



# Holographic Projection

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MAY 2004

## **Approval Sheet**

The Special Project titled  
'Holographic Projection'  
by Thomas George is approved  
for the partial fulfillment of the requirement  
for the degree of 'Master of Design'

**Project Guide**

**Chairperson**

**Internal Examiner**

**External Examiner**

**Date**

## **Acknowledgement**

I sincerely thank my guide Prof.Suresh Sethi for giving me the opportunity and pales of freedom to do this project. Your thoughts and valuable guidance were a source of inspiration along every step of the way. Thank-you Sir for your kind words, and sharing your wisdom and vast experience.

I thank the entire faculty at IDC.

I would also like to thank my family and friends for all these years of wonderful companionship, support and strength.



“If photography can be defined as the representation of a particular instant in time, holography offers the possibility to capture duration in space”

Jean François Moreau

## **Abstract**

A quest into the age old – epochal conflict between the noble scholars and mystic sages of yore.

A new perspective – the Holographic Paradigm.

“The brain is a hologram perceiving and participating in a holographic universe.”

Each part contains the whole and the whole is in each part.

the medium, light.

my interpretation.....the Oedipus waltz.

the journey begins.....

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## 1. Introduction

Three dimensional, being that we are it is only natural that we live and interact with a 3 dimensional world with greatest ease and comfort. From the houses we live in, the cars we drive, the clothes we wear, the food we eat; everything envelopes and enfolds our very existence.

Holography, a science that is more than fifty years old is only now coming into its own. In the 1970's skilled researchers from wide ranging fields such as physics, biology, psychology, neurology etc were making startling discoveries. The very facts of science, they were saying, the actual data (from physics to physiology) seemed to make sense only if we assume some sort of implicit or unifying or transcendental ground underlying the explicit data. Moreover- and here was the shock- this transcendental ground, whose very existence seemed necessitated by experimental-scientific data, seemed identical, at least in description to the timeless and spaceless ground of being so universally described by the world's great mystics and sages, Hindu, Buddhist, Christian, Taoist.

There was first, the pioneering research of Stanford neurosurgeon Karl Pribram, whose studies in brain memory and functioning led him to the conclusion that the brain operates, in many ways like a hologram. A hologram is a special type of optical storage system that can be best explained by an example

: if you take a holographic photo of, say, a horse and cut one section of it eg. the horse's head, and then enlarge that section to the original size, you will get, not a big head but a picture of the *whole* horse. In other words, each individual part of the picture contains the whole picture in condensed form. The part is in the whole and the whole is in each part – a type of unity-in-diversity and diversity-in-unity. The key point is simply that the *part* has access to the *whole*.

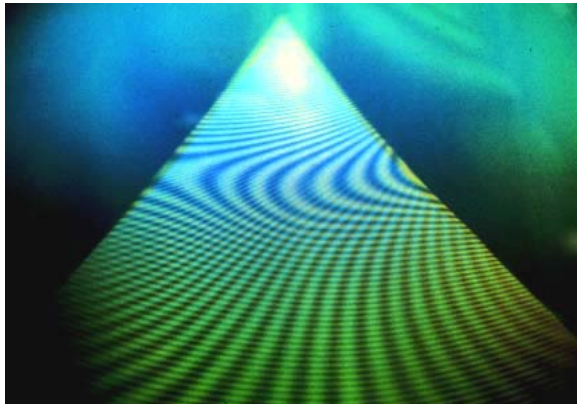
Thus, if the brain did function like a hologram, then it might have access to a larger whole, a field domain or “holistic frequency realm” that transcended spatial and temporal boundaries. And this domain, reasoned Pribram, might very well be the same domain of transcendental unity-in-diversity described (and experienced) by the world's great mystics and sages.

It was approximately at this time that Pribram became aware of the works of English physicist David Bohm. Bohm's work in subatomic physics and the “quantum potential” had led him to the conclusion that physical entities which seemed separate and discrete in space and time were actually linked or unified in an implicit or underlying fashion. In other words, the physical universe itself seemed to be a gigantic hologram, with each part being in the whole and the whole being in each part.

It was at this point that the “holographic paradigm” was born : the brain is a hologram perceiving and participating in a holographic universe.

(ref : The Holographic Paradigm and other paradoxes- Edited by Ken Wilber)

## 2. What is a Hologram?



A hologram is often described as a three-dimensional picture. While this is a good way to get a general idea of what you would experience looking at one, holography has very little in common with traditional photography.

Unlike photography or painting, holography can render a subject with complete dimensional fidelity. A hologram creates everything your eyes see -- depth, size, shape, texture, and relative position -- from many points of view. The resulting image, either behind or in front of the holographic film, has all the dimensions of the original object and looks so real that you are tempted to reach out and touch it -- only to find nothing there but focused light.



The part is in the whole and the whole is in each part

The light reflected by a three dimensional object forms a very complicated pattern that is also three-dimensional. In order to record the whole pattern, the light used must be highly directional and must be of one color. Such light is called coherent. Because the light from a laser is one color, and leaves the laser with one wave in perfect step with all others, it is perfect for making holograms.

