高解析實境顯示基礎原理
Basic principles of high-resolution reality displays

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Chapter 10:全像顯示的發展與趨勢

Outline

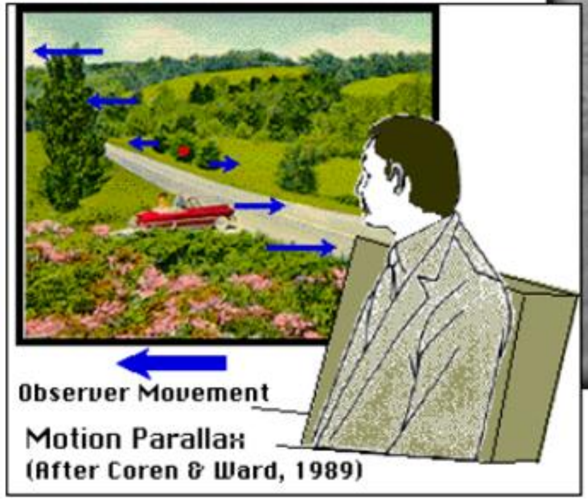
1. 立體顯示原理
2. 甚麼是全像術?
3. 全像術的發展與趨勢
4. 於車載顯示上的應用
5. 結論與未來展望

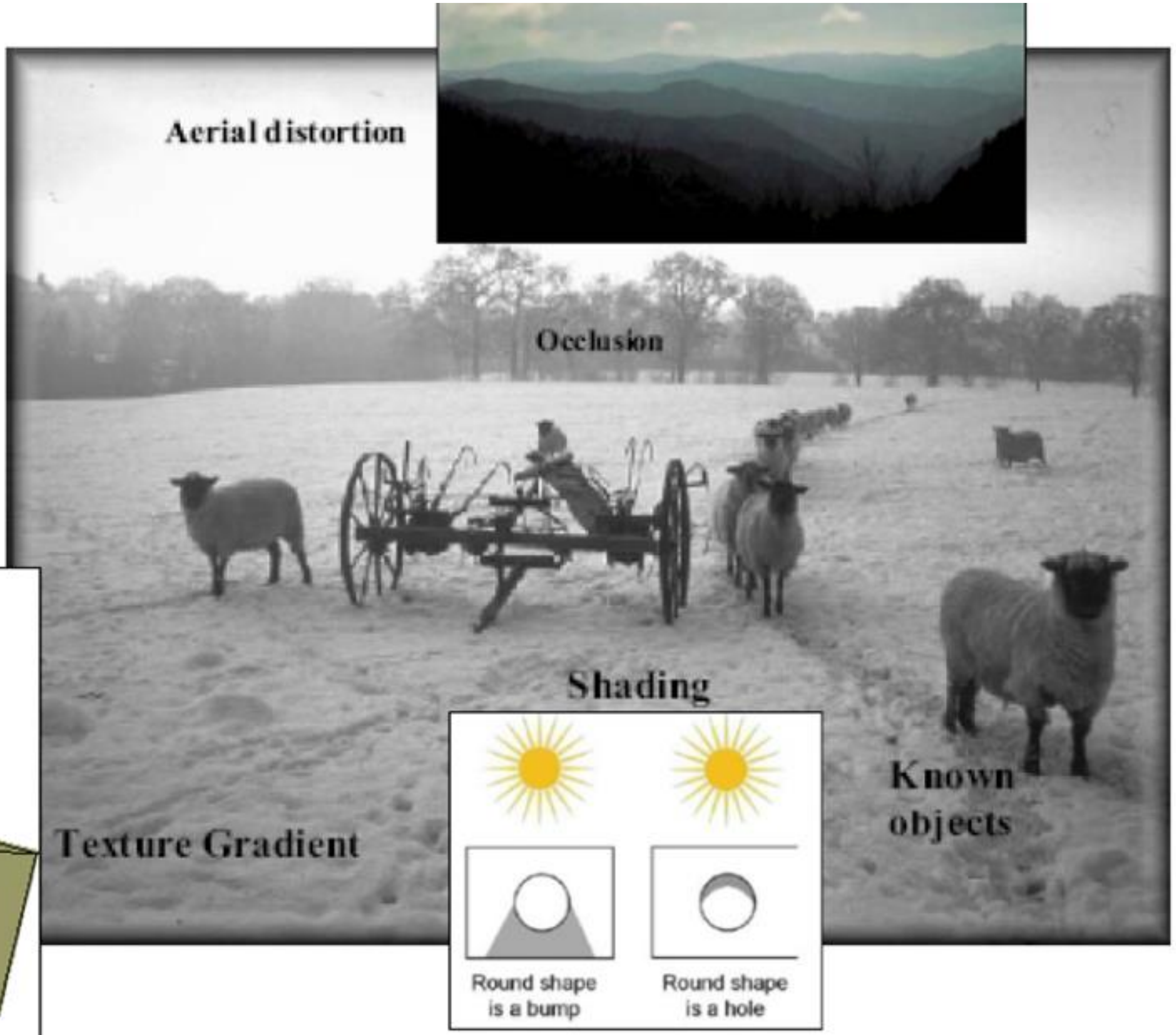
立體顯示原理

立體視覺怎麼來?(1/3)

心理認知

交疊程度	• Interposition
線性配景	• Linear perspective
大氣散射	• Aerial perspective
物體大小	• Object Size
紋理變化	• Texture Gradient
明暗遮蔽	• Shadows & Shading
動態視差	• Motion Parallax



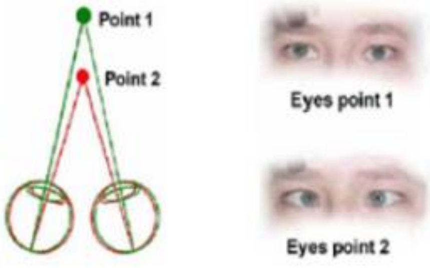


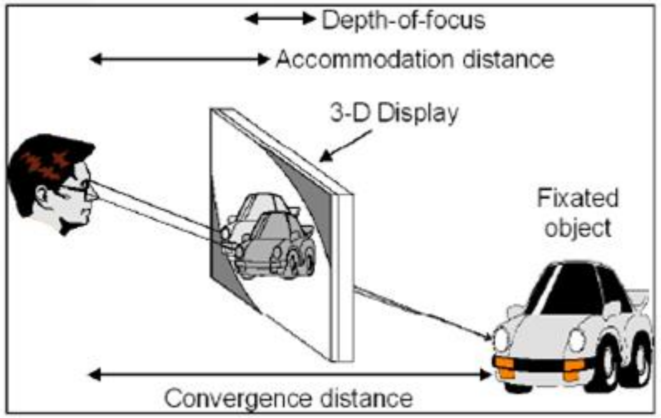
立體視覺怎麼來?(2/3)

生理機制

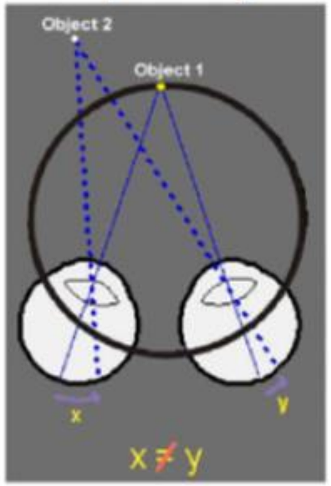
- Accommodation
  (Single eye focusing)

- Convergence
  (Two eyes convergence)

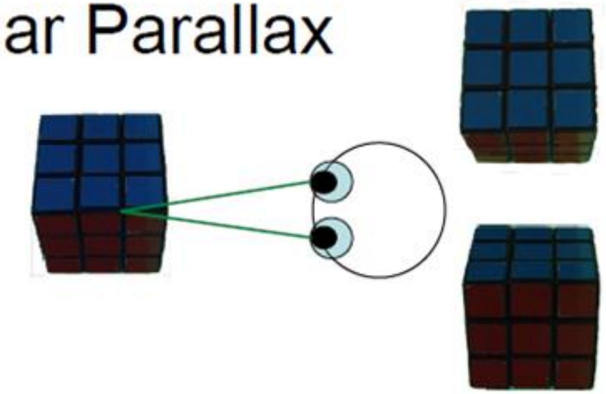




- Disparity



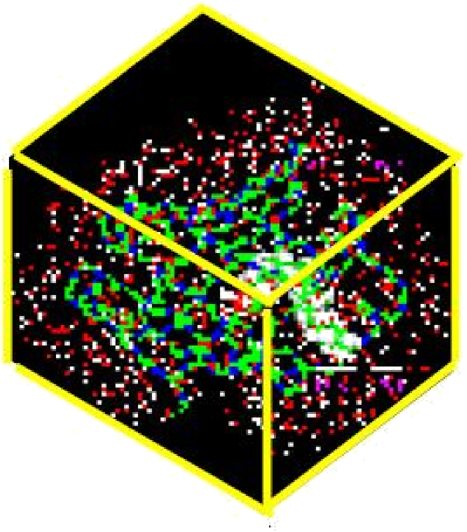
- Binocular Parallax



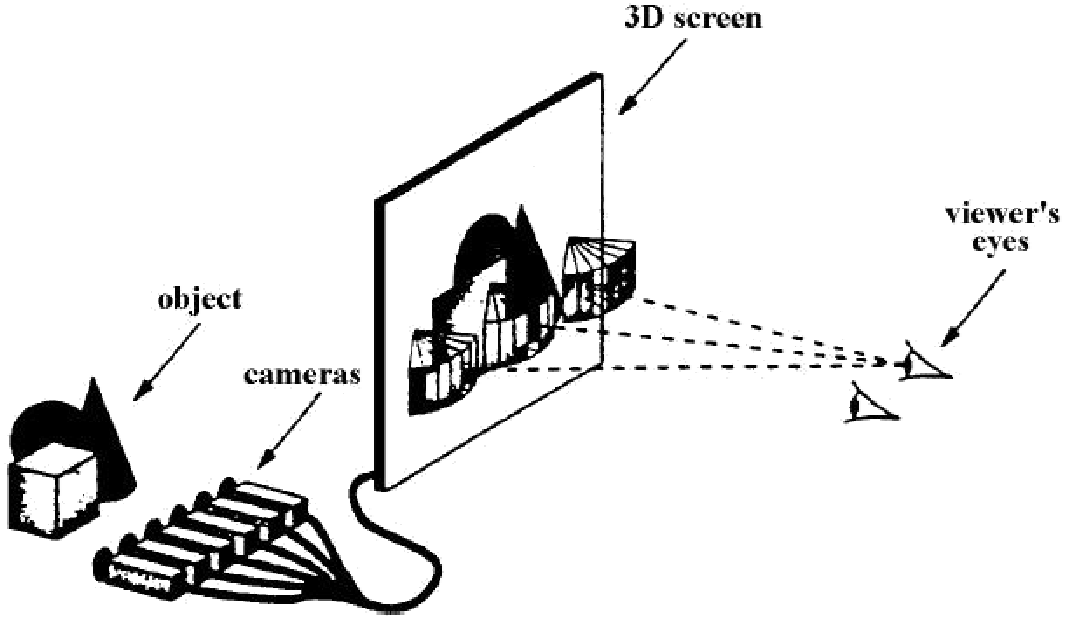
立體視覺怎麼來?(3/3)

人為產生立體視覺的想法

體積式：
在空間中模擬產生物體表面的光點



螢幕式：
透過平面螢幕呈現三度空間影像資訊

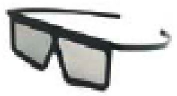


3D顯示技術分類

3D顯示技術

- 戴眼鏡式 **With glasses**
  - •快門眼鏡(Shutter glasses)

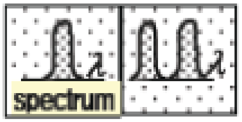
    
  - •偏光眼鏡(Polarization glasses)
    - -線偏光　-Retarder
    - -圓偏光　-iZ3D

  - •紅綠眼鏡(Anaglyph)

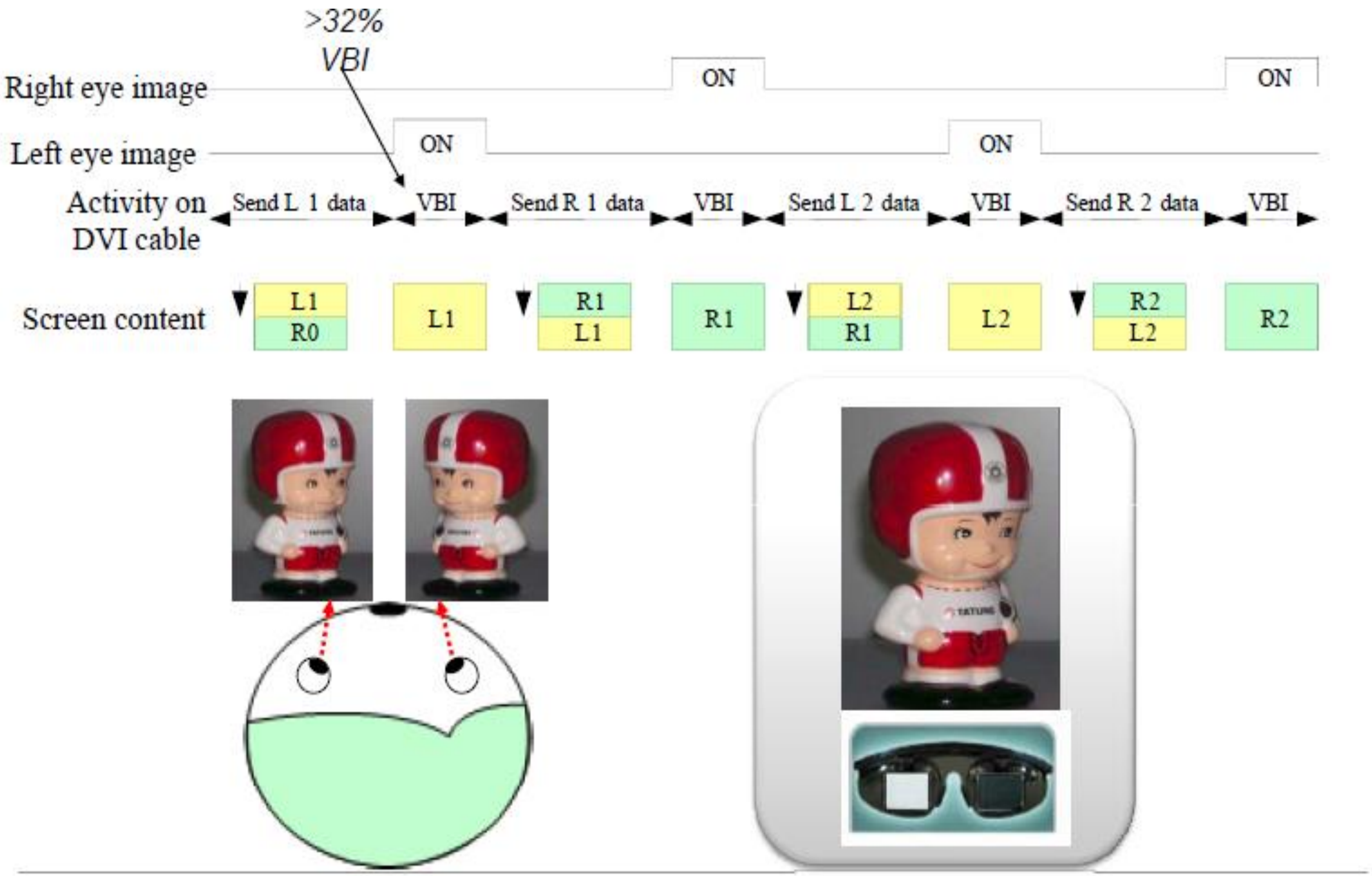
    

  - •頭戴式(Head mount displays)

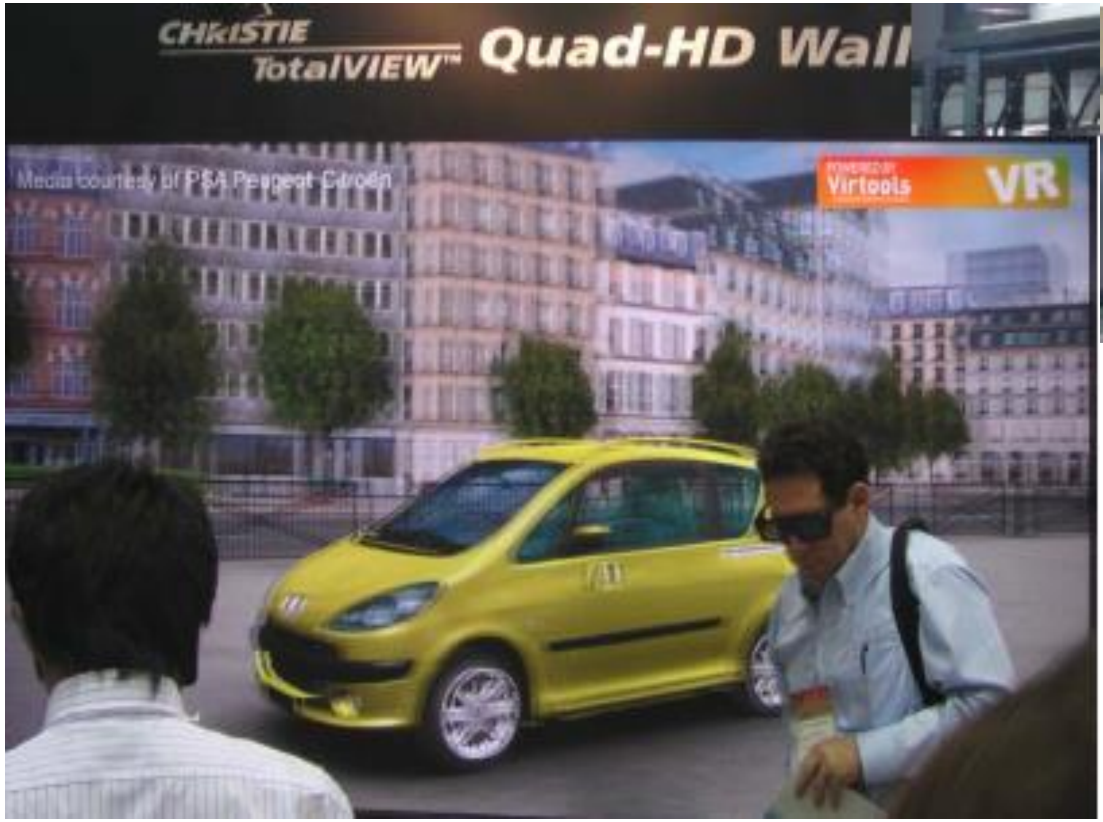
    
- 裸眼式 **Without glasses**
  - •全像式(Holographic)
  - •體積式(Volumetric)
  - •2-D多工式(Multiplexed 2-D)
    - -Barrier
    - -Lenticular
    - -Depth
    - -3M Time Seq. B/L

