國立臺灣科技大學
TAIWAN TECH National Taiwan University of Science and Technology

International Color Consortium

ICC Display and 3D Print Meeting
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Introduction to 3D Holographic Display Technologies

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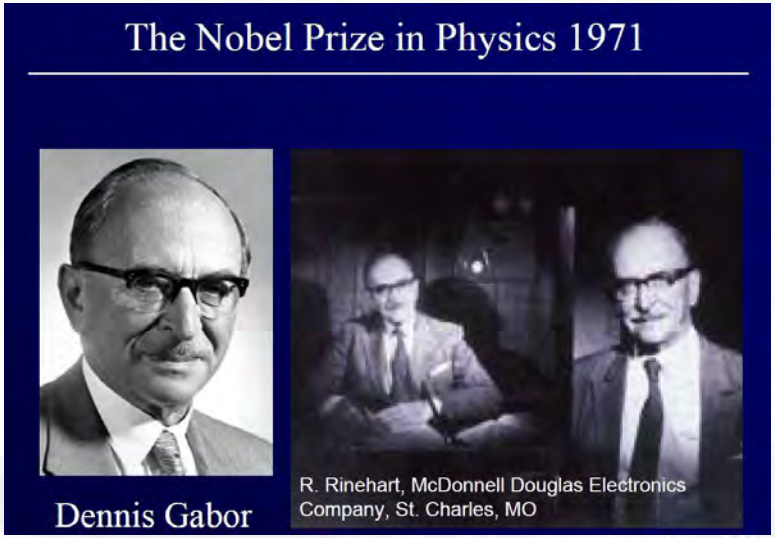
Outline

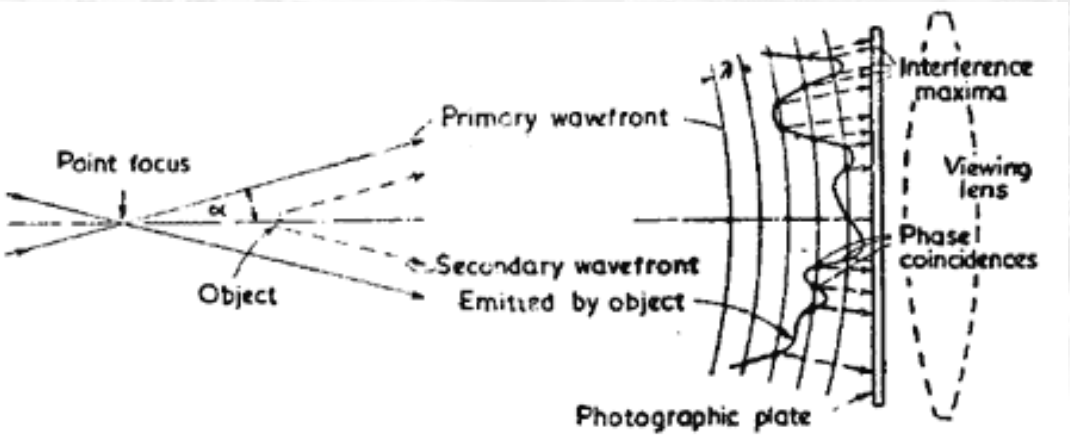
1. Introduction to holography
2. The research teams of CGH
3. CGH researched in my team
4. The future of CGH

Introduction to holography

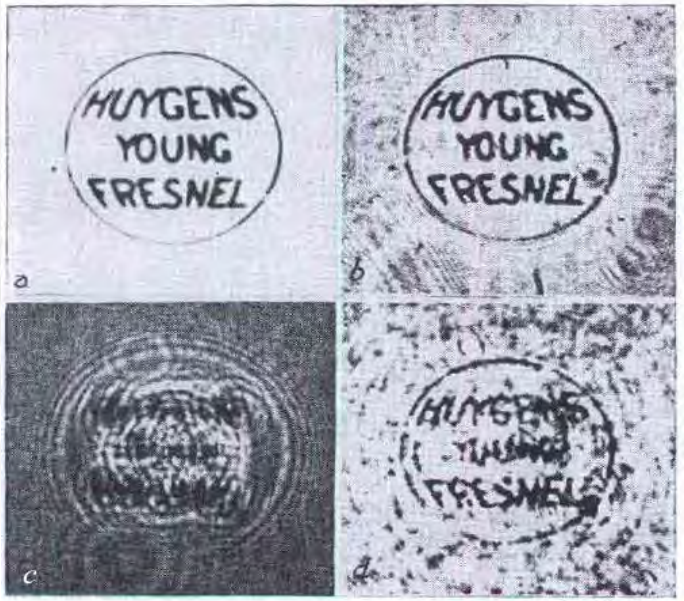


Holography is proposed by D.Gabor in 1948, it initially aimed at solving the resolution problem of electron microscope with coaxial holography (In-line Hologram) . Because the invention of coherent light source (laser) (1964), holography was able to be realized.

