said image display screen around one or more bearings to which it is coupled (e.g. mounted) about said rotation axis. It may be that said motor is configured to rotate said image display screen and said mount about said rotation axis. It may be that said motor is configured to rotate said image display screen and said shaft about said rotation axis.

It may be that the image display apparatus further comprises a counterbalance coupled to the rotatable image display screen (such that said counterbalance and said rotatable image display screen are rotatable together about said rotation axis). The counterbalance and rotatable image screen may be at opposite ends of a rotatable shaft. The counterbalance may be on the other side of the motor to the rotatable image screen. The counterbalance may be configured (for example, in terms of position, shape, size, and/or mass) such that a combined centre of mass of the rotatable image display screen and said counterbalance is: (i) proximate a bearing, or (ii) at a position which, in projection on the rotation axis, is between two bearings, which may be two bearings of the motor.

The counterbalance may be configured (for example, in terms of position, shape, size, and/or mass) such that a combined centre of mass of the rotatable image display screen and said counterbalance is proximate the rotation axis. The counterbalance may be configured such that the distance between the combined centre of mass and the motor, or the one or more bearings and/or rotation axis is shorter (e.g. less than 25% of, more typically less than 10% of) than the distance between the centre of mass of the rotatable image display screen and the bearing and/or rotation axis. Displacement of said combined centre of mass towards the motor, bearings and/or towards the rotation axis typically results in more stable rotation (i.e. less wobble) of the image display screen about the rotation axis.

It may be that the counterbalance is attached to the mount, the counterbalance being configured such that a combined centre of mass of the rotatable image display screen, the mount and the counterbalance is proximate one or more bearings and/or the rotation axis. It may be that the combined centre of mass of the rotatable image display screen, the mount and the counterbalance is, in projection on the rotation axis, between two spaced apart bearings. This results in more stable rotation (i.e. less wobble) of the image display screen about the rotation axis.

It may be that the counterbalance is (further) configured to lower (a (vertical) height of) the combined centre of mass of the image display screen and the counterbalance or the combined centre of mass of the image display screen, the mount and the counterbalance. Lowering (the (vertical) height of) either combined centre of mass typically results in more stable rotation (i.e. less wobble) of the image display screen about the rotation axis.

It may be that the counterbalance is coupled to (e.g. attached to) the shaft. It may be that the counterbalance is coupled to (e.g. attached to) the mount. For example, it may be that the counterbalance is coupled to (e.g. attached to) an underside of the mount.

It may be that the (external) perimeter (e.g. the peripheral edge) of the image reflecting surface describes (a portion of) a closed conic and/or cylindrical section. For example, it may be that the (external) perimeter (e.g. the peripheral edge) of the image reflecting surface is elliptical. Alternatively, it may be that the (external) perimeter (e.g. the peripheral edge) of the image reflecting surface describes any other section of a cone or cylinder.

It may be that the image reflecting surface is (substantially) planar (i.e. flat). Alternatively, the image reflecting surface may be curved.

It may be that the mount is formed in the shape of a truncated cone or cylinder. For example, it may be that the mount is formed in the shape of a portion of (e.g. a section of) a cone or cylinder. The mount (e.g. an external surface of the mount) may therefore be frustoconical. Alternatively, said mount (e.g. the external surface of the mount) may be cylindrical.

It may be that the image display apparatus further comprises an image projector configured to project an image in a principal projection direction onto the rotatable image display screen. The rotatable image display screen is typically positioned and/or oriented such that light emitted by the projector and thereby forming the projected image is incident on the image reflecting surface at an oblique angle. For example, said light emitted by the projector is typically incident on the image reflecting surface at an (acute) angle of between 25° and 65°, or more typically between 35° and 55°, or even more typically between 40° and 50°. It may be that said light emitted by the projector is incident on the image reflecting surface at an (acute) angle of (approximately) 45°.

The image projector typically emits visible light (i.e. light in the visible spectrum having wavelengths in the range 390nm - 700nm). The image projected by the image projector is typically visible by the human eye.

The principal projection direction is typically the direction along which light is emitted by the image projector at the centre of a cone of projected light. Light emitted by the image projector along said principal projection direction typically forms a central portion of the projected image. The principal projection direction may be the averaged direction in which the image projector projects light.

It may be that the principal projection direction and the rotational axis are substantially parallel. For example, the principal projection direction and the rotation axis typically intersect at an (acute) angle of less than 25°, or more typically less than 15°, or even more typically less than 5°.

The principal projection direction and the rotational axis are typically not collinear. The principal projection direction typically intersects the centre of the image reflecting surface. Consequently, the centre of the projected image is typically coincident with the centre of the image reflecting surface.

It may be that the image reflecting surface comprises (is formed by) an optically anisotropic layer. The optically anisotropic layer is typically the uppermost layer of the image reflecting surface (at least partially e.g. obliquely) facing the image projector. The optically anisotropic layer may be provided on top of one or more base layers.

The optically anisotropic layer typically reflects incident light anisotropically. The optically anisotropic layer may comprise one or more of a lenticular diffuser and/or reflector (i.e. a lenticular lens), a lenslet array diffuser and/or reflector, and/or a holographic diffuser and/or reflector. The optically anisotropic layer may comprise an array of aligned lenses or lenslets. For example, the optically anisotropic layer may comprise an array of aligned, mutually parallel lenses or lenslets. The optically anisotropic layer may comprise an array of aligned, mutually parallel (substantially) hemicylindrical lenses. The optically anisotropic layer may reflect incident light specularly in a first reflection plane and diffusely in a second reflection plane (said first and second planes typically being perpendicular to one another).