When you shine a light on the hologram, the information that is stored as an interference pattern takes the incoming light and re-creates the original optical wavefront that was reflected off the object. Your eyes and brain now perceives the object as being in front of you once again.

## 2.1 Holography

Holography is a technique which allows the recording and playback of true, three-dimensional images. The image is called a hologram. Unlike other 3-D "pictures", holograms provide what is called "parallax". Parallax allows the viewer to move back and forth, up and down, and see different perspectives -- as if the object were actually there.

Holography dates from **1947**, when British/Hungarian scientist Dennis Gabor developed the theory of holography while working to improve the resolution of an electron microscope. Gabor, coined the term hologram from the Greek words holos, meaning "whole," and gramma, meaning "message."



Dr. Dennis Gabor

Received the 1971 Nobel Prize in Physics for his work in holography

Gabor's holography was limited to film transparencies using a mercury arc lamp as the light source. His holograms contained distortions and an extraneous twin image. Further development in the field was stymied during the next decade because light sources available at the time were not truly "coherent" (monochromatic or one-color, from a single point, and of a single wavelength).

This barrier was overcome in **1960** with the invention of the laser, whose pure, intense light was ideal for making holograms. For the next ten years, holography techniques and applications mushroomed.



In **1962** Emmett Leith and Juris Upatnieks of the University of Michigan recognized from their work in side-reading radar that holography could be used as a 3-D visual medium. In **1962** they read Gabor's paper and "simply out of curiosity" decided to duplicate Gabor's technique using the laser and an "off-axis" technique borrowed from their work in the development of side-reading radar. The result was the first laser transmission hologram of 3-D objects (a toy train and bird). These transmission holograms produced images with clarity and realistic depth but required laser light to view the holographic image.



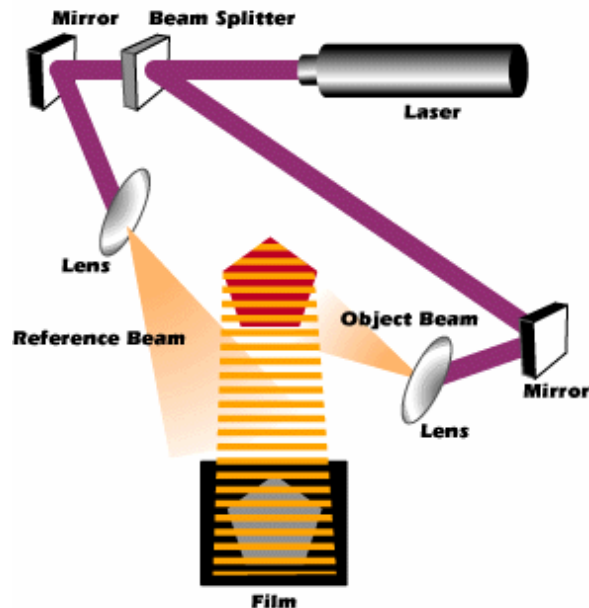
Their pioneering work led to standardization of the equipment used to make holograms. Today, thousands of laboratories and studios possess the necessary equipment: a continuous wave laser, optical devices (lens, mirrors and beam splitters) for directing laser light, a film holder and an isolation table on which exposures are made. Stability is absolutely essential because movement as small as a quarter wave- length of light during exposures of a few minutes or even seconds can completely spoil a hologram. The basic [off-axis technique](#) that Leith and Upatnieks developed is still the staple of holographic methodology.

'Train and Bird' is the first hologram ever made with a laser using the off-axis technique. This pioneer image was produced in 1964 by Emmett Leith and Juris Upatnieks at the University of Michigan only four years after the invention of the laser

## 2.2 Off Axis Technique

A beam of laser light is optically separated into two beams. One, the reference beam, is directed toward a piece of holographic film and expanded (its diameter increased) so that the light covers the film evenly and completely. The second (object) beam is directed at the subject of the composition and similarly expanded to illuminate it.

When the object beam reflects off the subject, it carries with it information about the location, size, shape and texture of the subject. Some of this reflected object beam then meets the reference beam at the holographic film, producing an interference pattern which is recorded in the light sensitive emulsion.



Holographers use basically the same kinds of film and developers as photographers. The standard silver-halide film (or glass plate) is similar to its photographic counterpart; but it is slower and requires longer exposure times, has a finer resolution, and is more sensitive to red light. Processing involves the same developer, hypo and fixer used in photography. Bleaches are used to brighten the image, and more exotic chemicals are used occasionally to shrink or swell the emulsion to control the image color.

After the film is developed, the hologram is illuminated at the same angle as the "reference" beam during the original exposure to reveal the 3-D image.

A hologram must be illuminated to produce the image. Although laser light is used to make holograms, holograms are usually illuminated with normal incandescent spotlights. To see the image, the viewer must look at the film. "Projected" images appear in the space between the film and the viewer. Images cannot be projected from the film to a distant point as in cinematography. The projected image of Princess Leia from the chrome-dome of R2D2 in the 1977 movie *Star Wars* was a film special effect – not holography. Perhaps holography will make this a reality in the future.

