Sculpting Light
Holography and Applications

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June 2014

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Dedication

To
Dr. Yuri N. Denisyuk -
Father of White-Light Holography.
Organization of the Presentation

- Holography
- General Applications
- Advanced Applications
- Light Logics Holography and Optics
Optical Holography

...a method to record and reconstruct light fields with its whole information content.
Visual Perception

Light Logics
Machines and fine structures for light harnessing
A PARADOXICAL SITUATION
MAN'S EFFORTS TO MAP SCENES AND OBJECTS AND COMMUNICATE PERSPECTIVES
PHOTOGRAPHY

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Beautiful, but not whole!
INABILITY OF PHOTO EMULSIONS -

Records only partial information content of a light field. A photograph is just an intensity mapping, monochrome or color!

Where is the depth gone?
IDEAL MATERIAL RESPONDS TO BOTH INTENSITY AND PHASE and recreate a virtual piece of space. ... BUT STILL A DREAM!
EARLY DREAMERS

DENNIS GABOR (1900-79) in 1948 INVENTED wave front recording and reconstruction, for which he received Nobel Prize in Physics in 1971.
What brought **Nobel Prize** for Gabor?

Photograph of an INTRFERENCE PATTERN!
What is an interference pattern?

PHASE ENCRYPTED INTENSITY!
How Does Light Scattering Micro Structures record and recreate whole Information?
Light Harnessing Micro Structures

A complex grating that scatters light
PHOTOGRAPH OF A TRANSMISSION HOLOGRAM and micro structures of holograms.
Scattering of light by apertures modifies the input light fields and in the resulting output is decided by the aperture.
A Hologram is a complex grating that is unique for a specific object and object orientation.
A true hologram
How to Produce Complex Light Harnessing Micro Structures?

Just through interference of light waves, photograph the interference pattern to have a HOLOGRAM.

Recording of the interference pattern functions as complex diffracting structures that uniquely sculpt light.
Holography needs to create easy and stable Interference Pattern
Lasers
Power of simplicity and togetherness

Light

- Weightless and Tiny
- Travels about 300,000 Km/sec
- Cuts steel and diamond
- Gives us a major portion of information
- Entertain us and
- Helps us to communicate with the universe, both the micro and macro.
LASERS CREATE EASY INTERFERENCE PATTERN

**Ordinary Light + Light → More Light**

**Noise**

**Laser Light + Light**

**Music**

**DARKNESS**

**BRIGHTNESS**

**INTERFERENCE PATTERN**
Wavelength of visible light is about 0.5 micron and for recording stable interference patterns the system stability requirement is to be more than this. Vibrations and movements of sub-micron order can mix up the maxima and minima of the interference structure and the information stored is lost.

\[
\begin{align*}
\lambda &= 0.5 \text{ MICRON} = 1/2000 \text{ m m} \\
\lambda/2 &= 1/4000 \text{ m m}
\end{align*}
\]
A BASIC HOLOGRAM RECORDING SCHEME

1. Laser
2. BS
3. Mirror
4. Lens
5. Reference Beam
6. Object Beam
7. Object
8. Photoplate
A beam splitter

Interference needs at least two light beams. Hence the laser beam has to be split into two parts. One part illuminates the object and the other part adds to the scattered beam from the object to form the interference pattern. An ordinary glass piece or a coated glass can form a BS.
Beam size of a laser is usually about a millimeter and hence it is required to expand the laser beam so that the entire object area is illuminated well. But, expansion of laser beams by using a lens leads to creation of lots of noise fringes due to dust and other non-uniformities. A Spatial Filter (SF) is used to expand and filter the laser beam.
A SF is a combination of a tiny high power lens and a pinhole. The noise fringes can be considered as a spatial distribution and at the back focal point of the lens the DC portion is focused and the high spatial frequency noise surrounds it. In reality the, lens is bringing the Fourier Pattern of the light field to its back focal plane.
SPATIAL FILTER

If a pinhole of proper size is used to filter the central DC portion of the light field at the focal plane of the lens, we will get a uniform expanded laser beam with all the spatial noise eliminated. In reality, a microscope objective (say 10X or 20X) in conjunction with a 30 or 20 micron pinhole arranged on a small four-degrees-of-freedom mount forms the SF.

