Information photonics technologies over time, space and frequency domains

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Dr. Yamamoto received Young Scientist Award for the Presentation of an Excellent Paper, The Japan Society of Applied Physics, Outstanding Poster Paper Award at IDW'03, IDW'04, IDW'07, IDW'08, IDW'09, IDW'10, IDW'11, IDW/AD'12, IDW'13, IDW'14, and IMID2014, Best Paper Award at DHIP2011, IDW'11, and IWH2014, Best 3D Demonstration Award at SPIE/IS&T Electronic Imaging 2012, Excellent Poster Award at IEEE GCCE 2013, and the Gen-Nai Grand Prize from the Ozaki Foundation of Japan.

Information Photonics

Background

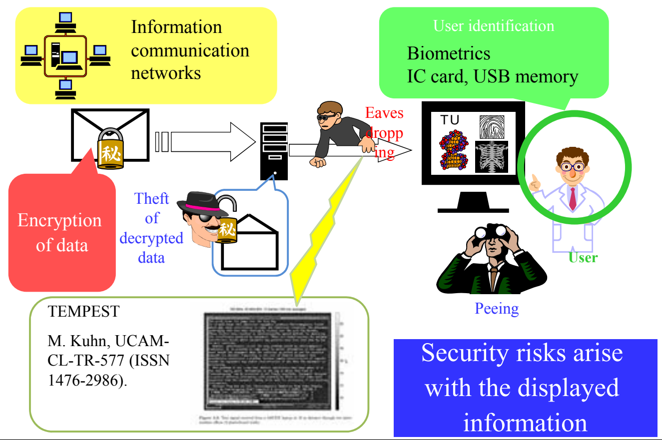
1. Optical Information Processing
   - A) Fourier optics
   - B) Holographic optical elements and information processing
   - C) Optical logics
2. Optical Computing
3. Optics in Computing
   - A) Optical interconnection
   - B) Optical data storage
   - C) Photonic networking

Current trends

1. Information displays including, secure display, 3D display, and aerial display
2. Compressive sensing
3. Optical measurements and processing by utilizing optical information processing techniques
4. Nature-inspired computing such as DNA computing and nano-field processing
5. Digital holographic microscope
6. Information systems incorporating with human vision
7. Novel (and enjoyable) demonstrations by use of light as an information carrier

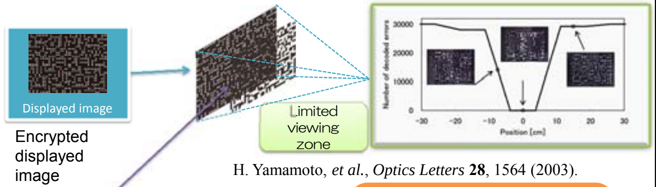
Mainly Inf.

