# The Application of the Light Valve to Holographic Stereograms

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## ABSTRACT

Holography as a medium for exploration by artists faces several major limitations. Conventional holography is restricted to that which can be brought in to the lab and illuminated with coherent light.

Holographic stereograms have made possible the creation of holograms of both *real objects* in natural or studio lighting and *virtual objects* created using three-dimensional graphics. There are several approaches for creating holograms from digital graphics. This paper discusses the application of the light valve to the process along with other related developments. Artists can now produce high quality inexpensive, medium-format holograms using this direct-link to digital media. Future developments will led to even higher resolution Digital Image-Light-Amplifier (D-ILA) systems.

**Keywords:** Holography, Digital Holography, Light Valve, ILA, D-ILA, Holographic Stereograms, LSD, SLM

## INTRODUCTION

For several years, faculty and students at the Ontario College of Art & Design have utilized LCD technology as a light gate for the production of holographic stereograms from computer graphics. The size, resolution, contrast ratio, and insertion losses of this technique created serious limitations. Recently, our collaboration with Photonics Research Ontario has led to the development of The Light Valve Printer. The light valve or Image Light Amplifier provides a direct link from digital graphics to holography. Its high resolution and contrast ratio makes it an excellent choice for small and medium format (50cm X 60cm) holograms.

Historically, the light valve arose out of a research effort begun in 1970 at Hughes Research involving the holographic and laser groups along with the solid state and liquid crystal science departments. The goal was to develop a new device that would convert an incoherent light image into a coherent image using an expanded laser beam, the application being as a SLM (Spatial Light Modulator) for the creation of holographic movies. The light valve concept was invented, patented and, in 1972, reduced to practice, showing real-time high resolution images projected from a CRT on the photo-sensor side. Both lasers and arc lamps could be used to read-out the light valve.

The light valve was first successfully applied as a data projector. The Display Division of Hughes Aircraft was developing command/control displays for the US Navy ships and US Air Force Command Centers. The projection displays used in the early 1970s consisted of a Sailor writing with an oil pencil on a glass sheet over a map slide to show ship positions. The introduction of the light valve projector used with an arc lamp revolutionized large screen command/control displays. In 1978 the first projectors made with prototype light valves at the Research Labs were installed in a critical Command Center which was the first actual use of a light valve projector. The Research Labs and the Display Division then worked together to develop new projection systems that utilized the light valve device. In 1980, actual production of commercial projectors began.

LCD panels are often used in the production of holographic stereograms, however they lack resolution and contrast ratio and contain the familiar "fish-scale" patina. Motion picture film is used to produce larger images in greater detail, however, registration is often a problem and film-recording costs have largely limited production to commercial projects. Full colour work requires the additional expense of producing colour separated film footage. Few artists have been able to afford the production costs of associated with medium and large format stereograms.

The light valve projector, after some modification, is well suited to the needs of holographers who require digital images in the form of coherent light. It utilizes polarized light, red phosphor CRTs, and a variety of optics including an ILA or Image Light Amplifier. (See figure A)