SHUTTER GLASSES



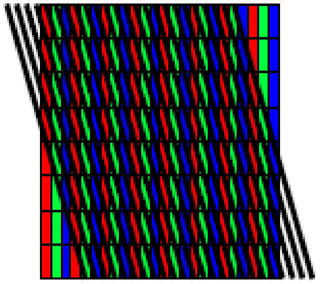
POLARIZATION GLASSES

- Linear or Circular Polarizer Glasses

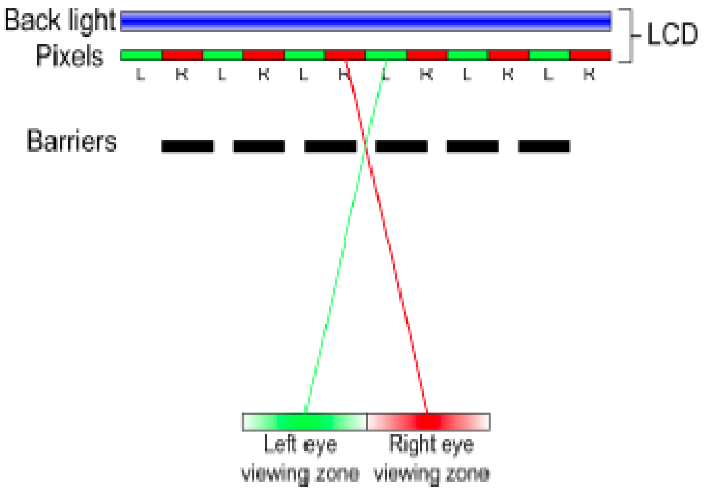


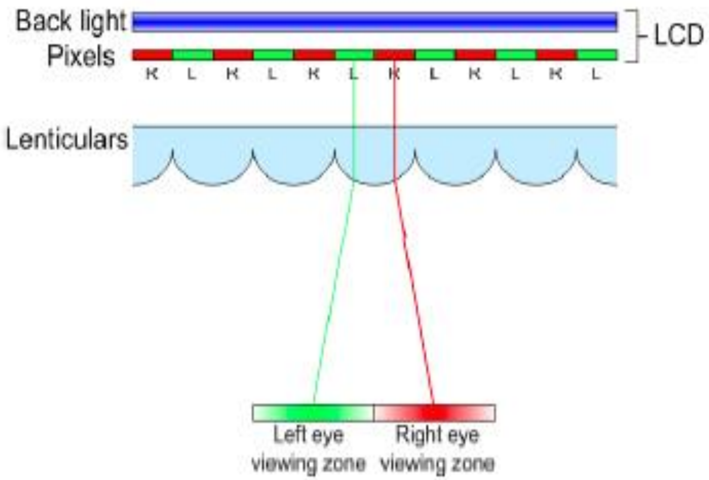
Spatial Multiplexed 3D display

Barriers(Slanted)



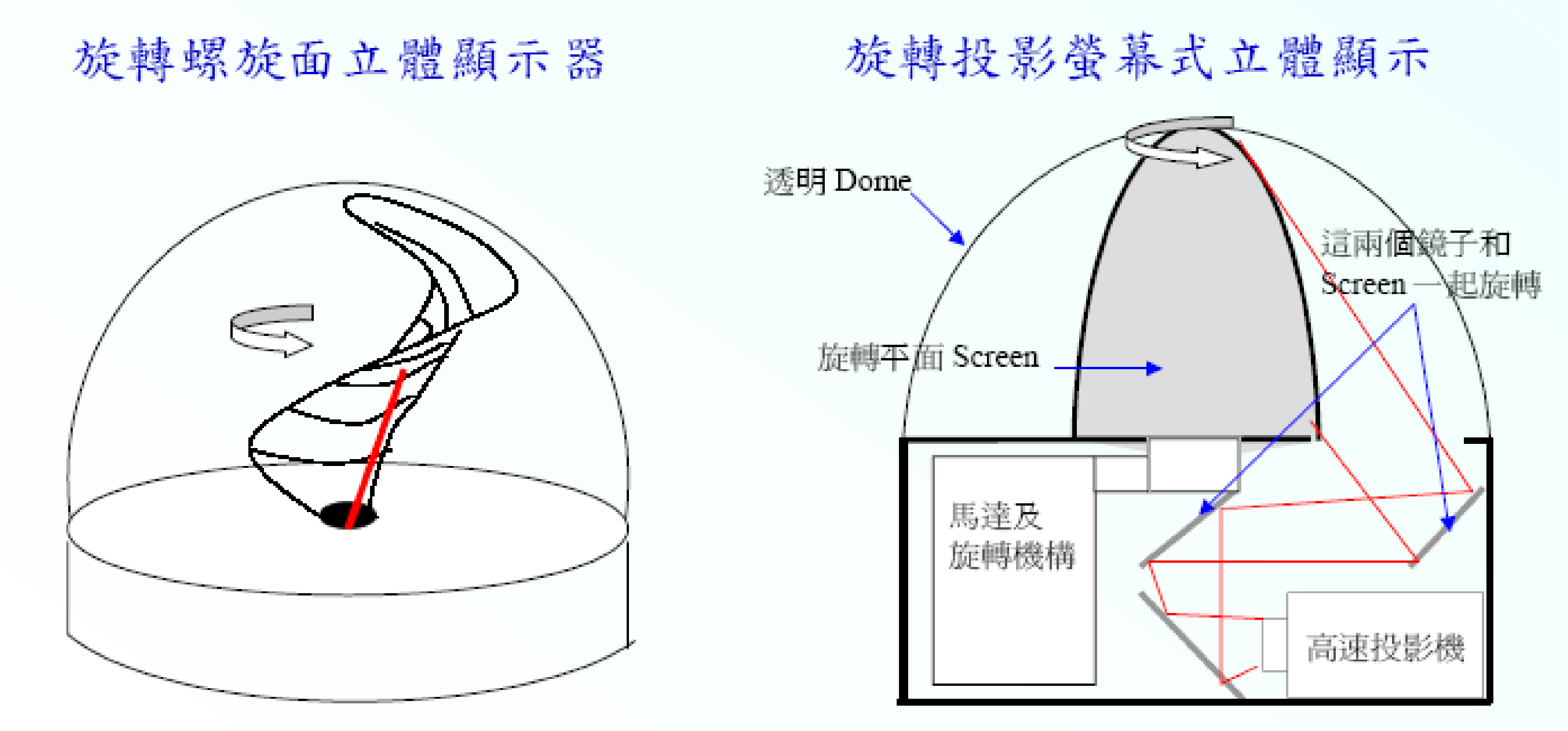
Lenticulars





Volumetric 3D Display

原理-在空間中模擬產生物體上的散射光點



https://www.youtube.com/watch?v=I7vgha_N5s8

氣幕式立體顯示技術

https://www.youtube.com/watch?v=yzIeiyzRLCw

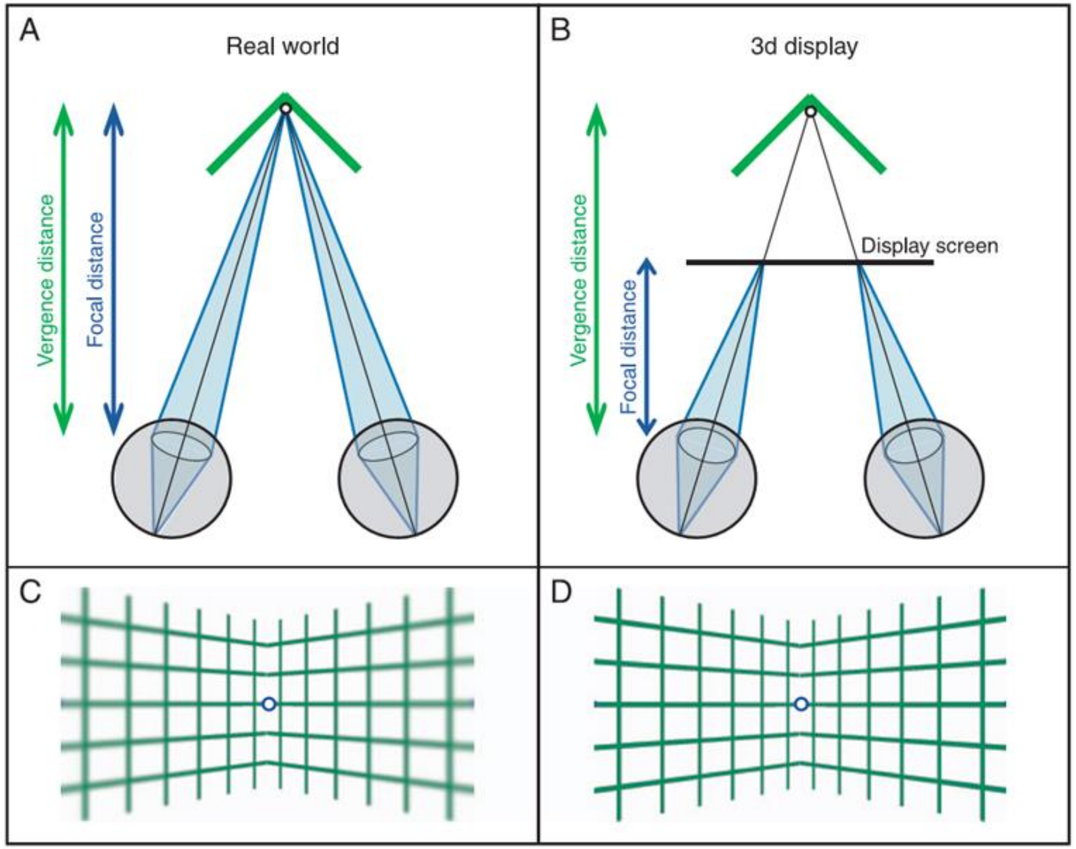
眼球三連動機制

看哪裡、打哪裡、清楚哪裡

看遠→看近
- PD(瞳距縮小)
- pupil縮小
- (環狀肌,放射肌)

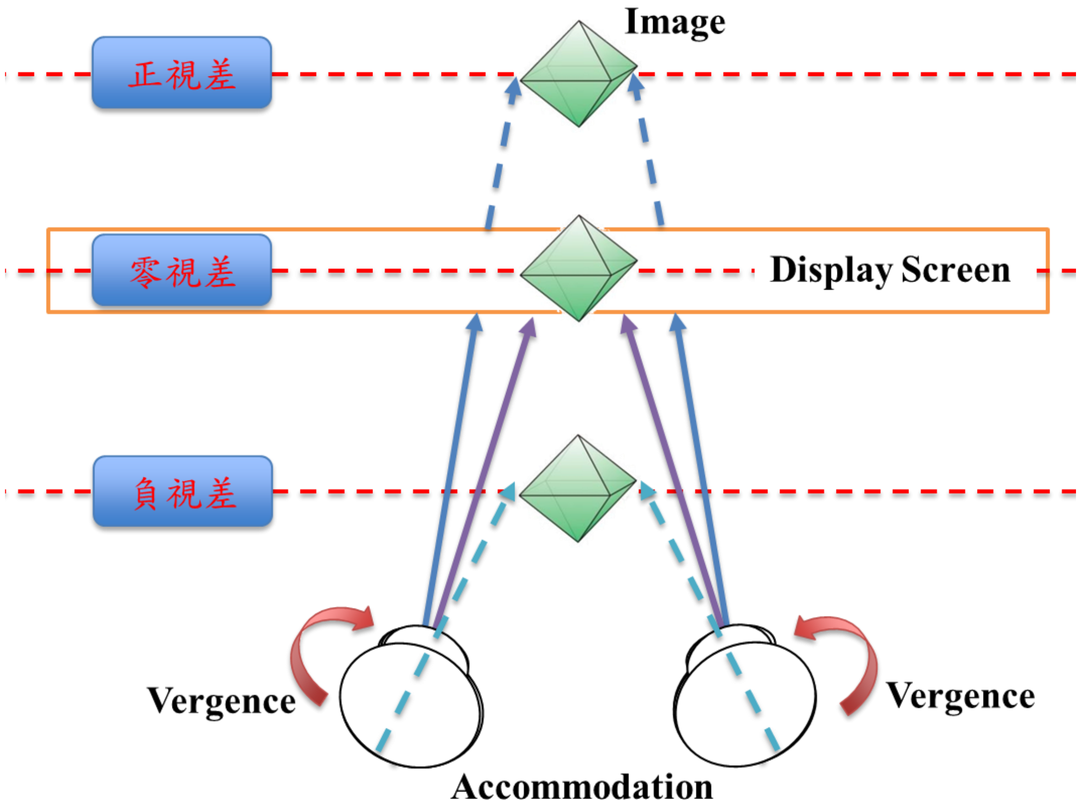
Convergence
- (眼內肌,眼外肌)

Accommodation
- (睫狀肌)



觀看立體影像所產生的衝突

Convergence(眼內肌,眼外肌)不斷變化，而Accommodation(睫狀肌)仍在同一焦平面上。

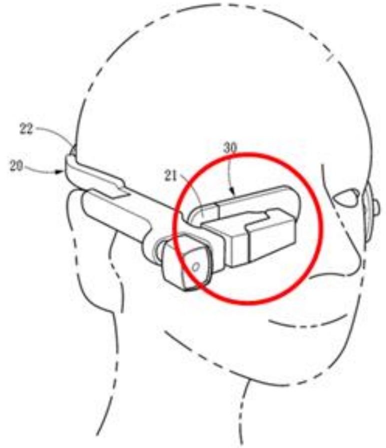


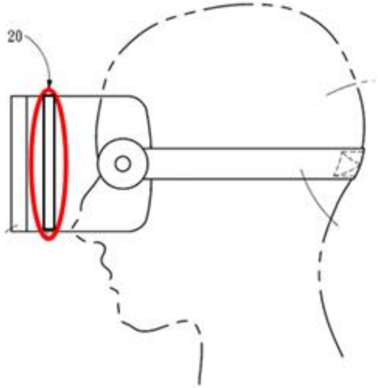
Binocular 3D Display

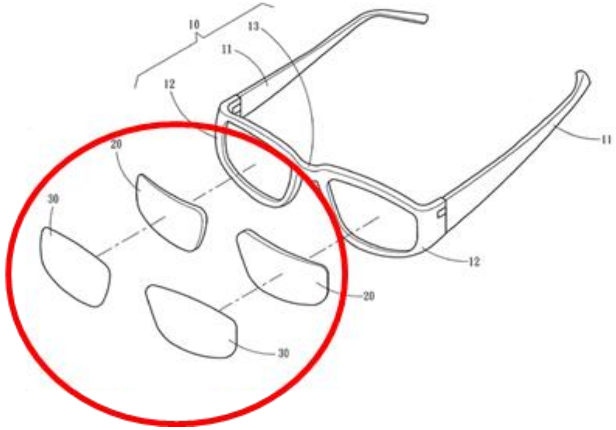
無法符合人眼的自然視覺認知!!!

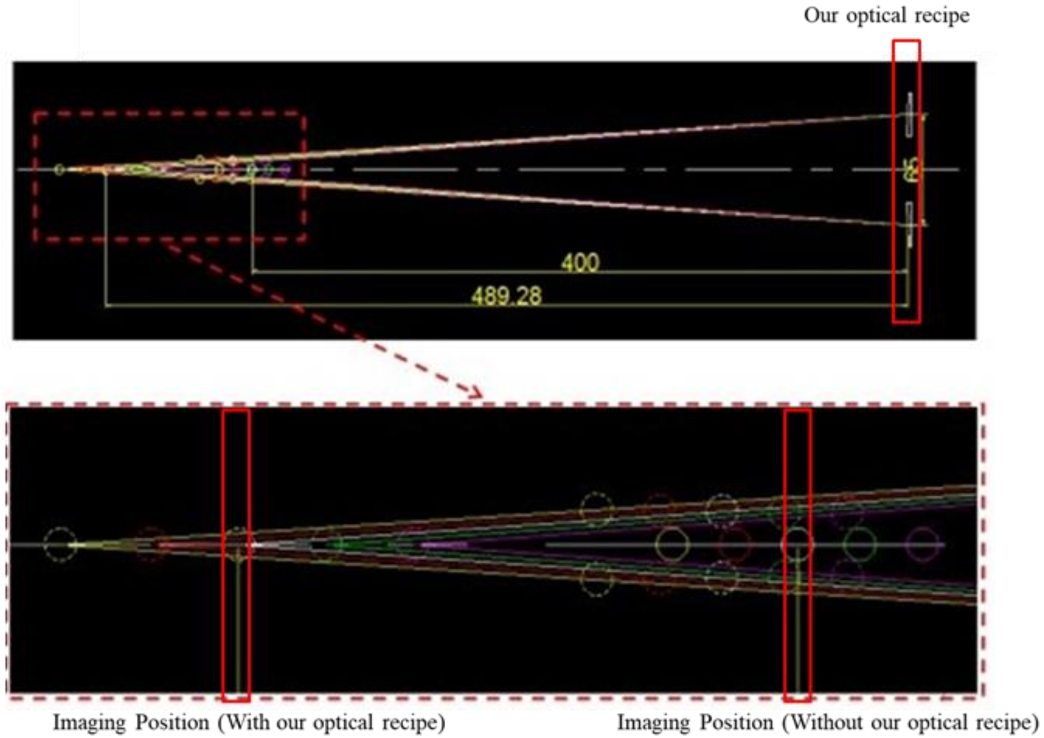
What is the solution???