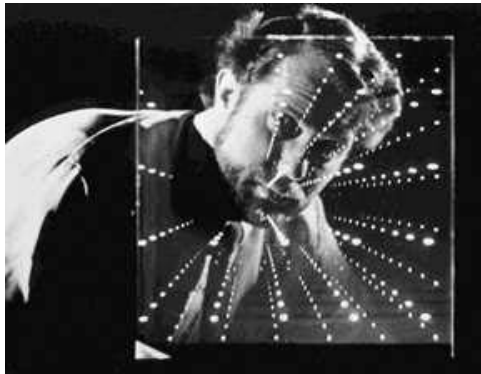
There are two basic types of holograms -- reflection and transmission. They can be distinguished by the way in which they are illuminated.

**Reflection holograms** are lit from the front, reflecting the light to you as you view it, like a painting or photograph hung on a wall. Different film emulsions produce images with different characteristics.

**Transmission holograms** are lit from the rear (like a photographic transparency) and bend light as it passes through the hologram to your eyes to form the image.

A major advance in display holography occurred in **1968** when Dr. Stephen A. Benton invented white-light transmission holography while researching holographic television at Polaroid Research Laboratories. This type of hologram can be viewed in ordinary white light creating a "rainbow" image from the seven colors which make up white light. The depth and brilliance of the image and its rainbow spectrum soon attracted artists who adapted this technique to their work and brought holography further into public awareness

Benton's invention is particularly significant because it made possible mass production of holograms using an embossing technique. With this technique, developed by Michael Foster in 1974 and brought to commercial viability by Steve McGrew in 1979, holographic information is transferred from light sensitive glass plates to nickel embossing shims. The holographic images are "printed" by stamping the interference pattern onto plastic. The resulting hologram can be duplicated millions of times for a few cents apiece. Consequently, embossed holograms are now being used by the publishing, advertising, banking and security industries.



*Dr. Stephen A. Benton, Massachusetts Institute of Technology, seen through "Crystal Beginning," a white light transmission hologram produced at the Polaroid Corporation in 1977.*

## 2.3 Holograms over the years and in few of their many applications

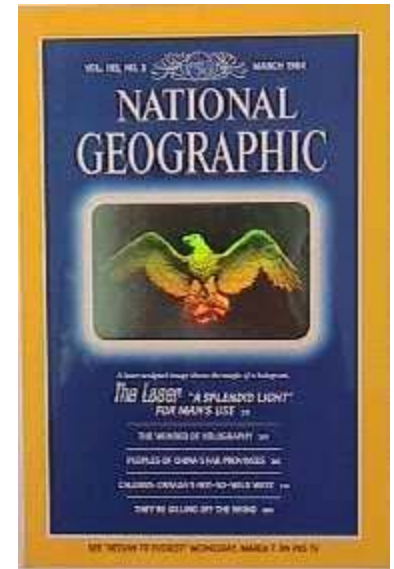


In **1983** MasterCard International, Inc. became the first to use hologram technology in bank card security.

The 2-channel holograms were the widest distribution of holography in the world at that time.



The form of a 2300-year-old Iron Age man unearthed from Lindow Moss, a peat bog in Cheshire, England, was recorded by a pulsed laser hologram for study by researchers



National Geographic magazine was the first major publication to put a hologram on its cover. The March **1984** issue carried nearly 11 million holograms throughout the world.

### 3. 3D Holographic Projection – Science or Fiction?

Holographic Projection still remains in the realms of science fiction and movie special effects. The impact that this technology can have on fields such as entertainment, science, engineering, communication etc could be very profound. A documentation of various attempts at simulating a 3-dimensional projection system has been carried out to understand the progress and effects at bringing this technology out of science fiction and into hardcore reality.



A clip from the 1977 movie, Star Wars – A New Hope, depicting a 3d holographic projection of Princess Leia.



Movies have provided ample evidence of this kind of 3d projection systems,bringing them to life on the big screen using advanced computer graphics. Films such as Star Wars,Star Trek,Matrix,Minority Report etc have depicted a wide variety of uses such as communications, personal advertising, various kinds of interfaces even your very own personal tennis instructor.



## 3.1 3D Holographic Simulations



### 3.1.1 Laser - Cube

The LaserCube is an entirely new way of displaying laser imagery in three dimensional space without particulates in the air. Images projected into the LaserCube appear to float in space like holograms within the sculpture.

Each LaserCube consists of two elements, the Imaging Cube and the Projector.

The Imaging Cube is made of multiple parallel imaging screens created from a fiber optic-like material. This material acts as a holographic medium to display laser light images. Laser light in the form of line drawings and abstract images are projected into the LaserCube. Laser light is imaged on the first of the imaging screens and then passes through to the next and then the next and so on. The same image appears on each of several parallel planes creating the holographic illusion of depth and perspective.