IMAGE LIGHT AMPLIFIER - LIGHT VALVE - PRINCIPLES

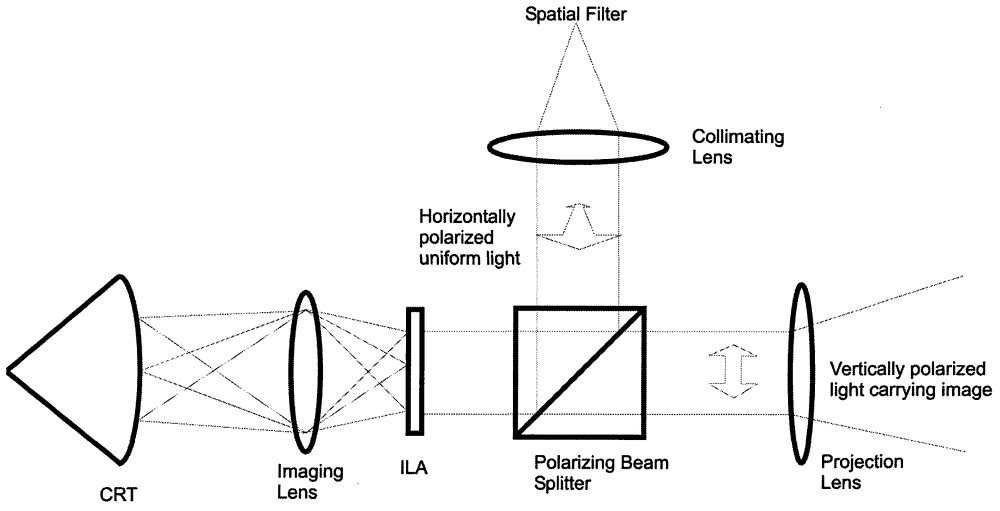



FIGURE A

First, an image taken from a video source, or output from a computer is displayed on a high resolution CRT. The image from the CRT is projected onto the rear of the ILA. The ILA itself is a multi-layer device. The central layer is comprised of liquid crystal (See Figure B).

The image on the rear face of the ILA is picked up by an amorphous silicon layer after passing through a conductive glass layer. There is an applied bias between this rear conductive glass layer and a similar layer on the front face of the ILA. The light striking the silicon surface will induce photo-conductivity in that layer in proportion to the brightness of the light at that point. The result is that the image displayed on the CRT is transferred into a matching resistance pattern in the silicon. The bias across the device then results in the same pattern of voltage across the liquid crystal and the liquid crystal is aligned to varying degrees corresponding to the image intensity. The overall functioning of the device is then to convert the image into a pattern of liquid crystal alignment.

The projection step occurs using polarized light and an effect known as birefringence. The liquid crystal is a birefringent material when it is aligned, meaning that the index of refraction is different for light polarized in different directions. Polarized light passing through a birefringent material often undergoes a change in polarization. The ILA is then read-out by bringing in polarized light from a laser or arc lamp. The light passes through the liquid crystal layer, reflects from the dielectric mirror, and passes through the liquid crystal again. The polarization is then altered to varying degrees spatially as dictated by the alignment of the liquid crystal, which is in turn determined by the original image on the CRT. Passing the returning beam through a polarizer then produces a polarized beam that is spatially imprinted with the image. As an aside, the light rejected by the polarizer contains the negative image. In Figure A, the polarizing beam splitter performs the function of bringing in the initial polarized beam and passing the polarized image for projection. The light blocking layer in Figure B is there to prevent any leakage from the high intensity read-out light causing photo-conductivity in the silicon layer, which would reduce contrast.