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We use back side coated mirrors to see our face. But, if such mirrors are used to reflect laser light, it will be reflected from the front surface and the back inner surface of the mirror and those reflected sets of beams interfere with each other to form Fringes of Equal Thickness, thus losing the uniformity of the laser beam. Hence, front coated mirrors are applied in laser optics and holography.
A PRACTICAL HOLOGRAPHY SET UP

Thus a practical holographic set-up uses laser, BS, SFs, mirrors, lenses, vibration isolation tables, shutters for exposure, apart from the object and the recording medium.
Holograms: Light harnessing microstructures

Can be -

• Transmittance variation
• Thickness variation
• Refractive Index variation
Different types of light sensitive media are used to record holograms. This range from high resolution photographic emulsion to photopolymer. Depending upon the physical change taking place in the medium, it can be classified as absorption, phase, relief hologram etc.

- Silver Halide Plates / Films
- DCG
- Photoresist
- Photopolymers
- Photorefractive Glass
- Photorefractive Crystals
Photographs of reconstructions of a few holograms recorded at CUSAT in 1984.

Photograph with a white light hologram of Dr. Y.N. Denisyuk
APPLICATIONS OF HOLOGRAPHY

Creative, Scientific and Technological

Holography has lots of applications ranging from road flatness testing to identification of supersonic fighter jets.
Holography is getting matured as a new arm of creative media with lots of exceptional capabilities. It has real depth, dimensional capabilities and color as the raw material for a creative mind. The creative artist can seek the help of an experienced heliographer to convert his ideas into a holograms. Holograms are used to archive images and creations of eternal value. Holographic Studio and Camera Systems that sculpt light to convert ideas into images.
A moment of one’s life, as frozen space time – Portraiture
Large Perspective Images in small area – a window to the third dimension.

Picture from Prof. Martin Richardson is gratefully acknowledged.
ADVERTISEMENT AND BRANDING

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SECURITY HOLOGRAMS

COUNTERFEITING - a global menace.
SECURITY AGAINST COUNTERFEITING

should start with the basic assumption that …*anything manmade can be counterfeited* !
...And it has reached such a stage that...

Even God made objects are counterfeited !!!
DIGITAL IMAGING AND PROCESSING

Modern digital tools see images as color or monochrome dots and easily copy, scan, or capture…, process and print…..

Counterfeiting / forgery made easy….

The good old sanctity of photographic evidence was lost !!!

During the first half of the 80s….

Security Holography evolved as an effective tool to fight against counterfeiting and forgery.

Acknowledge pictures taken from the internet
Sculpting Light - Man on Mother Nature’s Trail
Micrograph of a peacock feather - Diffracting structures with Specific order
Diffracting structures with Specific order

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Diffracting structures with specific order
MAN ON MOTHER NATURE’S TRAIL

Acknowledge picture from Prof. Graham Saxby's bool
SECURITY HOLOGRAM

is generally, a hologram with a microscopic relief structure
Categories

2D/3D

Dot-matrix

e-beam

Photopolymer
A 2D/3D Mastering

• 2D Layers of Images are Superposed at Different Depth to form a 3D Structure.

• Specific Colors are Assigned
2D/3D Hologram

• Security Depends a lot on the Design and the Skill of the Holographer.
DOT-MATRIX HOLOGRAMS

- Security depends mainly on the integrity of the origination company.
Image-matrix System

- Creates complex relief structures
- Creates identical structures if repeated

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E-BEAM ORIGINATION

- Creates Very Complex Patterns with High Resolution
- Less number of Players

Acknowledge picture from Dr. Anton
Security depends mainly on the integrity of the origination company.
Why security holograms?