* 1971 Nobel Prize for Physics



Original micrograph | Micrograph



Interference diagram | Reconstruction

D. Gabor, "A new microscopic principle," *Nature* **161**, 777-778 (1948).

Categories of Holography

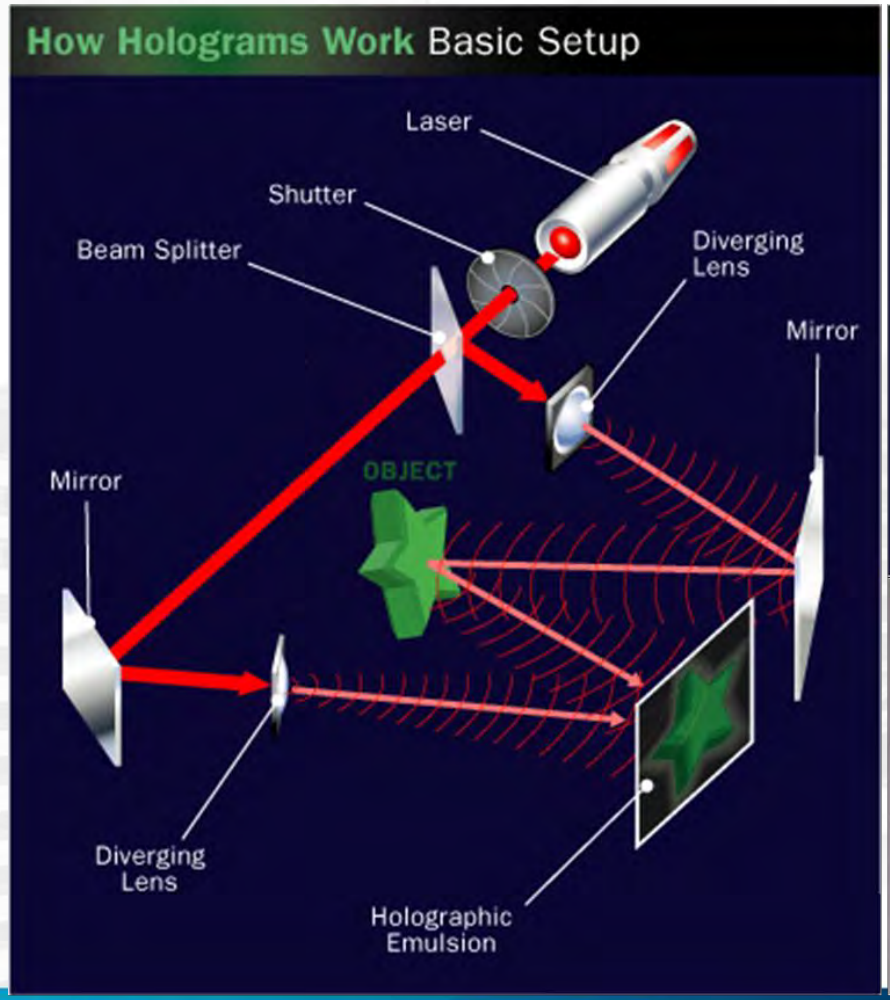
Category	Interference fringe	Recording of interference fringes	Reconstruction
Holography	optical interference	DCG or PDLC	Interference has been recorded as the photosensitive material hologram.
Digital Holography	optical interference	CCD or CMOS	Spatial Light Modulator
Computer Generated Holography	phase calculation with computer	Lithography or etching	[1] Diffractive optical element after lithography or etching [2] Spatial Light Modulator

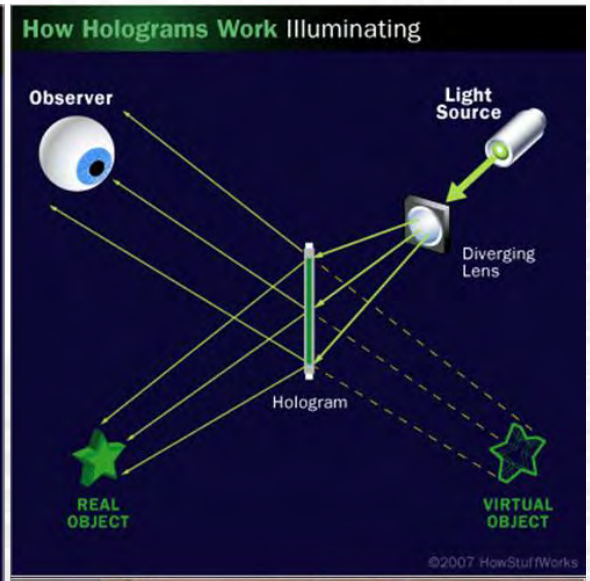
The difficulties of holography 1.The photosensitive material formulations

2.The diffraction efficiency is vulnerable to decay after long time.

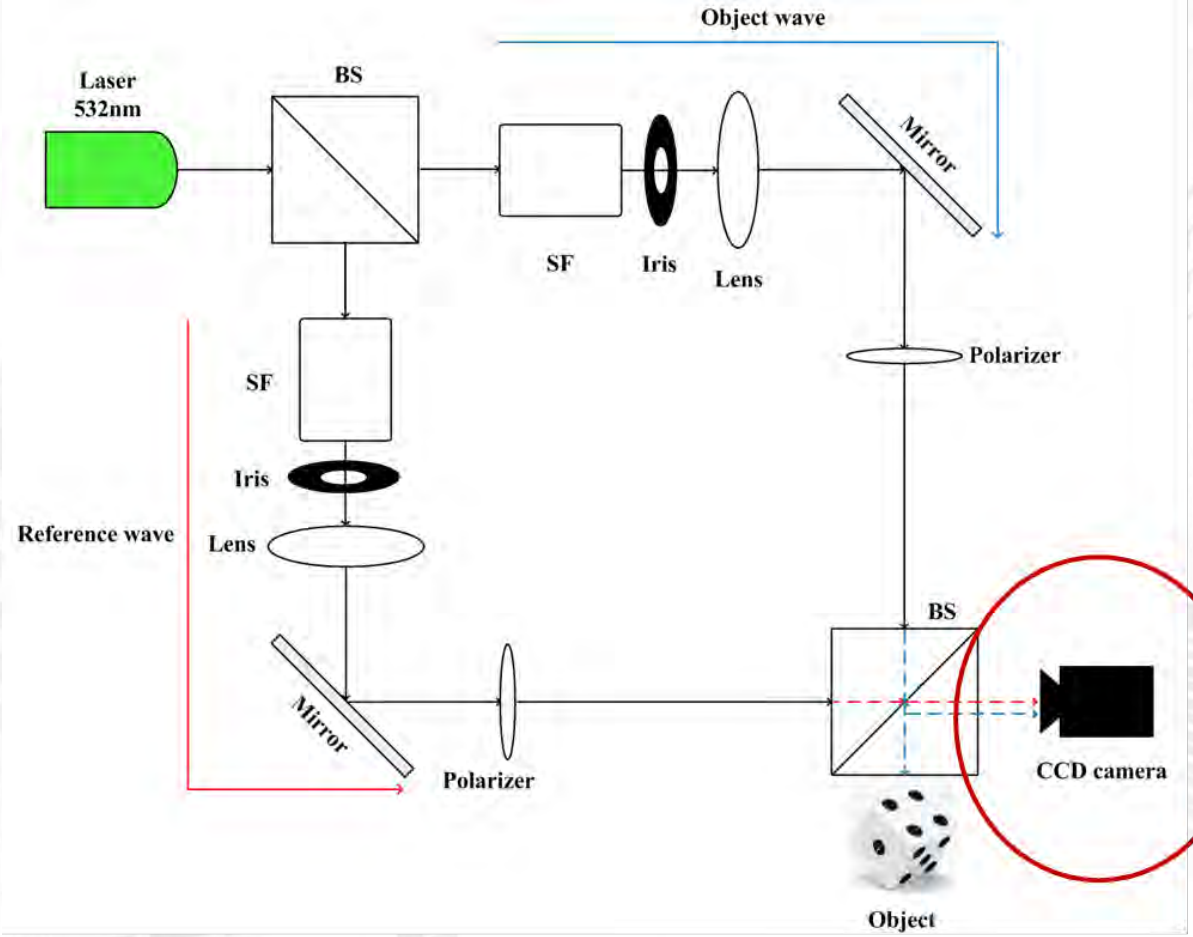
In recent years, the development of holography gradually toward to **digital holography** and **computer generated holography**.