One or more of said one or more base layers may comprise (e.g. may be formed by) a contrast layer and/or a reflection attenuation layer (configured to attenuate secondary reflections of light) and/or a diffusely reflective layer. The one or more base layers may comprise one or more pigments. The one or more base layers may comprise a layer of paint comprising one or more pigments, such as a layer of acrylic paint comprising one or more pigments and/or a plurality of reflective particles (such as metallic particles, e.g. aluminium particles).

It may be that the image projector is a video projector configured to project a video output. For example, it may be that the image projector is a digital video projector configured to project digital video output.

A fifth aspect of the invention provides image display apparatus comprising an image projector, an image display screen and an image rotation system, the image projector being configured to project an image along an image projection path and onto the image display screen, the image display screen being configured to rotate about a rotational axis at a principal rotational speed, and the image rotation system being configured to rotate the image projected onto the image display screen at said same principal rotational speed (and in the same direction of rotation, i.e. with the same sense).

Because the image projected onto the image display screen rotates at the same principal rotational speed (and in the direction of rotation) as the image display screen itself, the image reflected by the image display screen visible by an observer is not distorted by the rotation of the image display screen. In particular, the orientation of the image visible by an observer should not be changed by the rotation of the image display screen, such that the same image is visible in its correct orientation from multiple viewing locations around the rotating image display screen.

The image projection path is typically a path along which light emitted by the image projector travels from said image projector to the image display screen. The image projection path is typically the path along which light emitted by the image projector at the centre of a cone of projected light travels from said image projector to the image display screen. Light emitted by the image projector along the image projection path typically forms a central portion of the projected image.

The image projection path may lie along a straight line between the image projector and the image display screen. Alternatively, the image projection path may comprise two or more non-collinear image projection path portions. Each individual projection path portion typically comprises a straight path along which light travels. Individual projection path portions may be connected to another, to thereby form the image projection path, by light redirection means such as reflectors (e.g. mirrors) or optical prisms.

The image display apparatus is typically configured such that the image is projected onto the image display screen in a principal projection direction. The principal projection direction is typically a direction along which light projected by the image projector travels as it is incident on the image display screen. The principal projection direction is typically the direction along which light emitted by the image projector at the centre of the cone of projected light is incident on the image display screen. Light emitted by the image projector incident on the image display screen in the principal projection direction typically forms a central portion of the projected image. For example, it may be that the image projector is configured to project the image onto the image display screen in the principal projection direction. The principal projection direction typically lies along at least a portion of the image projection path. It may be that the principal projection direction lies along the entirety of the image projection path. It may be that the principal projection direction lies along at least a final straight line portion of the image projection path.

The image display screen is typically configured to reflect in a principal reflection direction a substantial portion of the image projected thereupon. Said principal reflection direction is typically inclined with respect to said principal projection direction (i.e. said principal reflection direction is typically not parallel to said principal projection direction). An (acute) angle between the principal reflection direction and the principal projection direction is typically between 25° and 65°, or more typically between 35° and 55°. The (acute) angle between the principal reflection direction and the principal projection direction may be (approximately) 45°.

It may be that the image rotation system is configured to rotate the image projected in the principal projection direction in a plane intersecting said principal projection direction at an (acute) angle of less than 15°, or more typically less than 10°, or even more typically less than 5°. It may be that the image rotation system is configured to rotate the image projected in the principal projection direction in a plane (substantially) perpendicular to said principal projection direction.

It may be that the image rotation system is configured to rotate the image projected onto the image display screen in a plane intersecting the principal projection direction at an (acute) angle of less than 15°, or more typically less than 10°, or even more typically less than 5°. It may be that the image rotation system is configured to rotate the image projected onto the image display screen in a plane (substantially) perpendicular to said principal projection direction.

It may be that the principal projection direction and the rotational axis are substantially parallel. For example, the principal projection direction and the rotation axis typically intersect at an (acute) angle of less than 25°, or more typically less than 15°, or even more typically less than 5°.

The principal projection direction and the rotational axis are typically not collinear. The principal projection direction typically intersects a centre of the image display screen (or the centre of an image reflecting portion thereof). Consequently, the centre of the projected image is typically coincident with the centre of the image display screen (or the centre of said image reflecting portion).

It may be that the image rotation system comprises at least one optical prism. Said at least one optical prism is typically formed of optically transparent material. The term ‘optically transparent material’ will be understood to mean a material capable of allowing (at least a portion of) incident light to pass therethrough (i.e. being light permeable) without scattering the light (substantially). Light passing through an optically transparent material typically obeys Snell’s Law of refraction. The at least one optical prism may be formed of glass, plastic (such as acrylic) or mineral crystalline materials (such as fluorite or quartz) or any other suitable optically transparent material. The at least one optical prism typically comprises two or more flat, polished surfaces capable of refracting incident light.

The at least one optical prism may be provided in the image projection path between the image projector and the image display screen such that light travelling from the image projector along the image projection path towards the image display screen passes through said at least one optical prism. The at least one optical prism may be configured to rotate at a secondary rotational speed such that the image transmitted through the prism, and subsequently projected onto the image display screen, rotates at the principal rotational speed. The at least one optical prism is typically configured to rotate at said secondary rotational speed such that the image transmitted through the prism, and subsequently projected onto the image display screen, rotates at the principal rotational speed in a plane (substantially) perpendicular to the image projection path in the vicinity of the prism (i.e. passing through said prism).