A very attractive and efficient security device

- Difficult to copy by conventional digital tools
- Virtually impossible to duplicate, even by the originator
- Image formation through diffraction.
Complex content of e-beam holograms
Entry Level Feature Readers

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Opportunities
HoloSecure™ Card

Light Logics Holo-Secure ID Cards

- Holographic high security electron beam features
- Machine readable holograms
- Fully metallic card base
- Laser engraved relief image
- Photopolymer holographic data
- Laser engraved variable data
HoloSecure™ Card - Charm

- Fully Holographic
- Fully Metallic
- Tough and Highly Durable
- Tamper Evident and Copy Proof
- Delivers Contact and Contactless Smart Functions
- High Storage Capacity
- Can Hold Biometric and DNA Features
HoloSecure™ Card - Charm

- Secure and Hybrid Data Switching
- Holographic Data Storage and Recognition
- Laser Engraved Variable Data
- Holds Hundreds of Security Features
- Hybrid Machine Readability
- Multilevel Holographic Security
- Possibility of Unique, Non-repeatable and
- Random Holographic Features
- Optical Switching
HoloSecure™ Card - Features

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NON-DESTRUCTIVE TESTING AND EVALUATION

MEDICAL IMAGING

Pictures taken from the internet is acknowledged
Holographic live fringe stress measurement of thin films, conducted by the author, at the Cochin University of science and Technology, in 1995. The method has lots of applications in remote temperature measurement and stress measurement.
TIME-AVERAGED Holography

HOLOGRAM OF A VIBRATING LOUD SPEAKER RECORDED BY THE AUTHOR IN 1995

FIRST EVER RECORDED TIME-AVERAGED HOLOGRAMS OF MUSICAL WIND INSTRUMENTS (INDIAN FLUTES) RECORDED BY THE AUTHOR IN 1997

Fig. 2. Vibration patterns of the flute for various frequencies: (a) 2350 Hz, (b) 2560 Hz, (c) with the same column length as in (b) but with blowing pressure slightly increased, (d) 2800 Hz, (e) 3200 Hz, (f) 3400 Hz.
Fig. 15.7. Photographs of images of a vibrating guitar generated by time-average holograms: (a) 185 Hz, (b) 285 Hz. The fringes are characteristic of the first two vibration modes of a guitar made by Georg Bolin, Stockholm. The holograms were recorded by N. E. Molin and K. A. Stetson at the Institute of Optical Research, Stockholm, Sweden.
Holographic Optical Elements (HOEs)

HOEs are diffractive optical elements with a variety of special applications. HOEs can be categorized as lenses, gratings, mirrors, filters and multiple function elements.

Recording of a Holographic Lens
HOEs are diffractive optical elements with a variety of special applications. HOEs can be categorized as lenses, gratings, mirrors, filters and multiple function elements.
Hologratings have several applications in imaging, photonics systems, optical communication, integrated optics etc. Volume Gratings are applied in laser beam shaping, multiplexing and de-multiplexing of CWDM, DWDM channels etc.
Light Logics CUSTOM MADE HOLOGRAPHIC Gratings

If two plane beams are allowed to interfere and form a hologram, the internal fringe structure will be a set of closely spaced lines with a sinusoidal modulation, forming a line grating. Hologratings have several applications in imaging, photonics systems, optical communication, integrated optics etc.
HOEs are diffractive elements and hence wavelength sensitive. Holographic mirrors, lenses, gratings and combination elements yield power spectrum generally similar to the refractive counterparts. Focus of a holographic parabolic mirror (top), power spectrum of a conventional grating and a holo-grating (middle) and that of a conventional lens and a holo-lens (bottom), recorded by the author in 1984.
VOLUME Bragg gratings VBGS

VOLUME Bragg gratings (VBGS) are volume holograms with great diffraction efficiency and wavelength selectivity. A great amount of research work on VBG element recorded in Corning photorefractive glass is acknowledged.
Yesterday

All Electronic

Info Transfer
Info Storage
Info Processing

Picture taken from the internet is acknowledged
Today

Opto Electronic

Info Transfer
Info Storage
Info Processing

Picture taken from the internet is acknowledged
Info Transfer
Info Storage
Info Processing

Tomorrow
All Optical

Acknowledged picture taken from the internet
All Optical

Massive Storage
3D Processing
Effective Coupling I/O)
Pattern Recognition
Immense Bandwidth
No Cross talk
Large Scale Integration

Acknowledged picture taken from the internet
As the Only Means to record and reproduce total light information...