### 3.1.2 Holo - Tank

The HoloTank is a 3D volumetric display created by projecting scanned laser light or vector video graphics into a special liquid medium resulting in 3D holographic type projections.

Moving laser or video images are projected into a liquid chamber (like an aquarium) in which proprietary microscopic particles are suspended. When vector graphics like words, line art, cartoons and abstract geometric images are projected into the Tank; they are imaged three dimensionally like holograms within the Tank. These multicolored, 3D images materialize mysteriously within the Tank.

HoloTanks can be built to any size specification and can be used as a high tech alternative to an aquarium. Because of the great efficiency of how the particles glow within the HoloTank, relatively low power and less expensive lasers can be used for a very bright holographic display.

### 3.1.3 Holo - Mirror

HoloMirror Projectors are 3D Volumetric Displays which produce moving, 3D images that appear projected into space. Like holographic projections in science fiction, HoloMirror projections can appear to float in space up to 4 feet in front of the HoloMirror Projector.

HoloMirror technology uses special parabolic optics to focus the real image of a hidden object or moving video image so that a lifelike 3D image appears to be projected floating in space. The 3D image of the object or video information is projected into the space in front of a kiosk or above a tabletop depending on the type of HoloMirror Display.

The illusion of "Holographic Projection" is so real that you can put your hand right through the image where it seems to be floating in thin air.





One hand is at the window plane and the other is on the image plane



HoloMirror Projector with finger directly under image

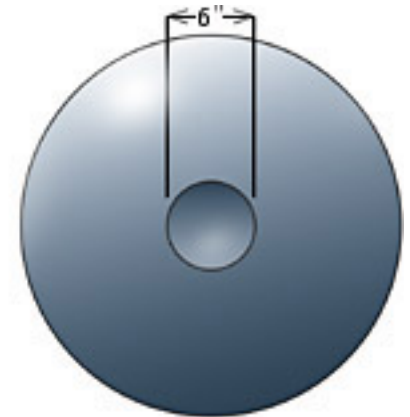
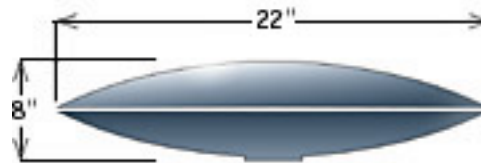
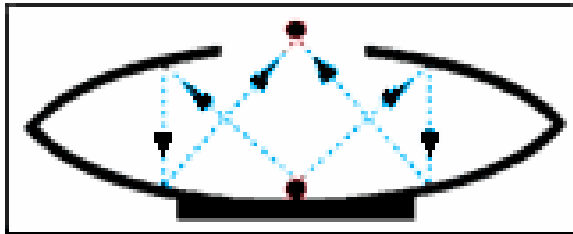


Touching image floating in front of kiosk



### 3.1.4 Holo - Mirror 360

To achieve these effects, the HoloMirror 360 utilizes a patented technology of two concealed, opposing parabolic mirrors. In overall appearance, HoloMirror 360 resembles a small wok with a 6-inch circular opening in the top. The physical object to be converted to a hologram is placed in the concave center of the bottom mirror. A hologram instantly projects up through this aperture, appearing to the viewer as a truly solid object.



## 4. Ingredients for Realization

The precursors of 3d holographic projection technology are and have been in existence for quite some time. Video conferencing via the internet and web-cam chats are common place events. Virtual reality environments are soon becoming powerful tools in the hands of scientist, doctors, engineers, architects and their applications in these various fields is soon becoming indispensable.



Cameras & Internet : Video conferencing



Virtual Reality Environments



Tele - Immersion

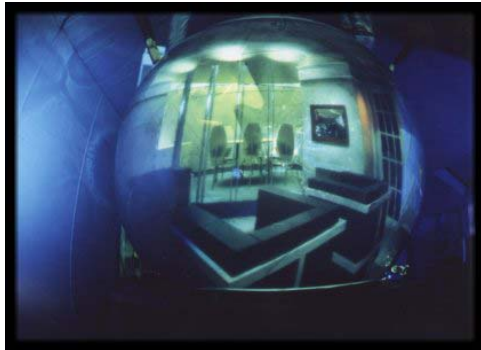
Tele-immersion is an advanced form of communication being developed today. It portrays a 3D image of a person miles away and allows interaction (audio/visual). It is created by the real time rendering of a real environment.

## 4.1 Cyber Sphere

The virtual reality world of Star Trek's Holodeck has been brought a step closer to reality by the development of a Cybersphere a collaboration between University of Warwick's Warwick Manufacturing Group and virtual reality company VR Systems UK.

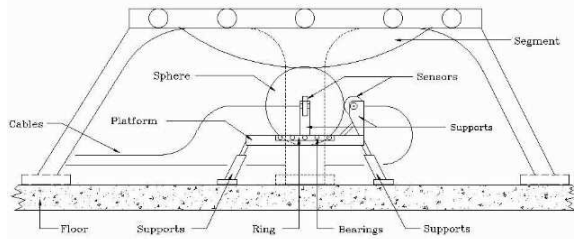


Virtual environments have been extensively used in planetariums and military flight simulators where images are projected onto the inside of a large hemispherical surface or in CAVE systems, whereby images are back-projected onto walls and the floor of a room. However all of these suffer one important limitation -- i.e. the inability to move around the virtual environment in a natural way.