It may be that the secondary rotational speed at which the at least one optical prism is configured to rotate is equal to the principal rotational speed. Alternatively, it may be that the secondary rotational speed at which the at least one optical prism is configured to rotate is different to the principal rotational speed. For example, it may be that the at least one optical prism is a Dove prism (i.e. a truncated right-angle prism) configured to rotate at a secondary rotational speed which is (approximately) one half the principal rotational speed.

It may be that the image rotation system comprises two or more (such) optical prisms provided in the image projection path between the image projector and the image display screen.

It may be that the image rotation system comprises one or more reflectors (i.e. mirrored surfaces, e.g. mirrors) provided in the image projection path between the image projector and the image display screen. It may be that said one or more reflectors (i.e. mirrored surfaces, e.g. mirrors) are configured (i.e. positioned and/or oriented) to direct light along the image projection path from the image projector towards the image display screen.

It may be that the image display screen is rotatably coupled to a bearing such that said image display screen is rotatable about said rotation axis. It may be that the image display screen is (rotatably) mounted on said bearing. It may be that the bearing defines the orientation of the rotation axis about which the image display screen is rotatable.

It may be that the image display screen is supported by (e.g. attached to) a mount, said mount and said image display screen being rotatable together about said rotation axis. It may be that said mount is rotatably coupled to the bearing. It may be that said mount is (rotatably) mounted on said bearing.

It may be that said image display screen is rotatably supported by (e.g. mounted on or attached to) a shaft, the shaft and the rotatable image display screen being rotatable together about said rotation axis. It may be that said shaft extends longitudinally parallel to said rotation axis. It may be that said shaft extends longitudinally along said rotation axis. It may be that said shaft is rotatably coupled to said bearing. It may be that said shaft is (rotatably) mounted on said bearing.

It may be that the image display apparatus further comprises rotation means (e.g. a rotation mechanism) configured to rotate the image display screen about said rotation axis. It may be that said rotation means (e.g. rotation mechanism) is configured to drive rotation of said image display screen on the bearing to which it is coupled (e.g. mounted) about said rotation axis. It may be that said rotation means (e.g. rotation mechanism) is configured to rotate said image display screen and said mount about said rotation axis. It may be that said rotation means (e.g. rotation mechanism) is configured to rotate said image display screen and said shaft about said rotation axis.

It may be that said rotation means (rotation mechanism) comprises a motor configured to drive rotation of said image display screen about said rotation axis. It may be that said motor is configured to drive rotation of said image display screen on the bearing to which it is coupled (e.g. mounted) about said rotation axis. It may be that said motor is configured to rotate said image display screen and said mount about said rotation axis. It may be that said motor is configured to rotate said image display screen and said shaft about said rotation axis.

It may be that the rotation means (rotation mechanism, e.g. motor) is further configured to drive rotation of the at least one optical prism. It may be that the rotation means (rotation mechanism, e.g. motor) is configured to drive rotation of the at least one optical prism about an axis lying in the image projection path (in the vicinity of said prism). It may be that the rotation means (rotation mechanism, e.g. motor) is configured to drive rotation of the at least one optical prism about an axis lying parallel to the image projection path.

It may be that the axis about which the rotation means is configured to drive rotation of the at least one optical prism and the principal projection direction are collinear. It may be that said axis about which the rotation means is configured to drive rotation of the at least one optical prism passes through a centre of said prism. It may be that said axis about which the rotation means is configured to drive rotation of the at least one optical prism passes through a centre of at least one polished face of said prism.

It may be that the image projector is configured to project the image (substantially) vertically downwards onto the image display screen. For example, it may be that the principal projection direction is (substantially) vertical. It may be that the image projector is provided (substantially) vertically above the image display screen.

It may be that the image projector is configured (e.g. positioned and/or oriented) to project the image (substantially) vertically downwards onto the image display screen and that the image reflecting portion of the image display screen is inclined at an angle of between 35° and 55° with respect to the vertical, thereby reflecting in a (substantially) horizontal direction a substantial portion (e.g. a majority, preferably the entirety) of the image projected onto said image display screen.

It may be that the image projector is a video projector configured to project a video output. For example, it may be that the image projector is a digital video projector configured to project digital video output.

A sixth aspect of the invention provides a method for displaying a volumetric (video) image, the method comprising: rotating the image display screen according to any one preceding aspect of the invention about a rotation axis; and projecting an (video) image onto said image display screen by way of an (video) image projector. It may be that the rotation axis is a substantially vertical rotation axis. It may be that the method comprises the step of rotating the image display screen according to any one preceding aspect of the invention about the vertical rotation axis. It may be that the (video) image projector is configured to project an (video) image (downwards) in a substantially vertical projection direction onto the image display screen. It may be that the method comprises the step of projecting the (video) image (downward) in a substantially vertical projection direction onto the image display screen.

Optional features of any one aspect of the invention are, *mutatis mutandis*, optional features of any other aspect of the invention.

Description of the Drawings

An example embodiment of the present invention will now be illustrated with reference to the following Figures in which:

Figure 1 is a perspective view of a volumetric display unit;

Figure 2 is a cross-sectional view through the volumetric display unit of Figure 1;

Figure 3 is a perspective view of the volumetric display unit of Figure 1 in use reflecting an image projected by a video projector towards an observer;

Figure 4 is a detailed view of an image display screen of the volumetric display unit of Figure 1;

Figure 5 is a cross-sectional view of an external surface of a portion of the image display screen of Figure 4;

Figure 6 is a schematic illustration of parallel light rays being reflected by the external surface of Figure 5;

Figure 7 is a further schematic cross-sectional illustration of parallel light rays being reflected by the external surface of Figure 5 in a different orientation to Figure 6;

Figure 8 is a cross-sectional illustration of a light ray transmitted into one lenticular lens forming a portion of the external surface of Figure 5; and

Figure 9 is a schematic view of the volumetric display unit of Figure 1 in use in a different configuration to that illustrated in Figure 3.