1. Security risks on information display

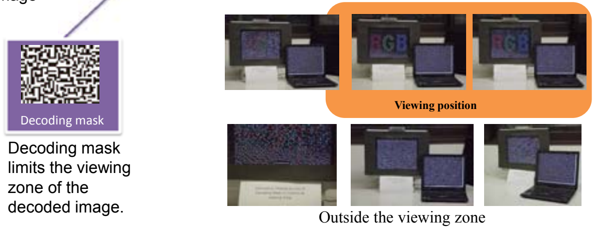


Hirotsugu Yamamoto

Secure display by use of visual cryptography

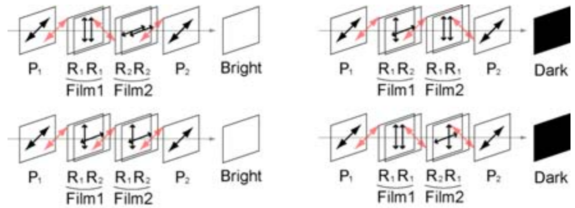


H. Yamamoto, *et al.*, *Optics Letters* **28**, 1564 (2003).



H. Yamamoto *et al.*, *Optics Express* **12**, 1258 (2004).

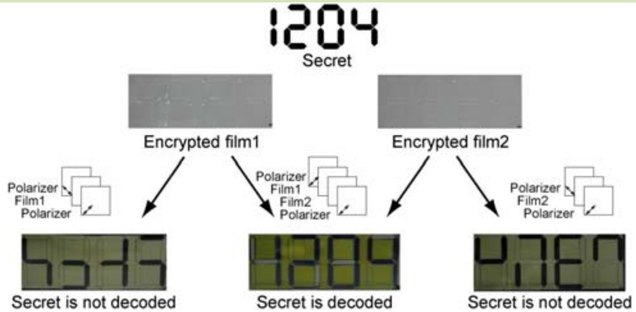
Visual cryptography by use of polarization



Single encrypted film is composed of two quarter-wave retarders and perform as a half-wave retarder or a normal film, depending on the directions of the retarder films.

Decoded results depend on the combination of retarder films.

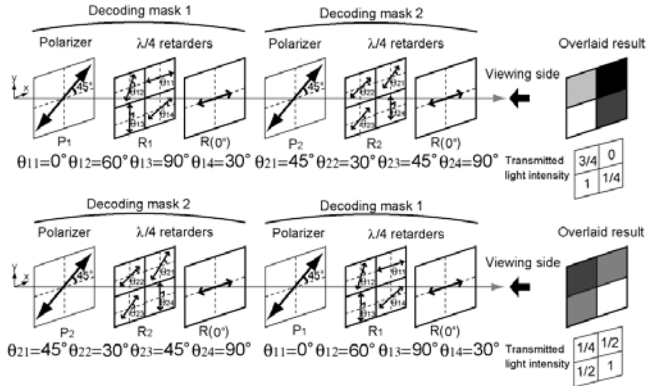
Examples of polarization encryption



First paper of polarization encryption (by use of spatial-light modulator):
S. Fukushima, T. Kurokawa, and Y. Sakai, *IEEE Trans. Photon. Tech. Lett.* **3**, 1133 (1991).
Our paper of polarization encryption by use of polarization films:
T. Imagawa, S. Suyama, and H. Yamamoto, "Construction of Visual Cryptography by Use of Polarization-Modulation Films," *Jpn. J. Appl. Phys.*, Vol. 48, No. 9, 09LC02 (2009).

Multiple encryptions with stacking order

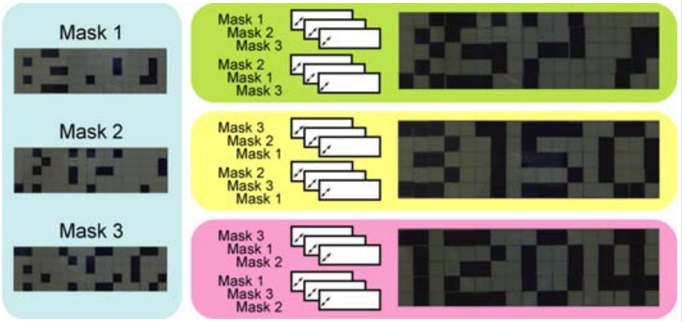
Principle



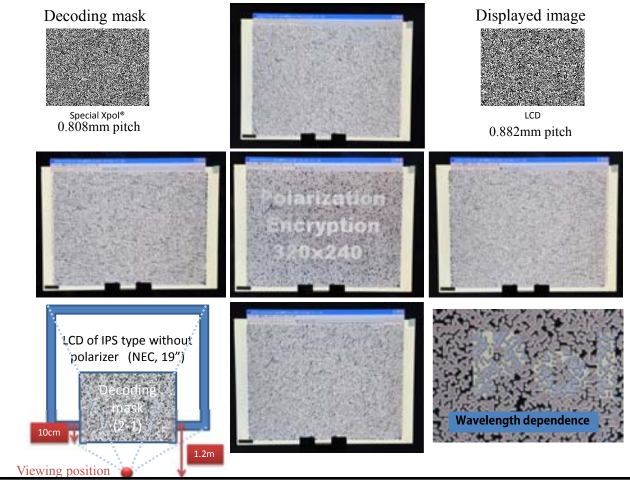
Overlaid results depend on the stacking order.