The Cybersphere can solve these problems by mounting a large (3.5 metres in diameter), hollow, translucent sphere on a ring of bearings with an additional low-pressure cushion of air allowing the sphere to rotate in any direction. The walking motion of the observer in the centre of the sphere causes it to rotate. The movement of the large sphere is transferred to a smaller secondary sphere which is held against the large projection sphere by means of spring loaded supports.

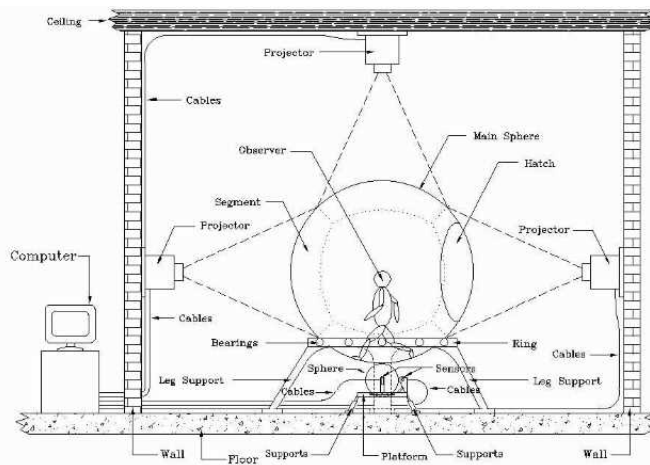
Totally immersive holographic environment



The movement of the smaller sphere is then measured by rotation sensors, and the signals are used to update the images projected on the surface of the large sphere allowing the observer to walk, run, or crawl in any direction.

A number of high power projectors are used in combination to project the images which combine to provide a fully immersive visual experience for the observer and gives the illusion of walking freely through the computer generated environment.

The collaborators are already in discussion with organisations wishing to use the technology for applications as diverse as computer gaming, military simulations and manufacturing engineering product and factory design projects.



## 4.2 Nebula

Phillips Design has employed 'experience design' to help develop their concepts for future products, services and environments. 'Experience design' is an approach which focuses on the quality of the user experience during the whole period of engagement with the product.

Nebula is an interactive projection system designed to enrich the experience of going to bed, sleeping and waking up. It provides intuitive and natural ways of physically participating in a virtual experience, through simple body movements and gestures. The aim was to create an atmosphere that encourages and enhances rest, reflection, conversation, intimacy, imagination and play. Nebula consists of a ceiling projector linked via the Internet to a database of content. Once users have selected the content for projection, they can manipulate it simply by adjusting their sleeping positions and interacting with their partner while in bed.



## 5. Technology : Booking Lack

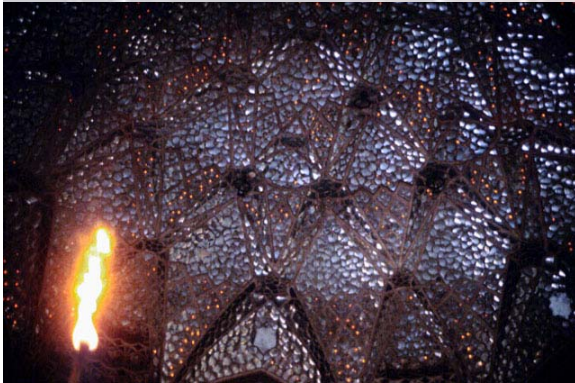
Technology is rooted in the creative nature of God and its appropriate use is a moral obligation in our stewardship of the earth. Technologies facilitate human actions, thereby shaping societies, and act like amplifiers of human aspirations, both good and bad. The Internet, mobile phones, genetic engineering, artificial intelligence, nanotechnology, therapeutic cloning and now holographic projection – the pace of technological change is leaving us breathless.

The word 'technology' derives from the Greek techne, meaning 'art', which in ancient Greece covered the making of laws as well as virtually any skill. But the practice of what we now call technology is as old as humankind and preceded the development of science by thousands of years. Prehistoric people developed impressive technologies for obtaining the necessities of life. They learned how to make tools, start fires, build shelter, and use weapons for hunting.

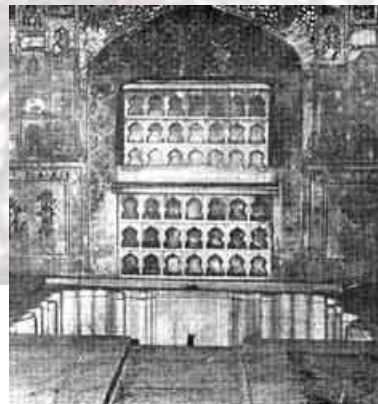
A peep into history can reveal treasure troves of man's ingenuity to not only make his life easier but also more pleasurable. Creativity and an imaginative conscience are the essence of what makes us human.