Optical holography

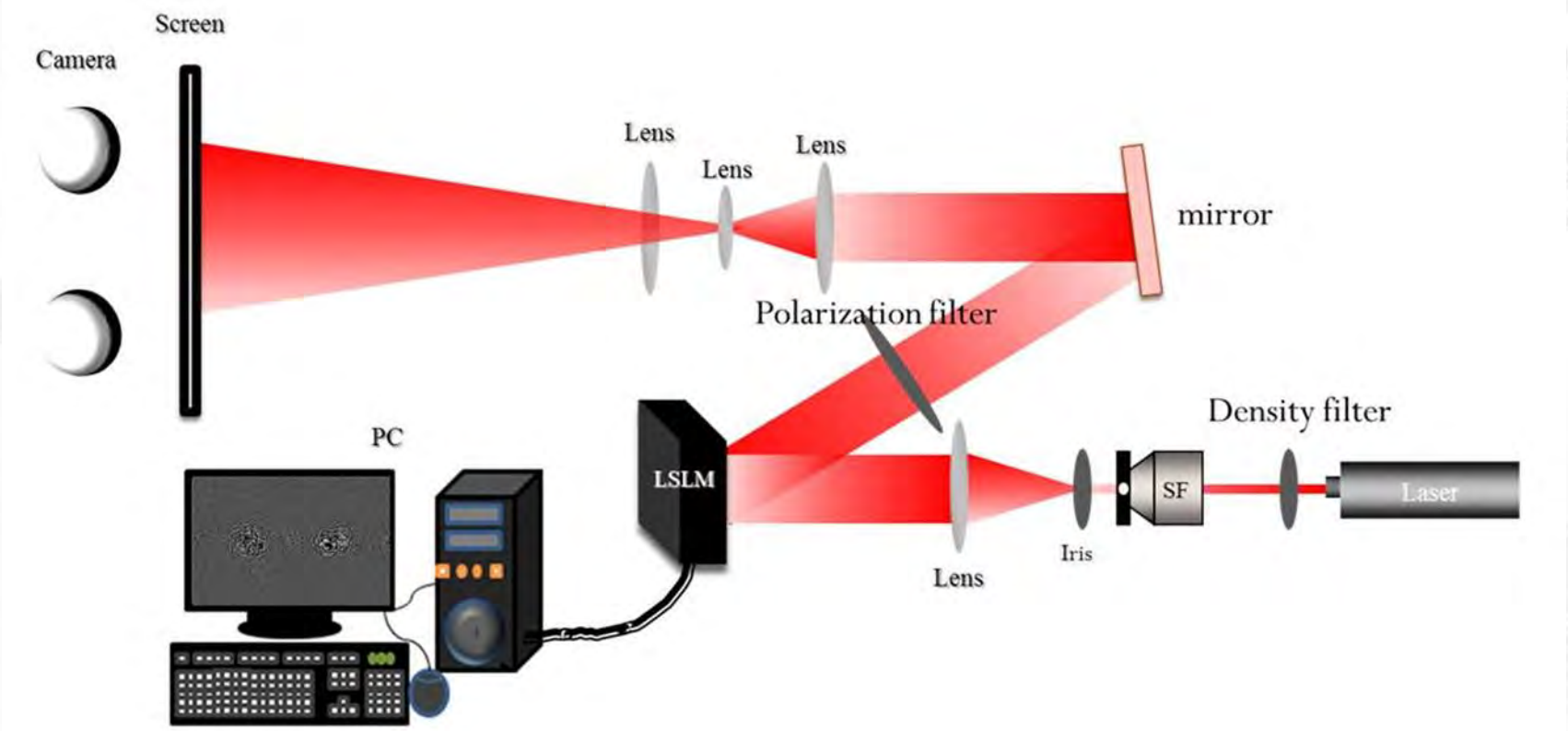




Digital holography



Computer generated hologarphy



The research teams of CGH

Famous Teams of CGH in the world

USA

Dr. Bahram Javidi , University of Connecticut3D

- Integral imaging technology

UK

Dr. Daping Chu, Cambridge , UK

- phase-only 2D/3D holography and spatial light modulation
- large area multi-stable reflective colour displays