Multiple encryptions with stacking order

Experimental results



Limitation of viewing angle

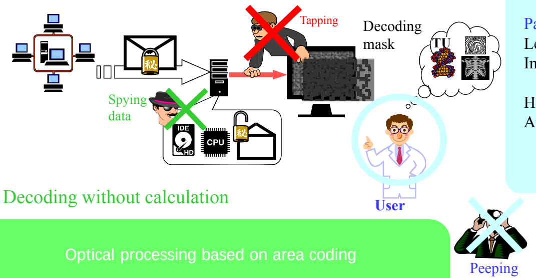


Visual cryptography for secure display

Visual cryptography

Visual secret sharing scheme was originally proposed by Naor & Shamir in 1994.

Control of viewing zone



3D display
- Parallax barrier
- Lenticular sheet
- Integral photography
- Holography
- And other 3D-ray-generating methods.

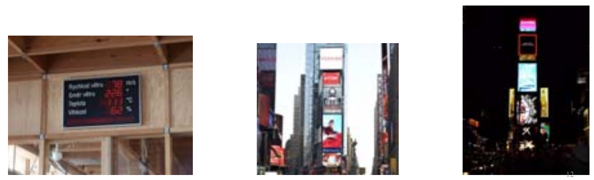
Decoding without calculation

Optical processing based on area coding

Optical logic array processor by J. Tanida & Y. Ichioka (1983)
Optical space-variant logic-gate array by T. Yatagai (1986)
Polarization encryption by S. Fukushima & T. Kurokawa (1991)

Motivation: to draw attention of crowd to the digital signage

1. Use of LED for digital signage is increasing.
2. Audience measurement for digital signage is being conducted.
   > How many people? > how long ? > how many times?
3. It is required to keep attention of many people to the signage as long time as possible.

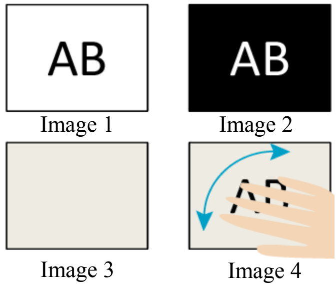


Waving-hand steganography

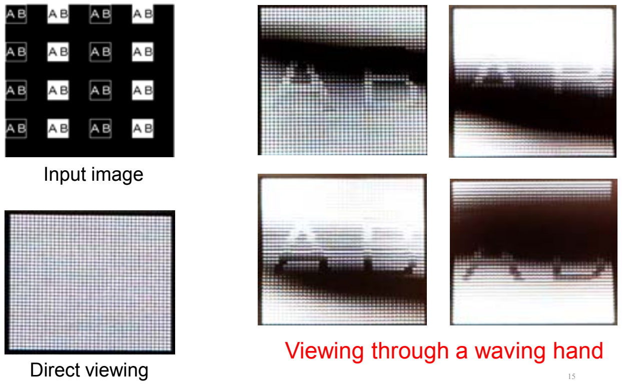
We aim to propose a new way of displaying information or messages so that watching digital signage will not only receive information but will become an **enjoyable** experience to viewers.

Principle of hand-waving steganography

1. A positive image (Image 1) and its negative image (Image 2) are switched rapidly.
2. Luminance addition (Image 3) is perceived when the screen is viewed directly.
3. Partially decoded information (Image 4) is perceived when the screen is viewed through a waving hand.



Results of hand-waving steganography

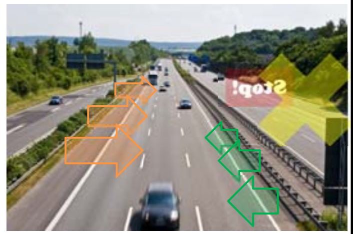


Aerial display

Aerial 3D display provides a new world for digital signage.

Advantages:

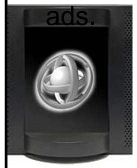
- High sense of reality
- No physical contact
- Precise position



Prior developments on floating/aerial display

Floating display enables direct touch inputs for 3D interaction and ads.