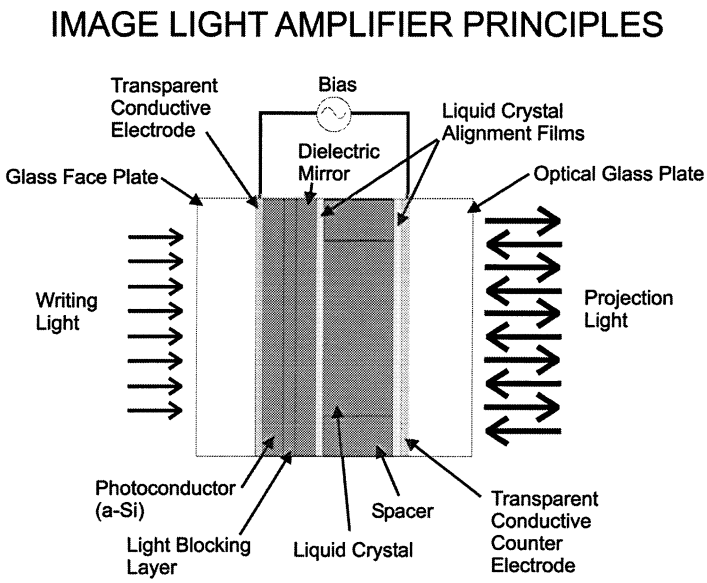



FIGURE B

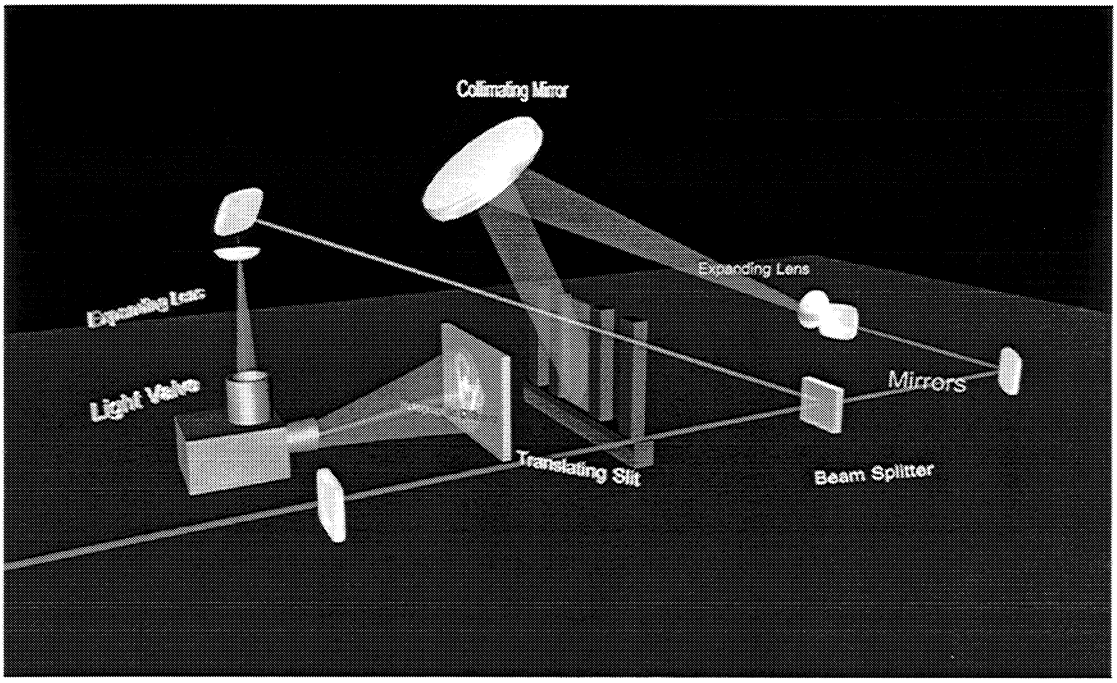


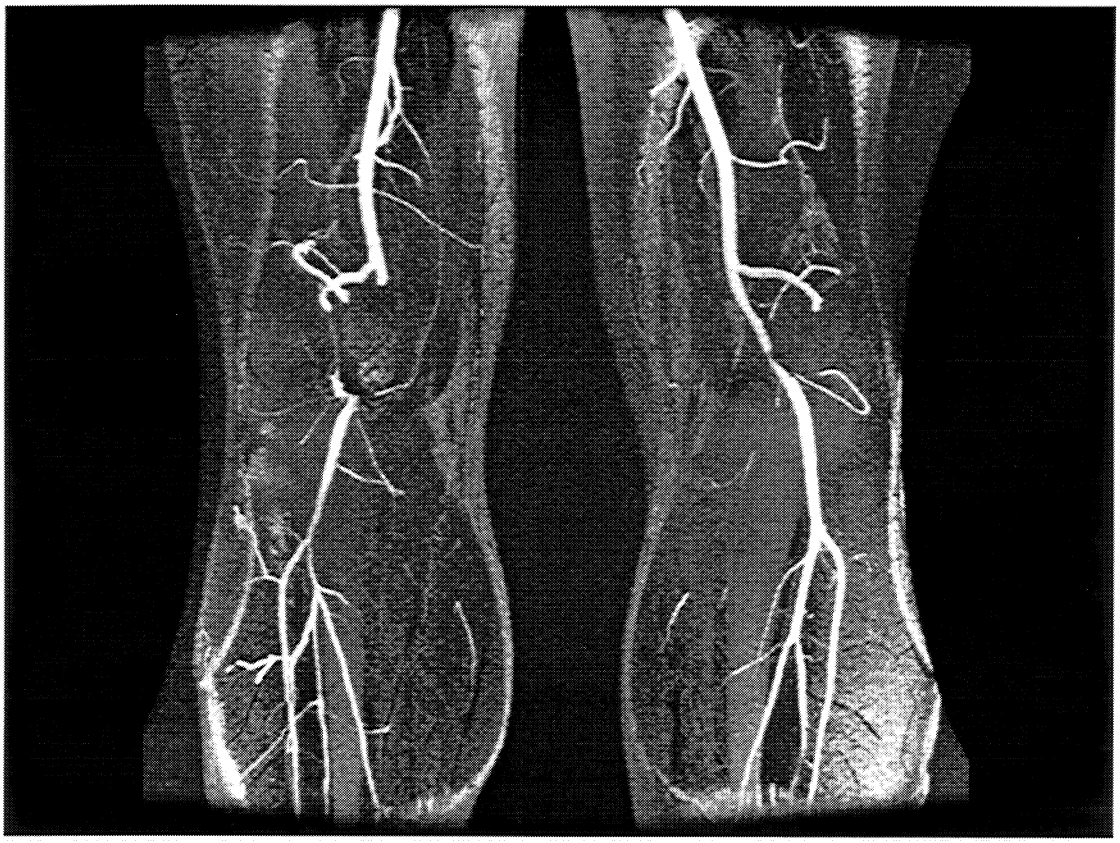

**Diagram of Light Valve Stereogram Printer**

The light valve stereogram printer eliminates the time, effort and expense of production from motion picture film. The near photographic resolution and extremely high contrast ratio produce detailed holograms. The smoothing effect introduced by the finite bandwidth of the CRT reduces the evidence of

pixels adding to the film-like appearance. Full colour work is made easy with almost immediate colour separations and absolute registration from frame to frame.