Detailed Description of an Example Embodiment

A volumetric display unit 1 as shown in Figure 1 comprises a display screen 2 bolted to an upper surface 3 of a rotatable mount 4 supported on a base unit 5. The rotatable mount 4 is generally cylindrical in shape, the cylindrical body of the mount 4 extending longitudinally in a substantially vertical direction upwards from the base 5. The upper surface 3, and therefore also the display screen 2, are inclined at an angle of approximately 45° to a longitudinal axis 6 of the cylindrical mount 4 (see Figure 2). The upper surface 3 and the display screen 2 are therefore also inclined at an angle of approximately 45° to the vertical. The longitudinal axis 6 of the mount 4 is substantially perpendicular to a bearing surface 7 of the base 5.

As illustrated schematically in Figure 2, the mount 4, is fixedly attached to a rotation shaft 8 at the upper surface 3. The mount 4 and the display screen 2 are therefore rotatable about a rotation axis 9 which extends substantially vertically along a longitudinal axis 9 of the rotation shaft 8, parallel to the longitudinal axis 6 of the mount 4. The upper surface 3 of the mount 4 is fixedly mounted on the rotation shaft 8 such that the longitudinal axis 6 of the mount 4 and the rotation axis 9 are not collinear. Consequently, longitudinal axis 6 of the mount 4 passes through a centre point 10 of the display screen 2, whereas the rotation axis 9 intersects the display screen 2 at a point of intersection 11 displaced from centre point 10.

The rotation shaft 8 is mounted on two bearings 12 which are part of a motor 14 coupled to a power source (not shown). A counterweight 15 is fixedly attached to a bottom end 16 of the rotation shaft 8. The counterweight 15 is located on a side of the rotation shaft 8 further from the longitudinal axis 6 of the mount 4 and extends to an end 13 which aligns with the highest point of the upper surface 3. In use, the motor 14 drives rotation of the rotation shaft 8 in the bearings 12, about the rotation axis 9, thereby also driving rotation of the mount 4 and the display surface 2 about said substantially vertical rotation axis 9 on the bearing surface 7.

Figure 3 illustrates use of the volumetric display unit 1 to display a volumetric video image. The volumetric display unit 1 is positioned on a substantially horizontal surface 17 of a table 18. A digital video projector 19 is positioned vertically above the volumetric display unit 1 (for example, the digital video projector 19 is mounted on a ceiling vertically above the volumetric display unit 1). The digital video projector 19 projects a video image by the medium of visible light. In particular, the digital video projector 19 projects a cone of light 20 substantially vertically downwards onto the volumetric display unit 1. The volumetric display unit 1 and the digital video projector 19 are positioned and oriented relative to one another such that the projected cone of light 20 illuminates the entire image display screen 2 and such that the entire width of the cone of light 20 is intercepted by the image display screen 2. Because the image display screen 2 is inclined at approximately 45° to the vertical direction in which the video projector 19 projects the cone of light 20, the image display screen 2 reflects a portion of the light incident thereon from the cone of light 20 in a reflection direction away from the image display screen 2 and away from the digital video projector 19. An image projected onto the image display screen 2 by the video projector 19 is therefore visible by an observer 21 positioned in front of the image display screen 2.

When the motor 14 is connected to the power supply and switched on, the motor 14 drives rotation of the image display screen 2 about the rotation axis 9 in a rotational direction indicated by arrow 22. Because the rotation axis 9 is not collinear with the longitudinal axis 6 of the mount 4 (passing through the centre 10 of the image display screen 2), a peripheral edge 23 of the display screen 2 traces a conical surface in space as the display screen 2 rotates. The display screen 2 is therefore fully illuminated by the cone of light 20 projected by the video projector 19 throughout a full rotation cycle of the display screen 2 about the rotation axis 9. Similarly, the entire cone of light 20 is therefore also incident on the display screen 2 throughout said full rotation cycle.

As the video display screen 2 rotates about the rotation axis 9, the reflected image is visible from multiple locations around the volumetric display unit 1. When the display screen 2 rotates at a rotation speed greater than a threshold rotation speed, the reflected image is continuously visible by different human observers simultaneously from multiple viewpoints, i.e. all locations around the volumetric display unit 1, due to human persistence of vision. The video display screen 2, in use, typically rotates at a rotation speed of 700 to 2500 rpm, for example 1250 rpm. As the video display screen 2 rotates about the rotation axis 9, the counterbalance 15 reduces unstable rotation (i.e. wobble) of the screen 2 because the mass of said counterbalance 15 is chosen to ensure that the combined centre of the mass of the display screen 2, the mount 4, the rotation shaft 8 and the counterweight 15 is within a horizontal plane passing between bearings 12. Reduction in unstable rotation of the display screen 2 results in reduction of wobble or blurring of the image reflected by said display screen 2.