JAPN

Dr. T. Kurihara & Dr. Y. Takaki,
Tokyo University of Agriculture and Technology

- Scanning three-dimensional holographic
- Multi-level shadow depth holographic image

KORA

Dr. Hwi Kim, and Dr. Byoungho Lee,
Seoul National University

- Polygonal Surface reconstruct stereoscopic image
- Three-dimensional parallax stereoscopic display

CHIA

Dr. Yongtian Wang, Beijing Institute of Technology

- Full color of digital holography and computer-generated holograms

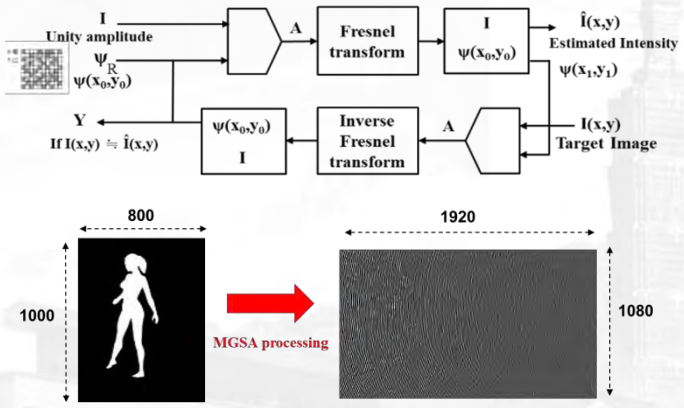
CGH researched in my team

- **Novel algorithm**
  - Modified Gerchberg-Saxton algorithm
- **New application**
  - Vision Training
- **IICGH**
  - Integral computer-generated hologram
- **Full color CGH display system**
  - Full color mode
  - Reduce speckle noise

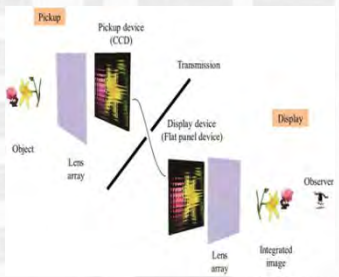
CGH researched in my team

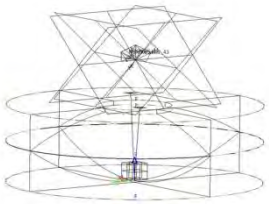
Novel MGSA applied in CGH

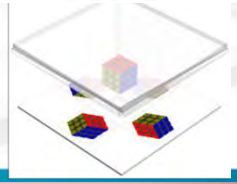
- Modified Gerchberg -Saxton Algorithm



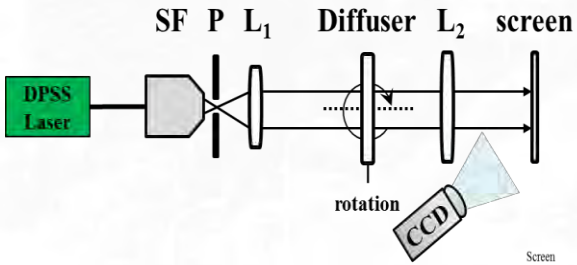
- Optical structure of projection system