There is a rebirth of

Optical Holography
Holographic DATA STORAGE

HOLOGRAPHIC VERSE TILE DISK

Acknowledge pictures taken from the internet
Array of Stored Holograms

Acknowledged picture taken from the internet
The data arrays are fed to a Spatial Light Modulator (SLM) and hologram of a laser beam modulated with the information is recorded. Arrays of such tiny holograms are formed by spatial, angular and peristrophic multiplexing.
Commercial level large volume holographic data storage is getting matured and a set of devices with promising features are being developed by various Companies. STX Aprilis, In-Phase Technologies, Optware were some of the earlier birds into holographic data storage device development.
OPTICAL DATA STORAGE in Bio-photonic Material

Bacteriorhodopsin, the purple membrane protein found developed from the Halobacteria, found in deep salty water is being tried as a bio-photonic storage medium for holography and dynamic hologram formation.

Acknowledge picture from IIT - Mumbai
Light Logics developed a photopolymer data strip for variable data storage and security. Own developed LCSLM based data writer/reader is used to record and read data on a real-time manner in the HoloMer 06A photopolymer.
Experimental setup
Photopolymer Based System

Figure 2

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System

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Hologram Verification
Screen capture
DATA TRANSFER

Wireless Optical LAN using HOE

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INTEGRATED OPTICS

Fig 5 Optical Hybrid IC Using Optical Waveguide: The PLC is formed on the SiO$_2$ film, on top of the Si substrate, creating an optical coupler (divider). 1.3μm laser diodes and photodiodes are then created at the ends of the substrate. Under development by firms including NEC, Oki Electric, Fujitsu, Hitachi/Hitachi Cable, and Mitsubishi Electric.

Massive Optical Neural Connections By Applying Holography

Acknowledge pictures taken from the internet
INFO COUPLING

Acknowledge pictures taken from the internet
ICT

Info Transfer
Info Storage
Info Processing

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UNIQUE BRAIN

Massive Storage
Processing
Effective Coupling (I/O)
Pattern Recognition
Cognitive Ability
In synthetic holography, the fringe structure of a hologram is calculated by using special algorithms and sampled to form an array of holograms, recorded one after another. Holograms of non-existing subjects and those with interesting visual effects can be created through CGH. Two CGHs created at C-DIT in 1992, by the Team lead by the author.
In conventional electronic processors more and more elements are squeezed into lesser and lesser space to achieve speed. But, this can not be continued beyond certain limit due to electron tunneling. Hence alternate processor architectures are being tried. Optical Processors with holographic elements are being tried in lightning fast data and image processing/pattern recognition applications and the area is getting matured.
Holographic matched filtering can be used for several interesting applications. The above pictures show the word recognition system developed by the author at the Cochin University in 1987. Correlation peaks are obtained wherever the word HOLOGRAPHY is recognized optically. A post-processing of the power spectrum yields sensible results.
HOLOGRAPHIC DATA SEARCH

Data pages on SLM

MULTIPLEXED RECORDING

DATA SEARCH

PARTIAL DATA SEARCH

High speed parallel search possible

Diffracted light in each beam is proportional to the match between stored page and the search argument

EXAMPLE SEARCH OPERATION RESULT

Pictures from Dr. Joby Joeph, IIT, Delhi is gratefully acknowledged
Search Capabilities

- Parallel Multiple Correlations
- Extremely fast search

- If 500 holograms at single location
- Use SLM of 1000 frames/sec
- Gives 500,000 correlations per sec.
- One correlation searches 1Mb of data
- Search of 500,000 images per sec.
- Limited by detector array processing speed

Pictures from Dr. Joby Joeph, IIT, Delhi is gratefully acknowledged
THANKS

a lot for your kind attention
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www.lightlogics.in

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