Volumetric 3D display of CT data for medical and real objects for ads.

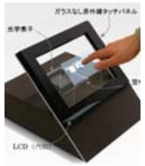


http://pioneer.jp/fv/fv_01/index.html

Pioneer

http://provision.tv/

Provision



http://www2.nict.go.jp/pub/whatsnew/press/h21/090415/090415-3.html

NICT

D. Miyazaki, etl.al, Applied Optics, vol. 52(1) A281 (2013).

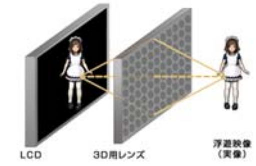
Osaka City Univ.

http://aerialimaging.tv/aip_2d_gazoueizou.html

Asuka Net

Optics to form floating/aerial display

Refraction based floating display

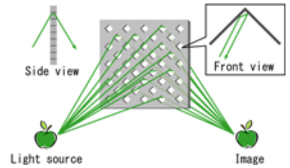


Pioneer

http://pioneer.jp/fv/fv_01/floatingvision.html#fv2

Imaging with lens/lens array

Reflection based floating display



NICT

- Dihedral corner reflectors [1].
- Slit mirror array

[1] S. Maekawa: Proc. SPIE 6392 (2006) 63920E.

Imaging with mirror array

Challenges for Aerial LED signage

In order to install LED signage for the general public,

- Directivity:
  wide viewing angle
- Readability:
  smooth lines
- Robustness:
  safety issues
- Scalability:
  large size

are required.

Image forming by use of dihedral corner reflectors

Incident ray to Mirror A at θ degrees and reflects at 2θ degrees.

Then, incident to Mirror B at 90 - θ degrees and reflects at 180 - 2θ degrees.

- Total change of direction:
  2θ + 180 - 2θ = 180°
- Every outgoing ray is directed to the reverse direction of the incident ray.

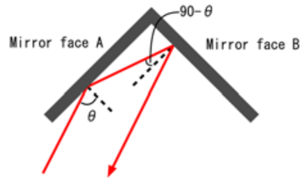
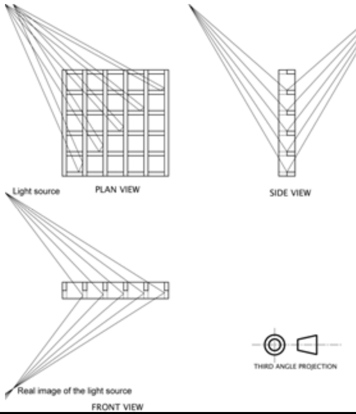
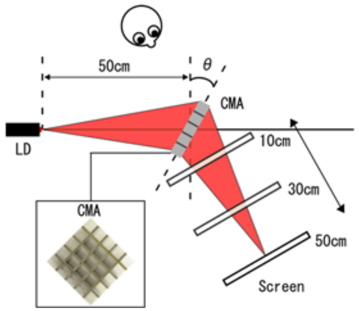


Image forming by use of dihedral corner reflectors



Experimental setups

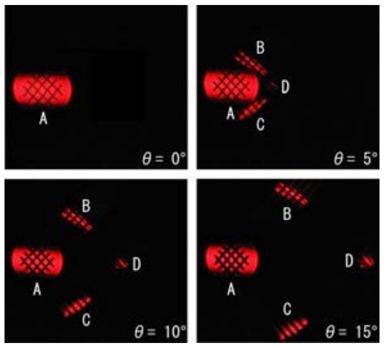
- Reflected light distributions were investigated by changing the incident angle
  (θ = 15°, 30°, 45°)
- Observation of differences in converged lights by thickness of CMA.
- The light source is located at 50 cm apart from the CMA



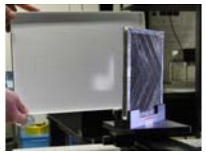
Observations under changing the incident angle

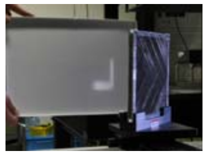
- Stainless steel mirror (Thickness 8mm)
- Screen distance 30cm