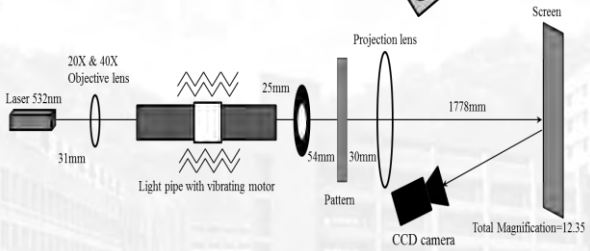


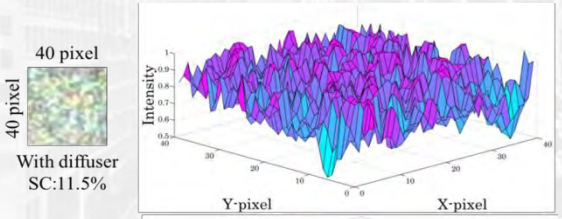


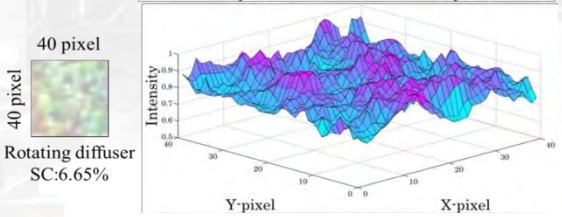


- Reduce speckle



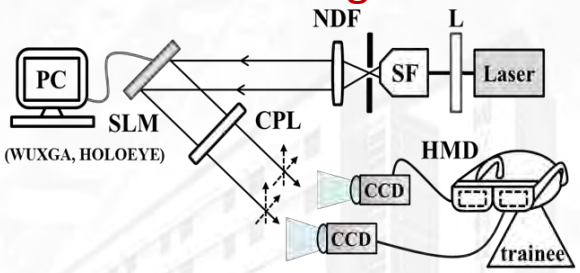




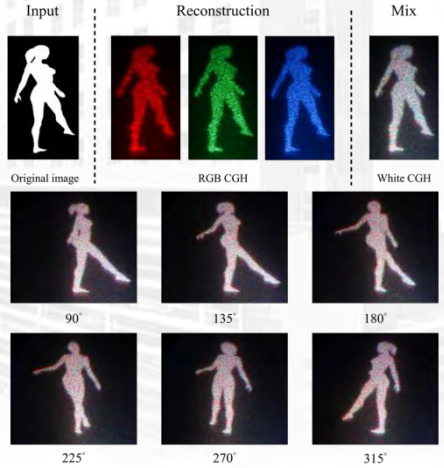


Application

- Vision training

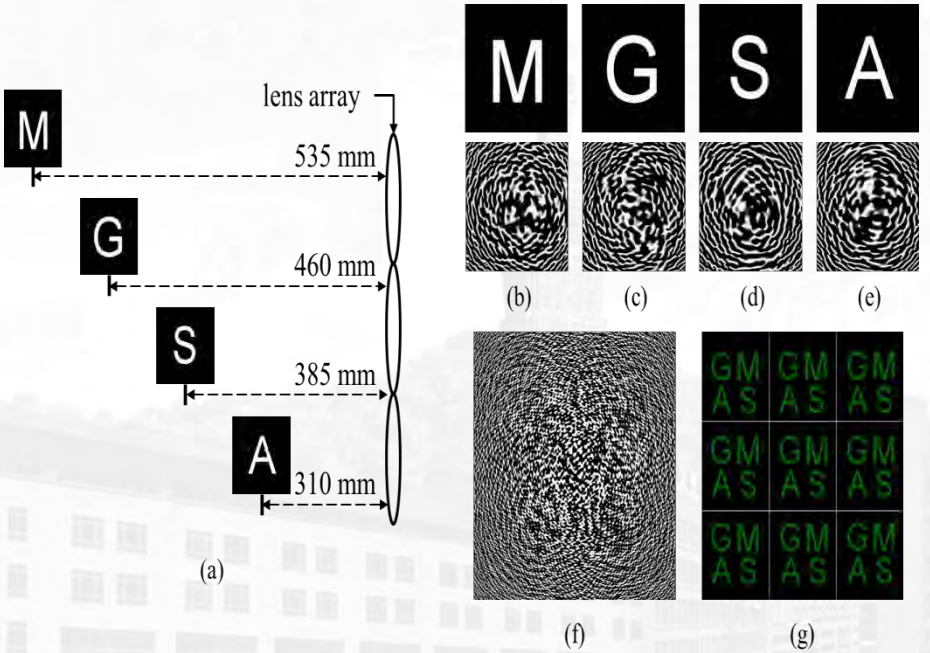


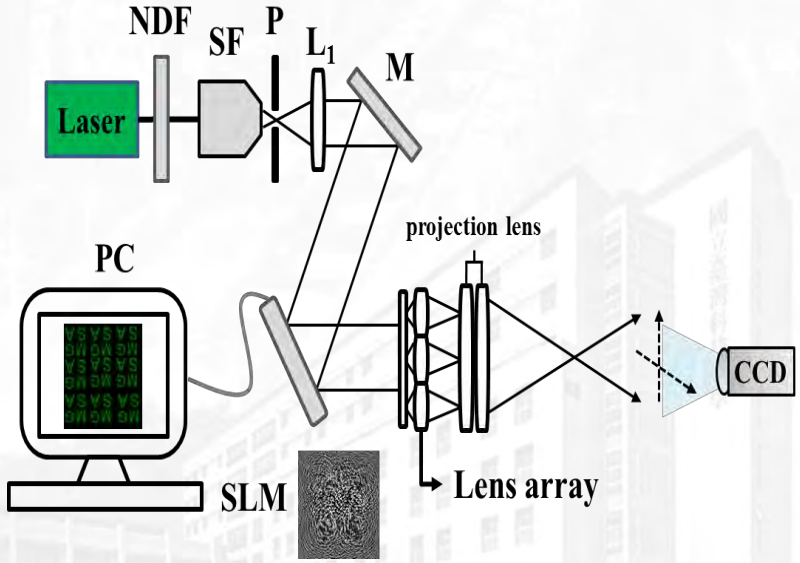
- Full-color dynamic CGH



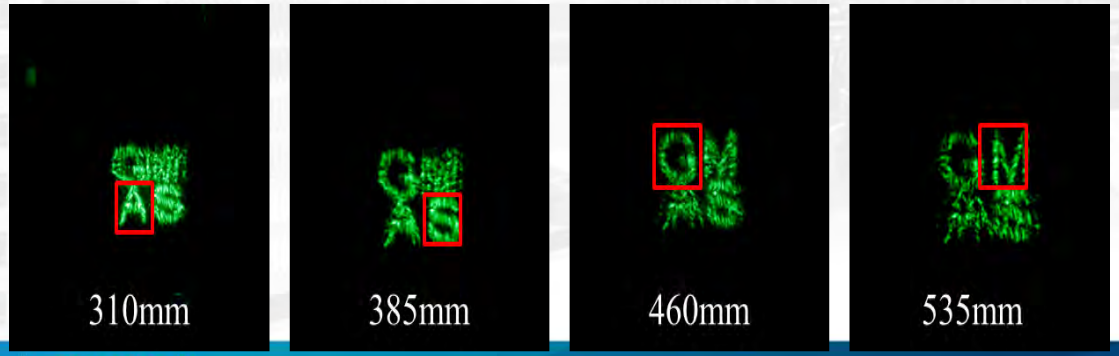
Integral computer-generated hologram

The flow chart of an integral MGSA-type CGH diagram





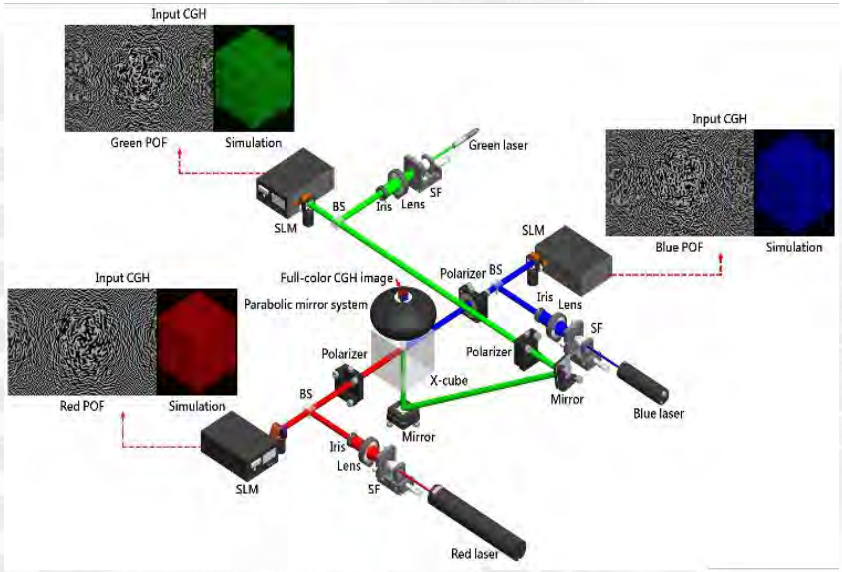
A ▸ S ▸ G ▸ M

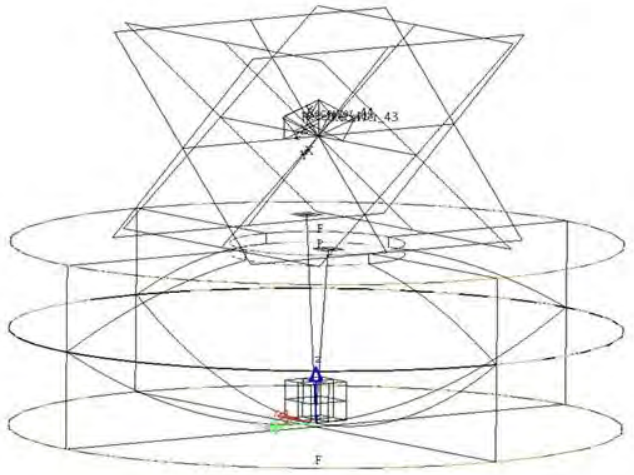


Full-color computer-generated hologram (I)

→A Double Parabolic Mirror Projection System

