(12) UK Patent Application (19) GB (11) 2 436 676 (13) A

(43) Date of A Publication **03.10.2007**

(21) Application No: **0606123.8**

(22) Date of Filing: **28.03.2006**

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(51) INT CL:
H04N 5/74 (2006.01) ***G02B 5/32*** (2006.01)
G03H 1/08 (2006.01)

(52) UK CL (Edition X):
N0T CLASSIFIED

(56) Documents Cited:
GB 2379351 A **EP 0952468 A1**
WO 2006/134398 A2
Carcole, Campos & Juvells: "Phase quantization effects on Fresnel lenses encoded in low resolution devices", Optics Communications 132 (1996) 35-40.

(58) Field of Search:
UK CL (Edition X) **H4F**
INT CL **G02B, G03H, H04N**
Other: **WPI, EPODOC, INSPEC**

(54) Abstract Title: **Image projection system with lens optics encoded in hologram**

(57) A holographic image projection system comprises a spatial light modulator (SLM) for displaying a hologram, first and second optics providing respective input and output beams to and from the SLM, and a hologram processor receiving image data for display and outputting data to the SLM to provide a displayed image, and at least one lens of the first or second optics is encoded in the hologram. That is, the SLM itself displays a function equivalent to the lens, removing one or more of lenses L_2, L_3 in the prior system in Figure 2. Also independently claimed is an optical module for a holographic projection system comprising an optical input, an SLM modulating the input to provide an output, a reflector one side of the SLM such that the optical path passes through the SLM twice (input and output on same side of SLM), and demagnification optics to enlarge the generated output image.