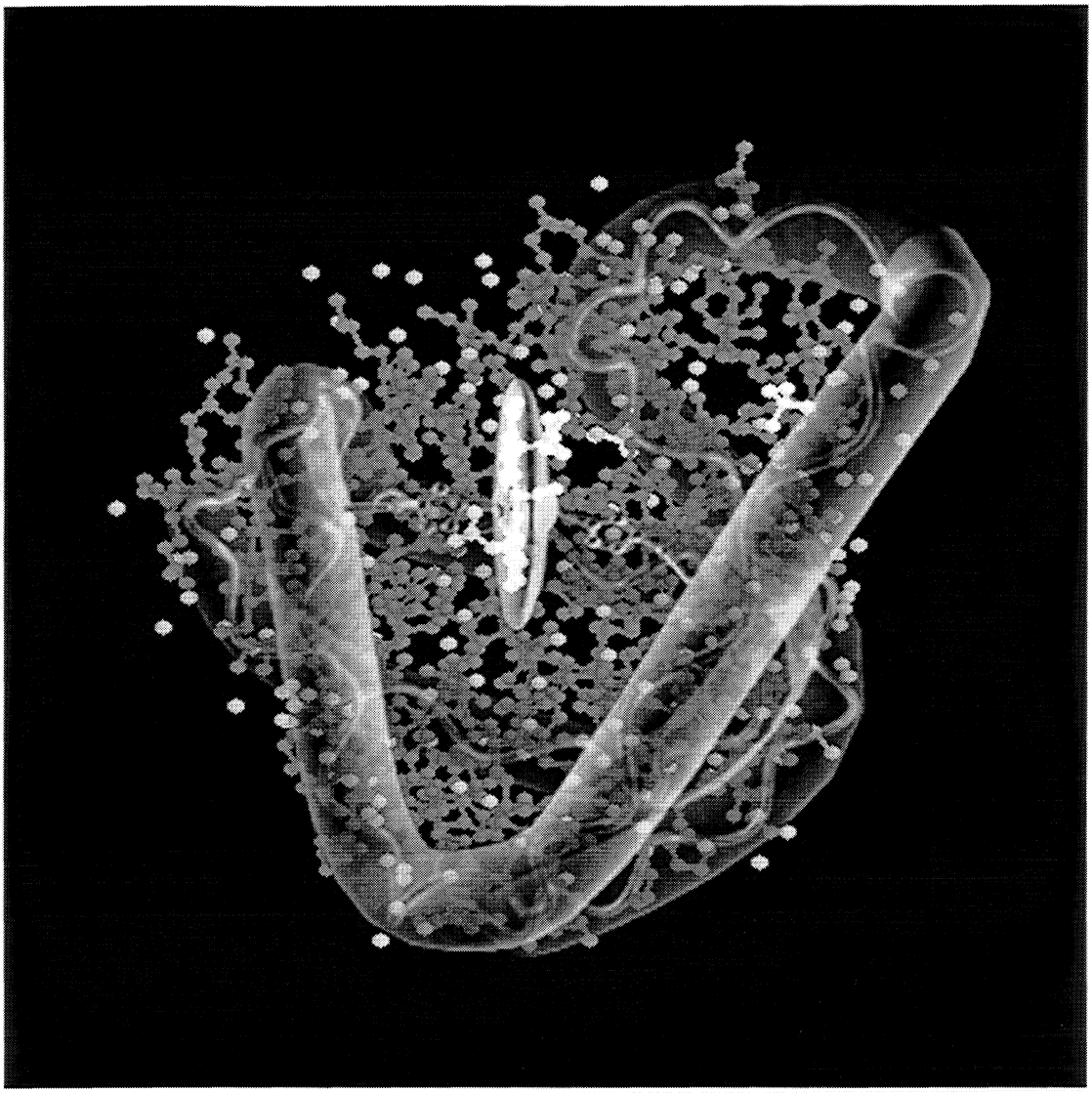
Holographers who work in medium and large format stereograms are all too aware of need for pre-visualization. Particularly when working with digital graphics as content. Finally, one must "make one to see one" when it comes to holographic stereograms. The process can be stifling, creatively. The light valve printer shortens the feedback loop and radically reduces the costs for artists.

Researchers in the field of biomedicine routinely utilize volumetric displays of data from CAT scans, MRI and con-focal microscopy for various applications including treatment planning of radiation therapy. Recently, the medical community has express strong interest in hardcopy, auto-stereoscopic displays. We have begun to develop importation filters and other software tools to permit the direct printing of Dicom standard images. Users can then send images from hospital PAC systems via the Internet using utilities such as E-film to be printed as holograms.



**Single frame used in a hologram produced using the light valve printer.**
**The Hologram clearly presents an image of the arteries at knee level in a patient with bilateral popliteal entrapment syndrome, acquired with contrast-enhanced magnetic resonance angiography.**

**Courtesy of Dr. Graham Wright SWCHSC (Sunnybrook and Women's College Health Science Centre) and Dr. Naeem Merchant, University Health Network**



**Single frame of animated hologram produced with the light valve printer.**
**The hologram depicts the contraction of the "Hem" during the oxygenated state of the molecule**

**Images courtesy of Professor R.J. Dwayne Miller**
**Departments of Chemistry and Physics, University of Toronto**

The light shaping diffusers are holographically recorded randomized surface structures that provide nearly 90% transmission (see figure C).