The double parabolic projection system is composed of double parabolic mirrors. The full-color computer-generated hologram is a real image, which could be remade a virtual image through the double parabolic projection system. The image magnification appears 1.2. The horizontal viewing angle appears 360° and the vertical viewing angle 15-75°.



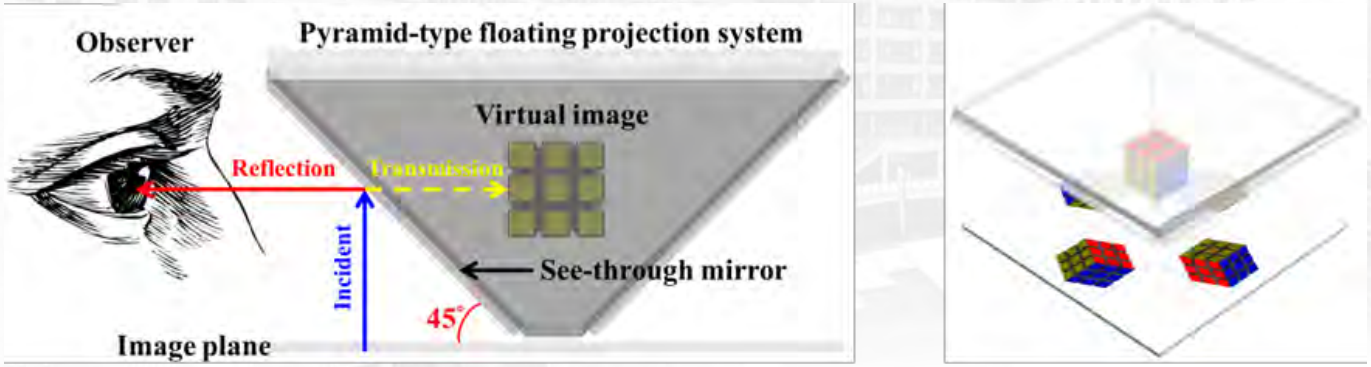


C.Y Chen, H.T Chang, T.J Chang, C.H Chuang, "Full-Color and Less-Speckle MGSA Computer Generated Hologram Floating on a Dual Parabolic Projection System", Chinese Optics Letters, August, 2015

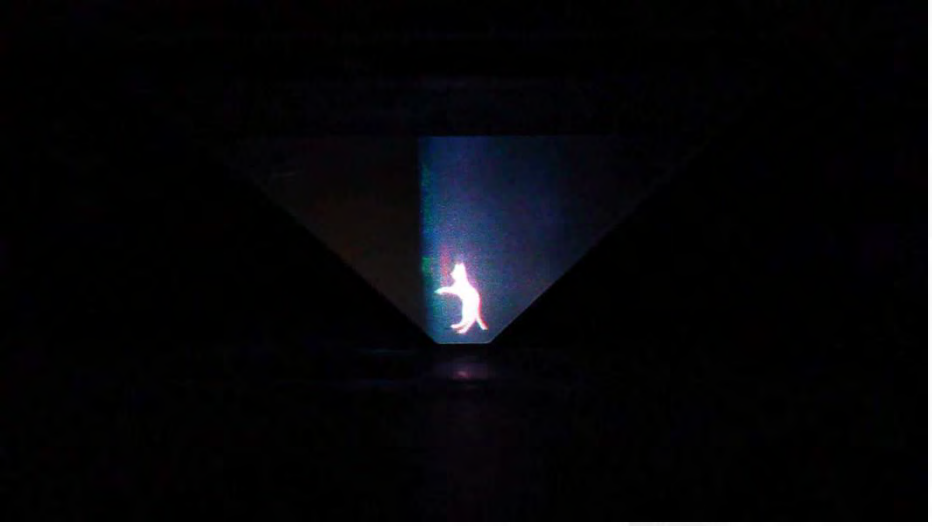
Full-color computer-generated hologram (II)