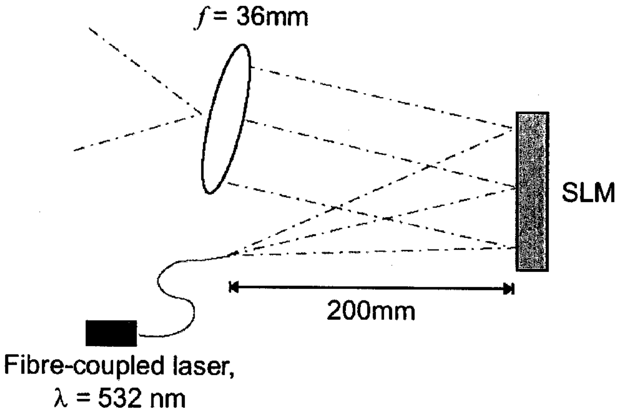

Figure 14

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

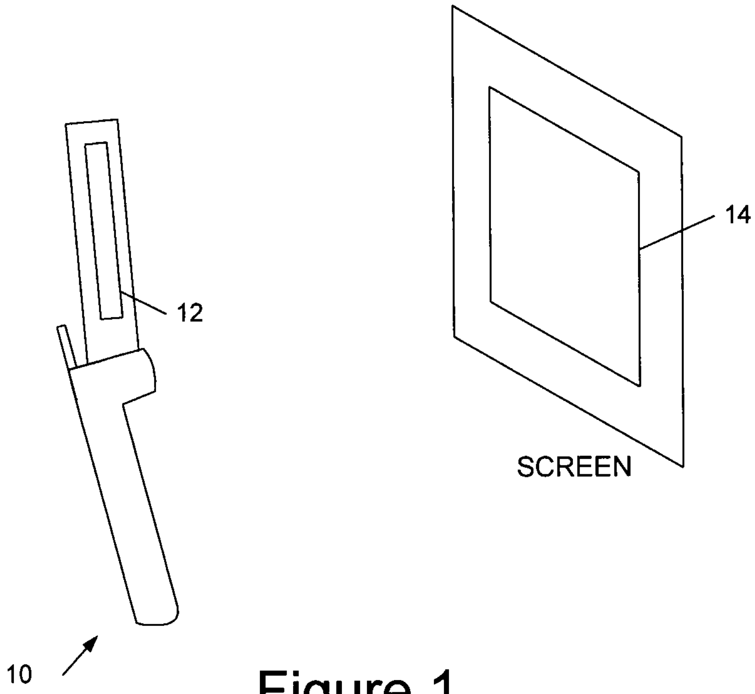


Figure 1

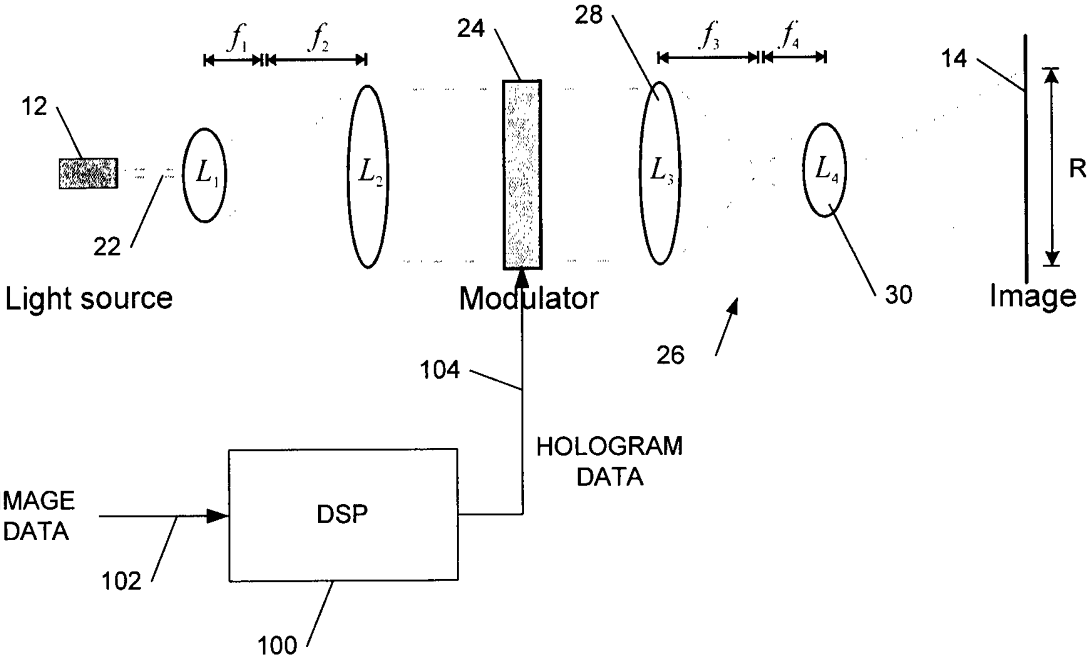


Figure 2

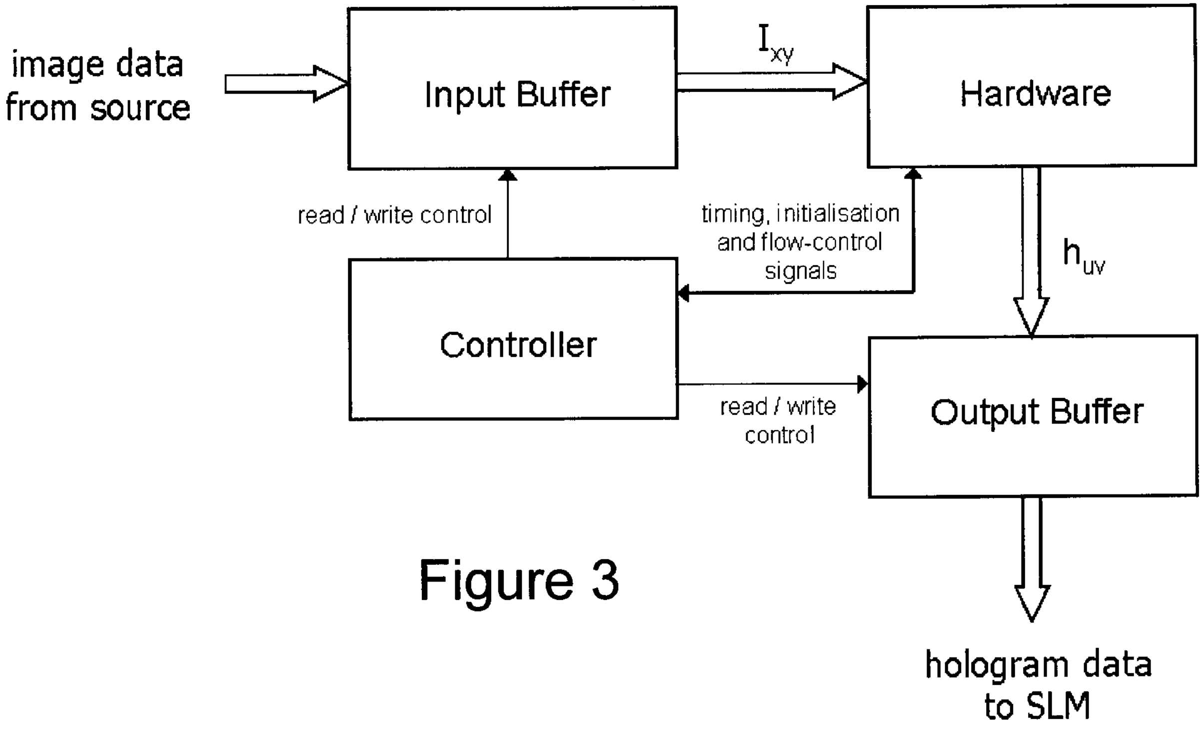


Figure 3

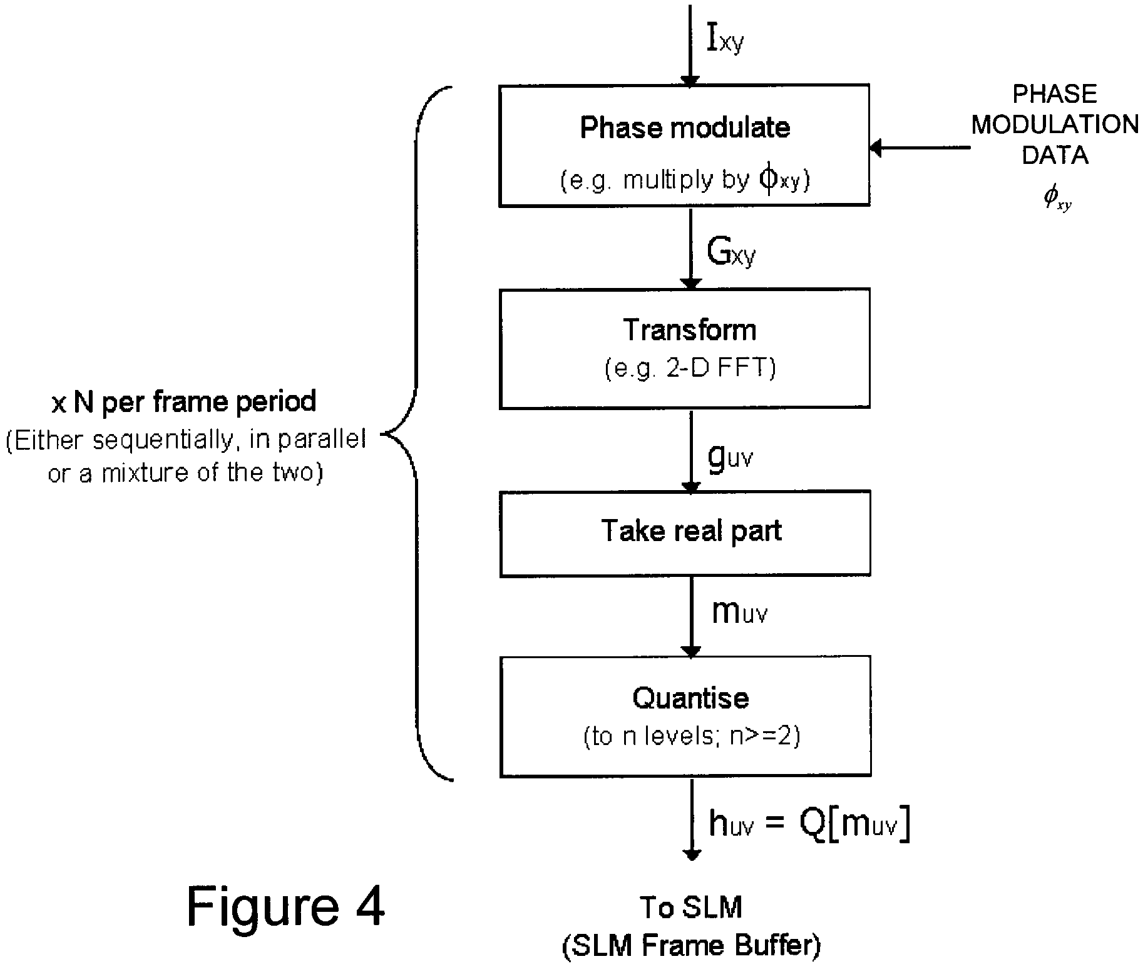
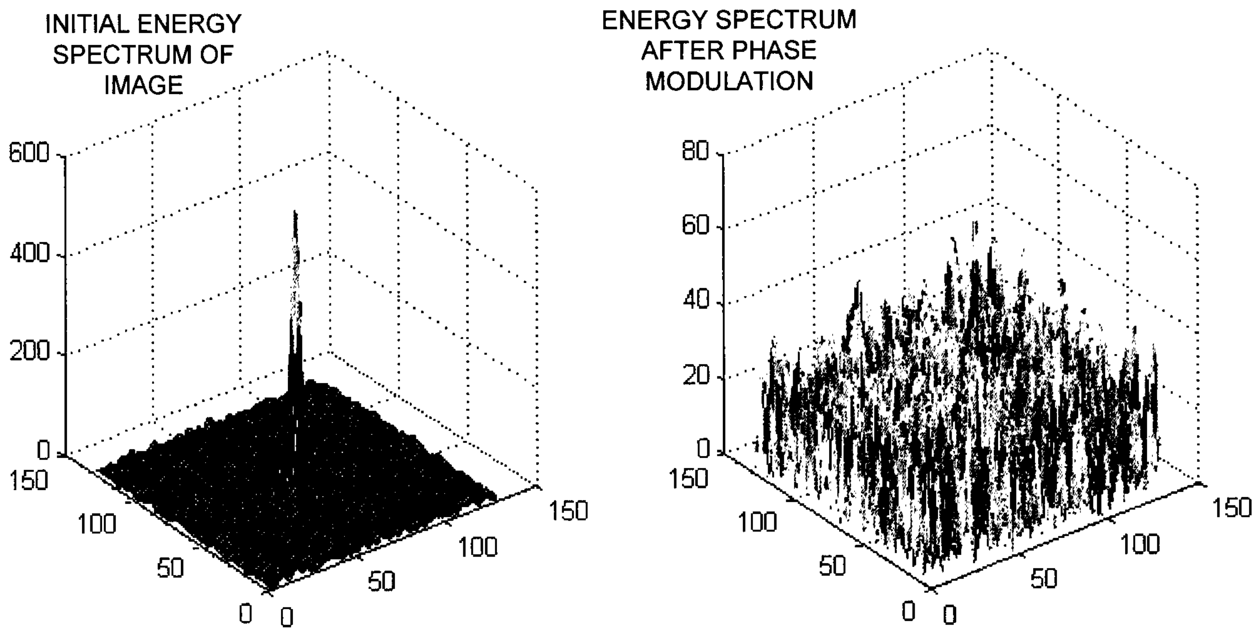