看不累眼鏡-光學式撖隆巴斯







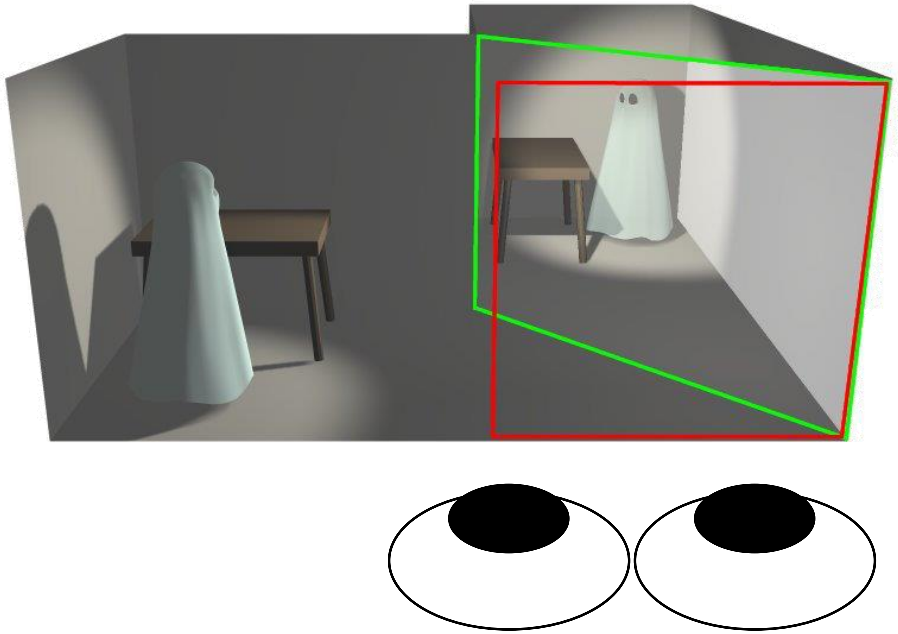


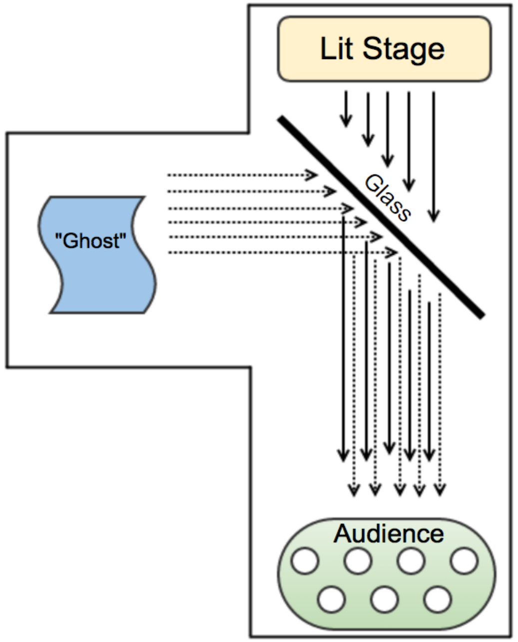
甚麼是全像術?

3D image? Hologram?

Please don't call those virtual images “holograms.”

1. This is actually an optical projection system.
2. In the 19th century, the Englishman John Pepper applied it to stage performance.
3. Easy optical technology + powerful computer rendering





What is hologram?

Dennis Gabor

Holo

→whole or wholly

What is hologram?

Dennis Gabor

graphy

→indicating a form or process of writing, representing.

What is hologram?

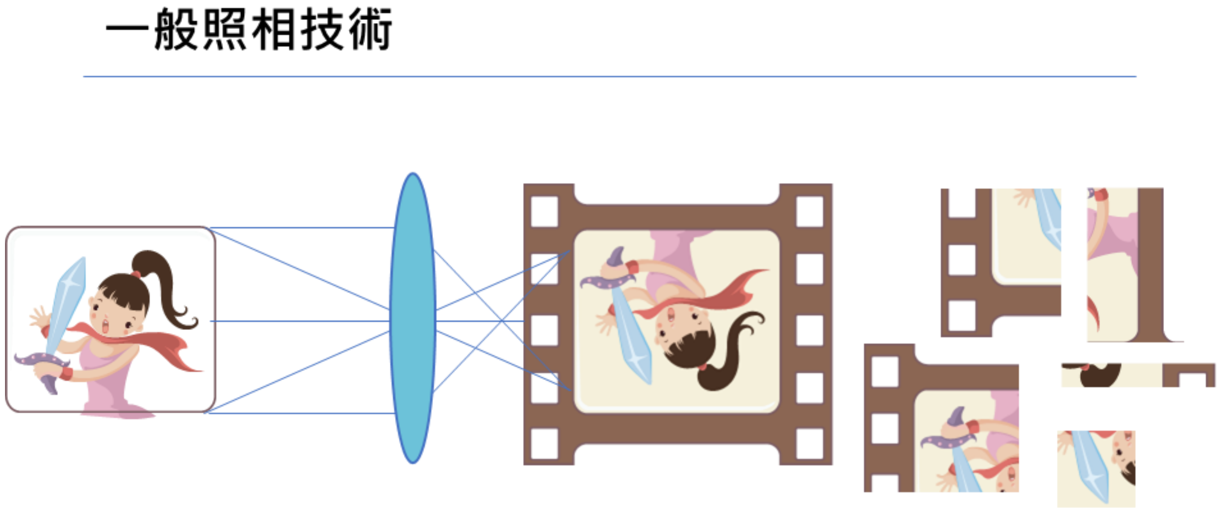
Dennis Gabor

Holography

→the process or technique of making holograms

全像術是甚麼?

- 一般底片僅記錄“光強度”資訊,顯示二維的圖像資訊
- 藉由干涉的方式同時記錄”光強度”與”相位”資訊,可得三維圖像資訊(實際位置)
- 藉由相同光源可重現原物立體影像。

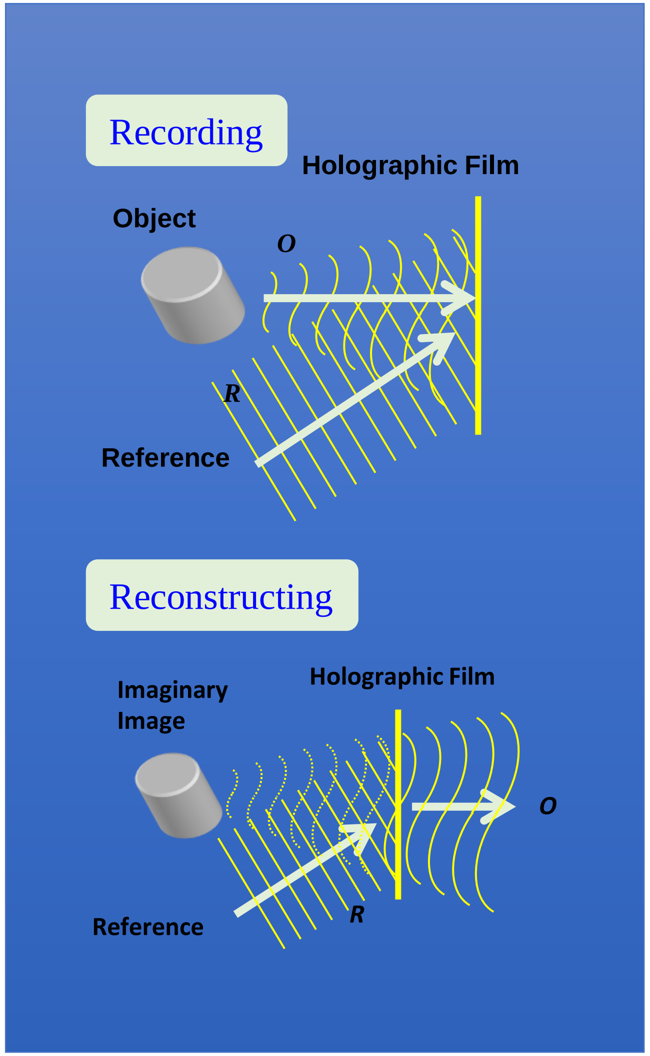


Basic principle of holography

Method of Wavefront Reconstruction

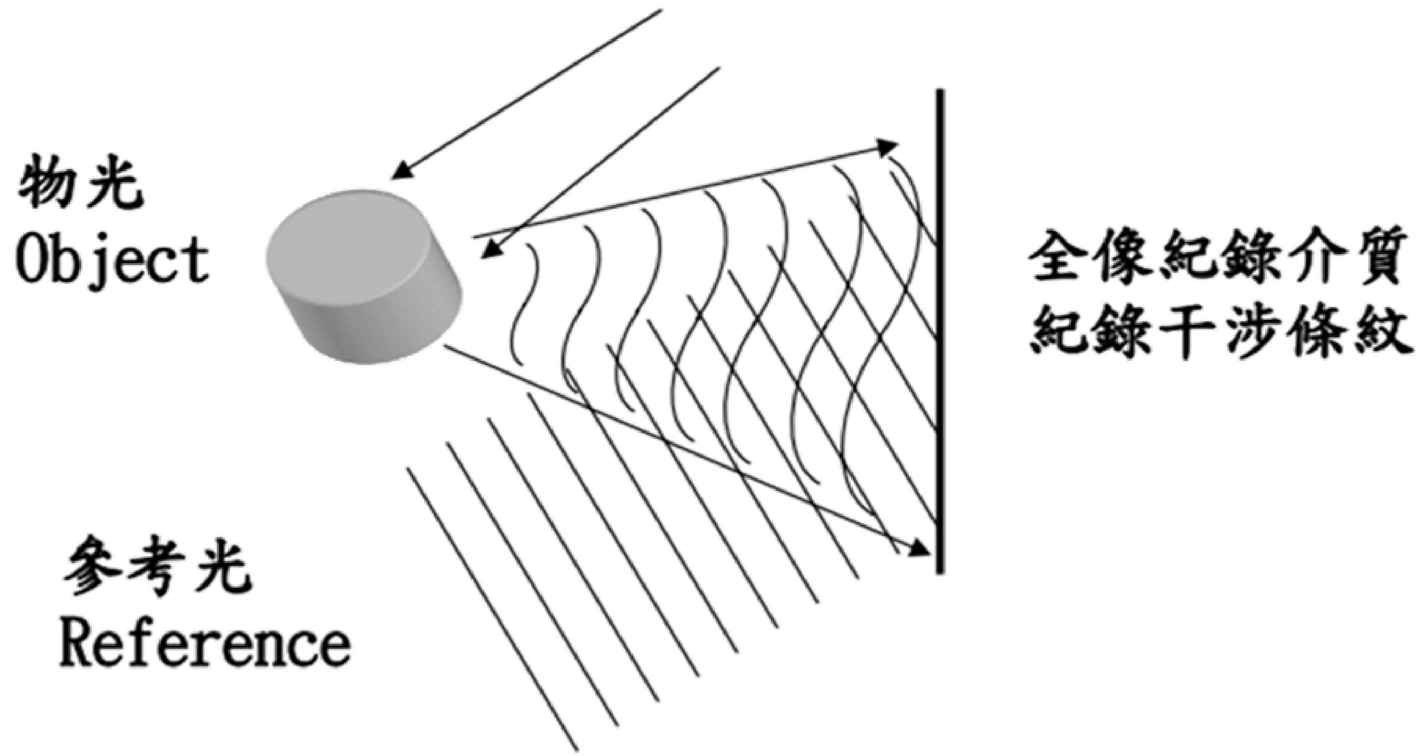
1. The grating is the negative exposure record (copy) of the two light interference patterns obtained, so optical interference and exposure of the negative is a holographic film, the production of this hologram film is made by optical photography.

2. The image information is derived from the diffraction, and the diffraction of the hologram can be reconstructed to present a specific wave field, which is the wave field generated by the object information (complete reconstruction of the object wavefront).



全像術原理:干涉+繞射

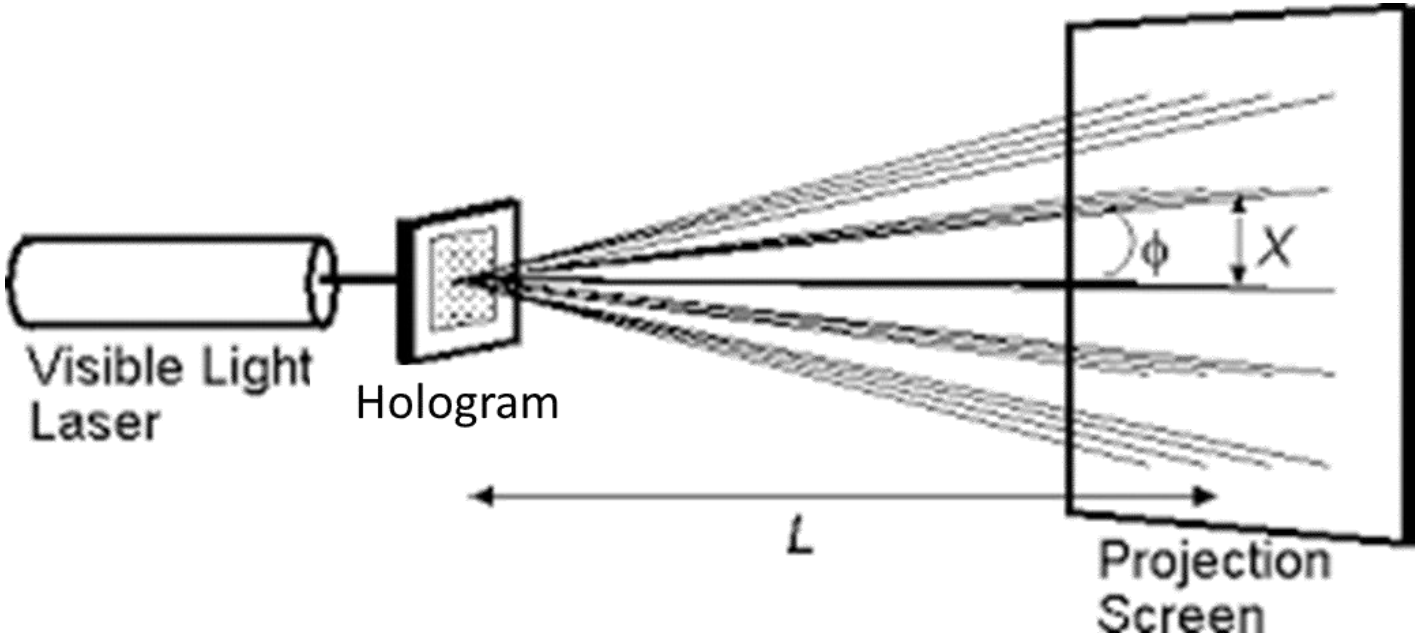
全像片的紀錄→干涉



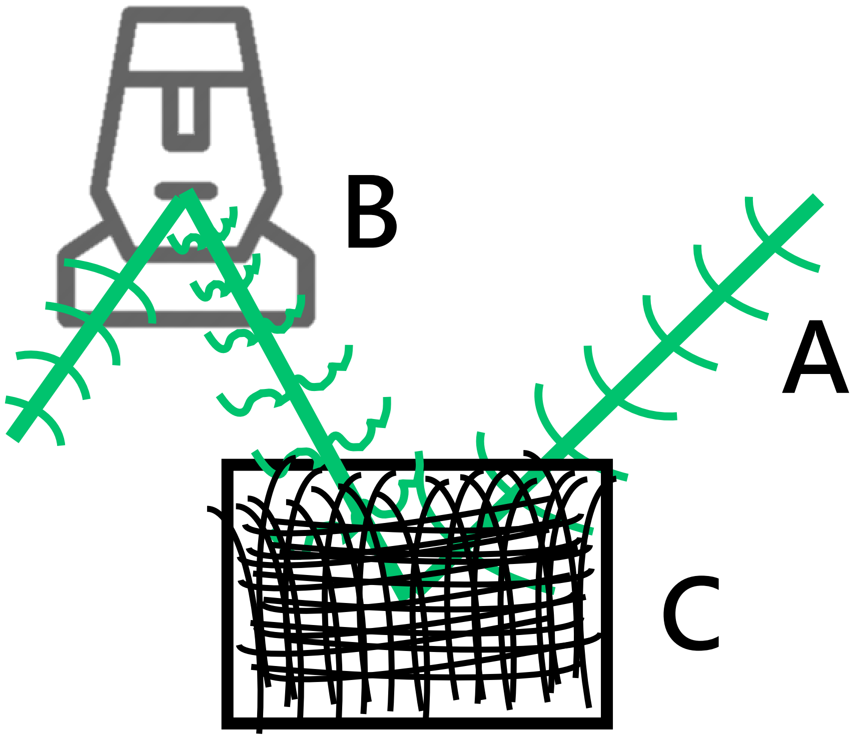
全像術原理:干涉+繞射

全像片的影像重建→繞射

拍攝好之全像片因複製了複雜的干涉條紋，因此全像片本身形成一複雜的光柵，當光入射時便產生繞射。

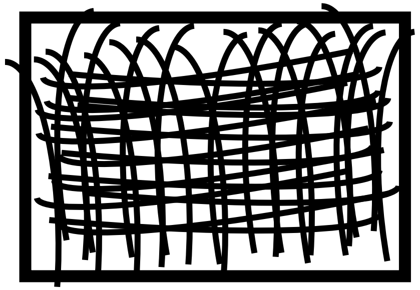


全像術原理:



全像術原理:

A+B=C



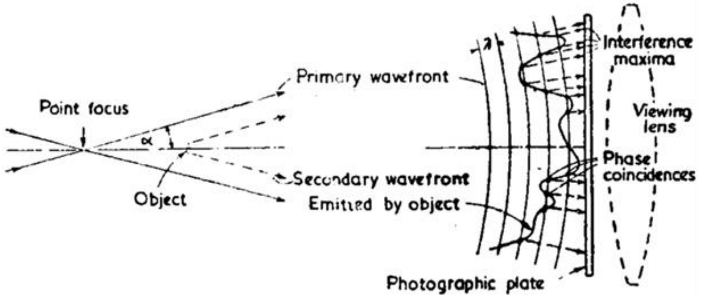
C-A=B

全像術發展

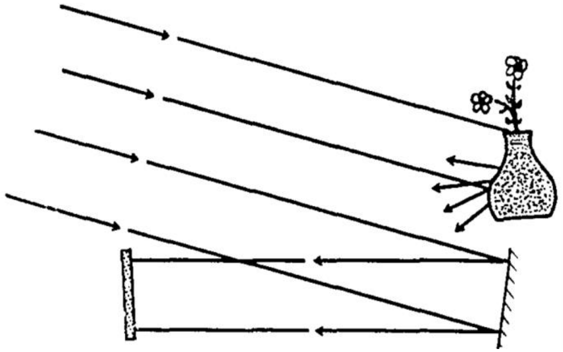
製造雷射成功

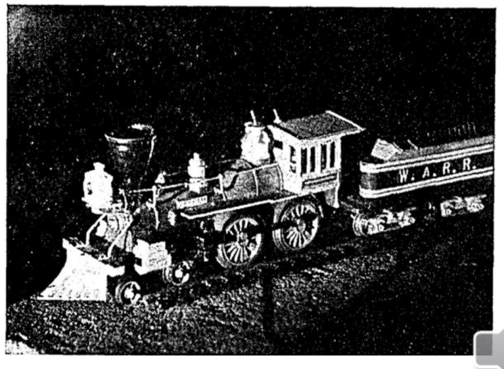
1948	1960	1964

1. **物理學家D. Gabor提出全像術**
2. **採用同軸(On-axis)的方式即物光與參考光的傳播方向相同**
3. **兩大缺點**
   - 目標物必須為透明
   - 觀看重建影像(虛像)時會同時看見參考光與重建影像的實像。