These devices can be considered as a superposition of numerous random gratings, having the effect of efficiently scattering light through a multitude of angles. By design, light shaping diffusers can be made to have viewing angles ranging from a few to over a hundred degrees and can have different spreads in different directions. Therefore holographers can have dramatically increased control over the uniformity of illumination while still concentrating the light within an effective area. This results in a substantial saving of laser energy, which permits shorter exposure times. Furthermore, the light shaping diffusers do not rely on multiple scattering events, so there is no loss in coherence or polarization information.

Conventional Diffraction Grating

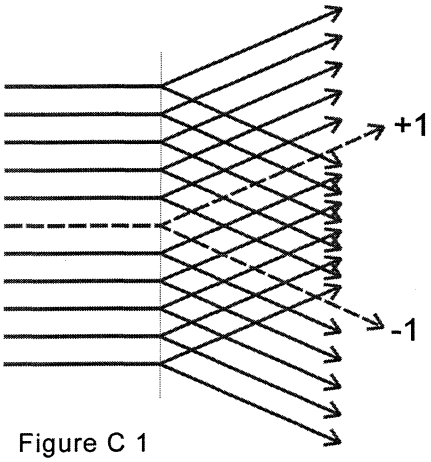



Figure C 1

Light Shaping Diffuser

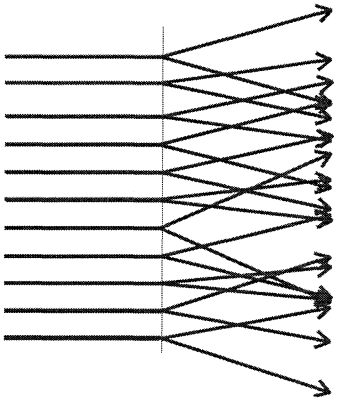
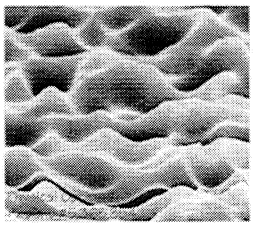


Figure C 2



**SEM image of Light Shaping Diffuser**
**courtesy of Physical Optics Corp.**

Huges/JVC Technologies has recently developed projection systems that incorporate ILAs with newly developed liquid crystal technology termed D-ILAs, (Digital Image Light Amplifiers). This has radically reduced the size of the high resolution digital projection systems. D-ILAs applied in digital holography

will be much better suited as they eliminate many of the heat generating components, (CRTs and associated electronics). As liquid crystal display technology improves, so will the resolution of the D-ILAs. Resolutions comparable to 70MM motion picture film are forecasted.

## CONCLUSION

Holographic stereograms have made possible the creation of holograms of both *real objects* in natural & studio lighting and *virtual objects* created using three-dimensional graphics. Holography represents a powerful visual medium for the presentation of volumetric imagery. By eliminating the extra step to motion picture film. The light valve printer provides an inexpensive means of production of 3D hard copy for artists and designers working in dimensional imaging.

The development of D-ILAs will mean ever increasing resolution SLMs for use in holographic applications.

Medical researchers and physicians using volumetric displays would benefit from an inexpensive, high resolution, direct recording system for auto-stereoscopic displays

Light shaping diffusers serve as efficient projection media for the production of holographic stereograms.

Interest in 3D imaging from the art & design communities is ever increasing. There is, evidently, a never-ending array of software tools that become more powerful and less expensive each month. This new digital link to the holographic medium, the light valve, is a giant step towards digital convergence.

Digital convergence will mean that the user-base in holography will expand to include artists, designers, architects and others involved in 3D imaging. As digital technology and image creation tools become more and more sophisticated, holography as a medium is no longer solely responsible for its own evolution.

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Tom Cvekovich /Chromagem.
Digital Processing Systems
Realviz Corp.
Somerville House Books.

## REFERENCE

D-ILA Projector Technology: The Path to High Resolution Projection Displays, W. P. Bleha JVC Digital Image Technology Center