Figure 4


INITIAL ENERGY SPECTRUM OF IMAGE

ENERGY SPECTRUM AFTER PHASE MODULATION

Figure 5

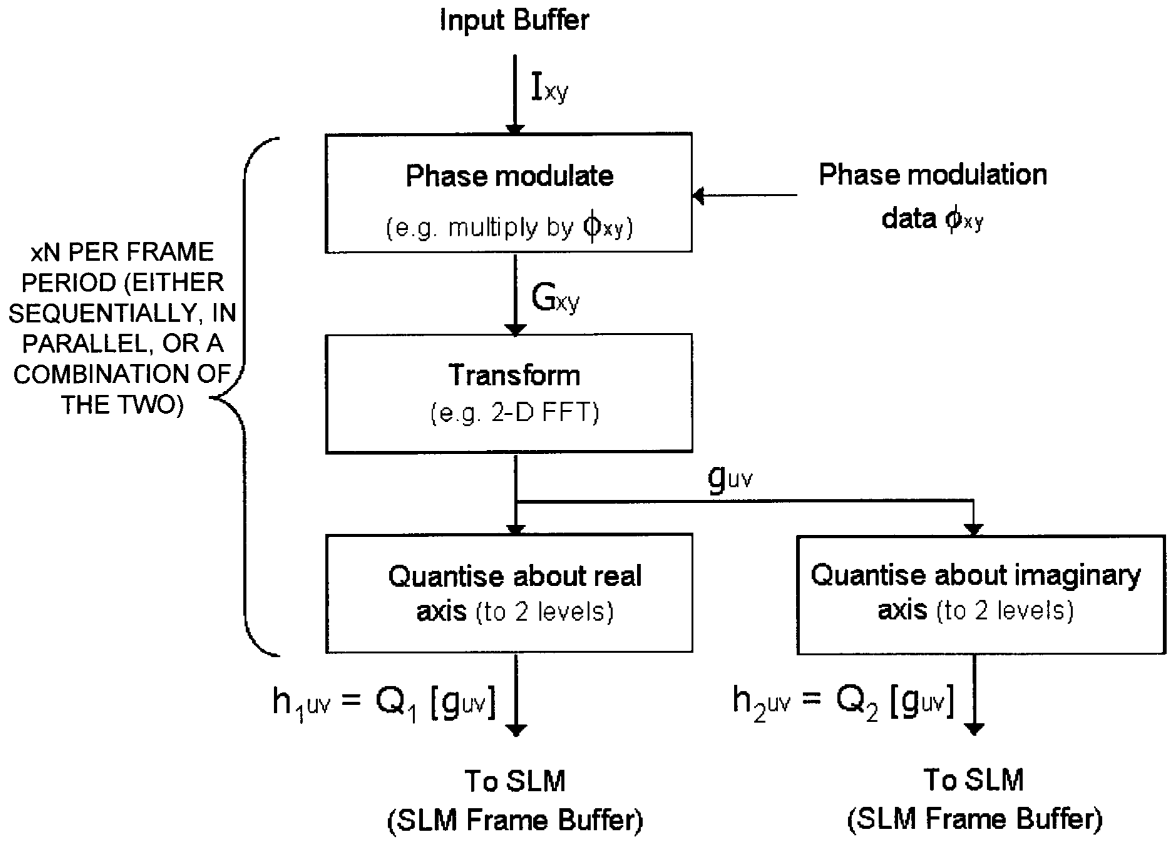


Figure 6

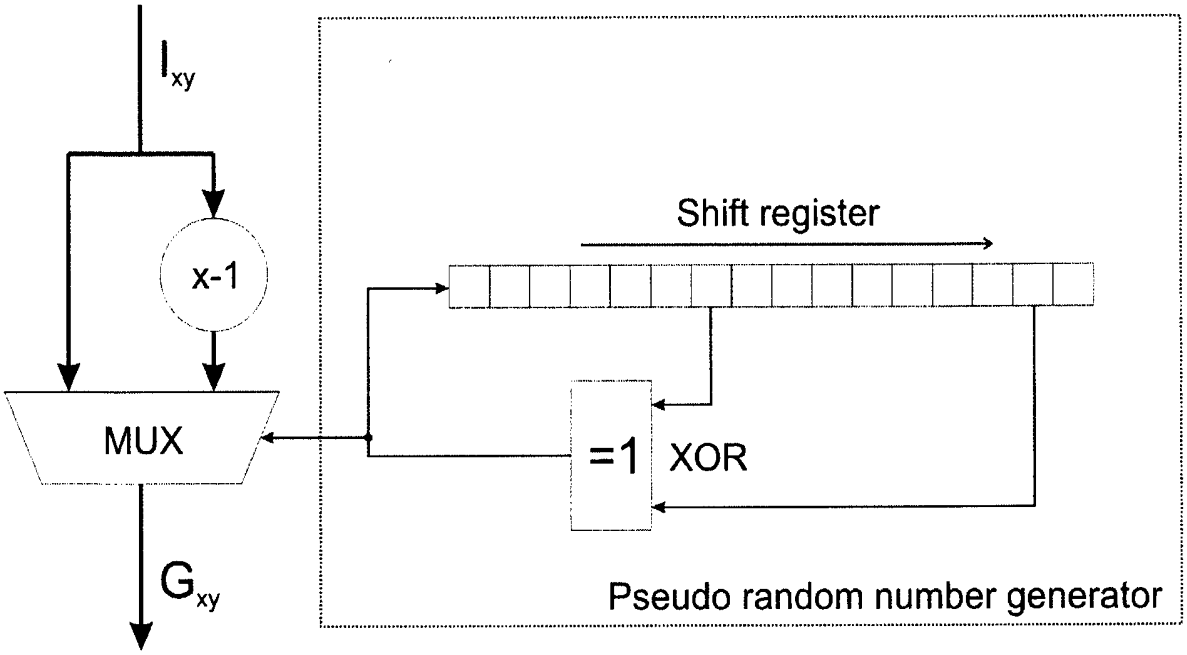


Figure 7

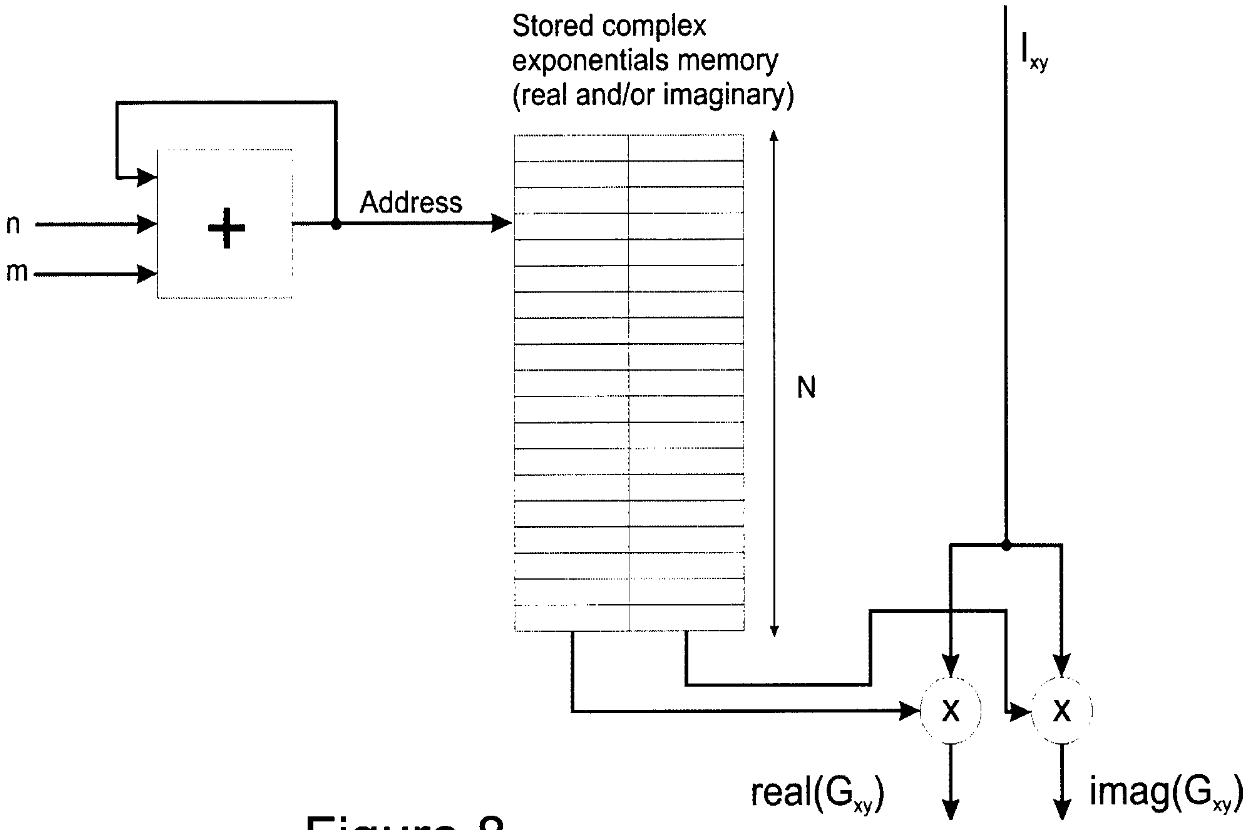


Figure 8

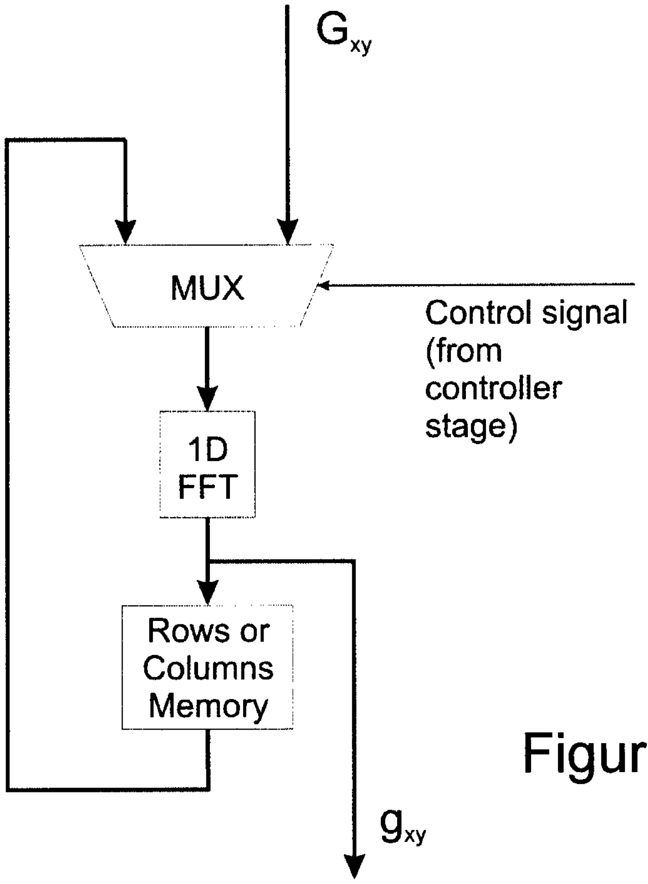


Figure 9

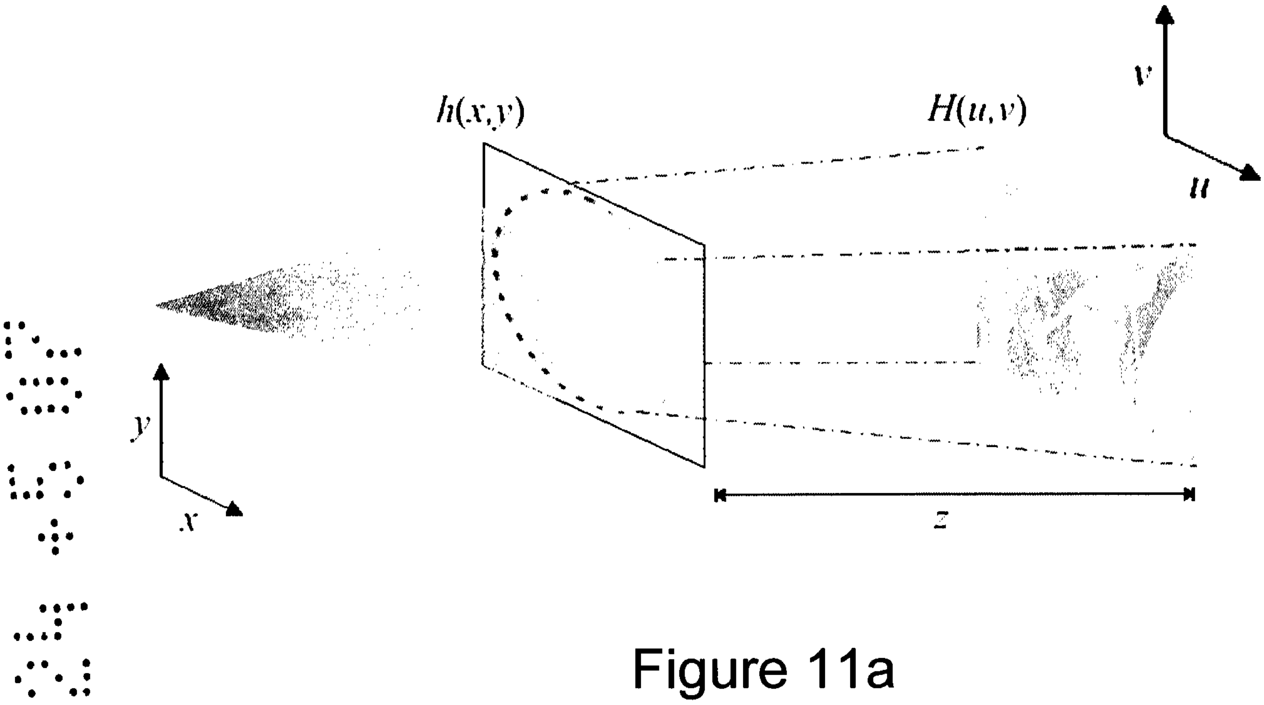


Figure 11a

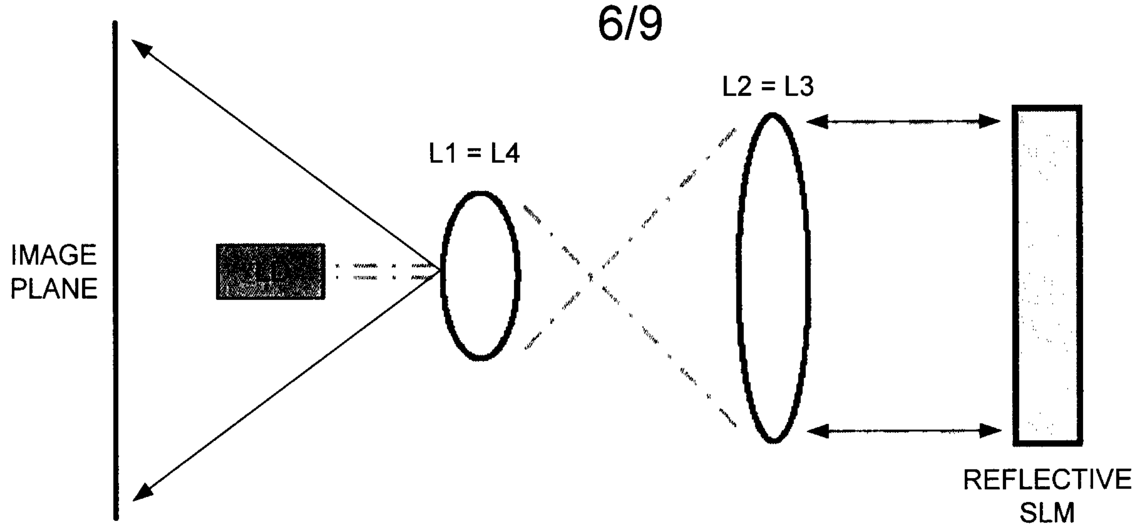


Figure 10a

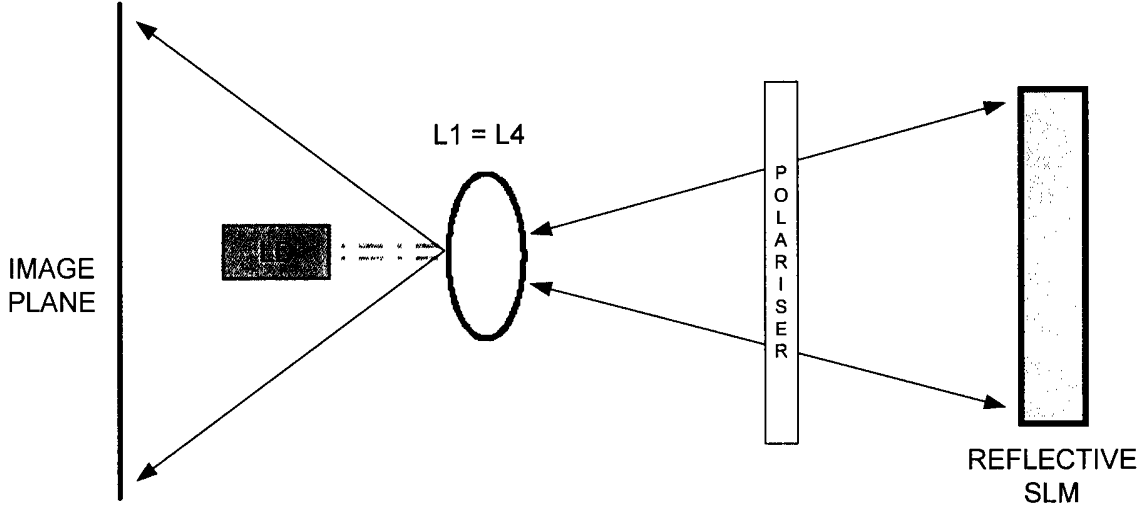


Figure 10b

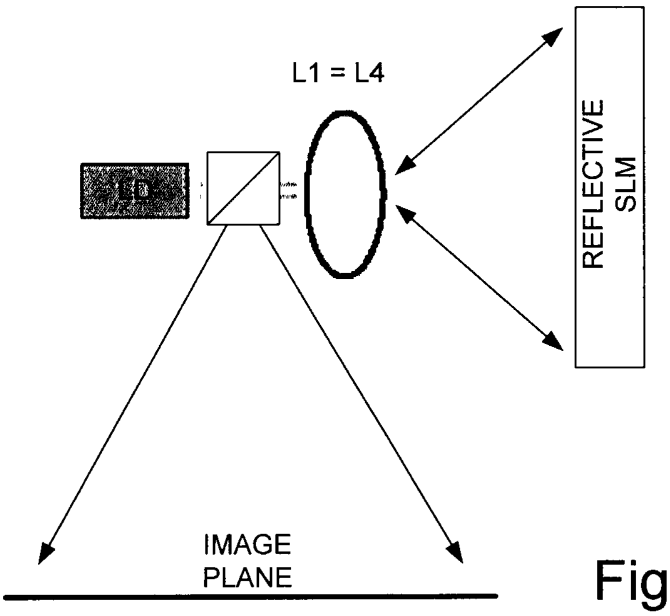


Figure 10c

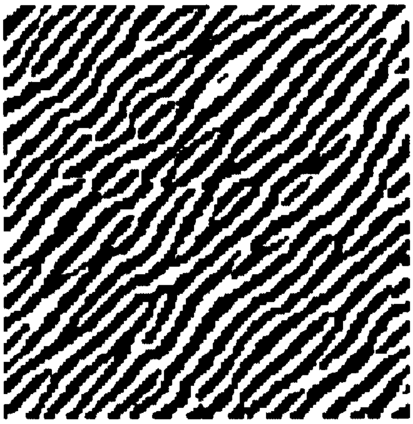


Figure 11b

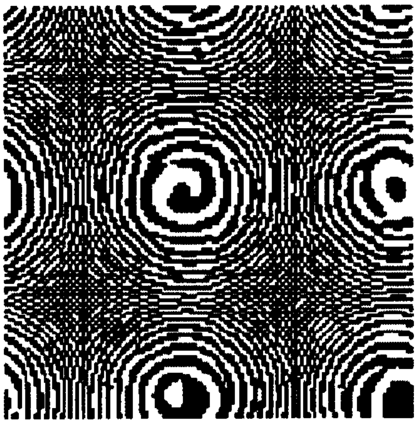


Figure 11c

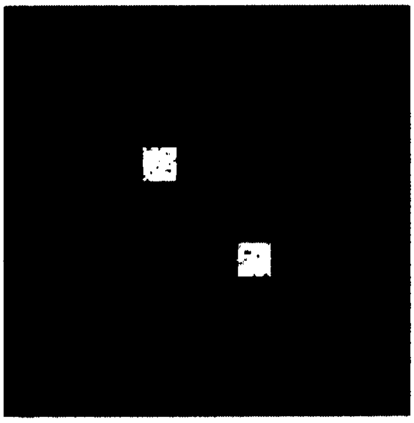


Figure 11d

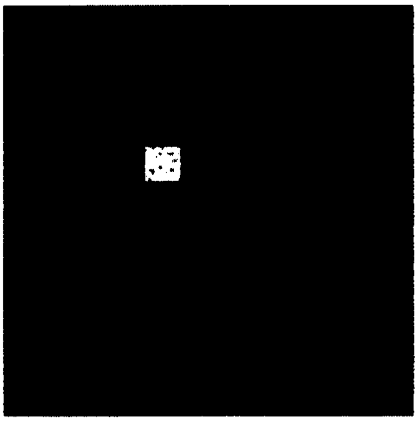


Figure 11e

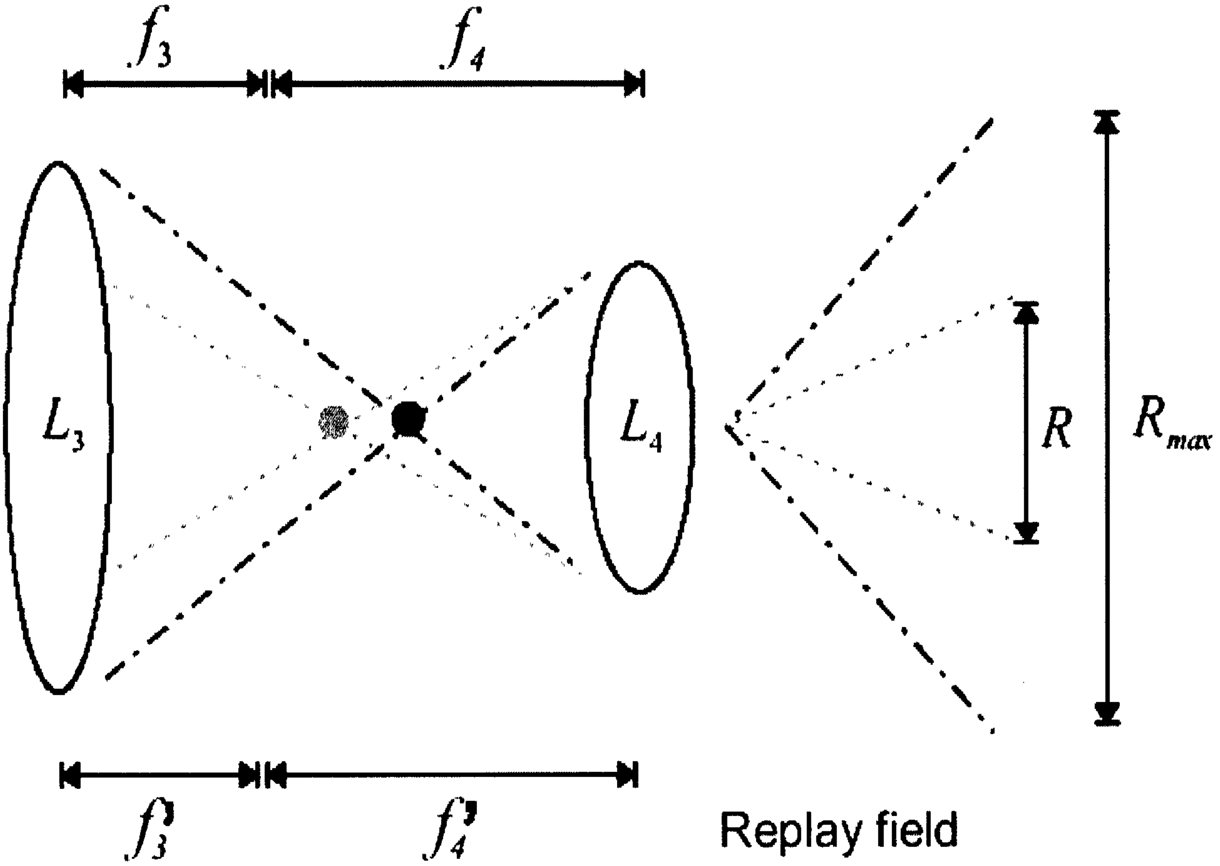


Figure 12

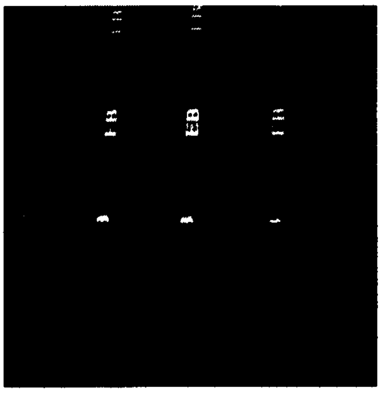


Figure 13a

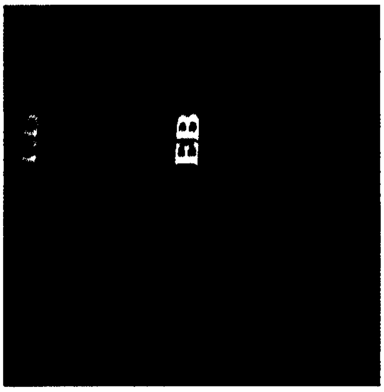


Figure 13b

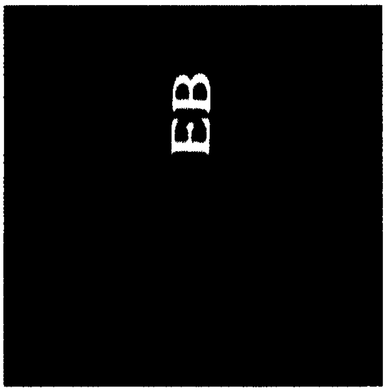


Figure 13c

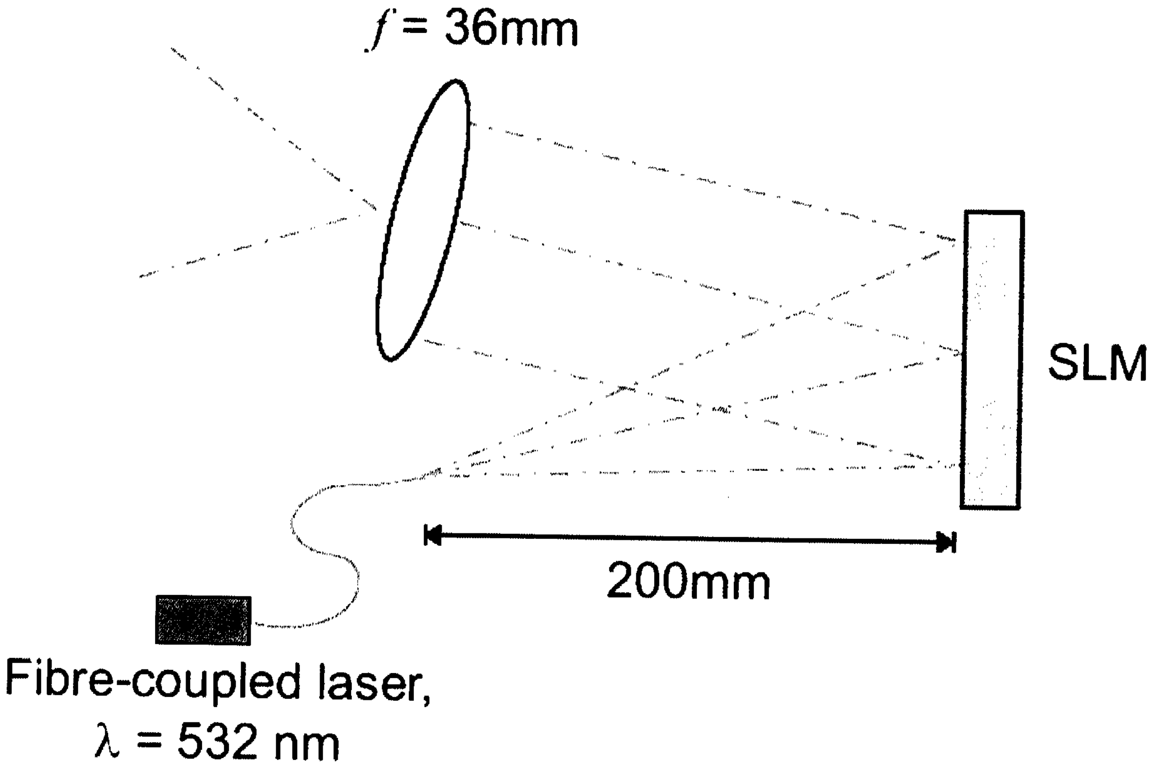


Figure 14

Figure 15

M&C Folio: GBP290673

Holographic Display Devices

This invention relates to optical systems for holographic projectors.

Many small, portable consumer electronic devices incorporate a graphical image display, generally a LCD (Liquid Crystal Display) screen. These include digital cameras, mobile phones, personal digital assistants/organisers, portable music devices such as the IPOD (trade mark), portable video devices, laptop computers and the like. In many cases it would be advantageous to be able to provide a larger and/or projected image but to date this has not been possible, primarily because of the size of the optical system needed for such a display.

We have previously described, in UK patent application number 0512179.3 filed 15 June 2005, incorporated by reference, a holographic projection module comprising a substantially monochromatic light source such as a laser diode; a spatial light modulator (SLM) to (phase) modulate the light to provide a hologram for generating a displayed image; and a demagnifying optical system to increase the divergence of the modulated light to form the displayed image. Absent the demagnifying optics the size (and distance from the SLM) of a displayed image depends on the pixel size of the SLM, smaller pixels diffracting the light more to produce a larger image. Typically an image would need to be viewed at a distance of several metres or more. The demagnifying optics increase the diffraction, thus allowing an image of a useful size to be displayed at a practical distance. Moreover the displayed image is substantially focus-free: that is the image is substantially in focus over a wide range or at all distances from the projection module.