- **E. N. Leit與J. Upatnieks**
- 提出離軸(Off-axis)全像的拍攝架構
- 將物光與參考光由不同方向入射，成功解決重建影像其虛像、實像在同一方向的限制，使全像拍攝的自由度大幅提高。
- 此階段的特點就是全像圖由雷射記錄和再現。



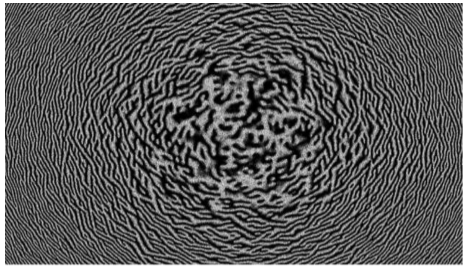


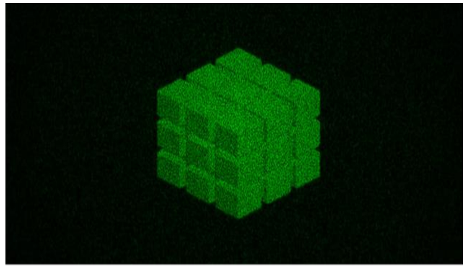
全像術發展

1966	1994

1966

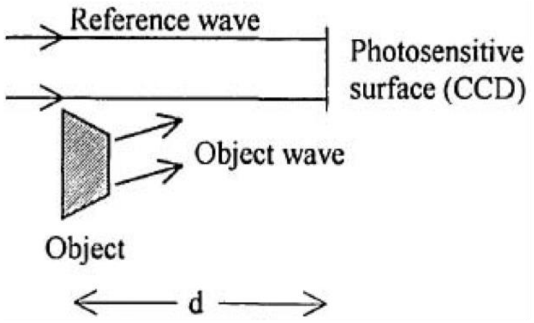
1. **B. R. Brown與A.W. Lohmann提出電腦全像**
2. 不需要實際物體
3. 以電腦繪圖技術結合全像原理，即可以電腦計算的方式模擬物光與參考光的干涉過程
4. 並將干涉條紋以數位的形式儲存
5. 不需要經過光學干涉的記錄與化學沖洗的過程，在製作時可免除光波干涉的嚴苛環境限制與複雜的記錄過程，大幅提高重建結果之品質與穩定性。

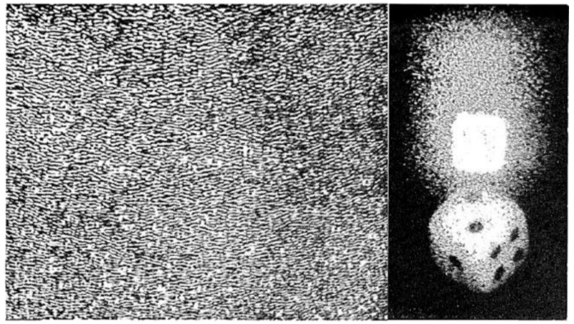




1994

- **U. Schnars與W. P. Jueptner**
- 率先以CCD相機記錄目標物光場之振幅及相位資訊
- 以電腦數值演算的方式模擬光學重建的過程。
- 以數位化的方式記錄及呈現為其一大特色，當以數值運算時能自由的操控及分析光波的變化。



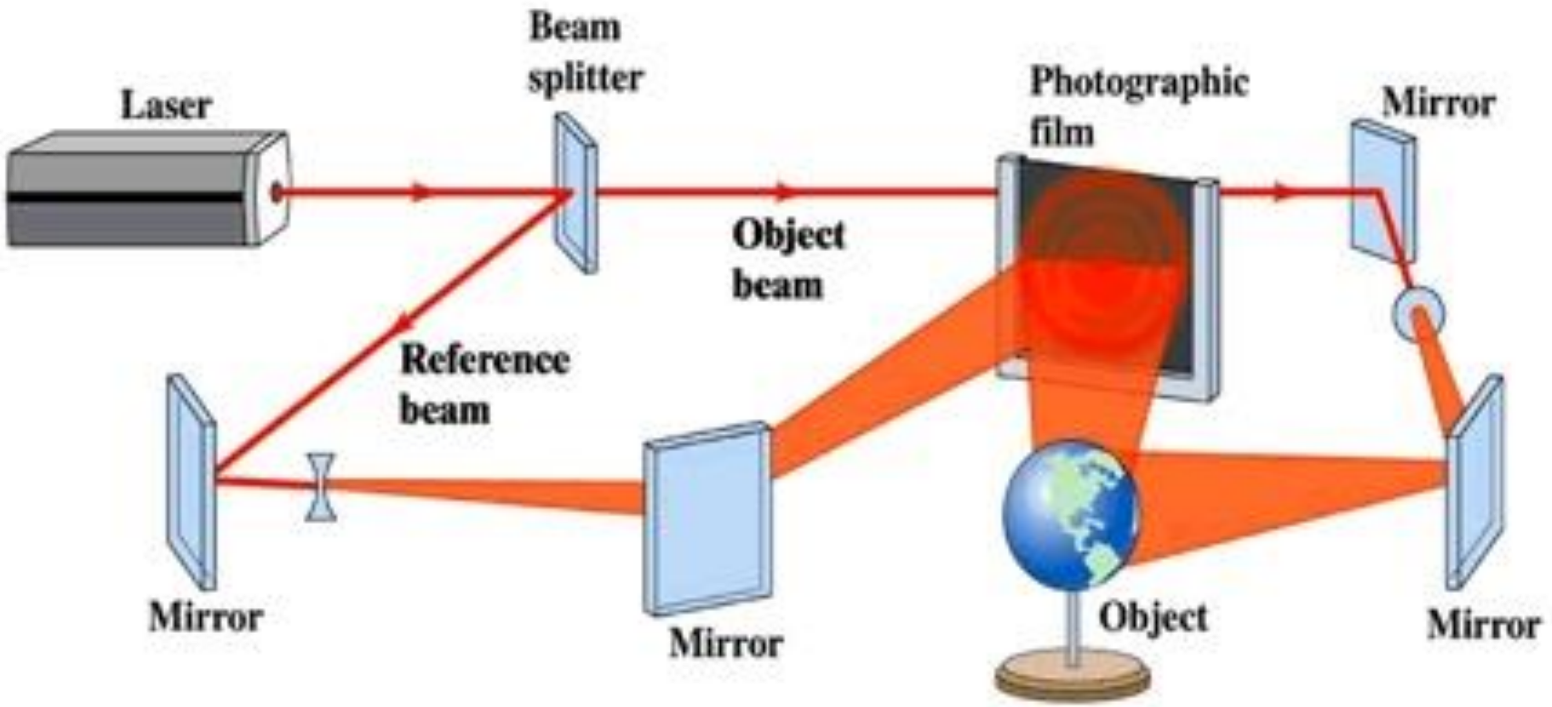


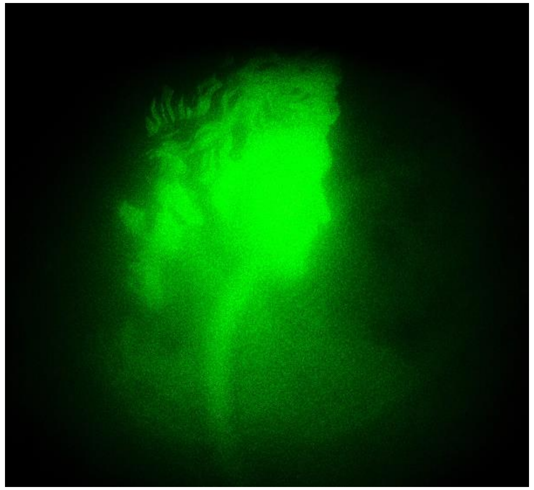
Categories of Holography

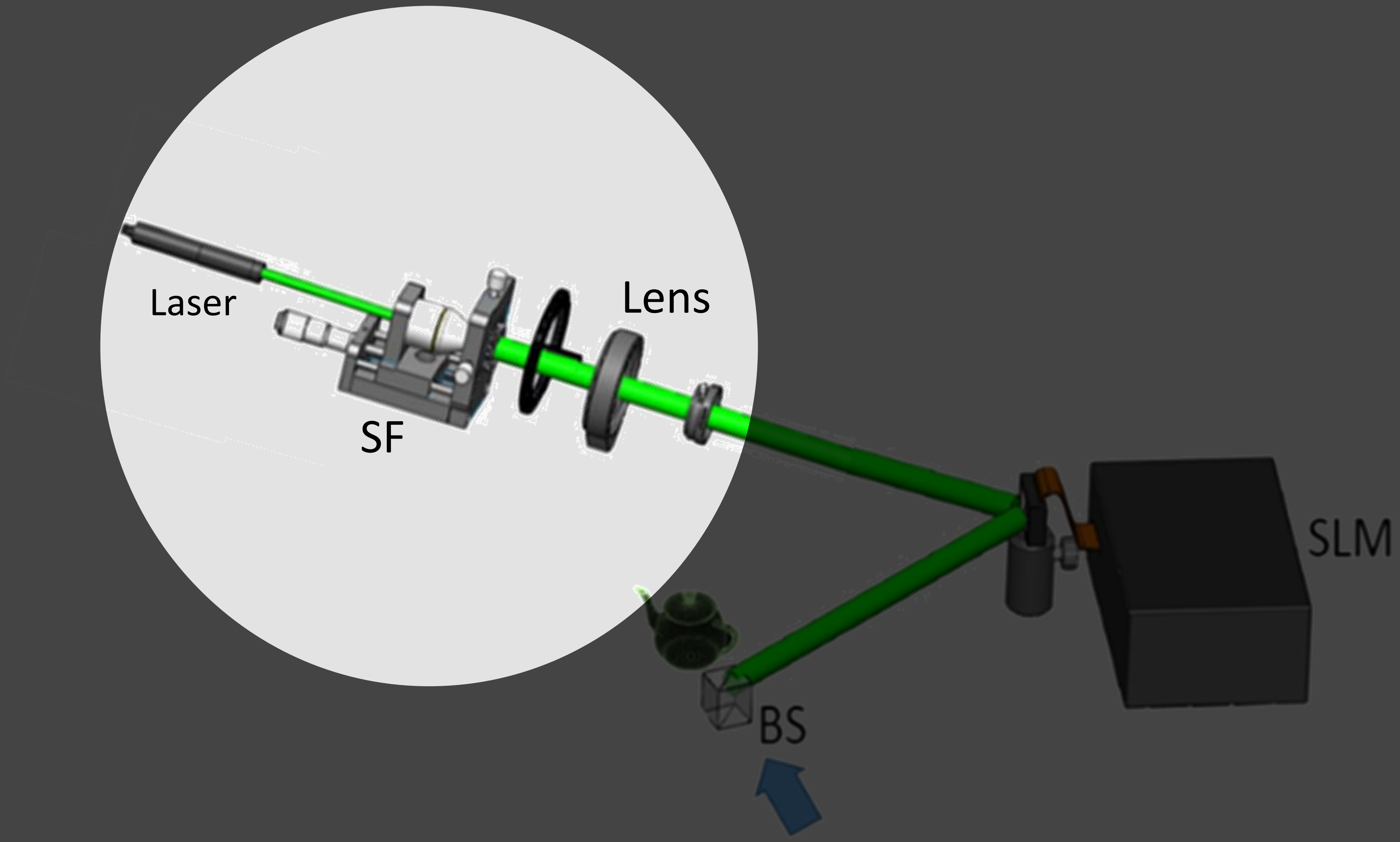
Category	Interference fringe	Recording of interference fringes	Reconstruction
Holography	Optical interference	Holographic film	Holographic film (with recording)
Digital Holography	Optical interference	CCD or CMOS	Spatial Light Modulator
Computer Generated Holography	Phase calculation with computer	unnecessary	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.