- A : transmitted light
- B, C : single reflected light
- D : double reflected light (converges)

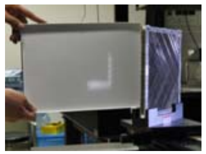


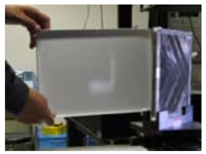
Observation of the imaging position by moving the screen


Close range


→


Focused distance

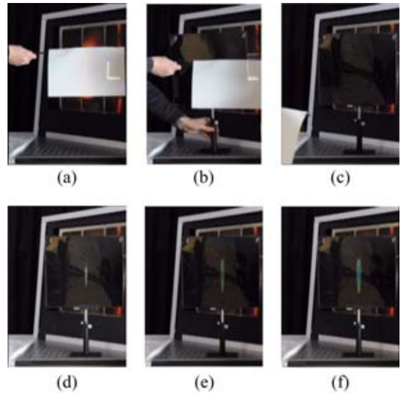

→


Long range

Warm Signage

- People can walk through the aerial signs.
- Walkers feel warmth of the signs with their skins.
- *3D Signs for blind people can be realized.*

Observation of thermal image with thermo-chromic screen



Purpose of AIRR (aerial imaging by retro-reflection)

To realize a new aerial 3D LED display that overcomes the three problems.

1. Stray lights  → No stray light
2. Alignment problems  → No precise tiling
3. Noticeable overlaying pattern  → No mesh

We utilize retroreflective sheeting for aerial display.

Application of retroreflective devices

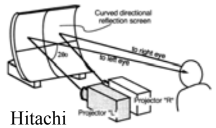
Traffic signs

http://www.kiwa-chemical.co.jp/film/reflection/capsule_prism/capsule_prism-index-j.html

Indicators

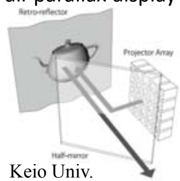
http://www.kiwa-chemical.co.jp/film/reflection/capsule_lens/capsule_lens-index-j.html

Stereoscopic display



Hitachi
Ohshima et al., SPIE **3012** (1997) 140.

Full-parallax display

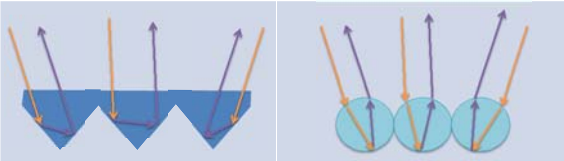


Keio Univ.
Yoshida et al., J. ITE **66** (2012) 1.

Optical camouflage

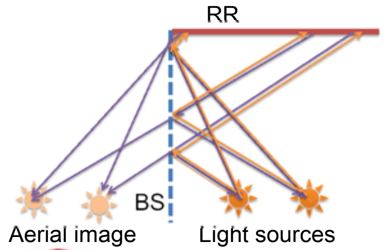
http://tachilab.org/

Composition of retroreflective sheeting



	Corner-cube type	Micro-beads type
Structure		
Advantages	Precise reflected angle High reflectance	Wide viewing angle Freedom in shape Flexible
Problems	Narrow viewing angle Only flat shape Thermal stability	Not precise reflected angle A little scattering