The display screen 2 is shown in more detail in Figure 4. An external principal reflecting surface 24 of display screen 2 is formed from a layer of lenticular lenses 25. The layer of lenticular lenses 25, as shown in more detail in Figure 5, is formed from polyethylene terephthalate (PET). The layer of lenticular lenses 25 comprises a periodic array of hemicylindrical lenses 26. The hemicylindrical lenses 26 are mutually aligned such that a longitudinal axis of each lens 26 is parallel to the longitudinal axis of each adjacent lens 26, and the spacing between each adjacent lens 26 is generally uniform across the layer 25. For example, the hemicylindrical lenses 26 typically form the lenticular lens layer 25 at a density of 290 lines (i.e. lenses) per inch (measured in a direction in the plane of the lenticular lens layer 25 and perpendicular to the longitudinal axis of each individual hemicylindrical lens 26). The lenticular lens layer 25 is fixedly attached to the display screen 2 such that the longitudinal axis of each hemicylindrical lens 26 is approximately horizontal.

The lenticular lens layer 25 is provided directly on top of a layer of black acrylic paint 28 in which reflective aluminium particles 29 are dispersed. A smooth (i.e. sharp) interface 30 separates the lenticular lens layer 25 from the layer of paint 28.

As illustrated in Figure 6, in use, light which is incident on lenticular lens layer 25 (which forms the external principal reflecting surface 24 of the display screen 2) from the cone of projected line 20 is partially reflected by said external surface 24. Due to the periodic variation in the curvature of the external surface 24 in any transverse plane (a transverse plane being any plane perpendicular to the longitudinal axis of each hemicylindrical lens 26), light rays 31 (indicated in Figure 6 by full arrows) which are parallel in said transverse plane and which are incident on the external surface 24 will be partially reflected by said external surface 24 over a range of reflection angles (i.e. over a range of reflection directions) in said transverse plane (reflected rays are indicated in Figure 6 by dashed arrows 32). This is because the local angle of incidence in the transverse plane for each incident ray 31 varies significantly across the external surface 24. Since the layer of lenticular lenses 25 is arranged such that the longitudinal axes of the lenticular lenses 26 are approximately horizontal, the transverse plane is also a plane perpendicular to the horizontal, meaning that incident light rays are partially reflected by the external surface 24 through a range of reflection angles in a substantially vertical reflection plane, i.e. the light rays are at least partially vertically scattered. In other words, reflection from the external surface 24 is substantially diffuse in the vertical plane.

In contrast, as illustrated in Figure 7, the external surface 24 of the lenticular lens layer 25 is essentially flat (i.e. not curved) along any longitudinal plane (i.e. any plane parallel to the longitudinal axes of the hemicylindrical lenses 26). Light rays 33 which are parallel in the longitudinal plane and which are incident on the external surface 24 are each partially reflected (see partially reflected light rays 34) through substantially similar (i.e. the same) reflection angles in the longitudinal plane. This is because the local angle of incidence in the longitudinal plane for each incident ray 33 is substantially similar (i.e. the same). Incident light rays are therefore partially reflected by the external surface 24 through a narrow range of reflection angles in a substantially horizontal plane, i.e. reflection from the external surface 24 is substantially specular (i.e. minor-like) in the horizontal plane.

Because light emitted by the video projector 19 and incident on the image display screen 2 is reflected by said image display screen 2 substantially diffusely in the vertical plane, a reflected image is generally visible from a range of vertical positions (i.e. heights) around the volumetric display unit 1. That is to say an observer 21 need not be positioned at one specific height in order to view the reflected image. In contrast, because light emitted by the video projector 19 and incident on the image display screen 2 is generally reflected specularly by the image display screen 2 in the horizontal plane, a reflected image is generally visible only when the observer 21 is positioned directly in front (in the horizontal plane) of the image display screen 2. In fact, for a given position of the observer 21, only a portion (such as a thin vertical strip) of the reflected image is typically visible by the observer 21 when the display screen 2 is stationary. As the display screen 2 rotates about the rotation axis 9, the portion of the reflected image visible by a stationary observer 21 changes, in fact it typically sweeps across the display screen 2 in a direction opposite to the direction of travel of the screen and at the same speed of rotation of the screen. When the display screen 2 rotates above the threshold rotational speed, the vertical strip of the reflected image (which is visible at the position of the stationary observer) sweeps across the observer’s field of view so quickly that the entire sharp image is observed (due to human persistence of vision).

As illustrated in Figure 8, when a light ray 35 is incident on the external surface 24 of the lenticular lens 26, a portion 36 of the light ray is also transmitted into the body of the lens 26. The portion 36 of the light ray is refracted on transmission into the lens 26. The portion 36 of the light ray is subsequently incident on the interface 30 between the lens 26 and the layer of paint 28. Because the refractive index of the layer of paint 28 is substantially similar to the refractive index of the acrylic glass forming the lens 26, there is no total internal reflection of the portion 36 of the light ray at the interface 30. Only a small portion 37 of the light ray is reflected by the interface 30 and a large portion 38 of the light ray is transmitted into the layer of paint 28. The layer of paint 28, because it is pigmented black, absorbs a majority of the light ray transmitted therein. Consequently, only the small portion 37 of the portion 36 of the light ray transmitted into the lens body 26 is reflected back out of the lens towards an observer 21. The result is that the observer perceives a substantially singular, clear, sharp image and does not perceive a double-image or multiple images which could be formed from substantially secondary or tertiary reflections of light from within the lens 26 or from the interface 30 or from the layer of paint 28.