A wide range of different optical arrangements can be used to achieve this effect but one particularly advantageous combination comprises first and second lenses with respective first and second focal lengths, the second focal length being shorter than the first and the first lens being closer to the spatial light modulator (along the optical path) than the second lens. Preferably the distance between the lenses is substantially equal to the sum of their focal distances, in effect forming a (demagnifying) telescope. In some embodiments two positive (i.e., converging) simple lenses are employed although in other embodiments one or more negative or diverging lenses may be employed. A filter may also be included to filter out unwanted parts of the displayed image, for example a bright (zero order) undiffracted spot or a repeated first order image (which may appear as an upside down version of the displayed image).

This optical system (and those described later) may be employed with any type of system or procedure for calculating a hologram to display on the SLM in order to generate the displayed image. However we have some particularly preferred procedures in which the displayed image is formed from a plurality of holographic sub-images which visually combine to give (to a human observer) the impression of the desired image for display. Thus, for example, these holographic sub-frames are preferably temporally displayed in rapid succession so as to be integrated within the human eye. The data for successive holographic sub-frames may be generated by a digital signal processor, which may comprise either a general purpose DSP under software control, for example in association with a program stored in non-volatile memory, or dedicated hardware, or a combination of the two such as software with dedicated hardware acceleration. Preferably the SLM comprises a reflective SLM (for compactness) but in general any type of pixellated microdisplay which is able to phase modulate light may be employed, optionally in association with an appropriate driver chip if needed.

Referring now to figure 1, this shows an example a consumer electronic device 10 incorporating a hardware projection module 12 to project a displayed image 14. Displayed image 14 comprises a plurality of holographically generated sub-images each of the same spatial extent as displayed image 14, and displayed rapidly in succession so as to give the appearance of the displayed image. Each holographic sub-frame is generated along the lines described below. For further details reference may be made to GB 0329012.9 *(ibid).*

Figure 2 shows an example optical system for the holographic projection module of Figure 1. Referring to figure 2, a laser diode 20 (for example, at 532nm), provides substantially collimated light 22 to a spatial light modulator 24 such as a pixellated liquid crystal modulator. The SLM 24 phase modulates light 22 with a hologram and the phase modulated light is provided a demagnifying optical system 26. In the illustrated embodiment, optical system 26 comprises a pair of lenses 28, 30 with respective focal lengths f_1, f_2, $f_1<f_2$, spaced apart at distance f_1+f_2. Optical system 26 increases the size of the projected holographic image by diverging the light forming the displayed image, as shown.

Still referring to Figure 2, in more detail lenses L_1 and L_2 (with focal lengths f_1 and f_2 respectively) form the beam-expansion pair. This expands the beam from the light source so that it covers the whole surface of the modulator.

Lens pair L_3 and L_4 (with focal lengths f_3 and f_4 respectively) form a demagnification lens pair. This effectively reduces the pixel size of the modulator, thus increasing the diffraction angle. As a result, the image size increases. The increase in image size is equal to the ratio of f_3 to f_4, which are the focal lengths of lenses L_3 and L_4 respectively.

Continuing to refer to Figure 2, a digital signal processor 100 has an input 102 to receive image data from the consumer electronic device defining the image to be displayed. The DSP 100 implements a procedure (described below) to generate phase hologram data for a plurality of holographic sub-frames which is provided from an output 104 of the DSP 100 to the SLM 24, optionally via a driver integrated circuit if needed. The DSP 100 drives SLM 24 to project a plurality of phase hologram sub-frames which combine to give the impression of displayed image 14 in the replay field (RPF).

The DSP 100 may comprise dedicated hardware and/or Flash or other read-only memory storing processor control code to implement a hologram generation procedure, in preferred embodiments in order to generate sub-frame phase hologram data for output to the SLM 24.

We now describe a preferred procedure for calculating hologram data for display on SLM 24. We refer to this procedure, in broad terms, as One Step Phase Retrieval

(OSPR), although strictly speaking in some implementations it could be considered that more than one step is employed (as described for example in GB0518912.1 and GB0601481.5, incorporated by reference, where "noise" in one sub-frame is compensated in a subsequent sub-frame).

Thus we have previously described, in UK Patent Application No. GB0329012.9, filed 15th December 2003, a method of displaying a holographically generated video image comprising plural video frames, the method comprising providing for each frame period a respective sequential plurality of holograms and displaying the holograms of the plural video frames for viewing the replay field thereof, whereby the noise variance of each frame is perceived as attenuated by averaging across the plurality of holograms.

Broadly speaking in our preferred method the SLM is modulated with holographic data approximating a hologram of the image to be displayed. However this holographic data is chosen in a special way, the displayed image being made up of a plurality of temporal sub-frames, each generated by modulating the SLM with a respective sub-frame hologram. These sub-frames are displayed successively and sufficiently fast that in the eye of a (human) observer the sub-frames (each of which have the spatial extent of the displayed image) are integrated together to create the desired image for display.

Each of the sub-frame holograms may itself be relatively noisy, for example as a result of quantising the holographic data into two (binary) or more phases, but temporal averaging amongst the sub-frames reduces the perceived level of noise. Embodiments of such a system can provide visually high quality displays even though each sub-frame, were it to be viewed separately, would appear relatively noisy.

A scheme such as this has the advantage of reduced computational requirements compared with schemes which attempt to accurately reproduce a displayed image using a single hologram, and also facilitate the use of a relatively inexpensive SLM.

Here it will be understood that the SLM will, in general, provide phase rather than amplitude modulation, for example a binary device providing relative phase shifts of zero and π (+1 and −1 for a normalised amplitude of unity). In preferred embodiments, however, more than two phase levels are employed, for example four phase modulation (zero, $\pi/2$, π, $3\pi/2$), since with only binary modulation the hologram results in a pair of images one spatially inverted in respect to the other, losing half the available light, whereas with multi-level phase modulation where the number of phase levels is greater than two this second image can be removed. Further details can be found in our earlier application GB0329012.9 *(ibid)*, hereby incorporated by reference in its entirety.

Although embodiments of the method are computationally less intensive than previous holographic display methods it is nonetheless generally desirable to provide a system with reduced cost and/or power consumption and/or increased performance. It is particularly desirable to provide improvements in systems for video use which generally have a requirement for processing data to display each of a succession of image frames within a limited frame period.

We have also described, in GB0511962.3, filed 14th June 2005, a hardware accelerator for a holographic image display system, the image display system being configured to generate a displayed image using a plurality of holographically generated temporal sub-frames, said temporal sub-frames being displayed sequentially in time such that they are perceived as a single reduced-noise image, each said sub-frame being generated holographically by modulation of a spatial light modulator with holographic data such that replay of a hologram defined by said holographic data defines a said sub-frame, the hardware accelerator comprising: an input buffer to store image data defining said displayed image; an output buffer to store holographic data for a said sub-frame; at least one hardware data processing module coupled to said input data buffer and to said output data buffer to process said image data to generate said holographic data for a said sub-frame; and a controller coupled to said at least one hardware data processing module to control said at least one data processing module to provide holographic data for a plurality of said sub-frames corresponding to image data for a single said displayed image to said output data buffer.

In this preferably a plurality of the hardware data processing modules is included for processing data for a plurality of the sub-frames in parallel. In preferred embodiments the hardware data processing module comprises a phase modulator coupled to the input data buffer and having a phase modulation data input to modulate phases of pixels of the image in response to an input which preferably comprises at least partially random phase data. This data may be generated on the fly or provided from a non-volatile data store. The phase modulator preferably includes at least one multiplier to multiply pixel data from the input data buffer by input phase modulation data. In a simple embodiment the multiplier simply changes a sign of the input data.

An output of the phase modulator is provided to a space-frequency transformation module such as a Fourier transform or inverse Fourier transform module. In the context of the holographic sub-frame generation procedure described later these two operations are substantially equivalent, effectively differing only by a scale factor. In other embodiments other space-frequency transformations may be employed (generally frequency referring to spatial frequency data derived from spatial position or pixel image data). In some preferred embodiments the space-frequency transformation module comprises a one-dimensional Fourier transformation module with feedback to perform a two-dimensional Fourier transform of the (spatial distribution of the) phase modulated image data to output holographic sub-frame data. This simplifies the hardware and enables processing of, for example, first rows then columns (or vice versa).

In preferred embodiments the hardware also includes a quantiser coupled to the output of the transformation module to quantise the holographic sub-frame data to provide holographic data for a sub-frame for the output buffer. The quantiser may quantise into two, four or more (phase) levels. In preferred embodiments the quantiser is configured to quantise real and imaginary components of the holographic sub-frame data to generate a pair of sub-frames for the output buffer. Thus in general the output of the space-frequency transformation module comprises a plurality of data points over the complex plane and this may be thresholded (quantised) at a point on the real axis (say zero) to split the complex plane into two halves and hence generate a first set of binary quantised data, and then quantised at a point on the imaginary axis, say $0j$, to divide the complex plane into a further two regions (complex component greater than 0, complex component less than 0). Since the greater the number of sub-frames the less the overall noise this provides further benefits.

Preferably one or both of the input and output buffers comprise dual-ported memory. In some particularly preferred embodiments the holographic image display system comprises a video image display system and the displayed image comprises a video frame.

In an embodiment, the various stages of the hardware accelerator implement a variant of the algorithm given below, as described later. The algorithm is a method of generating, for each still or video frame $\mathbf{I} = I_{xy}$, sets of N binary-phase holograms $\mathbf{h}^{(1)} \ldots \mathbf{h}^{(N)}$. Statistical analysis of the algorithm has shown that such sets of holograms form replay fields that exhibit mutually independent additive noise.

1. Let $G_{xy}^{(n)} = I_{xy} \exp\left(j\varphi_{xy}^{(n)}\right)$ where $\varphi_{xy}^{(n)}$ is uniformly distributed between 0 and 2π for $1 \leq n \leq N/2$ and $1 \leq x, y \leq m$
2. Let $g_{uv}^{(n)} = F^{-1}\left[G_{xy}^{(n)}\right]$ where F^{-1} represents the two-dimensional inverse Fourier transform operator, for $1 \leq n \leq N/2$
3. Let $m_{uv}^{(n)} = \Re\{g_{uv}^{(n)}\}$ for $1 \leq n \leq N/2$
4. Let $m_{uv}^{(n+N/2)} = \Im\{g_{uv}^{(n)}\}$ for $1 \leq n \leq N/2$
5. Let $h_{uv}^{(n)} = \begin{cases} -1 & \text{if } m_{uv}^{(n)} < Q^{(n)} \\ 1 & \text{if } m_{uv}^{(n)} \geq Q^{(n)} \end{cases}$ where $Q^{(n)} = \text{median}\left(m_{uv}^{(n)}\right)$ and $1 \leq n \leq N$

Step 1 forms N targets $G_{xy}^{(n)}$ equal to the amplitude of the supplied intensity target I_{xy}, but with independent identically-distributed (i.i.t.), uniformly-random phase. Step 2 computes the N corresponding full complex Fourier transform holograms $g_{uv}^{(n)}$. Steps 3 and 4 compute the real part and imaginary part of the holograms, respectively. Binarisation of each of the real and imaginary parts of the holograms is then performed in step 5: thresholding around the median of $m_{uv}^{(n)}$ ensures equal numbers of -1 and 1 points are present in the holograms, achieving DC balance (by definition) and also minimal reconstruction error. In an embodiment, the median value of $m_{uv}^{(n)}$ is assumed to be zero. This assumption can be shown to be valid and the effects of making this assumption are minimal with regard to perceived image quality. Further details can be found in the applicant's earlier application (*ibid*), to which reference may be made.