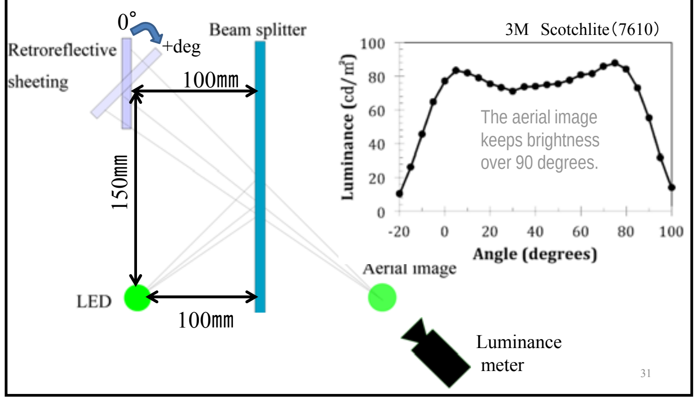
Separating light source and image



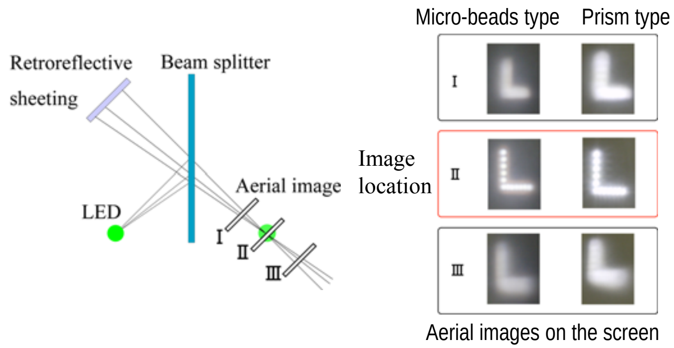
Aerial image is separated from the light source.

Retroreflective sheet is behind the half mirror.

Luminance change of an aerial LED image when a retro-reflector is rotated.

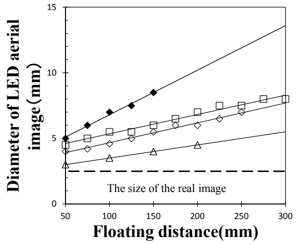


Observation of aerial LED sign on a screen.



Aerial image size linearly increases with floating distance.

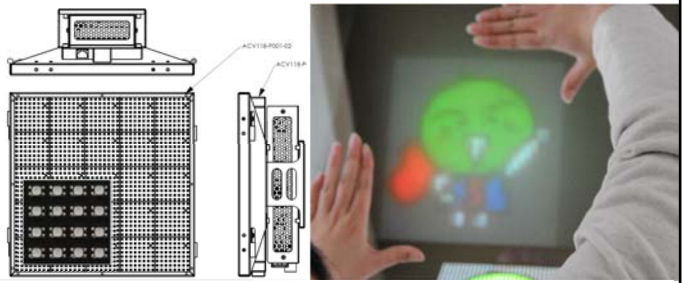
Experimental results on aerial-image size by AIRR (aerial imaging by retro-reflection) suggest that prism type forms a fine aerial image rather than micro-beads type.



◆	A	Enclosed type of micro-beads (black)
□	B	Exposed type of micro-beads (white)
◇	C	Enclosed type of micro-beads (white)
△	D	Prism type

Demonstration of aerial LED screen

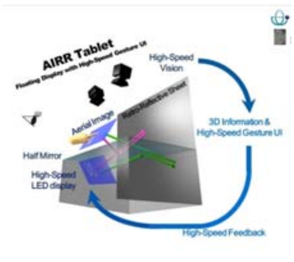
We have utilized a full-color LED panel for an aerial screen.



1. Color: 24-bit full color
2. Pixel pitch : 6mm
3. Luminance: 2000 cd/m^2

1. Number of pixels: 40 × 40 pixels
2. Floating distance: 50 cm
3. Visible under room lighting

AIRR Tablet: configuration



"AIRR Tablet" on YouTube http://youtu.be/iJd7fpH8n6M

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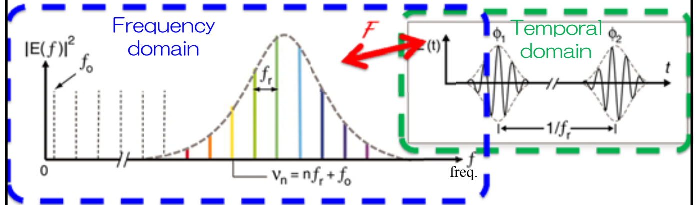
Applications of optical frequency comb for information photonics