An alternative setup of the volumetric display unit 1 is illustrated schematically in Figure 9. In this alternative setup, the video projector 19 is located beneath the volumetric display unit 1 and the observer 21. The cone of light 20 projected by the video projector 19 is directed onto the image display screen 2 of the volumetric display unit 1 by three mirror surfaces 38, 39 and 40. Each of the mirror surfaces 38, 39 and 40 is oriented at 45° to the incoming light cone so that the light is sequentially reflected vertically upwards by mirror surface 38, then in a horizontal direction by mirror surface 39 and finally vertically downwards onto the image display screen 2 by mirror surface 40. In addition, an image rotator 41 is provided in the projection path of the cone of light 20 between the video projector 19 and the mirror surface 38 such that the cone of light 20 passes through the image rotator 41. The image rotator 41 comprises a Dove prism (not shown) as is known in the field of optics (i.e. an optical prism formed from acrylic glass in the shape of a truncated right-angle prism comprising two sloping faces), the Dove prism oriented with respect to the projection path such that light emitted by the projector 19 enters the Dove prism through a first sloping face and exits the Dove prism through a second sloping face. The image rotator 41 is coupled to the same motor 14 which drives rotation of the rotatable screen 2. The Dove prism is coupled to the motor 14 by way of a transmission (not shown) such that the motor 14 drives rotation of the Dove prism about an axis parallel to and extending along the centre of the projection path (i.e. along the centre of the cone of light 20) at a rotational speed which is one half the rotational speed at which the image display screen 2 rotates. Rotation of the Dove prism at the rotational speed one half the rotational speed at which the image display screen 2 rotates causes rotation of the image projected thereon to rotate at the same rotational speed at which the image display screen 2 rotates. The image display screen 2 and the image projected thereon therefore rotate at the same rotational speed. Consequently, as an observer 21 moves around the volumetric display unit 1 in a horizontal plane, as the image display screen 2 rotates, the orientation of the reflected image visible by the observer 21 appears fixed, i.e. the orientation of the reflected image visible by the observer 21 is not view-dependent. This differs from known volumetric display units comprising rotatable display screens in that, typically, as an observer moves around the volumetric display unit, the perceived image rotates. For example, when the observer moves from a first viewing position to a second viewing position diametrically opposed to said first viewing position (e.g. when the observer travels 180° around the volumetric display unit), the reflected image appears inverted due to the change in relative orientation of the rotating display screen 2 and the projected image source. This effect is overcome in the present invention by rotating the projected image in phase with the rotation of the display screen.

Further variations and modification may be made within the scope of the invention herein disclosed.

The volumetric display unit described herein is suitable for use as a floor-standing display unit or is positionable on a table or other substantially flat, e.g. horizontal, surface. Alternatively, the volumetric display unit may be wall-mountable or ceiling-mountable, depending on the desired display and viewing conditions. In such alternative embodiments, the video projector will typically be located and oriented with respect to the image display screen of the volumetric display unit such that the projected cone of light is incident on the image display screen at an angle of approximately 45°.

The video image projector is typically a digital video image projector configured to project digital video images. However, the video image projector may also be an analogue video image projector. Alternatively, the video image projector may be replaced by an image projector, i.e. a static image projector, configured to project static images.

The motor which drives rotation of the rotatable image display screen may be controllable or otherwise variable. A transmission or system of gears may be provided between the motor and the rotation shaft such that the rotational speed of the image display screen may be varied. The motor and/or the drive shaft may be coupled to a programmable computer processor for programmable control of the rotational speed of the image display screen.

The mount is typically formed in the shape of a portion of a cylinder. However, the mount may take other shapes. For example, the mount may be formed in the shape of a portion of a cone. If the mount shape is substantially conical, it may be that the rotation shaft is positioned relative to the image display screen such that the rotation axis passes through the centre of the image display screen.

The layer of lenticular lenses may be replaced by any suitable optically anisotropic (e.g. anisotropically reflective) material. For example, the layer of lenticular lenses may be a layer of holographic diffuser or reflector material, or a lenslet array layer. The layer of lenticular lenses may be formed by a period array of elongate lenses having one or more different cross-sectional shapes. For example, the elongate lenses forming the layer of lenticular lenses are typically prismatic, but they may specifically be substantially cylindrical, hemicylindrical or elliptically cylindrical. The elongate lenses may comprise elongate triangular prisms, rectangular prisms, square prisms or prisms formed from any other suitable polygonal bases.

The layer of paint is typically a layer of acrylic paint. However, the layer of paint may be formed from any suitable variety of paint capable of forming a smooth interface on a rear surface of the layer of lenticular lenses. The layer of paint may contain one or more pigments. For example, the layer of paint may be pigmented white, black or any shade of grey therebetween. Reflective particles such as particles of aluminium may be dispersed in the layer of paint or the layer of paint may not contain any reflective particles.

The image rotator may use any suitable method known in the field of optics for achieving rotation of the image passing therethrough. For example, the Dove prism disclosed herein may be replaced with one or more of any suitable optical prisms (including, for example, roof prisms including the Amici roof prism, the Abbe-Koenig prism, the Schmidt-Pechan prism, the roof pentaprism or the Porro prism), the relative orientation of the suitable optical prisms being selected such that rotation of the prism about a suitable axis at a suitable rotational speed results in rotation of the transmitted image at the same rotational speed as the speed at which the image display screen rotates about the rotation axis. The image rotator may comprise one or more reflective surfaces (e.g. mirror surfaces) used to rotate the image transmitted there through.

In embodiments in which the video projector is positioned directly above the image display screen, the image rotator may be provided between the video projector and the image display screen in the projection path such that the projected cone of light passes through the image rotator before reaching the image display screen.