Figure 3 shows a block diagram of an embodiment of a hardware accelerator for the holographic image display system of the module 12 of Figure 1. The input to the system is preferably image data from a source such as a computer, although other sources are equally applicable. The input data is temporarily stored in one or more input buffer, with control signals for this process being supplied from one or more controller units within the system. Each input buffer preferably comprises dual-port memory such that data is written into the input buffer and read out from the input buffer simultaneously. The output from the input buffer shown in Figure 1 is an image frame, labelled I, and this becomes the input to the hardware block. The hardware block, which is described in more detail using Figure 2, performs a series of operations on each of the aforementioned image frames, I, and for each one produces one or more holographic sub-frames, h, which are sent to one or more output buffer. Each output buffer preferably comprises dual-port memory. Such sub-frames are outputted from the aforementioned output buffer and supplied to a display device, such as a SLM, optionally via a driver chip. The control signals by which this process is controlled are supplied from one or more controller unit. The control signals preferably ensure that one or more holographic sub-frames are produced and sent to the SLM per video frame period. In an embodiment, the control signals transmitted from the controller to both the input and output buffers are read / write select signals, whilst the signals between the controller and the hardware block comprise various timing, initialisation and flow-control information.

Figure 4 shows an embodiment of a hardware block as described in Figure 3, comprising a set of hardware elements designed to generate one or more holographic sub-frames for each image frame that is supplied to the block. In such an embodiment, preferably one image frame, I_{xy}, is supplied one or more times per video frame period as an input to the hardware block. The source of such image frames may be one or more input buffers as shown in Figure 3. Each image frame, I_{xy}, is then used to produce one or more holographic sub-frames by means of a set of operations comprising one or more of: a phase modulation stage, a space-frequency transformation stage and a quantisation stage. In embodiments, a set of N sub-frames, where N is greater than or equal to one, is generated per frame period by means of using either one sequential set of the aforementioned operations, or a several sets of such operations acting in parallel on different sub-frames, or a mixture of these two approaches.

The purpose of the phase-modulation block shown in the embodiment of Figure 4 is to redistribute the energy of the input frame in the spatial-frequency domain, such that improvements in final image quality are obtained after performing later operations.

Figure 5 shows an example of how the energy of a sample image is distributed before and after a phase-modulation stage in which a random phase distribution is used. It can be seen that modulating an image by such a phase distribution has the effect of redistributing the energy more evenly throughout the spatial-frequency domain.

The quantisation hardware that is shown in the embodiment of Figure 4 has the purpose of taking complex hologram data, which is produced as the output of the preceding space-frequency transform block, and mapping it to a restricted set of values, which correspond to actual phase modulation levels that can be achieved on a target SLM. In an embodiment, the number of quantisation levels is set at two, with an example of such a scheme being a phase modulator producing phase retardations of 0 or π at each pixel. In other embodiments, the number of quantisation levels, corresponding to different phase retardations, may be two or greater. There is no restriction on how the different phase retardations levels are distributed – either a regular distribution, irregular distribution or a mixture of the two may be used. In preferred embodiments the quantiser is configured to quantise real and imaginary components of the holographic sub-frame data to generate a pair of sub-frames for the output buffer, each with two phase-retardation levels. It can be shown that for discretely pixellated fields, the real and imaginary components of the complex holographic sub-frame data are uncorrelated, which is why it is valid to treat the real and imaginary components independently and produce two uncorrelated holographic sub-frames.

Figure 6 shows an embodiment of the hardware block described in Figure 3 in which a pair of quantisation elements are arranged in parallel in the system so as to generate a pair of holographic sub-frames from the real and imaginary components of the complex holographic sub-frame data respectively.

There are many different ways in which phase-modulation data, as shown in Figure 4, may be produced. In an embodiment, pseudo-random binary-phase modulation data is generated by hardware comprising a shift register with feedback and an XOR logic gate. Figure 7 shows such an embodiment, which also includes hardware to multiply incoming image data by the binary phase data. This hardware comprises means to produce two copies of the incoming data, one of which is multiplied by -1, followed by a multiplexer to select one of the two data copies. The control signal to the multiplexer in this embodiment is the pseudo-random binary-phase modulation data that is produced by the shift-register and associated circuitry, as described previously.

In another embodiment, pre-calculated phase modulation data is stored in a look-up table and a sequence of address values for the look-up table is produced, such that the phase-data read out from the look-up table is random. In this embodiment, it can be shown that a sufficient condition to ensure randomness is that the number of entries in the look-up table, N, is greater than the value, m, by which the address value increases each time, that m is not an integer factor of N, and that the address values 'wrap around' to the start of their range when N is exceeded. In a preferred embodiment, N is a power of 2, e.g. 256, such that address wrap around is obtained without any additional circuitry, and m is an odd number such that it is not a factor of N.

Figure 8 shows suitable hardware for such an embodiment, comprising a three-input adder with feedback, which produces a sequence of address values for a look-up table containing a set of N data words, each comprising a real and imaginary component. Input image data, I_{xy}, is replicated to form two identical signals, which are multiplied by the real and imaginary components of the selected value from the look-up table. This operation thereby produces the real and imaginary components of the phase-modulated input image data, G_{xy}, respectively. In an embodiment, the third input to the adder, denoted n, is a value representing the current holographic sub-frame. In another embodiment, the third input, n, is omitted. In a further embodiment, m and N are both be chosen to be distinct members of the set of prime numbers, which is a strong condition guaranteeing that the sequence of address values is truly random.

Figure 9 shows an embodiment of hardware which performs a 2-D FFT on incoming phase-modulated image data, G_{xy}, as shown in Figure 4. In this embodiment, the hardware required to perform the 2-D FFT operation comprises a 1-D FFT block, a memory element for storing intermediate row or column results, and a feedback path from the output of the memory to one input of a multiplexer. The other input of this multiplexer is the phase-modulated input image data, G_{xy}, and the control signal to the multiplexer is supplied from a controller block as shown in Figure 4. Such an embodiment represents an area-efficient method of performing a 2-D FFT operation.

In other implementations the operations illustrated in figures 4 and/or 6 may be implemented partially or wholly in software, for example on a general purpose digital signal processor.

Summary of the invention

Referring back to Figure 2, it is desirable to be able to reduce the number of optical components in a holographic projector.

According to the present invention there is therefore provided q holographic image projection system, the system comprising: a spatial light modulator (SLM) for displaying a hologram; first optics to provide an input beam to said SLM; second optics to process an output beam from said SLM to provide a displayed image; and a hologram processor to receive image data for display and to output data to said SLM to display a hologram to provide said displayed image; and wherein at least one lens of said first optics or said second optics is encoded in said hologram..

In embodiments by encoding at least one of the lenses into the hologram the size of the optical system is reduced. The lens which is encoded in the hologram preferably comprises a lens which, in a conventional configuration, would be adjacent the hologram, such as lens L_2 or lens L_3 of Figure 2. Thus the lens may comprise a collimation lens (collimation optics) of the first optics, for example forming part of a beam expander or Keplerian telescope and/or a lens of demagnification optics for the hologram.

The one or more lenses encoded in the hologram may comprise either a simple lens or a compound lens, and in embodiments an encoded lens may have a complex optical configuration, for example to correct for aberrations or distortions. In particular, the encoded lens may, for example, compensate for light source (laser) divergence and/or beam shape (for example elliptical rather than circular). Thus in embodiments the encoded lens may be an anamorphic lens.

In some particularly preferred embodiments two lenses are encoded into the hologram, one for the first optics and another for the second optics. This, in effect, folds the configuration of Figure 2 back on itself so that preferably these two lenses in fact comprise a single, shared lens with a reflecting surface being placed on the opposite side of the hologram (spatial light modulator) to the optics. In the example arrangement of Figure 2, therefore, the functions of L_2 and L_3 are performed by a single, common lens encoded in the hologram. Preferably the SLM comprises a reflective SLM to avoid the need for a separate reflecting surface.

In some particularly preferred embodiments the second (demagnification) optics comprises a single physical lens. This may either be shared with the first (beam expanding) optics or the first lens (L_1 in Figure 2) may be omitted and a diverging light source employed. In either case it will be appreciated that a holographic optical projection module may be constructed with just a single lens in addition to the spatial light modulator (hologram).

In a system with a single lens preferably the SLM modifies, for example rotates, the polarisation of the modulator light. Thus preferably the SLM comprises a liquid crystal SLM, for example a ferroelectric liquid crystal SLM. In such an arrangement a polariser is preferably included to, in effect, separate the input and output beams to and from the SLM; this polariser may be either linear or circular. Conveniently the polariser may comprise a polarising beam splitter. In this case the input and output optical paths for the holographic optical projection module can be configured to be at substantially 90 degrees to one another, for example a polarising beam splitter directing the output light for a displayed image out at 90 degrees to a normal to the surface of the spatial light modulator.

In embodiments where a (first) lens of the beam expander is encoded into the hologram a further advantage arises in that the power of the encoded lens may be altered by altering the pattern of modulation of the SLM. In other words the encoded lens may be a lens of controllable optical power (focal length), in which case variable demagnification may be applied to control the size of the displayed image. In such an arrangement the demagnification optics is preferably adjustable to take account of the variable optical power of the lens encoded into the hologram, for example by making a second lens of the demagnifying optics movable (along an optical axis) or variable, more particularly of variable focal length. A range of different technologies is available to provide such a variable power lens. In preferred embodiments the demagnifying optics, more particularly the power of the second lens, is electrically controlled by the hologram processor in conjunction with the power of the encoded lens to control the size of the displayed image.

The hologram preferably comprises a Fresnel hologram, which enables a lens to be encoded and which has the further advantage of allowing an image to be displayed without a conjugate image (with a Fourier hologram with binary modulation half the available light goes into this conjugate image, as described above). Like a Fourier hologram with a Fresnel hologram the displayed image is still in focus substantially irrespective of distance from the holographic projector.

In some preferred embodiments the hologram processor implements an OSPR – type procedure, as described above. However other procedures may also be employed for calculating the displayed hologram and embodiments of the invention are not restricted to any particular hologram calculation technique.

In another aspect the invention provides an optical module for a holographic projection system, the module comprising: an optical input; a spatial light modulator (SLM) for displaying a hologram, said SLM having an input optical path from said optical input passing through said SLM to provide a modulatable optical output; a reflector to one side of SLM such that said optical path through said SLM passes through said SLM twice, said optical input to said SLM and said optical output from said SLM being on the same side of said SLM; and demagnification optics coupled to said modulatable optical output to enlarge an image generated by a hologram modulating said SLM.

In some preferred embodiments of the above aspect and a previously described aspect of the invention, the optical input comprises an optical light guide such as a fibre optic. Then the optical path diverges from an output of the light guide, preferably substantially continuously up to the SLM.

The above described aspects of the invention, and features of the above described aspects may be combined in any permutation.

The invention further provides a consumer electronic device, in particular a portable device, including a holographic image projection system or optical module as described above.

These and other aspects of the invention will now be further described, by way of example only, with reference to the accompanying figures in which:

Figure 1 shows an example of a consumer electronic device incorporating a holographic projection module;

Figure 2 shows an example of an optical system for the holographic projection module of figure 1;

Figure 3 shows a block diagram of an embodiment of a hardware accelerator for the holographic image display system of Figures 1 and 2;

Figure 4 shows the operations performed within an embodiment of a hardware block as shown in Figure 3;

Figure 5 shows the energy spectra of a sample image before and after multiplication by a random phase matrix.

Figure 6 shows an embodiment of a hardware block with parallel quantisers for the simultaneous generation of two sub-frames from the real and imaginary components of the complex holographic sub-frame data respectively.