## 5.1 Shish Mahal

On the western side of the Muthamman Burj and just below the Diwan-i-Khas hall is the Shish Mahal or the Glass Palace. This was constructed by Shah Jehan sometime between 1631-40. Since it is believed that the building was used as imperial baths its walls were made extra thick to ensure maximum coolness in the interior. The name of the building is derived from the fact that its ceilings and walls are covered with innumerable pieces of mirror set in the plaster. Minimum openings were kept in this building to necessitate the use of artificial light, which was also necessary to obtain the picturesque effect of the glass work. **Abdul Hamid Lahauri**, the historian of Shah Jehan calls these glass pieces *shishye halabi* Haleb was the original name of Aleppo (Syria) which was the main centre for manufacturing these glasses.



Mirror decoration on the ceiling of Shish Mahal



View of the candle niches and a tank



The Shish Mahal comprises of two large chambers measuring 38'x22' each. Both these chambers are connected in the centre by a broad arched opening and on the sides by two narrow passages. Light penetrated only through two doors and a ventilator in the southern wall near the ceiling. Each chamber had a marble reservoir for water and there was also arrangement for hot and cold water. The chamber had marble doors so that steam bath could be had if needed. The northern wall of the interior hall has beautiful niches sunk in its centre which has two inlets for water. Water coming through this inlet fell into the tank sunk in the wall like a continuous sheet. From here through another channel the water fell into another tank. Two series of candle niches were also provided. Candles burning behind the falling water created a gorgeous effect. From the tank in the inner hall the water then flowed through a long canal into the tank in the outer hall. Both these tanks had fountains, which added to the mysterious effect of light.



Mirror decoration in the niches at Shish Mahal

## 6. Mirrors and Holographic projection?

The use of mirrors and light to create a simulation of a holographic projection have been studied and documented in the preceding pages. It is interesting to note that the spectacular effects produced by a vast array of computer controlled projection systems were and have been duplicated to a great extent in the past with the means of far less technically superior elements, as is the case with the Shish Mahal. The Mughals were able to conjure up an almost ethereal effect with the dance of light and reflections with the humble candle and numerous pieces of mirror on the walls and ceiling, over 400 years ago.

The project began with a quest to try and understand this subject (Holographic Projection) and its far reaching socio-psychological implications 'if any', when it 'does' indeed become reality, keeping in mind the pace of technological advancements. Mankind's dependence on technology has and always will be ever increasing. Keeping in mind the scope and duration of the project it was decided to further explore the possibilities of using light and mirrors to create a visual experience that could be comparable to the likes of those produced using more sophisticated means.



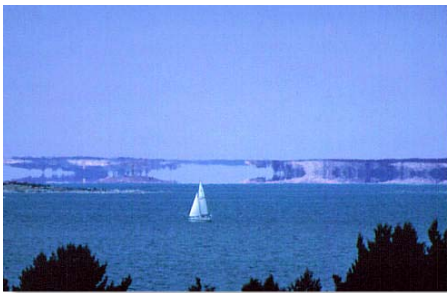
## 7.Sources of Inspiration

### Atmospheric Phenomena

#### Aurorae

One glorious effect seen when the solar wind interacts with a planet's magnetic field is **aurorae**. Aurorae are shimmering light displays produced by solar wind particles deflected toward the magnetic poles and colliding with molecules in the upper atmosphere. These collisions excite the atmosphere molecules (bumping their electrons to higher energy levels). The glow of the aurorae is the emission line spectra produced by the electrons in the rarefied gas dropping back down to lower atomic energy levels.





## Mirages

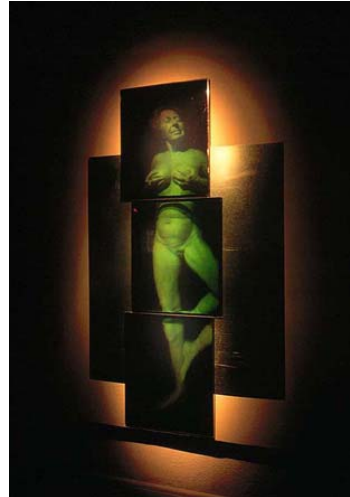
On June 23, 1744, a phantom army appeared floating above a mountain in Scotland. Twenty seven people, who later gave sworn testimony to what they'd seen, watched the strange vision for two hours till it ended with darkness.

In the summer of 1897 in Alaska, an expedition to the wilderness near Mount St. Elias saw a "Silent City" over a glacier. A member of the expedition, C. W. Thornton, wrote, "It required no effort of the imagination to liken it to a city, but was so distinct that it required, instead, faith to believe that it was not in reality a city." Another witness reported, "We could plainly see houses, well-defined streets, and trees. Here and there rose tall spires over huge buildings..."

The above incidents are examples of a startling optical atmospheric effect known as a mirage. Though we associate mirages with the illusion of distant water in a desert, the phantom oasis is actually just the simplest example of this bizarre effect.