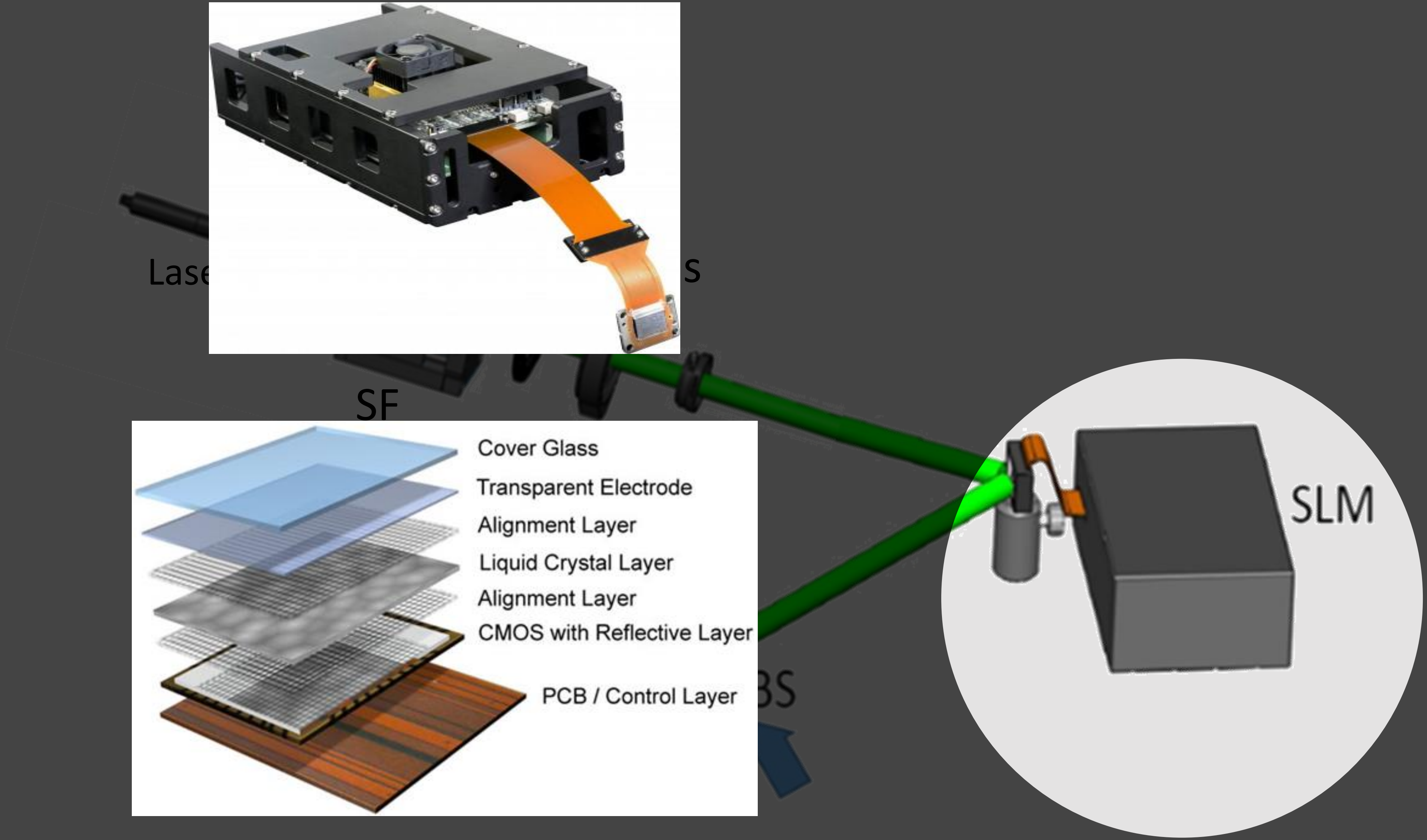
The process of holography

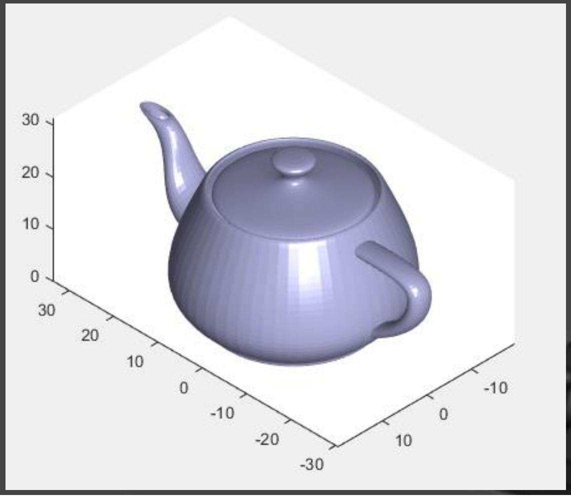


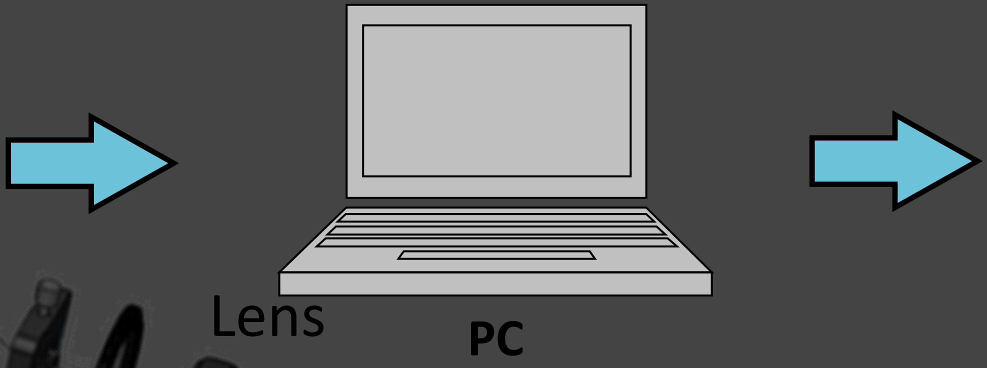


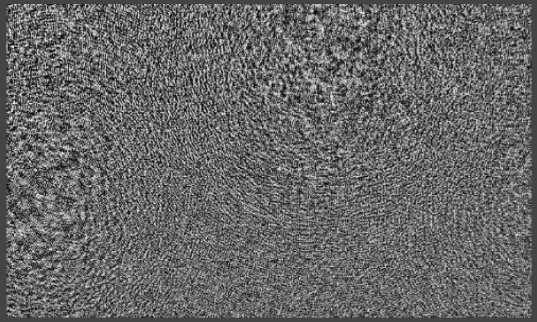


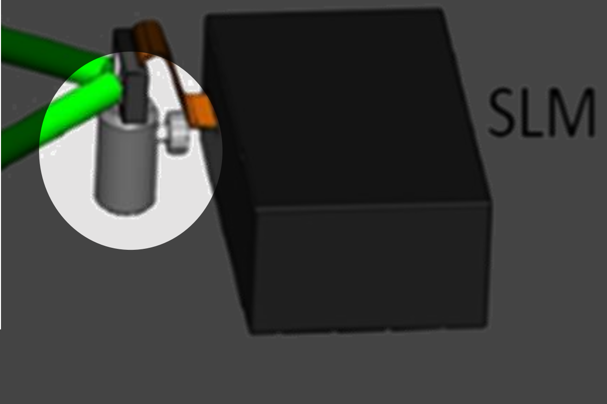
Laser
Lens
SF
SLM
BS

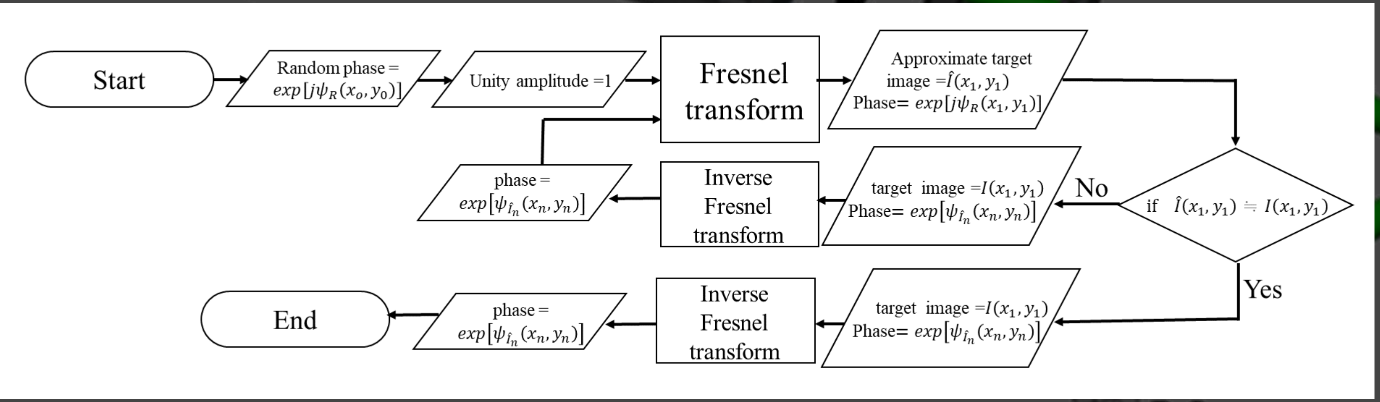

SF
Cover Glass
Transparent Electrode
Alignment Layer
Liquid Crystal Layer
Alignment Layer
CMOS with Reflective Layer
PCB / Control Layer
SLM





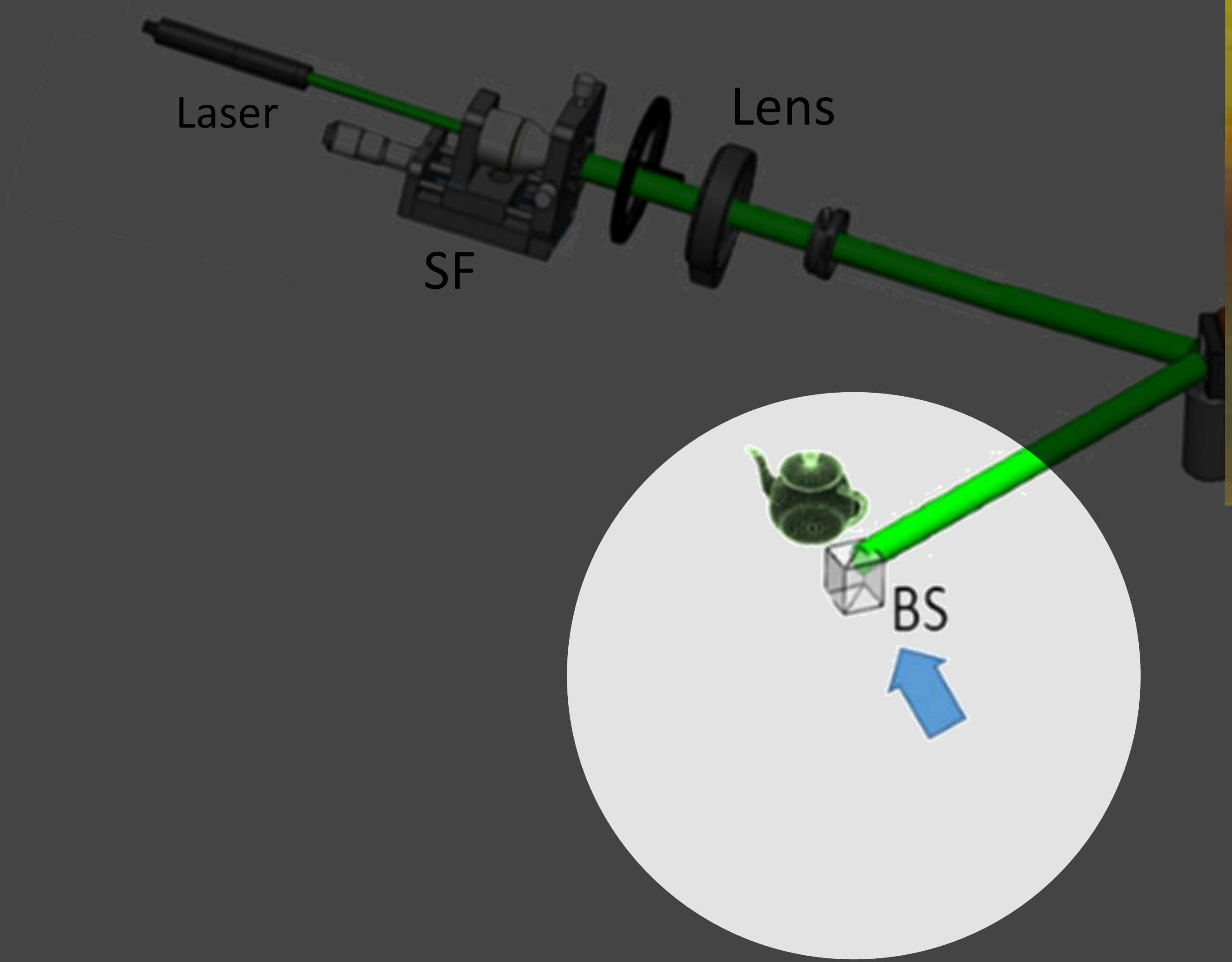


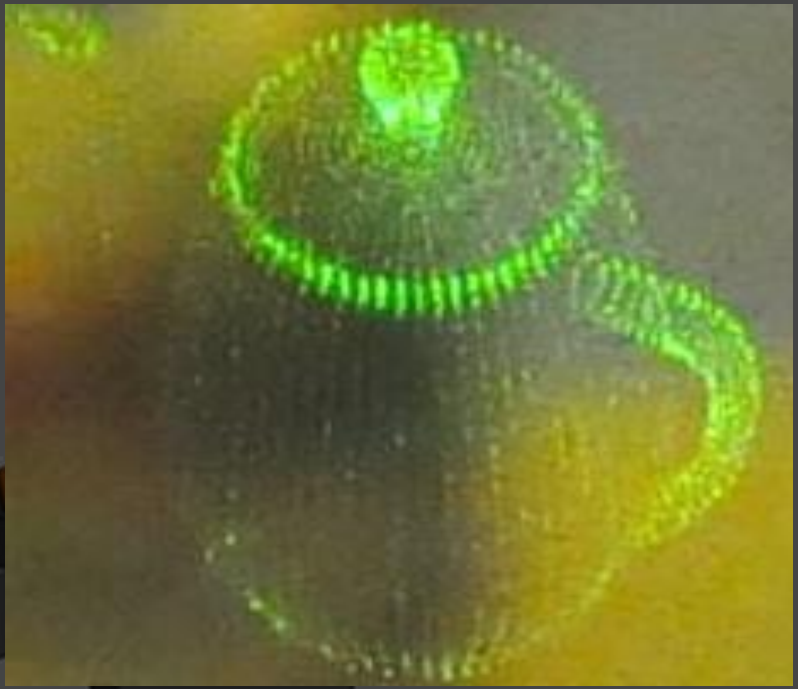




$$FrT\{1 \times exp[j\psi_R(x_o, y_0)]\}$$

$$IFrT\{I(x_1, y_1) \times exp[j\psi_{\hat{I}}(x_1, y_1)]; \lambda; z_n\}$$

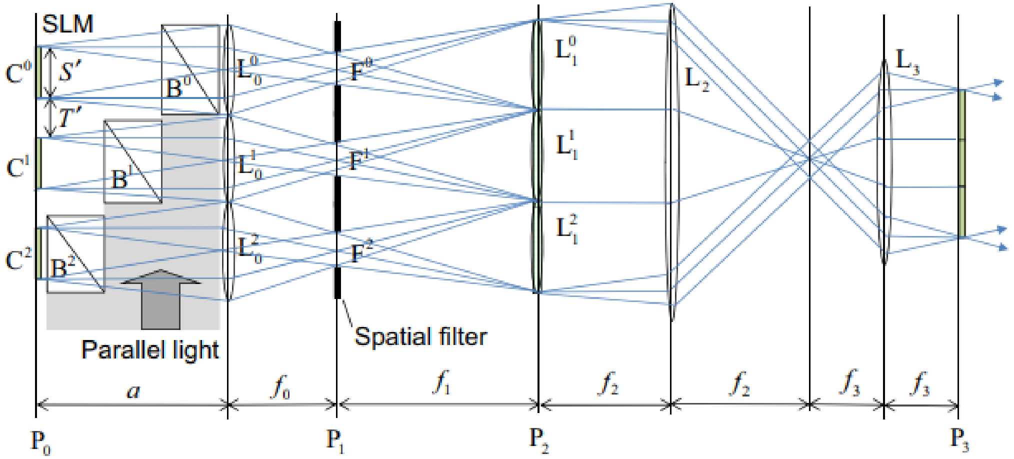

Laser
Lens
SF
BS

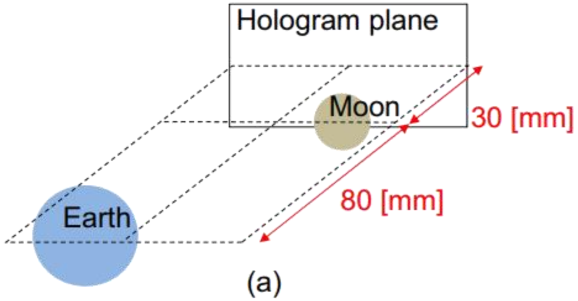


全像術的發展與趨勢

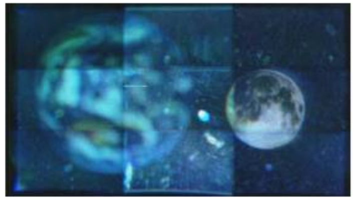
Larger field of view

National Institute of Information and Communications



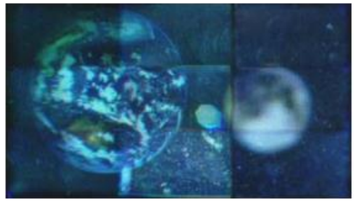


(a)

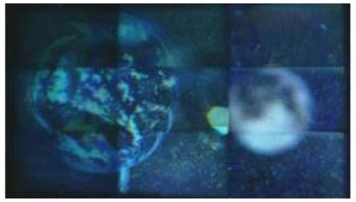


(b)

(c)

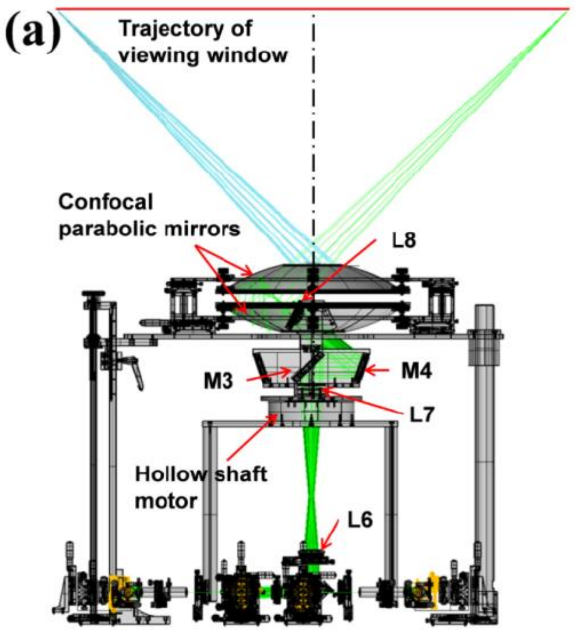


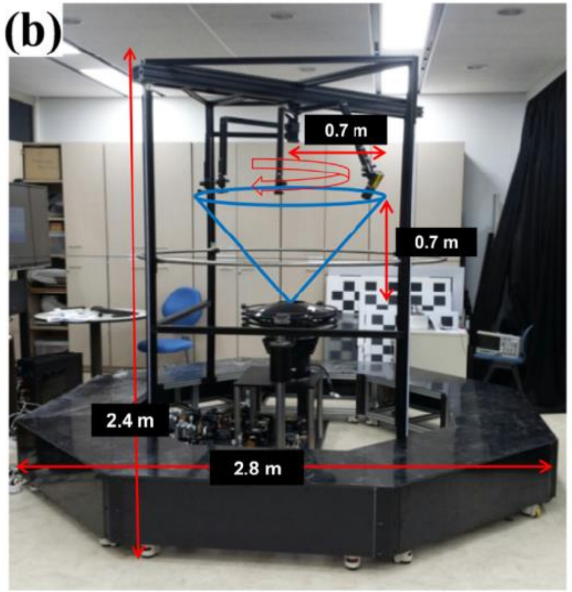
(d)



(e)

Electronics and Telecommunications Research Institute

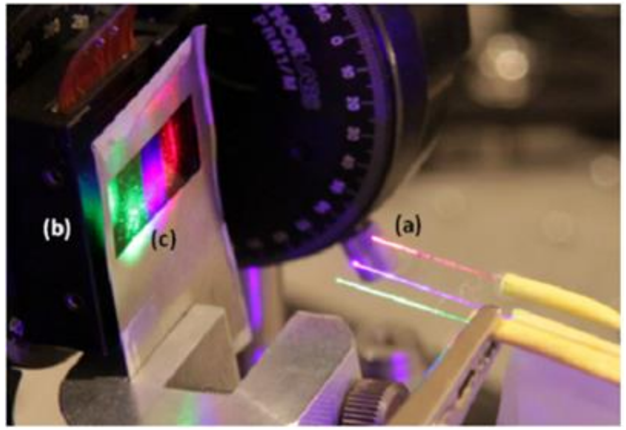




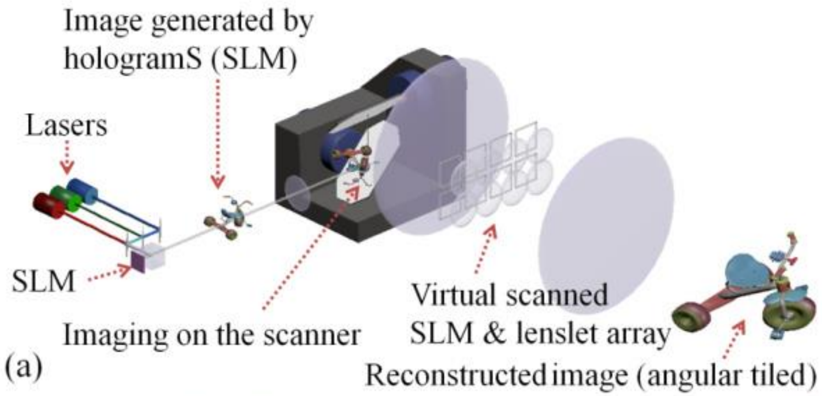
*H. Sasaki, K. Yamamoto, Y. Ichihashi, and T. Senoh, "Image size scalable full-parallax coloured three dimensional video by electronic holography," Sci. Rep. 4, 4000 (2014).
**Lim, Y., Hong, K., Kim, H., Kim, H. E., Chang, E. Y., Lee, S., ... & Hahn, J. (2016). 360-degree tabletop electronic holographic display. Optics express, 24(22), 24999-25009.