→Pyramid-type floating projection system

- Four image display surfaces could be used for presenting distinct information and switch the angle of view for the 360 degree viewing.
- The 3D perception of dynamic floating images could be reinforced by the pyramid structure.
- The matching of algorithms and optical mechanisms we developed could present various colors on different display surfaces.
- Large-size holographic image (surround splice)

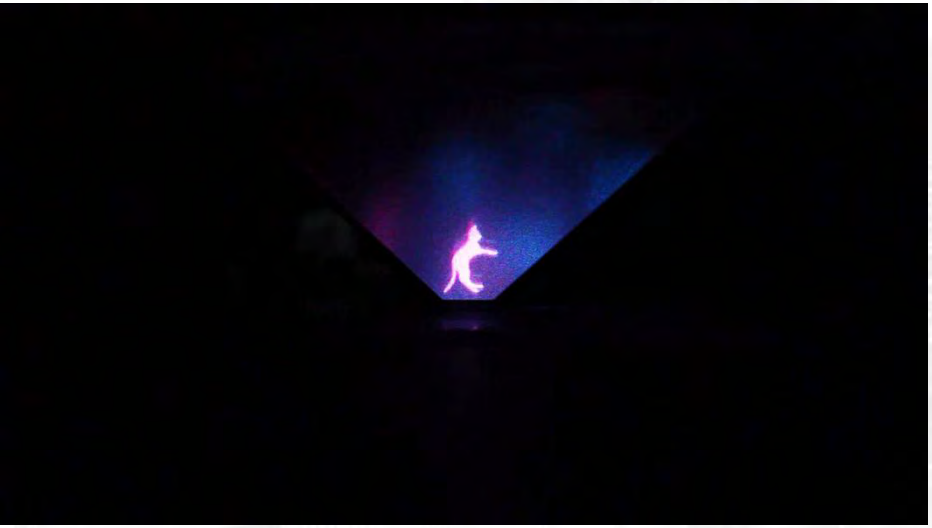


Pei-Jung Wu, Chih-Hao Chuang, Chien-Yu Chen*, Hsuan-Ting Chang, Tsung-Jan Chang, "A Full-color Computer Generated Holography for Panoramic Reconstruction", Society for Information Display (SID), San Francisco USA, May 2016.(Post)



The first surface-white CGH

The second surface-cyan CGH



The third surface-magenta CGH

The fourth surface-yellow CGH.

Publications

SCI Journal :

- **Chien-Yue Chen***, Hsuan-Ting Chang, Tsung-Jan Chang, Chih-Hao Chuang, “Full-Color and Less-Speckle MGSA Computer Generated Hologram Floating on a Dual Parabolic Projection System”, Chinese Optics Letters, August, 2015
- Pei-Jung Wu, **Chien-Yue Chen***, Qing-Long Deng, Hsuan-Ting Chang, Bor-Shyh Lin, Guan-Syun Huang, “Integral computer-generated hologram via a modified Gerchberg-Saxton algorithm”, Journal of Optics, Vol.17, No.1, 2014.
- **Chien-Yue Chen***, Qing-Long Deng, Pei-Jung Wu, BorShyh Lin,Hsuan-Ting Chang,Hone-Ene Hwang, and Guan-Syun Huang, “Speckle reduction by combination of digital filter and optical suppression in holographic display”, Applied Optics, Vol.53, No.27, pp. G163-G168, 2014.
- Qing-Long Deng, Bor-Shyh Lin, Pei-Jung Wu, Kuan-Yao Chiu, Ping-Lin Fan, and **Chien-Yue Chen***, “A Hybrid temporal and spatial speckle suppression method for laser display”, Optics Express, Vol.21, No.25, pp. 31072-31081, 2013.
- Qing-Long Deng, Bor-Shyh Lin, Hsuan T. Chang, Guan-Syun Huang, and **Chien-Yue Chen***, “MGSA type computer generated holography for vision training with head-mounted display”, IEEE/OSA Journal of Display Technology, Vol.10, No.06, pp.433-437, 2013. (SCI)
- Qing-Long Deng, Bor-Shyh Lin, Hsuan T. Chang, Guan-Syun Huang, and **Chien-Yue Chen***, “MGSA type computer generated holography for vision training with head-mounted display”, IEEE/OSA Journal of Display Technology, Vol.10, No.06, pp.433-437, 2013.
- **Chien-Yue Chen***, Wei-Chia Su, Ching-Huang Lin, Ming-De Ke, Qing-Long Deng, Kuan-Yao Chiu, “Reduction both of speckle and distortion in projection imaging system by using a rotating diffuser”, Optical Review, Vol.19, No.6, pp.440-443, 2012.

Patent:

- Invention patent of ROC , “The method of laser speckle reduction" (Patent No. 102120871)
- Invention patent of US, “Diffraction-type 3D display element and method for fabricating the same” (US 8,926,849 B2)

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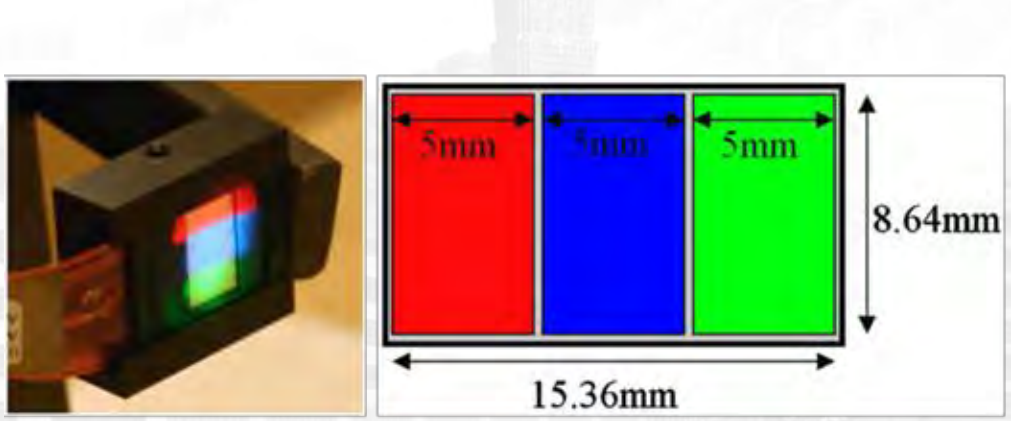
The future of CGH