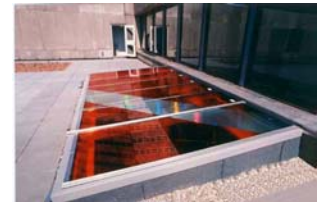
## 8. Light and Mirrors : Art Installations



## Palace of Justice : The Hague



Reflections in the waiting room by spectral mirrors in the light well

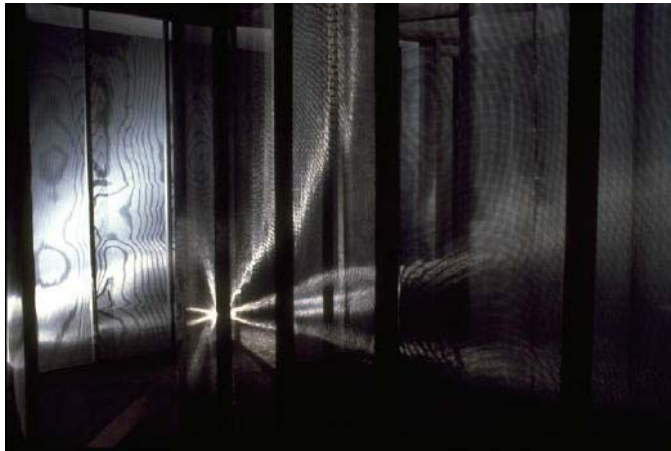


**Dark Field 1990**

Boston Center for the Arts Cyclorama, MA



This mazelike environment of black screen panels contains passageways and rooms through which viewers move. Interacting with piercing light, the screens project bold moiré patterns that seem to float in front of their surface, creating a shimmering and ambiguous space.





## Hiro Yamagata

The unifying element within the diversity of effects and experiences is the refractive holographic panels covering all surfaces of the gallery - walls, floor, and ceiling. These multiple refractive surfaces disperse and transform white laser beams into scattered spectrums of color. In addition, most of the rooms are filled with thousands of spinning, mirrored cubes suspended from the ceiling. The laser/lighting systems are run by an intricate series of computer programs designed to generate various rays of light, which travel across and between various galleries, bouncing and refracting off of mirrors and holograms.

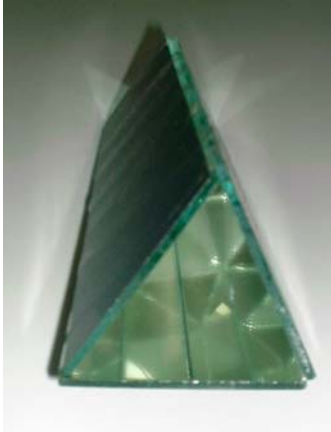


The viewer is immersed in a vast display of ever-changing lights, unlike any natural phenomenon but perhaps indicative of it.



## 9. Explorations

The experimentation began with trying to understand the qualities of reflections produced by mirrors, both plane and spherical and finally undulating reflective surfaces. A kaleidoscope was used to visualize the effect of multiple reflections produced by plane mirrored surfaces. Similarly several mirror coated marbles which simulate a spherical reflective surface were also used.



Kaleidoscope – mirrors and reflections in different planes



Mirror coated marbles



## 9.1 Spherical Mirrors

Mirror coated marbles were used to simulate spherical reflective surfaces and their interaction with a perpendicularly mounted light source was explored. The multiplicity of reflections caught on the numerous surfaces were akin to the characteristic of the hologram to have its information spread evenly over its entire volume(or surface as is the case here).

Apart from creating a visual effect of many lights from a single source the heat produced by the bulb actually warms the marble surfaces, which by the nature of its surface and colour are typically thought of as being cold to the touch. A kind of sensory experience which contradicts convention was 'accidentally' created along with the visual information.



## 9.2 Projected Reflections

The use of reflective surfaces such as mirror paper of various colours and a chrome plated sheet to project reflections on a screen or wall were attempted. The paper was placed on the table and either one or two spotlights were used to produce the reflections, the angles of light incident on the reflective surfaces were manipulated to produce the clearest reflection on the screen. These reflections were then bathed in a series of colour filters of varying intensity and the images caught on the wall were then photographed. At this stage there was very minimal control over the process and these explorations aided in understanding the kind of effects that could be produced. A few of the sample photographs of this experiment have been shown on the following pages. These photographs have an enhanced contrast compared to the original images to simulate a more powerful light source than which was available.