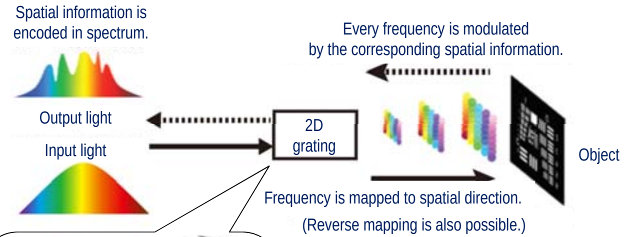
Frequency domain: ultimately precise ruler

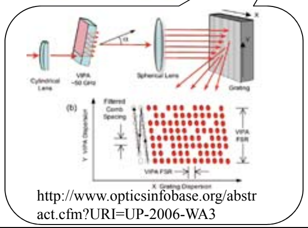
1. Sub-million coherent lasers with very narrow bandwidth
2. We propose IP applications by mapping frequency into space.

Temporal domain: ultra short pulses

1. Limited coherence length -> OCT, interferometry, DH by Dr. Dahi
2. Multi-photon absorption, ultimately high-speed imaging

Mapping of frequency into space

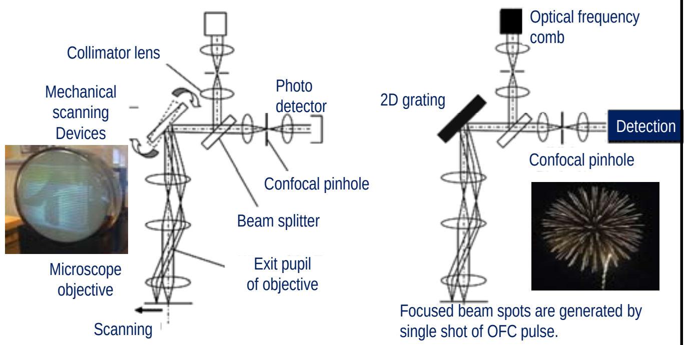




OFC enables digitizing space.

1. Descrete spectrum prevents crosstalk between pixels.
2. Frequency sweeping of OFC fills between pixels and enables superresolution.
3. Dual combs spectroscopy detects information of each pixel separately.

Application of optical frequency comb for one-shot full-field confocal



Mr. Hase and Mr. Miyamoto succeeded in getting images.

Application of OFC to digital holography
Scanless "optical scanning holography"

Optical scanning holography enables us to obtain hologram by use of a single pixel detector.

Dual combs spectroscopy detects all frequency components.

OFC enables one-shot 3D image detection at a very high frame rate.

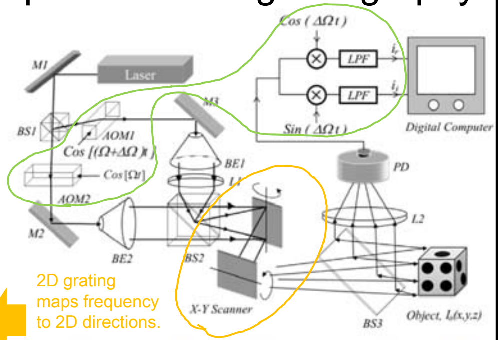
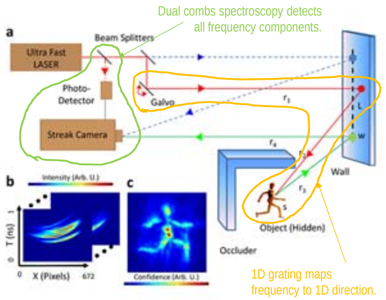


Fig. 1. Optical Scanning Holography (M's, mirrors; AOM1,2, acousto-optic modulators; BS1,2,3 beam splitters; BE1,2, beam expanders; L, focusing lens; x, electronic multiplexer; LPF, low pass filter).

Y. S. Kim, et al., Opt. Exp., Vol. 21, 8183 (2013).

Application of OFC to compressive sensing
One-shot imaging from scattered lights



Pre-calibrations: knowledge of scattered pattern for each modes by ghost imaging etc. (This may be a practically time-consuming problem.)

Imaging through a multi-mode optical fiber is also possible without lens nor imager.

Mapping of frequency to direction and dual-combs spectroscopy perform the above technique by one-shot of OFC.