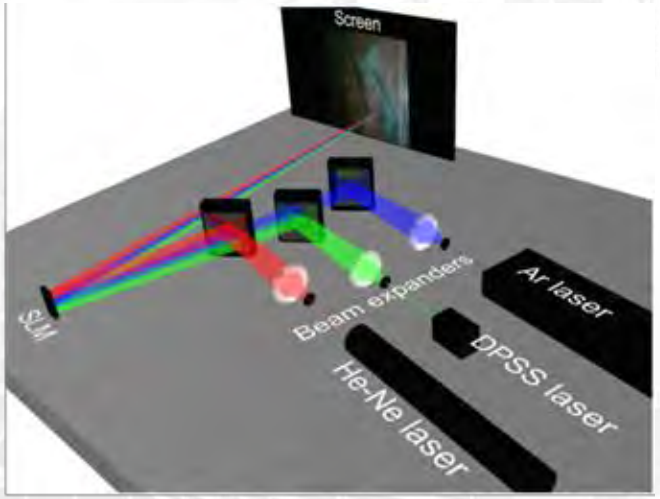
I) Single LCoS

Warsaw University of Technology, M. Makowski et al.

In 2010, M. Makowski et al.used a single SLM to keep the setup very simple. Division of the SLM area into three sections addressed by three Fourier holograms calculated for red, blue, and green color components



(a)



(b)

M. Makowski, I. Ducin, M. Sypek, A. Siemion, A. Siemion, J. Suszek, and A. Kolodziejczyk, "Color image projection based on Fourier holograms", Opt. Lett., Vol. 35, No. 8, pp. 1227-1229, 2010.

II) Micro optical system

Warsaw University of Technology, M. Makowski et al.

In 2012, M. Makowski et al.used three light fibers to simplify and miniaturize the system setup.

(a) (b)

(a)Optical system (b)Experimental result

M. Makowski, I. Ducin, K. Kakarenko, J. Suszek, M. Sypek, and A.Kolodziejczyk, "Simple holographic projection in color", Opt. Express, Vol. 20, No. 22, pp. 25130-25136, 2012.

III) Apply on HMD

KAIST, J. Hahn et al

In 2014, J. Hahn et al.used RGB LED as light source, and realized the non-intrusive CGH HMD. But it only display in single color.

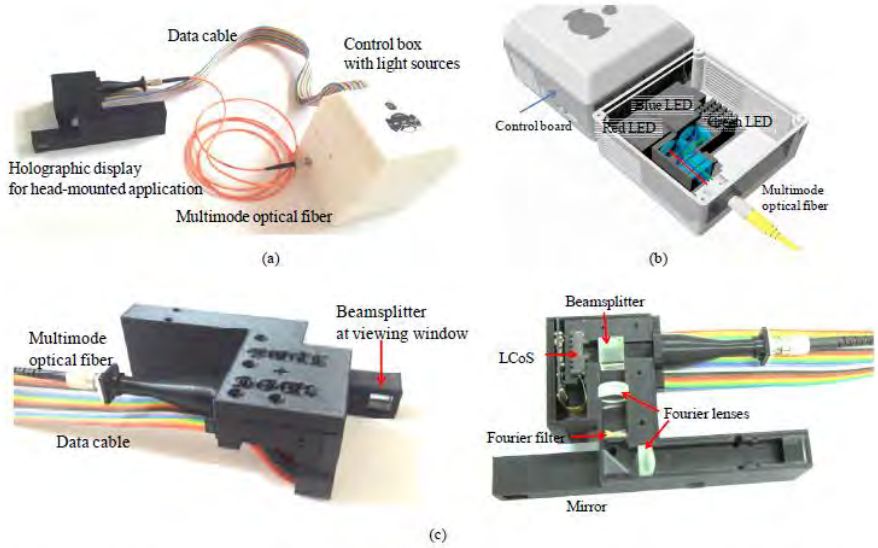


Fig. 6. (a) Full head-mounted holographic display system, (b) control box with RGB LEDs fed to a multimode optical fiber and (c) optics of the holographic display module

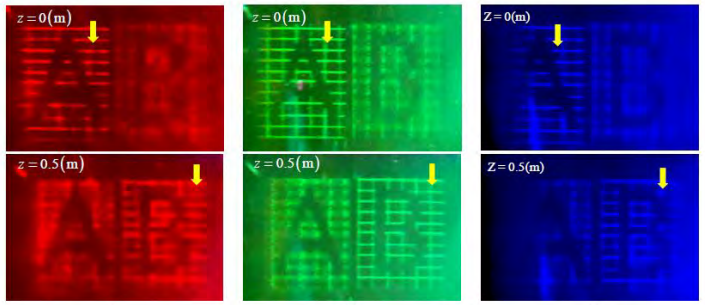


Fig. 8. Captured images with the camera set focused at different distances when (a) red, (b) green, and (c) blue LEDs are turned ON respectively.

Moon, E., Kim, M., Roh, J., Kim, H., & Hahn, J. (2014). Holographic head-mounted display with RGB light emitting diode light source. Optics express, 22(6), 6526-6534.

Applications

Image source:
http://www.hongkiat.com/blog/augmented-reality-next-big-thing/


Fantasy Interlaces Reality,
Holography Creates The Future!!
NISSAN