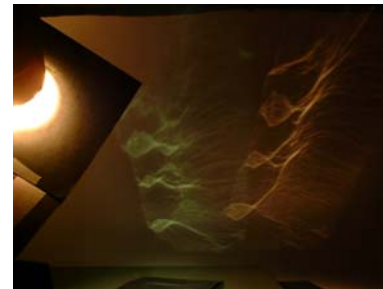
Coloured reflective paper



Projected reflections on a wall



Colour filters

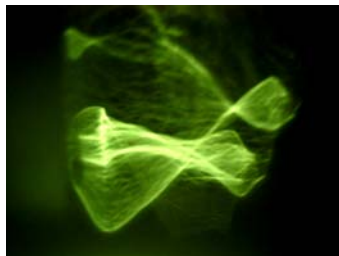


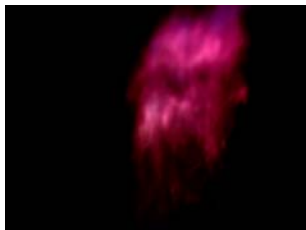
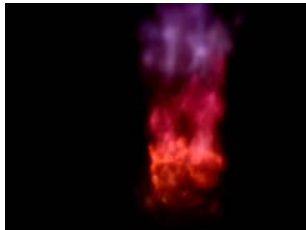
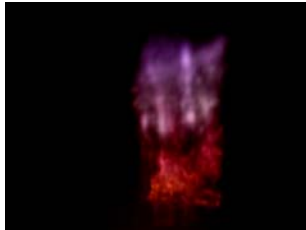
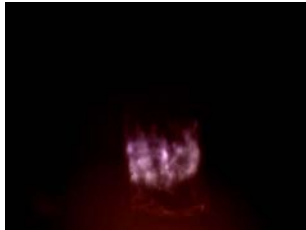
Final output



### 9.3 360 Degree Rotation

In order to achieve a certain degree of control over the process, the basic motions such as linear translation of the reflective surface (perpendicular and parallel to the light source) and rotation were carried out. The projected reflections off the undulated chrome plated sheet produced an almost three dimensional quality that is remarkably similar to computer simulations of an organic form folding in on itself.





#### 9.4 Animated Column of Light

A series of coloured reflective paper was used in sequence moving horizontally along the table surface towards the light source. The effect produced by the projected reflection is that of an animated column of light that continually changes hues as the frames advance. A primitive simulation of the aurorae, still very far from the spectacular natural phenomenon that has few parallels in terms of sheer beauty.

## 9.5 Flexing of the reflective plate

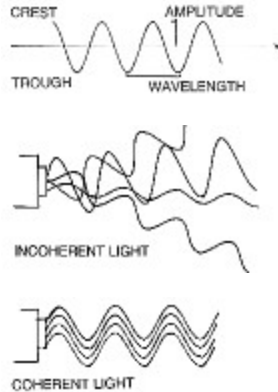


## 10. Conclusion

'The journey of a thousand miles begins with one step' goes the old Chinese saying, at the risk of sounding clichéd. This has been a thoroughly enjoyable experience personally, so much to see, so much to try out, so much to learn. This could be just the tip of the proverbial iceberg. The explorations so far are a humble effort to create an enjoyable visual experience using light and mirrors, that I hope in earnest has been moderately successful.

Further possibilities abound, variations in the kind of surfaces onto which the reflections are projected (plane, curved, opaque, translucent, semi-mirrored), the very surface nature of the reflective medium (plane, corrugated, dimpled), the quality of light and even the dynamic element that could eventually lead to a vibrant almost 'alive' dance of light need to be explored. Total mastery of the medium can only be accomplished with absolute control over the variables....

## Glossary of Terms



*Amplitude* - The height of a wave crest or depth of a wave trough, measured from the wave's mid-point.

*Beam splitter* - A device used to divide the light from the laser into two separate beams - the reference and object beams. It consists of a partially transparent mirror which reflects part of the laser beam and transmits the rest.

*Coherent light* - Light which is of the same frequency and is vibrating in phase. The laser produces coherent light.

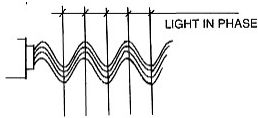
*Film* - Whether photographic or holographic, film consists of light sensitive chemicals (the emulsion) spread on a surface. A film's resolution measures its ability to distinguish between details. Because holographic films must be able to record very detailed information, they have a resolving power of 50 or more times that of photographic film. They require either exposure to a high intensity pulsed or a long exposure to a continuous wave laser. Holographic film is developed in a manner similar to photographic film, by bathing it in a series of chemical agents.

*Interference pattern* - When two waves overlap, their amplitudes add at every point. This results in an interference pattern which records the relative phase relationships between the two waves, storing each individual wave's characteristics. This is how a hologram works.

*Laser* - An acronym for "Light Amplification by Stimulated Emission of Radiation." A laser is a device that produces a concentrated beam of coherent light. Some, called continuous wave lasers, produce a continuous beam of light. Others, called pulsed lasers, emit more light in brief pulses which are able to freeze motion.

*Lenses* - Lenses are devices which redirect light. In photography, lenses are used to focus an image for the film. Holographers use lenses to widen the lasers beam to illuminate all of the subject which is to be holographed.

*Object beam* - The light from the laser beam that illuminates the object, and is reflected to the holographic film.



*Phase* - The position of a wave in space, measured at a particular point in time.

*Reference beam* - The portion of the laser beam that goes directly to the holographic film. The interference pattern which results from the object beam meeting the reference beam at the holographic film is recorded on the film.

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