Figure 7 shows an embodiment of hardware to generate pseudo-random binary phase data and multiply incoming image data, I_{xy}, by the phase values to produce G_{xy}.

Figure 8 shows an embodiment of hardware to multiply incoming image frame data, I_{xy}, by complex phase values, which are randomly selected from a look-up table, to produce phase-modulated image data, G_{xy};

Figure 9 shows an embodiment of hardware which performs a 2-D transform on incoming phase-modulated image data, G_{xy}, by means of a 1-D transform block with feedback, to produce holographic data g_{uv};

Figures 10a to 10c show, respectively, a conceptual diagram of an optical system according to an embodiment of the invention, and first and second examples of holographic image projection systems according to embodiments of the invention;

Figures 11a to 11e show, respectively, a Fresnel diffraction geometry in which a hologram $h(x,y)$ is illuminated by coherent light, and an image $H(u,v)$ is formed at a distance z by Fresnel (or near-field) diffraction, a Fourier hologram, a Fresnel hologram, a simulated replay field of a Fourier hologram, and a simulated replay field of a Fresnel hologram showing absence of a conjugate image from the diffracted near-field, in which the hologram pixels are $40\mu\text{m}$ square, and the propagation distance $z = 200\,\text{mm}$;

Figure 12 shows change in replay field size caused by a variable demagnification assembly of lenses L_3 and L_4 in which in a first configuration the demagnification is

$D = \frac{f_3}{f_4}$ with a corresponding replay field (RPF) size R_{max} in which in a second configuration the demagnification is $D = \frac{f_3}{f_4}$, giving rise to a RPF of size R;

Figures 13a to 13c show experimental results for variable demagnification as illustrated in Figure 12 for $f_3 = 100$ mm, $f_3 = 200$ mm, and $f_3 = 400$ mm respectively, in which the change in size of the replay field is determined by the focal length of lens L_3, which is encoded onto the hologram;

Figure 14 shows an optical arrangement according to an embodiment of the invention for a lens-sharing projector design, utilizing a $f = 100\,\text{mm}$ lens encoded onto a Fresnel hologram displayed on an SLM, in which (optional) polarisers have been are omitted for clarity; and

Figure 15 shows experimental results from the lens-sharing projector setup of Figure 14, in which the demagnification caused by the combination of L_4 and the hologram has caused optical enlargement of the RPF by a factor of approximately three.

Figure 10a shows a conceptual diagram of an embodiment of a holographic display device using a reflective spatial light modulator, illustrating sharing of the lenses for the beam expander and demagnification optics. In particular lenses L_2 and L_3 of Figure 2 are shared, implemented as a single, common lens which, in embodiments is encoded into the hologram displayed on the reflective SLM. Thus one embodiment of a practical, physical system is shown in Figure 10b, in which a polariser is included to suppress interference between light travelling in different directions, that is into and out of the SLM. In the arrangement of Figure 10b the laser diode results in a dark patch in the centre of the image plane and therefore one alternative is to use the arrangement of Figure 10c. In the arrangement of Figure 10c a polarising beam splitter is used to direct the output, modulated light at 90 degrees on the image plane, and also to provide the function of the polariser in Figure 10b.

We now describe encoding lens power into the hologram by means of Fresnel diffraction.

We have previously described systems using far-field (or Fraunhofer) diffraction, in which the replay field F_{xy} and hologram h_{uv} are related by the Fourier transform:

$$F_{xy} = F[h_{uv}] \qquad (1)$$

In the near-field (or Fresnel) propagation regime, RPF and hologram are related by the Fresnel transform which, using the same notation, can be written as:

$$F_{xy} = FR[h_{uv}] \qquad (2)$$

The discrete Fresnel transform, from which suitable binary-phase holograms can be generated, is now introduced and briefly discussed.

The Fresnel transform describes the diffracted near field $F(x,y)$ at a distance z, which is produced when coherent light of wavelength λ interferes with an object $h(u,v)$. This relationship, and the coordinate system, is shown in Figure 11a. In continuous coordinates, the transform is defined as:

$$F(\mathbf{x}) = \frac{e^{\frac{j2\pi z}{\lambda}}}{j\lambda z} \int h(\mathbf{u}) \exp\{-\frac{j\pi}{\lambda z}\|\mathbf{x}-\mathbf{u}\|^2\}\, d\mathbf{u} \qquad (3)$$

where $\mathbf{x} = (x,y)$ and $\mathbf{u} = (u,v)$, or

$$F(x,y) = \frac{e^{\frac{j2\pi z}{\lambda}}}{j\lambda z} e^{\frac{j\pi}{\lambda z}(x^2+y^2)}{}_{-\infty}^{\infty} h(u,v)\, e^{\frac{j\pi}{\lambda z}(u^2+v^2)} \exp\{-\frac{2j\pi}{\lambda z}(ux+vy)\}\, du\, dv. \qquad (4)$$

This formulation is not suitable for a pixellated, finite-sized hologram h_{xy}, and is therefore discretised. This discrete Fresnel transform can be expressed in terms of a Fourier transform

$$H_{xy} = F_{xy}^{(1)} \cdot F\left[F_{uv}^{(2)} h_{uv}\right] \tag{5}$$

where

$$F_{xy}^{(1)} = \frac{\Delta_x \Delta_y}{j\lambda z} \exp\frac{j2\pi z}{\lambda} \exp\frac{j\pi}{\lambda z}\left[\left(\frac{x}{N\Delta_x}\right)^2 + \left(\frac{y}{M\Delta_y}\right)^2\right] \tag{6}$$

and

$$F_{uv}^{(2)} = \exp\frac{j\pi}{\lambda z}\left(u^2\Delta_x + v^2\Delta_y\right). \tag{7}$$

In effect the factors $F^{(1)}$ and $F^{(2)}$ in equation (5) turn the Fourier transform in a Fresnel transform of the hologram *h*. The size of each hologram pixel is $\Delta_x \times \Delta_y$, and the total size of the hologram is (in pixels) $N \times M$. In equation (7), *z* defines the focal length of the holographic lens. Finally, the sample spacing in the replay field is:

$$\begin{aligned} \Delta_u &= \frac{\lambda z}{N\Delta_x} \\ \Delta_v &= \frac{\lambda z}{N\Delta_y} \end{aligned} \tag{8}$$

so that the dimensions of the replay field are $\frac{\lambda z}{\Delta_x} \times \frac{\lambda z}{\Delta_y}$, consistent with the size of replay field in the Fraunhofer diffraction regime.

The OSPR algorithm can be generalised to the case of calculating Fresnel holograms by replacing the Fourier transform step by the discrete Fresnel transform of equation 5. Comparison of equations 1 and 5 show that the near-field propagation regime results in very different replay field characteristics, resulting in two potentially useful effects. These are demonstrated in Figures 11b-11e, which show Fresnel and Fourier binary holograms calculated using OSPR, and their respective simulated replay fields.

The significant advantage associated with binary Fresnel holograms is that the diffracted near-field does not contain a conjugate image. In the Fraunhofer diffraction regime the replay field is the Fourier transform of the real term h_{uv}, giving rise to conjugate symmetry. In the case of Fresnel diffraction, however, equation 5 shows that the replay field is the Fourier transform of the complex term $F_{uv}^{(2)}h_{uv}$. The differences in the resultant RPFs are clearly demonstrated in Figures 11d and 11e.

It is also evident from equation 4 that the diffracted field resulting from a Fresnel hologram is characterised by a propagation distance z ,so that the replay field is formed in one plane only, as opposed to everywhere where z is greater than the Goodman distance [F. Wyrowski and O. Bryngdahl, "Speckle-free reconstruction in digital holography," *J. Opt. Soc. Am. A*, vol. 6, 1989] in the case of Fraunhofer diffraction. This indicates that a Fresnel hologram incorporates lens power, which is reflected in the circular structure of the Fresnel hologram shown in Figure 11c. This is particularly useful effect to exploit in a holographic projection system, since incorporation of lens power into the hologram means that system cost, size and weight can be reduced. Furthermore, the focal plane in which the image is formed can also be altered simply by recalculating the hologram rather than changing the entire optical design.

We describe below designs for holographic projection systems which exploit these advantageous features of Fresnel holograms. There is an increase SNR penalty but error diffusion may be employed as a method to mitigate this.

We next describe variable demagnification.

Referring back again to Figure 2, this shows a simple optical architecture for a holographic projector. The lens pair L_1 and L_2 form a Keplerian telescope or beam expander, which expands the laser beam to capture the entire hologram surface, so that severe low-pass filtering of the replay field does not result. The reverse arrangement is used for the lens pair L_3 and L_4, effectively demagnifying the hologram and consequently increasing the diffraction angle. The resultant increase in the replay field size R is termed the "demagnification" of the system, and is set by the ratio of focal lengths f_4 to f_3.

We have previously demonstrated the operation of a projection system using a reconfigurable Fourier hologram as the diffracting element. However, the preceding discussion indicates that it is possible to remove the lens L_3 from the optical system by employing a Fresnel hologram which encodes the equivalent lens power. The output image from the projector would still be in-focus at all distances from the output lens L_4, but due to the characteristics of near-field propagation, is free from the conjugate image artifact. L_3 is the larger of the lens pair, as it has the longer focal length, and removing it from the optical path significantly reduces the size and weight of the system.

The use of a reconfigurable Fresnel hologram forms the basis for a novel variable demagnification effect. The demagnification D, and hence the size of the replay field at a particular z, is dependent upon the ratio of focal lengths of L_3 and L_4. If a dynamically addressable SLM device is used to display a Fresnel hologram encoding L_3, it is therefore possible to vary the size of the RPF simply by altering the lens power of the hologram. If the focal length of the holographic lens L_3 is altered to vary the demagnification, then either the focal length or the position of L_4 should also be changed as shown in Figure 12. When the focal points of L_3 and L_4 coincide in a first configuration, the demagnification is at a maximum value $D_{max} = \frac{f_3}{f_4}$, thus giving rise to a replay field of size R_{max}. In a second configuration, however, the focal lengths f_3 and f_4 have changed to f_3 and f_4 respectively. Since $f_3 < f_3$, the demagnification D is now smaller than D_{max}. This is compensated by an increase in f_4 so that the focal points of each lens coincide.

An experimental verification of the variable demagnification principle was performed using a 100 mm focal length lens in place of L_4. Three Fresnel holograms were calculated using OSPR with $N = 24$ subframes, each of each were designed to form an image in the planes $z = 100$ mm, $z = 200$ mm and $z = 400$ mm. A CRL Opto Limited (Forth Dimension Displays Limited, of Scotland, UK) SXGA SLM device with pixel pitch $\Delta_x = \Delta_y = 13.62\mu$m was used to display the holograms, and the resulting replay fields - projected onto a nondiffusing screen - were captured with a digital camera. The results are shown in Figure 13, and clearly show the replay field scaling caused by the variable demagnification introduced by each of the Fresnel holograms.