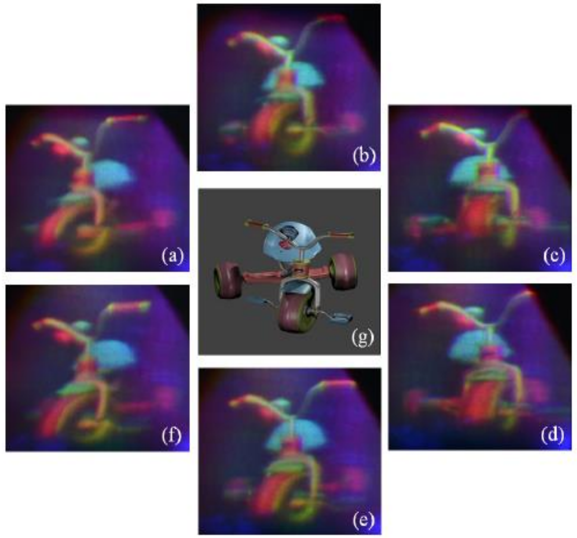
Full color display implementation

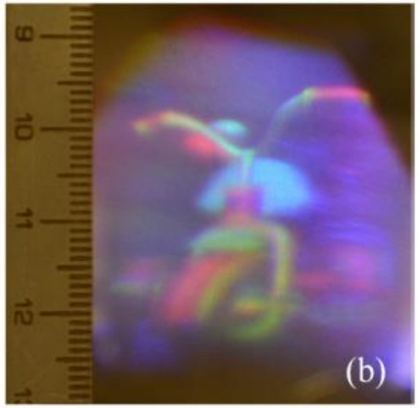
Politechnika Warszawska



University of Cambridge

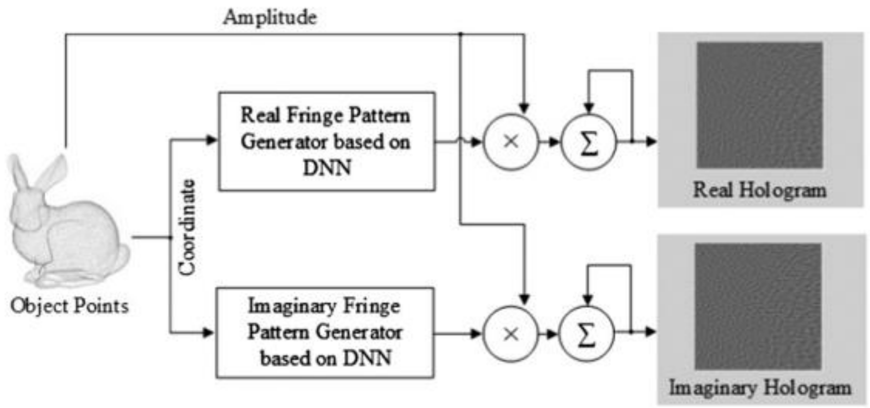


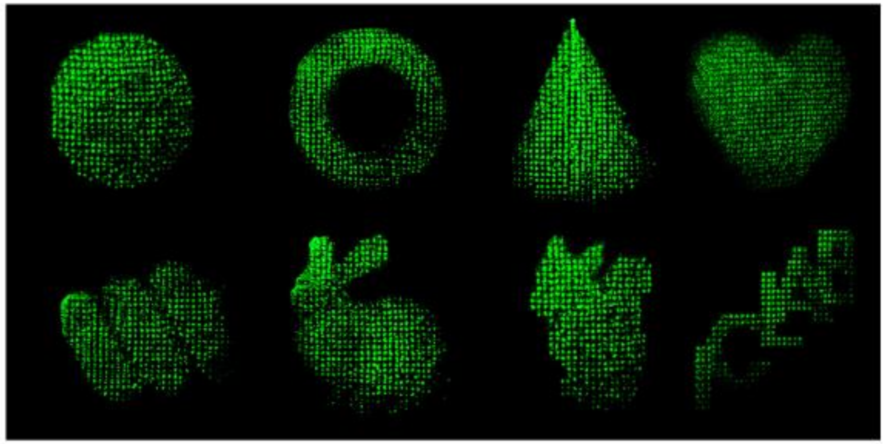




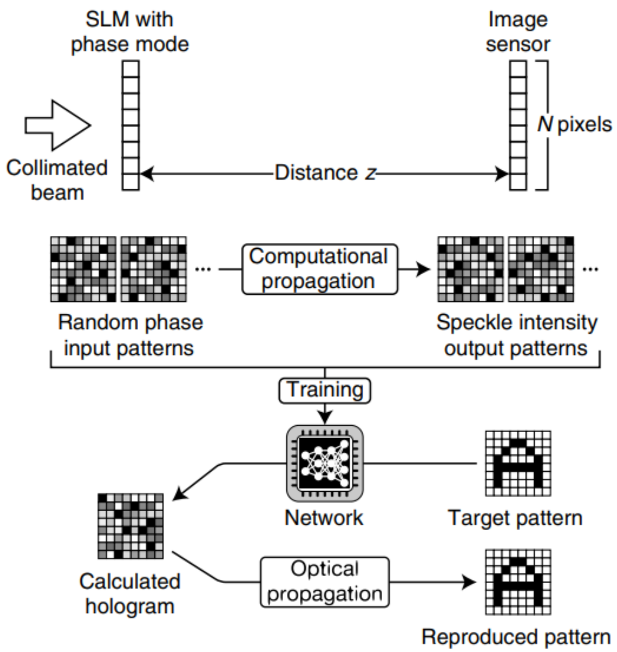
Faster computing speed

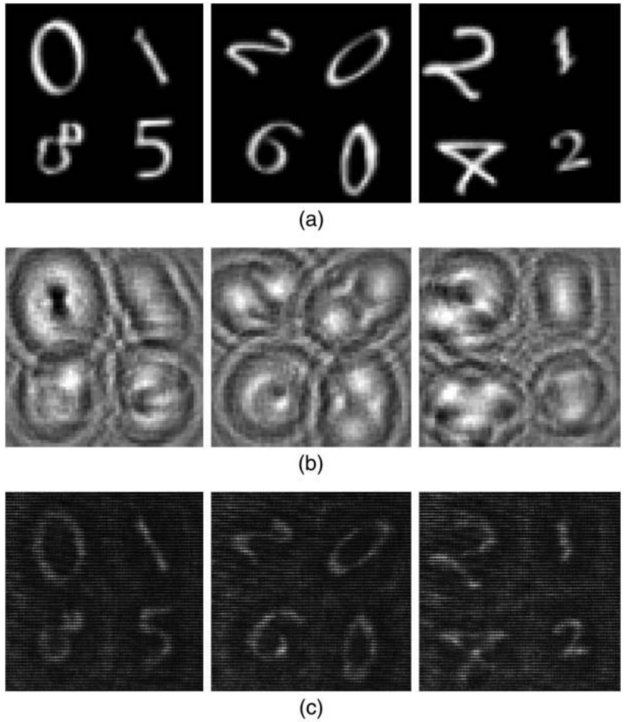
Kwangwoon University



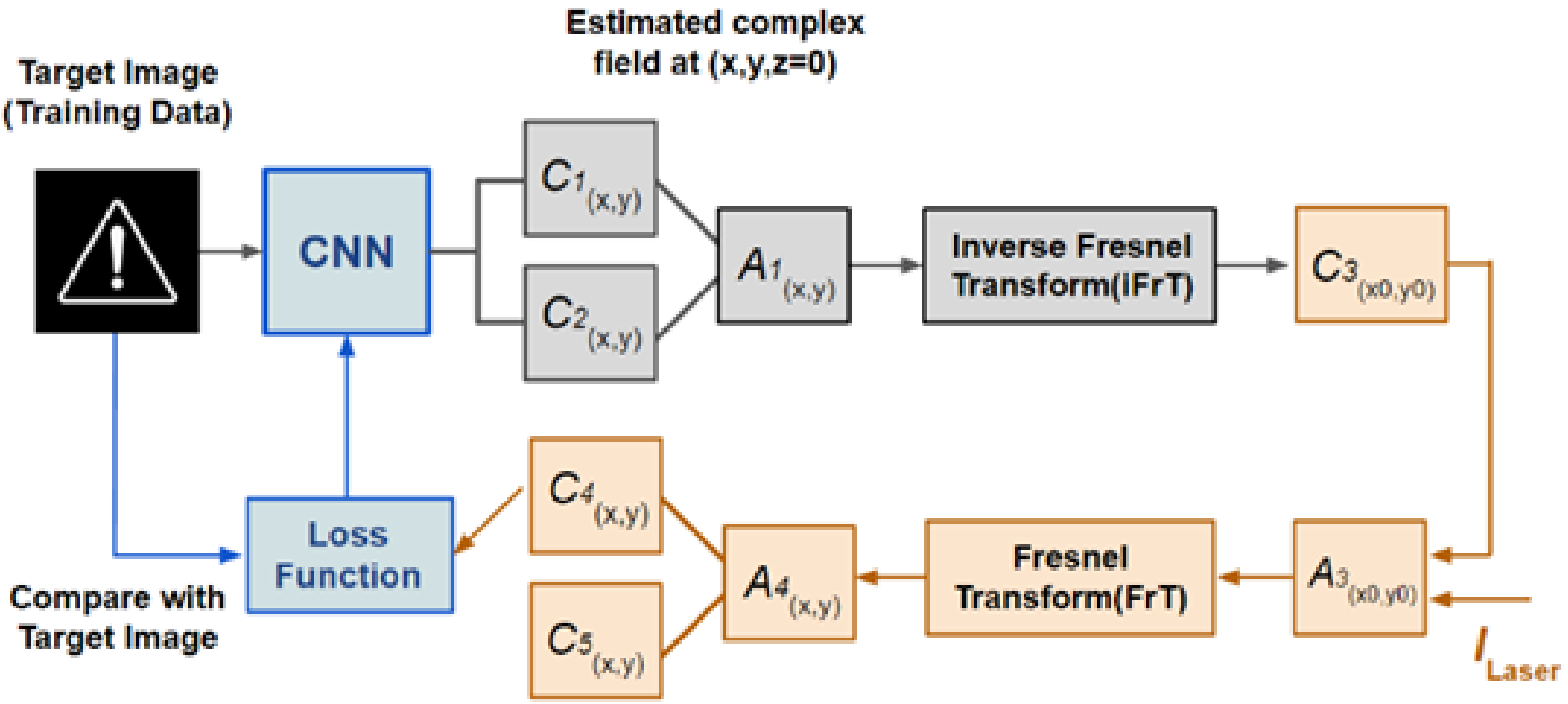


Osaka University





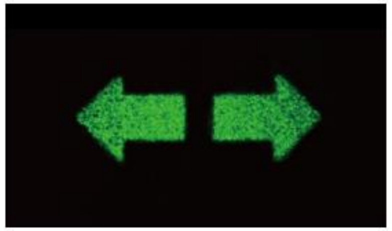
DL-GSA



Estimated complex field at (x,y,z=0)
Target Image (Training Data)
CNN
C1 (x,y)
C2 (x,y)
A1 (x,y)
Inverse Fresnel Transform(IFrT)
C3 (x0,y0)
C4 (x,y)
C5 (x,y)
A4 (x,y)
Fresnel Transform(FrT)
A3 (x0,y0)
I Laser
Loss Function
Compare with Target Image

DL-GSA

使用自創DL-GSA演算法大幅提升全像影像計算速度。



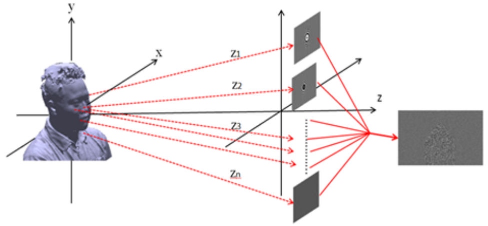

演算法	影像格式	箭頭方向圖	里程數字圖	速限指示圖	警告標誌圖
MGSA	1024×1024 迭代30次	31.87s	31.87s	32.78s	32.26s
DL-GSA	1024×1024	✓12.89ms	✓ 9.8ms	✓9.91ms	✓ 11.59ms

Our research in holographic display

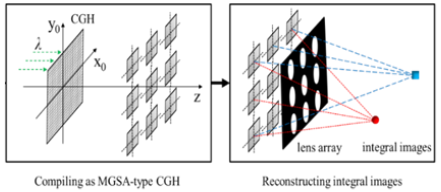
Computer Generated Hologram

Unique technique in CGH	Application

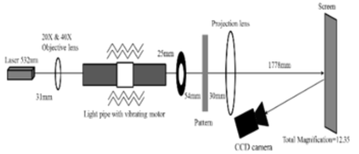
- 3D modified Gerchberg -Saxton algorithm