It may be that the video projector is configured to rotate the projected image at the same rotational speed as the speed at which the image display screen rotates about the rotation axis. For example, it may be that video projector is programmed to rotate the projected image at the same rotational speed as the speed at which the image display screen rotates about the rotation axis. Alternatively, it may be that the video image itself is digitally manipulated before projection by the video projector such that the image projected by the video projector rotates at the same rotational speed as the speed at which the image display screen rotates about the rotation axis.

The images which are projected in use may be any kind of digital or analogue video images. They may be videos of objects, which may be moving. They may be for example vector graphics, CAD drawings, 3D models such as point clouds, wire frames, rendered virtual models, animations of 3D models etc. The images may be interactive responsive to user instructions received through a control interface, such as a gesture sensor.

Claims

1. An image display screen comprising an image reflecting portion, the image reflecting portion comprising an optically anisotropic layer, the image reflecting portion configured such that light incident thereon is reflected principally by the optically anisotropic layer.

2. The image display screen according to claim 1, wherein an external surface of the image reflecting portion is formed by an outward facing surface of the optically anisotropic layer

3. The image display screen according to claim 1 or claim 2, wherein the optically anisotropic layer extends across the entire image reflecting portion of the image display screen.

4. The image display screen according to any one preceding claim, wherein the image reflecting portion is further configured to attenuate reflection of light transmitted through said optically anisotropic layer.

5. The image display screen according to any one preceding claim, wherein the image reflecting portion is further configured such that light incident thereon is reflected principally by a reflecting surface of the optically anisotropic layer.

6. The image display screen according to claim 5 dependent on claim 2, wherein said reflecting surface of the optically anisotropic layer is the outward facing surface of said optically anisotropic layer which forms the external surface of the image reflecting portion.

7. The image display screen according to any one preceding claim, wherein the image reflecting portion comprises a reflection attenuating layer configured to attenuate reflection of light transmitted through the optically anisotropic layer.

8. The image display screen according to any one preceding claim, wherein the image reflecting portion comprises a contrast layer.

9. The image display screen according to any one preceding claim, wherein the image reflecting portion comprises a diffusely reflective layer.

10. The image display screen according to any one preceding claim, wherein the optically anisotropic layer is provided on top of a backing.

11. The image display screen according to claim 10, wherein the backing is configured to attenuate reflection of light transmitted through the optically anisotropic layer.

12. The image display screen according to any one preceding claim, wherein the image reflecting portion comprises one or more pigments.

13. The image display screen according to claim 10, wherein the backing comprises one or more pigments.

14. The image display screen according to claim 10, claim 11 or claim 13, wherein the optically anisotropic layer is provided directly on top of, or is formed on top of, or is integrally formed with, the backing such that an interface is provided between said optically anisotropic layer and said backing, the backing having a refractive index of greater than 1.

15. The image display screen according to any one preceding claim, wherein the optically anisotropic layer comprises at least one of the following: a lenticular diffuser and/or reflector, a lenslet array diffuser and/or reflector, a holographic diffuser and/or reflector.

16. The image display screen according to any one preceding claim, wherein the optically anisotropic layer comprises an array of aligned, mutually parallel hemicylindrical lenses.

17. The image display screen according to claim 16, wherein the hemicylindrical lenses are aligned such that a longitudinal axis of each said lens is substantially horizontal.

18. The image display screen according to any one preceding claim, wherein a rearward facing surface of the optically anisotropic layer is coated with paint.

19. The image display screen according to claim 18, wherein said paint comprises a plurality of reflective particles.

20. Image display apparatus comprising the image display screen according to any one preceding claim, the image display screen being rotatable about a rotation axis which extends through said image display screen and intersects the image reflecting portion of the image display screen at an oblique angle at a point of intersection displaced from the centre of said image reflecting portion.

21. The image display apparatus according to claim 20, wherein the image display screen is rotatably coupled to one or more bearings such that said image display screen is rotatable about said rotation axis.

22. The image display apparatus according to claim 20 further comprising an image projector configured to project an image in a principal projection direction onto the image display screen, the image display screen being oriented such that light emitted by the projector and forming the projected image is incident on the image reflecting portion at an angle of between 35° and 55°.

23. The image display apparatus according to claim 20 or claim 22 dependent on claim 16, wherein the hemicylindrical lenses are aligned such that a longitudinal axis of each said lens is substantially perpendicular to the rotation axis.

24. The image display apparatus according to claim 22 dependent on claim 16, wherein the hemicylindrical lenses are aligned such that a longitudinal axis of each said lens is substantially perpendicular to the principal projection direction.

25. The image display apparatus according to any of claims 21 to 24, wherein the image projector is a video projector configured to project a video output.

26. An image display screen comprising an image reflecting portion comprising a lenticular reflector and a layer of paint, an outward surface of the lenticular reflector forming a majority of an external surface of the image reflecting

portion, the layer of paint extending directly beneath the majority of a rearwards surface of the lenticular reflector, a direct interface being thereby provided between the lenticular reflector and the layer of paint.

27. Image display apparatus comprising a rotatable image display screen comprising an image reflecting surface, the rotatable image display screen being rotatable about a rotation axis which extends through said rotatable image display screen and intersects the image reflecting surface at an oblique angle at a point of intersection displaced from the centre of said image reflecting surface.

28. The image display apparatus according to claim 27, wherein the rotatable image display screen is rotatably coupled to one or more bearings such that said rotatable image display screen is rotatable about said rotation axis.