Preferably, to avoid having to move the lens L_4, a variable focal-length lens is employed. Two examples of such a lens are manufactured by Varioptic [M. Meister and R. J. Winfield, "Local improvement of the signal-to-noise ratio for diffractive optical elements designed by unidirectional optimization methods," *Applied Optics*, vol. 41, 2002] and Philips [M. P. Chang and O. K. Ersoy, "Iterative interlacing error diffusion for synthesis of computer-generated holograms," *Applied Optics*, vol. 32, 1993]. Both utilise the electrowetting phenomenon, in which a water drop is deposited on a metal substrate covered in a thin insulating layer. A voltage applied to the substrate modifies the contact angle of the liquid drop, thus changing the focal length. Other, less suitable, liquid lenses have also been proposed in which the focal length is controlled by the effect of a lever assembly on the lens aperture size [R. Eschbach, "Comparison of error diffusion methods for computer-generated holograms," *Applied Optics*, vol. 30, 1991]. Solid-state variable focal length lenses, using the birefringence change of liquid crystal material under an applied electric field, have also been reported [R. Eschbach and Z. Fan, "Complex-valued error diffusion for off-axis computer-generated holograms," *Applied Optics*, vol. 32, 1993, A. A. Falou, M. Elbouz, and H. Hamam, "Segmented phase-only filter binarized with a new error diffusion approach," *Journal of Optics A: Pure and Applied Optics*, vol. 7, 2005, O. B. Frank Fetthauer, "On the error diffusion algorithm: object dependence of the quantization noise," *Optics Communications*, vol. 120, 1995].

The focal length of the tunable lens is adjusted in response to changes in f_3. An expression for the demagnification for a system employing a tunable lens in place of L_4 can be obtained by considering the geometry of Figure 12, in which the total optical path length is preserved between the two configurations, so that:

$$f_4 + f_3 = f_4 + f_3 \tag{9}$$

Using the definitions of D and D_{max}, then equation 9 this can be rearranged to give

$$\frac{D+1}{D_{max}+1} = \frac{f_4}{f_4} \tag{10}$$

If the Varioptic AMS-1000 tunable focal length lens (which has a tuning range of 20-25 diopters) is employed, then for $f_3 = 100$ mm the demagnification D is continuously variable from 1.8 to 2.5. Care should be taken to ensure that lens L_4 captures as much of the diffracted field as possible. From equation 8, the Fresnel field is approximately 4mm square at $z = 100$ mm, which is larger than the effective aperture of the Varioptic device. As a result, some low-pass filtering of the replay field is likely to result if this particular device is employed.

We now describe lens sharing.

It was shown above that one half of the demagnification lens pair could be encoded onto the hologram, thereby reducing the lens count of the projector design by one. It was especially useful that the encoded lens was the larger of the pair, thus giving rise to a compact optical system.

The same technique can also be applied to the beam-expansion lens pair L_1 and L_2, which perform the reverse function to the pair L_3 and L_4. It is therefore possible to share a lens between the beam-expansion and demagnification assemblies, which can be represented as lens function encoded onto a Fresnel hologram. This results in a holographic projector which requires only two small, short focal length lenses. The remaining lenses are encoded onto a hologram, which is used in a reflective configuration.

An experimental projector was constructed to demonstrate the lens-sharing technique, and the optical configuration is shown in Figure 14. A fibre-coupled laser was used to illuminate a CRL Opto reflective SLM, which displayed $N = 24$ sets of Fresnel holograms each with $z = 100$ mm. Since the light from the fiber end was highly divergent, this removed the need for lens L_1. The output lens L_4 had a focal length of $f = 36$ mm, giving a demagnification D of approximately three. Polarisers were used to remove the large zero order associated with Fresnel diffraction, but have been omitted from Figure 14 for clarity. The angle of reflection was also kept small to avoid defocus aberrations.

An example image, projected on a screen and captured in low-light conditions with a digital camera, is shown in Figure 15. The replay field has been optically enlarged by factor of approximately three by the demagnification of the hologram pixels and, as the architecture is functionally equivalent to the simple holographic projector of Figure 2, the image is in focus at all points and without conjugate image.

We next briefly discuss the SNR (signal-to-noise ratio) of images formed by Fresnel holograms.

Fresnel holograms have properties which are particularly advantageous for the design of a holographic projector. However, there is an associated cost associated with encoding a lens function onto a hologram, which manifests itself as a degradation of RPF SNR: Taking the real (or imaginary) part of a complex Fourier hologram does not introduce quantisation noise into the replay field - instead, a conjugate image results. This is not true in the Fresnel regime, however, because the Fresnel transform is not conjugate symmetric. The effect of taking the real part of a complex Fresnel hologram is to distribute noise, having the same energy as the desired signal, over the entire replay field. However it is possible to improve this by using error diffusion; two example algorithms for the design of Fresnel holograms using a modified error diffusion algorithm are presented by Fetthauer [L. Ge, M. Duelli, and R. W. Cohn, "Improved-fidelity error diffusion through blending with pseudorandom encoding," *J. Opt. Soc. Am. A*, vol. 17, 2000] and Slack [F. Fetthauer, S. Weissbach, and O. Bryngdahl, "Equivalence of error diffusion and minimal average error algorithms," *Optics Communications*, vol. 113, 1995]. This shows that a carefully chosen diffusion kernel can significantly increase the image SNR, thereby offsetting the degradation due to the use of a Fresnel hologram.

The use of near-field holography also results in a zero-order which is approximately the same size as the hologram itself, spread over the entire replay field rather than located at zero spatial frequency as for the Fourier case. However this large zero order can be suppressed either with a combination of a polariser and analyzer or by processing the hologram pattern [F. Fetthauer and O. Bryngdahl, "Use of error diffusion with space-variant optimized weights to obtain high-quality quantized images and holograms," *Optics Letters*, vol. 23, 1998].

We next describe an implementation of a hologram processor, in this example using a modification of the above described OSPR procedure, to calculate a Fresnel hologram using equation (5).

Referring back to steps 1 to 5 of the above described OSPR procedure, step 2 was previously a two-dimensional inverse Fourier transform. To implement a Fresnel hologram, also encoding a lens, as described above an inverse Fresnel transform is employed in place of the previously described inverse Fourier transform. The inverse Fresnel transform may take the following form (based upon equation (5) above):

$$\frac{F^{-1}\left[\dfrac{H_{xy}}{F_{xy}^{(1)}}\right]}{F_{uv}^{(2)}}$$

Similarly the transform shown in Figure 4 is a two-dimensional inverse Fresnel transform (rather than a two-dimensional FFT) and, likewise the transform in Figure 6 is a Fresnel (rather than a Fourier) transform. In the hardware of Figure 9 the one-dimensional FFT block is replaced by an FRT (Fresnel transform) block so that the hardware of Figure 9 performs a two-dimensional FRT rather than a two-dimensional FFT. Further because of the scale factors F_{xy} and F_{uv} mentioned above, one scale factor is preferably incorporated within the loop shown in Figure 9 and a second multiplies the result.

Applications for the above described holographic projection system and/or optics include, but are not limited to the following: Mobile phone; PDA; Laptop; Digital camera; Digital video camera; Games console; In-car cinema; Personal navigation systems (In-car or wristwatch GPS); Displays for automobiles; Watch; Personal media player (e.g. MP3 player, personal video player); Dashboard mounted display; Laser light show box; Personal video projector (the "video iPod" idea); Advertising and signage systems; Computer (including desktop); Remote control units. A projection system and/or optics as described above may also be incorporated into an architectural fixture. In general embodiments of the above described holographic projection system and/or optics may be incorporated into any device where it is desirable to share pictures or for more than one person to view an image at once.

No doubt many other effective alternatives will occur to the skilled person. It will be understood that the invention is not limited to the described embodiments and encompasses modifications apparent to those skilled in the art lying within the spirit and scope of the claims appended hereto.

CLAIMS:

1. A holographic image projection system, the system comprising:

a spatial light modulator (SLM) for displaying a hologram;

first optics to provide an input beam to said SLM;

second optics to process an output beam from said SLM to provide a displayed image; and

a hologram processor to receive image data for display and to output data to said SLM to display a hologram to provide said displayed image; and

wherein at least one lens of said first optics or said second optics is encoded in said hologram.

2. A holographic image projection system as claimed in claim 1 wherein said first optics comprises collimation optics, and wherein said at least one encoded lens comprises a collimation lens of said collimation optics.

3. A holographic image projection system as claimed in claim 2 wherein said first optics comprises beam expansion optics including said collimation optics.

4. A holographic image projection system as claimed in claim 1, 2 or 3 wherein at least one lens of said first optics and at least one lens of said second optics is encoded in said hologram.

5. A holographic image projection system as claimed in claim 4 further comprising a mirror configured such that said input beam and said output beam of said SLM are on the same side of said SLM, wherein said second optics comprises demagnification optics, and wherein at least one lens of said first optics and at least one lens of said second optics is encoded in said hologram.

6. A holographic image projection system as claimed in claim 5 wherein said SLM comprises a reflective SLM.

7. A holographic image projection system as claimed in claim 4, 5 or 6 wherein said second optics comprises a single physical lens.

8. A holographic image projection system as claimed in claim 7 wherein said first optics comprises said single physical lens, said single physical lens being shared with said second optics.

9. A holographic image projection system as claimed in any preceding claim wherein said second optics has a variable optical power.

10. A holographic image projection system as claimed in claim 9 wherein said second optics comprises a variable physical lens, and wherein said at least one lens encoded by said hologram processor comprises a variable focus lens of said second optics.

11. A holographic image projection system as claimed in claim 10 wherein said variable physical lens comprises a variable focus lens.

12. A holographic image projection system as claimed in any preceding claim wherein said hologram comprises a Fresnel hologram.

13. A holographic image projection system as claimed in any preceding claim wherein said SLM comprises a liquid crystal SLM.

14. A holographic image projection system as claimed in any preceding claim wherein said hologram processor is configured to generate a plurality of temporal holographic sub-frames for a single said displayed image.

15. An optical module for a holographic projection system, the module comprising:

an optical input;

a spatial light modulator (SLM) for displaying a hologram, said SLM having an input optical path from said optical input passing through said SLM to provide a modulatable optical output;

a reflector to one side of SLM such that said optical path through said SLM passes through said SLM twice, said optical input to said SLM and said optical output from said SLM being on the same side of said SLM; and

demagnification optics coupled to said modulatable optical output to enlarge an image generated by a hologram modulating said SLM.

16. An optical module as claimed in claim 15 wherein said SLM comprises a reflective liquid crystal SLM incorporating said reflector.

17. An optical module as claimed in claim 15 or 16 wherein said demagnification optics comprises a single lens.

18. An optical module as claimed in claim 17 wherein said single lens is located in said optical path between said optical input and said SLM.

19. An optical module as claimed in any one of claims 15 to 18 wherein said input optical path to said optical SLM and said optical output from said SLM have a portion of shared optical path, the system further comprising a polariser in said portion of shared optical path.

20. An optical module as claimed in claim 19 wherein said polariser comprises a polarising beam splitter.

21. An optical module as claimed in any of claims 15 to 20 wherein said optical input comprises an optical light guide, and wherein said input optical path diverges from an output of said optical light guide up to said SLM.

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Application No:	GB0606123.8	**Examiner:**	Matthew Males
Claims searched:	1	**Date of search:**	19 July 2007

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
A,E	-	WO 2006/134398 A2 LIGHT BLUE OPTICS LTD - see page 16, 3rd paragraph onward, esp. end of 1st paragraph, page 17; Figs 15a, b.
A	-	Carcole, Campos & Juvells: "Phase quantization effects on Fresnel lenses encoded in low resolution devices", Optics Communications 132 (1996) 35-40. See Abstract & Conclusions.
A	-	EP 0952468 A1 VICTOR COMPANY JAPAN - see abstract; paragraphs [0029]-[0031]; Fig 4.
A	-	GB 2379351 A HOLOGRAPHIC IMAGING - see abstract; Figure 2.

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

WPI, EPODOC, INSPEC

International Classification:

Subclass	Subgroup	Valid From
H04N	0005/74	01/01/2006
G02B	0005/32	01/01/2006
G03H	0001/08	01/01/2006