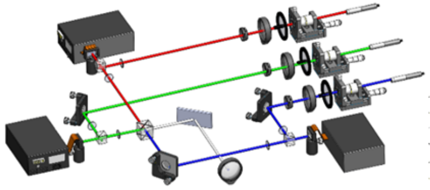


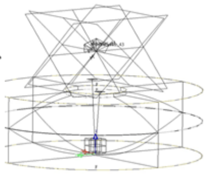
- Optical showcase



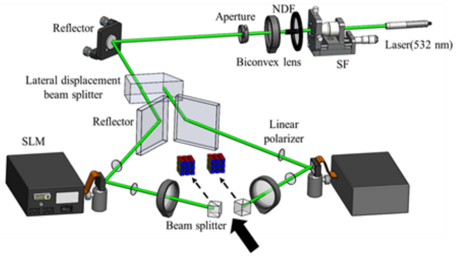
- Reduce speckle

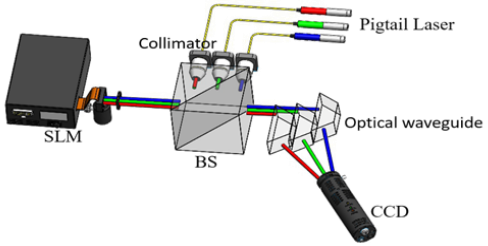




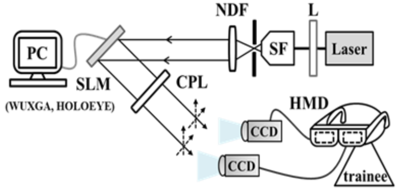


- Optical Design of CGH HMD System

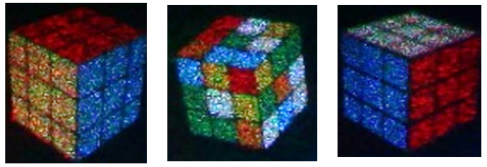




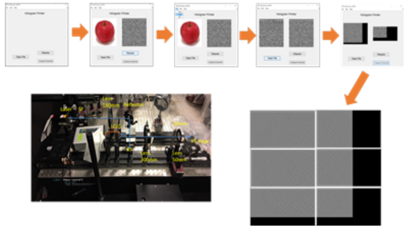
- Vision training

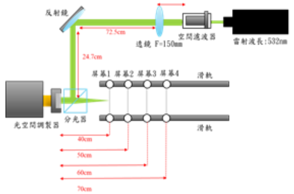


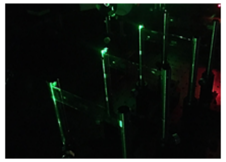
- Full-color dynamic CGH



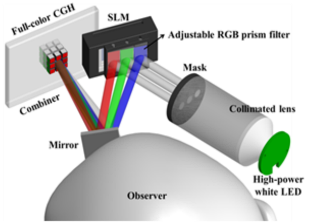
- Digital optics



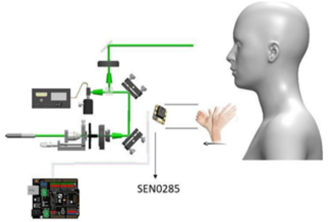




- AR display in CGH

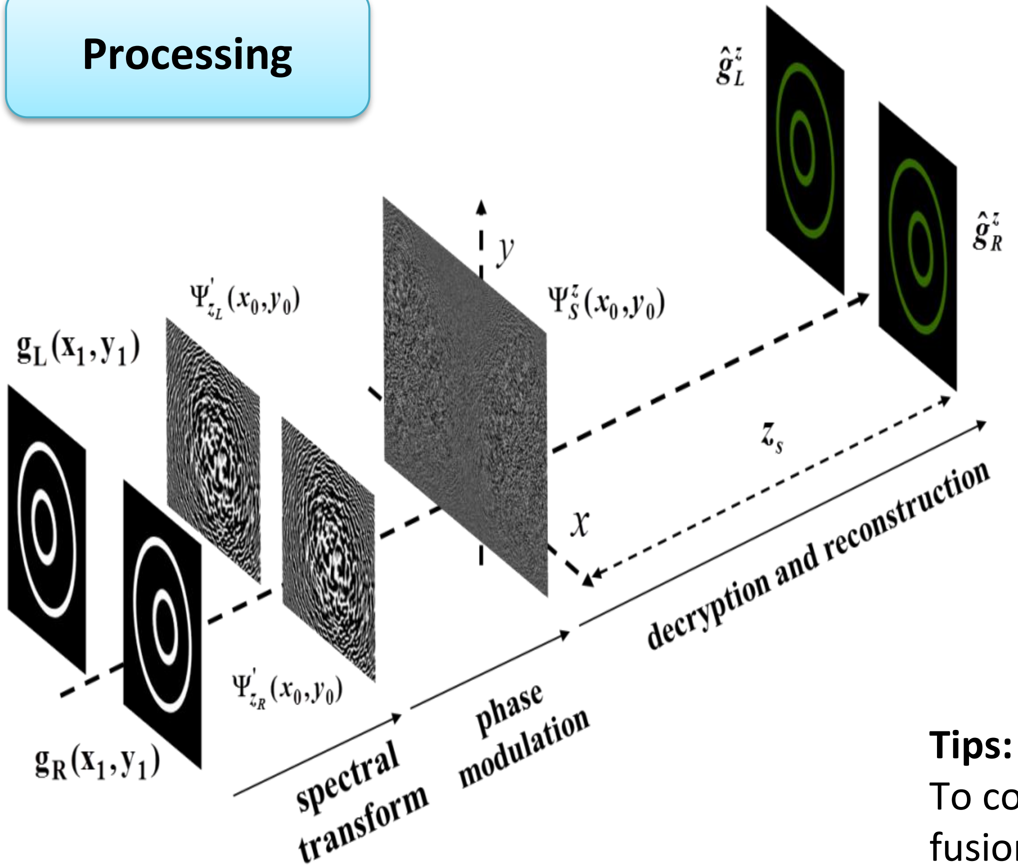


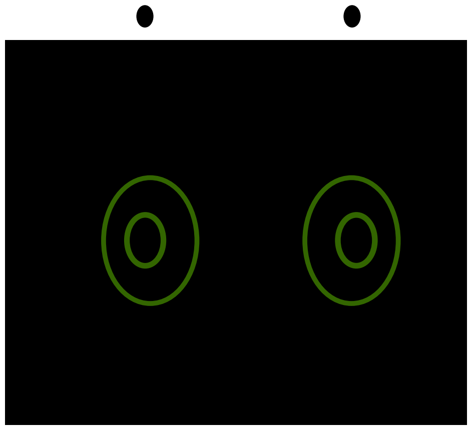
- HUD display in CGH



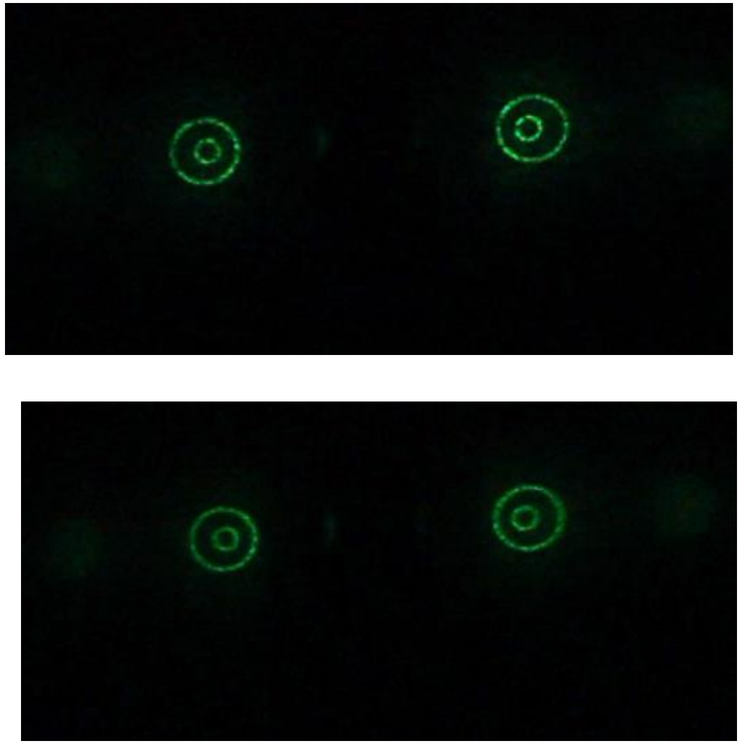
Vision training

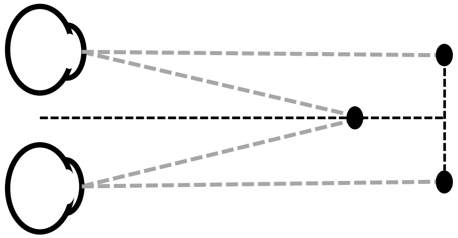
Processing





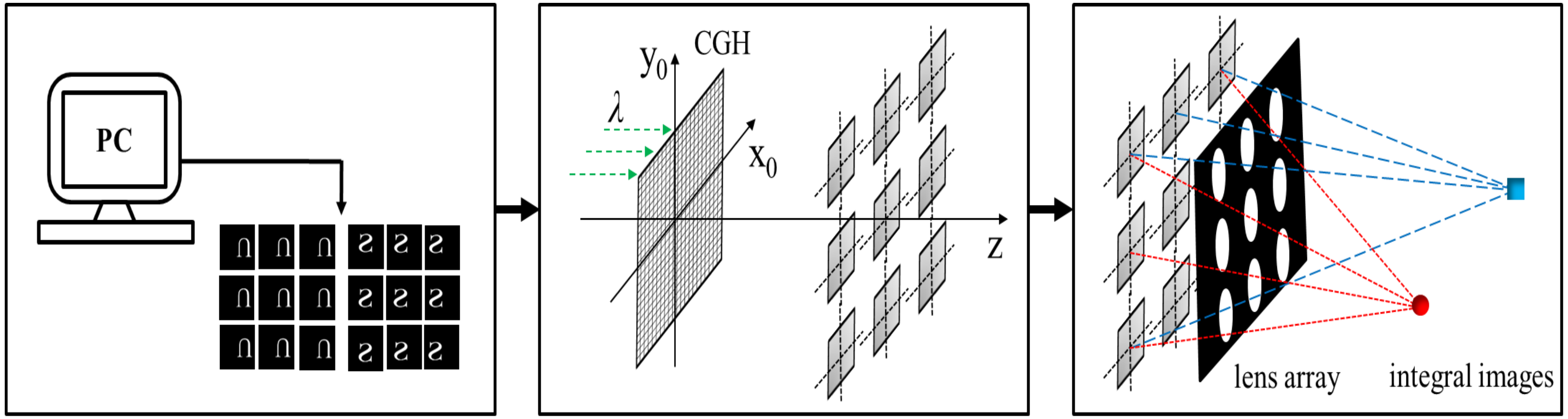
The simulation result of reconstructed stereo-image.





Tips:
To convergent the two dots to a point by fusion, you can feel the 3D effect of dual circle in the picture.

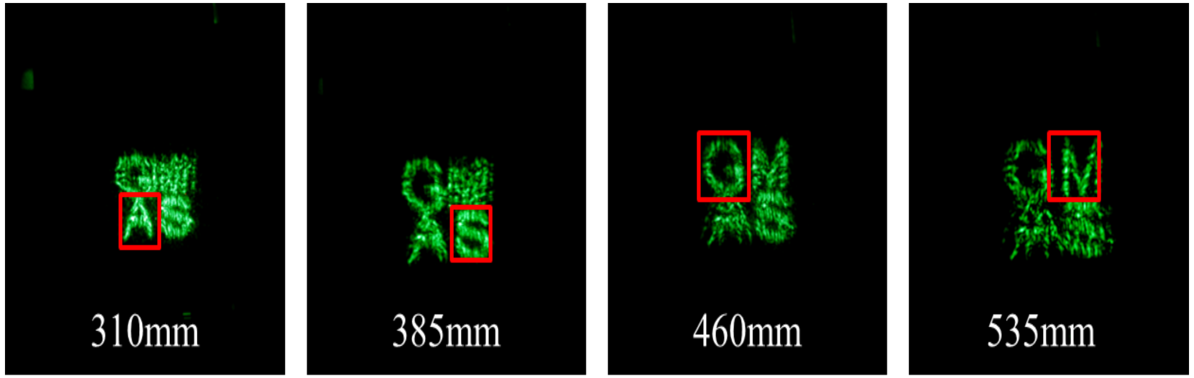
Light field display + holography



Calculating elemental images

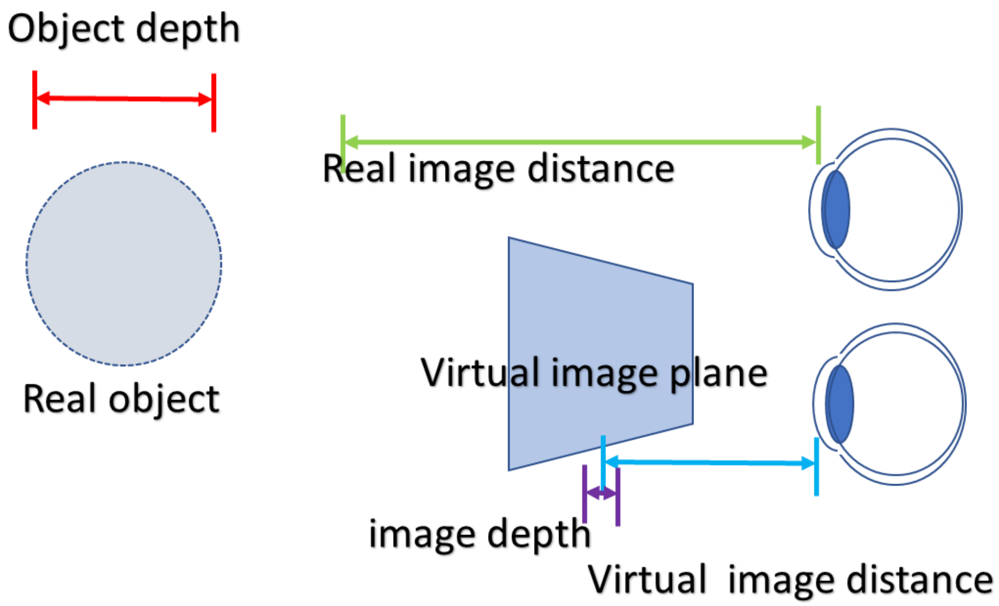
Compiling as MGSA-type CGH

Reconstructing integral images

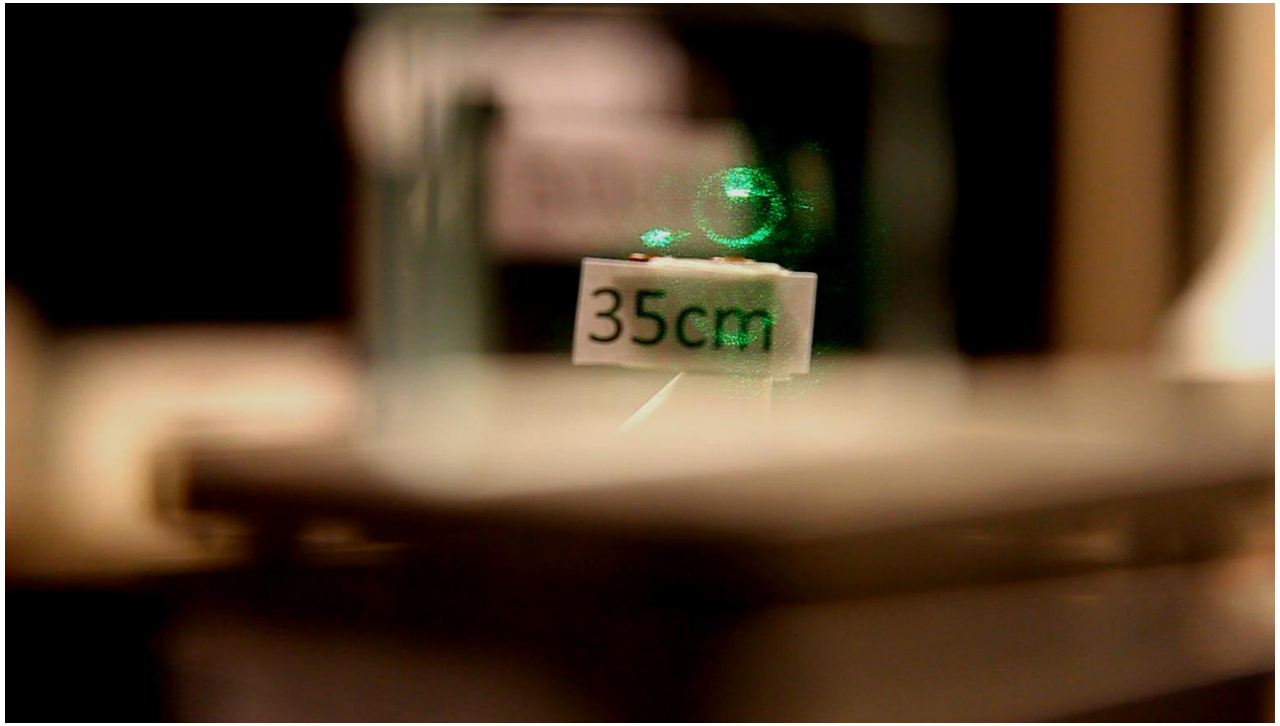


A → S → G → M

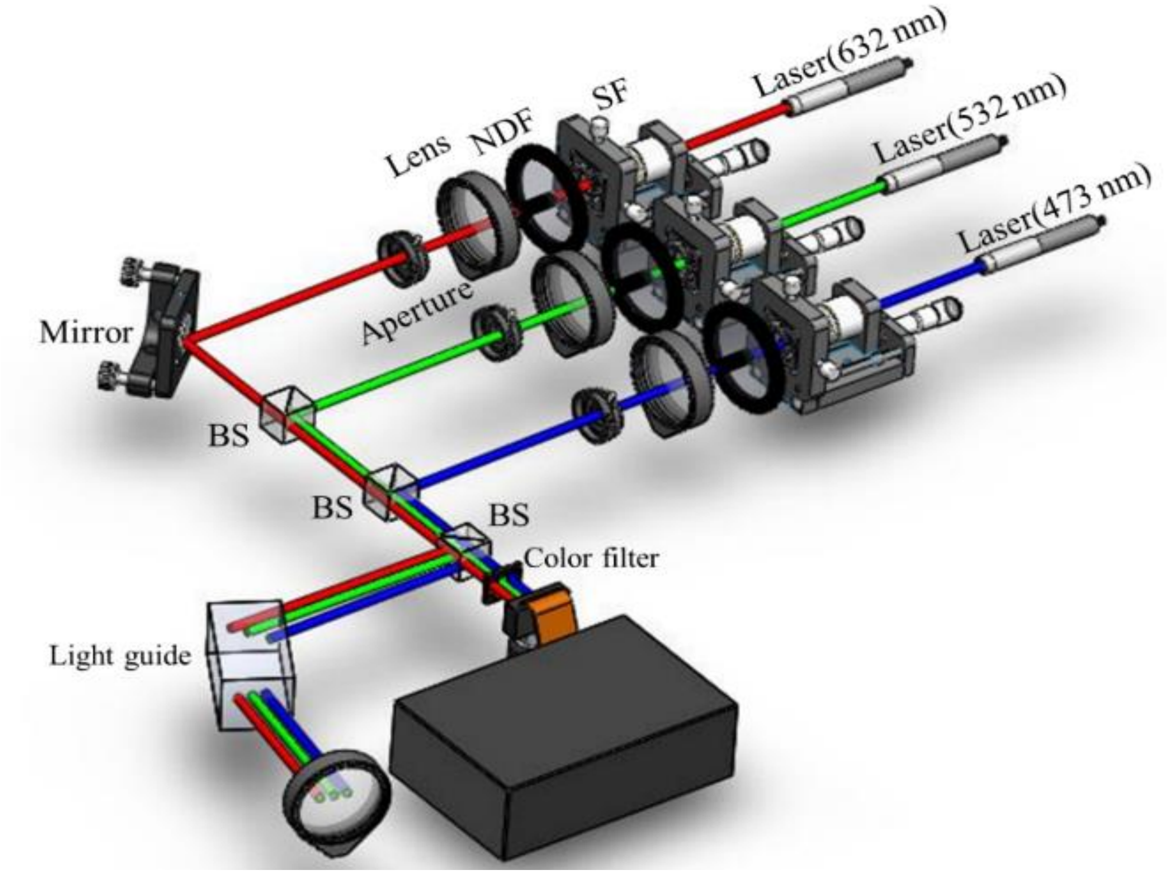
Holographic display for AR

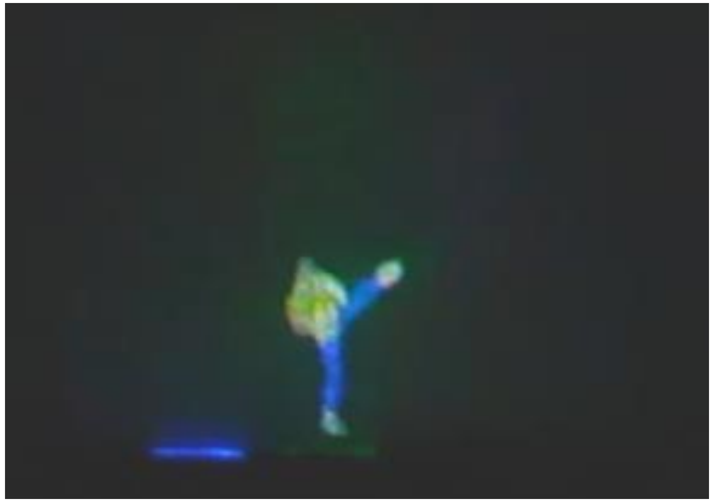


Hyper reality AR issue



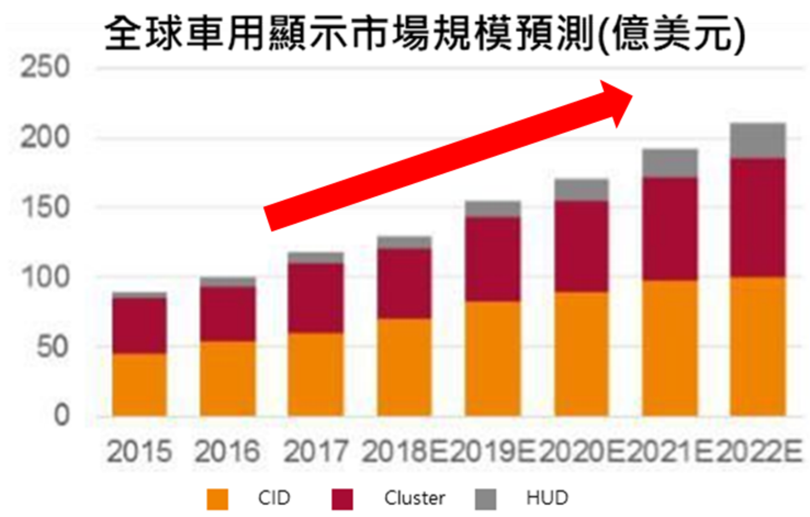
Miniaturized full-color holographic display system

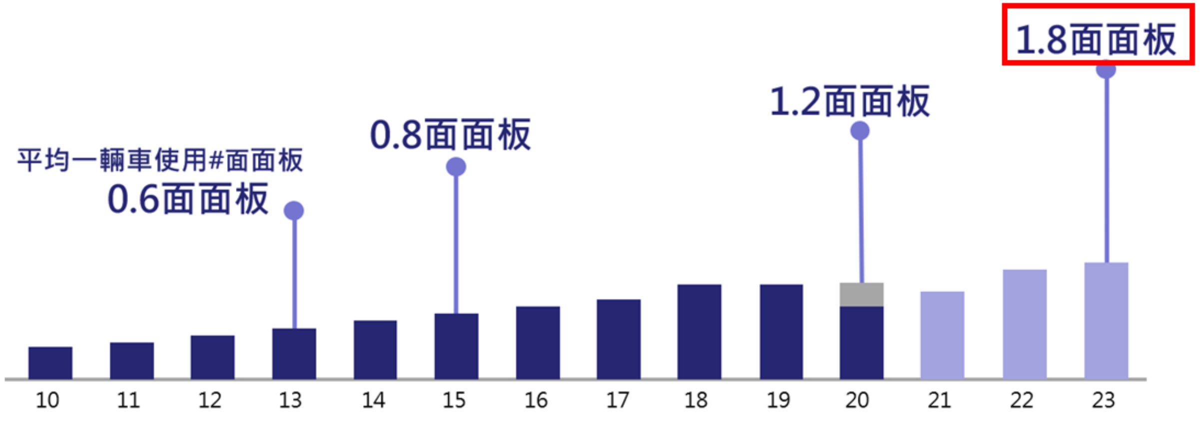




於車載顯示上的應用

車用面板市場概況





透過**<u>更先進顯示互動技術</u>**讓「面板產業」與「車電產業」共創雙贏!