29. The image display apparatus according to claim 27 or claim 28 further comprising rotation means configured to rotate the rotatable image display screen about said rotation axis.

30. The image display apparatus according to claim 29, wherein said rotation means comprises a motor configured to drive rotation of said rotatable image display screen about said rotation axis.

31. The image display apparatus according to any one of claims 27 to 29, wherein the rotatable image display screen is supported by a mount, said mount and said rotatable image display screen being rotatable together about said rotation axis.

32. The image display apparatus according to any one of claims 29 to 31 dependent on claim 20 further comprising a counterbalance coupled to the rotatable image display screen such that said counterbalance and said rotatable image display screen are rotatable together about said rotation axis.

33. The image display apparatus according to claim 32 dependent on claim 31, wherein the image display screen is rotatably mounted to more than one bearing and the counterbalance is attached to the mount, the counterbalance being such that a combined centre of mass of the rotatable image display

screen, the mount and the counterbalance projected on the rotation axis, is between the bearings.

34. The image display apparatus according to claim 32 or claim 33, wherein the counterbalance is further configured to lower the combined centre of mass.

35. The image display apparatus according to any one of claims 27 to 34, wherein the rotation axis intersects the image reflecting surface at an angle of between 35° and 55°.

36. The image display apparatus according to any one of claims 27 to 35, wherein a perimeter of the image reflecting surface is elliptical.

37. The image display apparatus according to any one of claims 27 to 36, wherein the image reflecting surface is substantially planar.

38. The image display apparatus according to any one of claims 32 to 37 dependent on claim 31, wherein the mount is formed in the shape of a truncated cylinder.

39. The image display apparatus according to claim 33, wherein the counterbalance is attached to an underside of the mount.

40. The image display apparatus according to any one of claims 27 to 39 further comprising an image projector configured to project an image in a principal projection direction onto the rotatable image display screen, the rotatable image display screen being oriented such that light emitted by the projector and forming the projected image is incident on the image reflecting surface at an angle of between 35° and 55°.

41. The image display apparatus according to claim 40, wherein the principal projection direction and the rotational axis are substantially parallel.

42. The image display apparatus according to any one of claims 27 to 41, wherein the image reflecting surface comprises an optically anisotropic layer.

43. The image display apparatus according to any one of claims 27 to 42, wherein the image projector is a video projector configured to project a video output.

44. Image display apparatus comprising an image projector, an image display screen and an image rotation system, the image projector being configured to project an image along an image projection path and onto the image display screen, the image display screen being configured to rotate about a rotational axis at a principal rotational speed, and the image rotation system being configured to rotate the image projected onto the image display screen at said same principal rotational speed.

45. The image display apparatus according to claim 44, wherein the image projector is configured to project the image onto the image display screen in a principal projection direction, the image display screen being configured to reflect in a principal reflection direction a substantial portion of the image projected thereupon, said principal reflection direction being inclined with respect to said principal projection direction.

46. The image display apparatus according to claim 45, wherein the image rotation system is configured to rotate the image projected onto the image display screen in a plane perpendicular to the principal projection direction.

47. The image display apparatus according to claim 45 or claim 46, wherein an angle between the principal projection direction and the principal reflection direction is between 35° and 55°.

48. The image display apparatus according to any one of claims 45 to 47, wherein the rotational axis and the principal projection direction are substantially parallel.

49. The image display apparatus according to any one of claims 44 to 48, wherein the image rotation system comprises at least one prism, comprising optically transparent material, provided in the image projection path between the image projector and the image display screen such that light travelling from the image projector along the image projection path towards the image display screen passes through said prism, the prism being configured to rotate at a secondary rotation speed such that the image transmitted through the prism,

and thereby projected onto the image display screen, rotates at the principal rotational speed.

50. The image display apparatus according to any one of claims 44 to 49 further comprising a motor configured to drive rotation of the image display screen about the rotational axis.

51. The image display apparatus according to claim 50 dependent on 49, wherein the motor is further configured to drive rotation of the prism about an axis lying in the image projection path.

52. The image display apparatus according to claim 51, wherein the axis lying in the image projection path and the principal projection direction are collinear.

53. The image display apparatus according to any one of claims 44 to 52, wherein the image projector is configured to project the image substantially vertically downwards onto the image display screen.

54. The image display apparatus according to claim 53, wherein an image reflecting portion of the image display screen is inclined at an angle of between 35° and 55° with respect to the vertical, thereby reflecting in a substantially horizontal direction a substantial portion of the image projected onto said image display screen.

55. The image display apparatus according to any one of claims 44 to 54, wherein the image projector is a video projector configured to project a video output.

Intellectual Property Office

Application No:	GB1601001.9	**Examiner:**	Mr Charles Durden
Claims searched:	1-25	**Date of search:**	30 March 2017

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,E	1-25	WO 2016/069631 A1 (BARCO INC) - see especially paragraph 122 and figure 11, also paragraphs 42, 49, 104
X	1-25	WO 00/17844 A1 (ACTUALITY SYSTEMS INC) - see eg. page 4 lines 10-21, page 5 lines 14-15, page 6 lines 18-25, page 7 lines 13-17
X	1-25	US 2010/0253916 A1 (GAO et al.) - see especially paragraph 111 and figure 12
X	1-25	EP 0385705 A2 (TEXAS INSTRUMENTS INC) - see eg. column 8 lines 5-18

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

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G02B; H04N

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
H04N	0013/04	01/01/2006
G02B	0027/22	01/01/2006
G02B	0027/24	01/01/2006