未來趨勢

Display 4.0：**智慧**、**互動**、**實境顯示**– 前瞻關鍵技術

前瞻顯示技術

- 超高解析度顯示技術
- 透明互動顯示技術
- 實體/浮空3D互動顯示技術

關鍵技術

- 先進人因工程
- 先進高效材料、光學元件、製程
- 先進智慧互動科技
- 內容、電腦圖學/視覺、高效即時計算、串流、AI、IC...

市場趨勢

市場趨勢一: 安全性的提升

市場趨勢二: 直覺操作及互動

市場趨勢三: 娛樂及辦公需求

市場趨勢一：安全性提升(輔助駕駛)

智慧儀表

電子後照鏡

數位A柱

市場趨勢二：直覺操作及互動

人因中控台

3D投影結合手勢操作

車內3D顯示

市場趨勢三：娛樂及辦公需求

AR桌面、RES個人化

自駕車成移動客廳

自駕車成移動辦公室

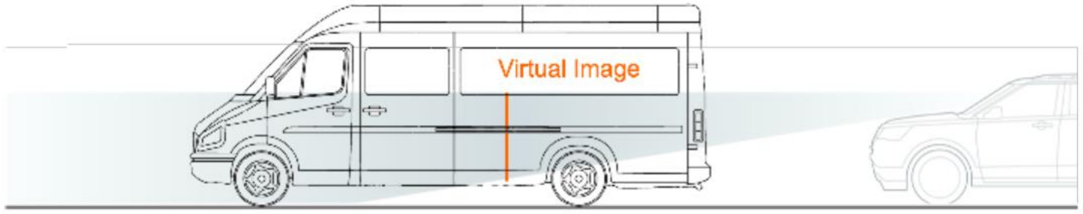
更多的面板需求

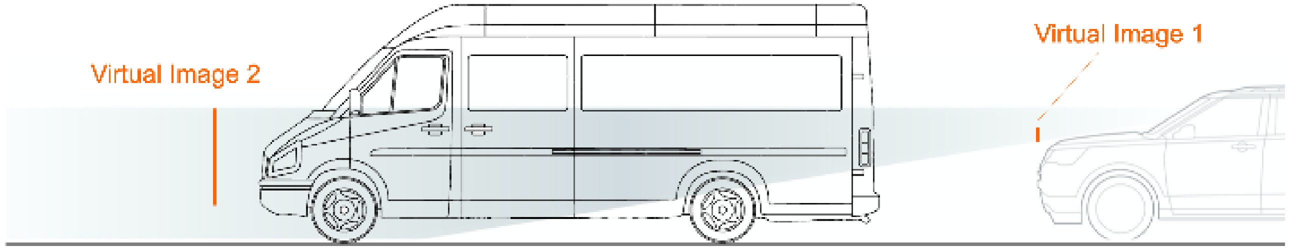
使用六螢幕顯示

大型曲面顯示&大型中控台

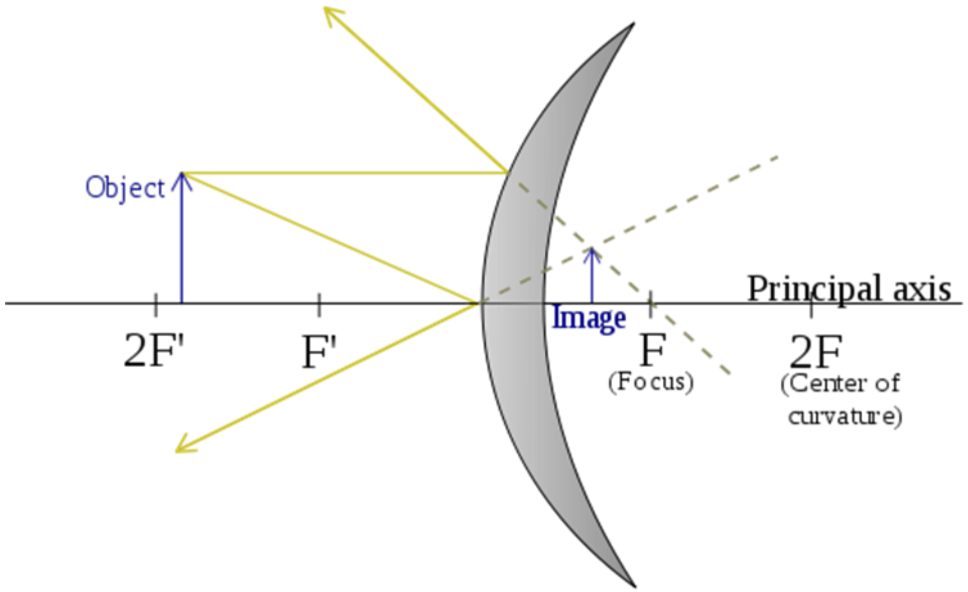
多深度HUD 的設計條件

- HUD 的最大好處是減少了調整人眼焦距的需求。
- 駕駛員在駕駛時注視無限遠，重新聚焦位於 1m 距離處的內部顯示器需要約 700 毫秒
- 在 2.3 米的 HUD 距離處顯示僅需要約 200 毫秒。
- 視覺生理在6m時，辨別能力很差。超過 6m 的虛擬圖像通常會被感知為與現實世界融合。
- 除了安全警報/警告符號外，顯示的HUD資訊需要非常接近場景的環境光級時呈現，以免它們分散注意力。

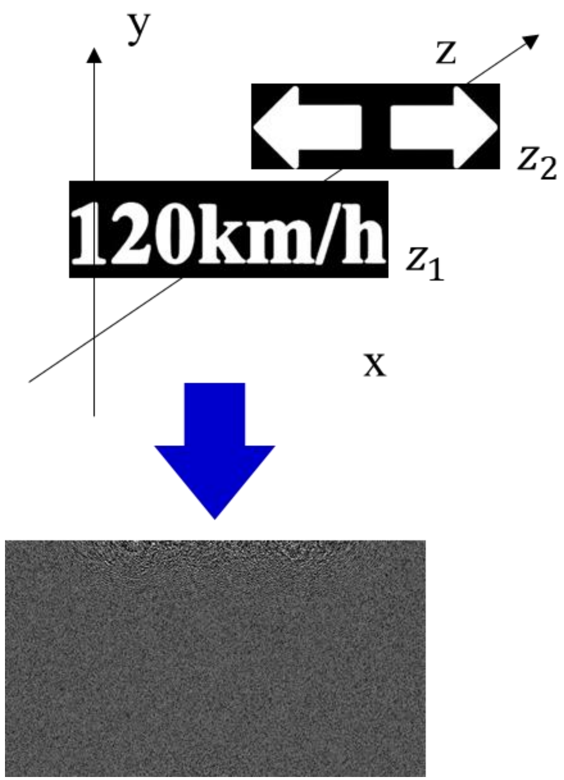




雙光路HUD系統

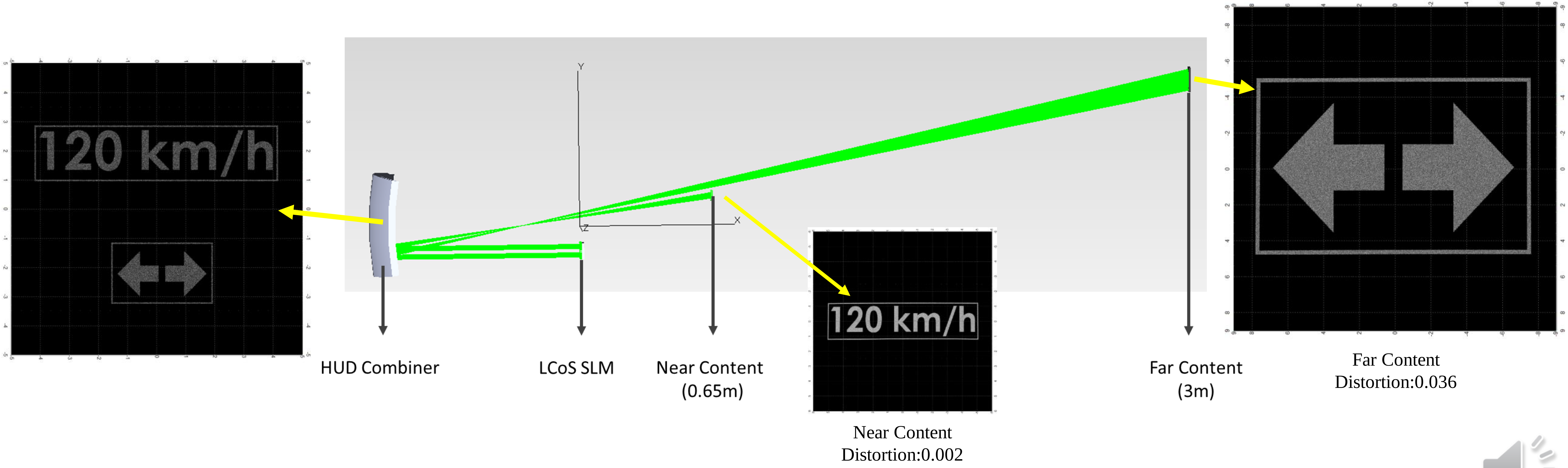


$$\frac{1}{z_n} + \frac{1}{z_I} = \frac{1}{f}$$

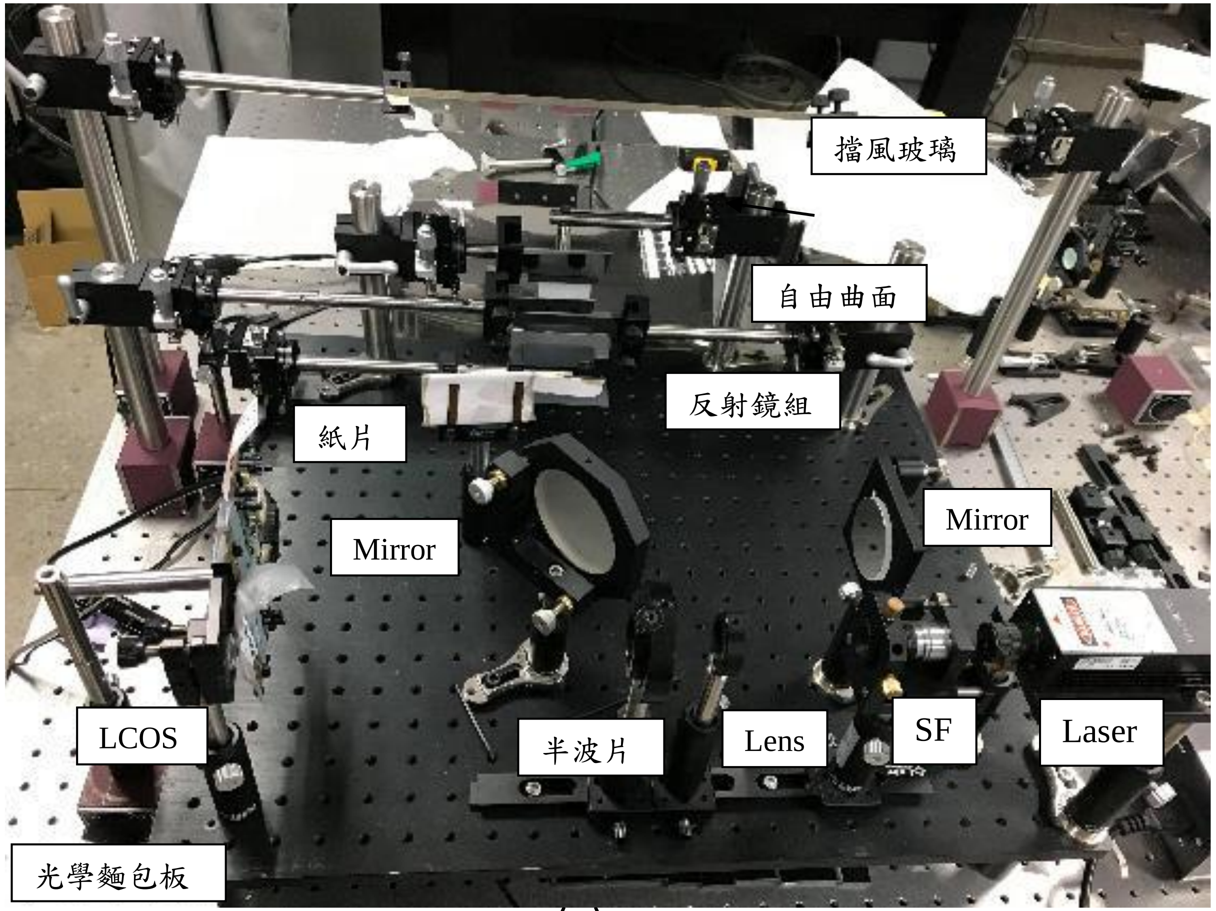


雙光路HUD系統

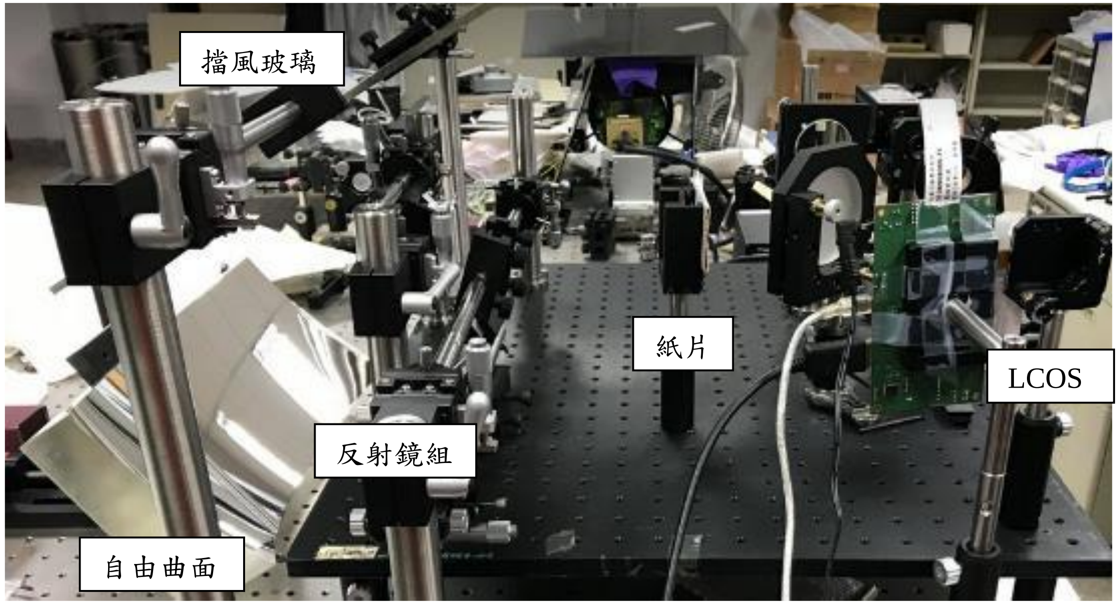
- Optical Structure : LCoS SLM with CGH
- Advantage : 1. Simple and miniature structure .
  2. Using single PGU can display dual-depth image



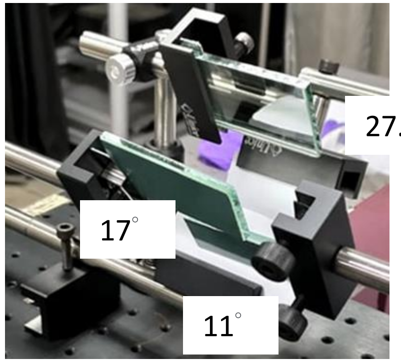
雙光路HUD系統



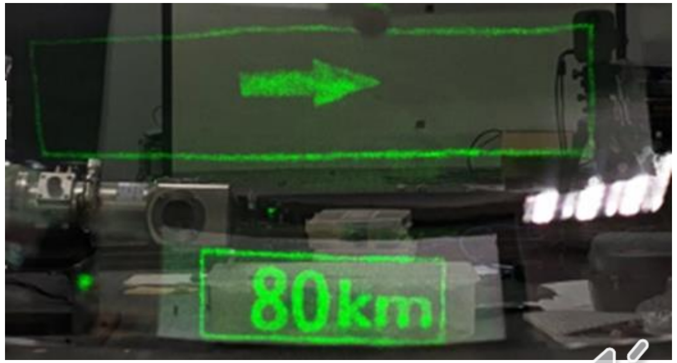
(a)



(b)



(c)

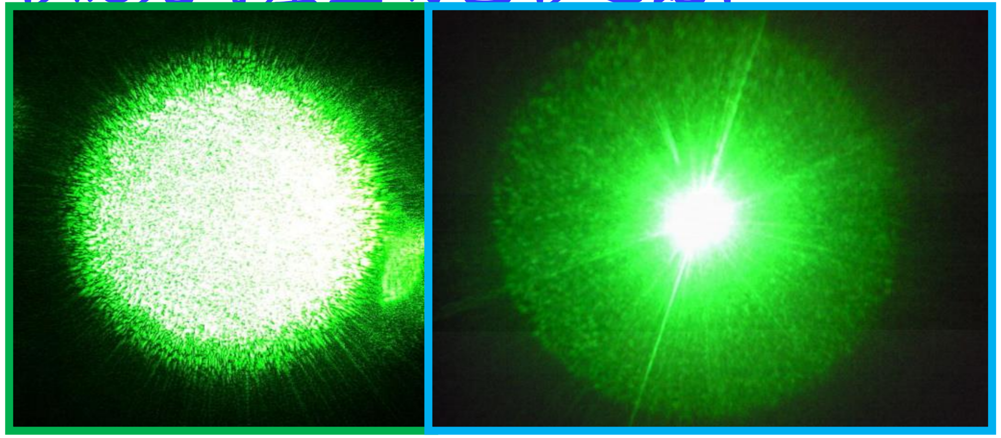


成果展示

結論與未來展望

電腦全像的限制

1. 輸入資訊龐大時需較多運算時間，較難實現動態性(dynamic)、即時性(real-time)。
2. 受硬體限制，FOV較小
3. 尚無最適合的介質影像的體積性(volume)。
4. 雷射光斑造成影像品質的降低。
5. 全彩混光時產生的色彩過飽和。



Conclusions & outlooks

克服軟體限制

→機器學習、CUDA加速、平行運算等

克服硬體限制

→波導元件、快速掃描鏡、新光學系統等

跨域整合與前瞻應用

→光刻、數位光學元件、浮空投影、AR/VR、HMD、HUD等

Thank you for your attention