反射型結像素子による空中スクリーンと空中ヒーターの形成

山本裕紹[1,2,3,4,5,6]

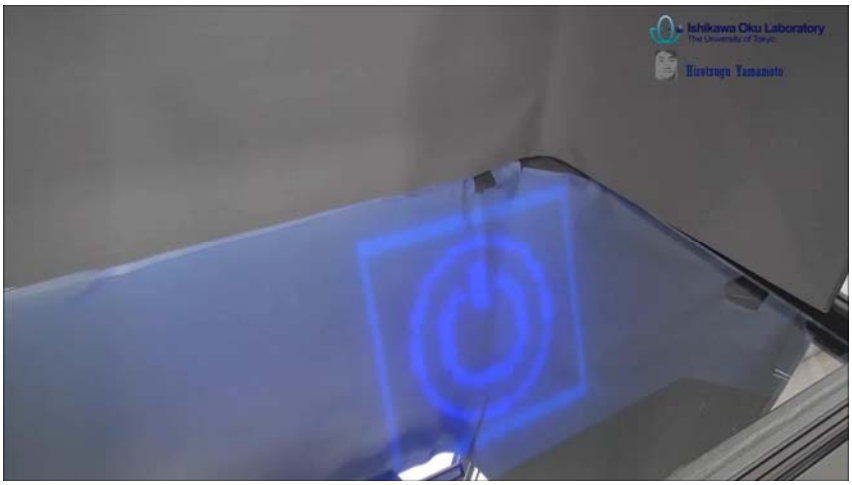
[1]宇都宮大学大学院工学研究科先端光工学専攻
[2]宇都宮大学オプティクス教育研究センター
[3]宇都宮大学工学部情報工学科
[4]徳島大学ソシオテクノサイエンス研究部
[5]JST ACCEL「高速画像処理を用いた知能システムの応用展開」
[6]JST ERATO美濃島知的光シンセサイザプロジェクト

Outline

1. はじめに
   1. 自己紹介
   2. 奥行き知覚の原理
2. 直交ミラーアレイを用いた空中結像
   1. LEDサイネージ向けの設計
   2. 光と熱の収束
3. 再帰反射による空中結像
   1. 原理と特長
   2. プロトタイプ

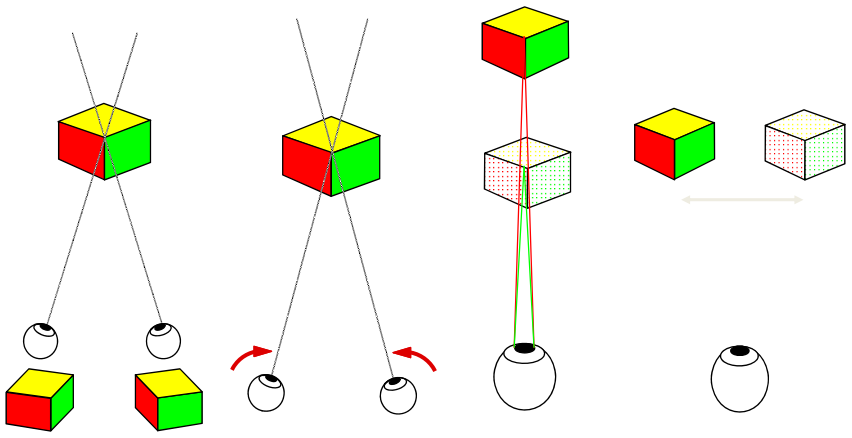
2

AIRR Tablet



Our movie on YouTube　　http://youtu.be/iJd7fpH8n6M　3

立体視の生理的要因

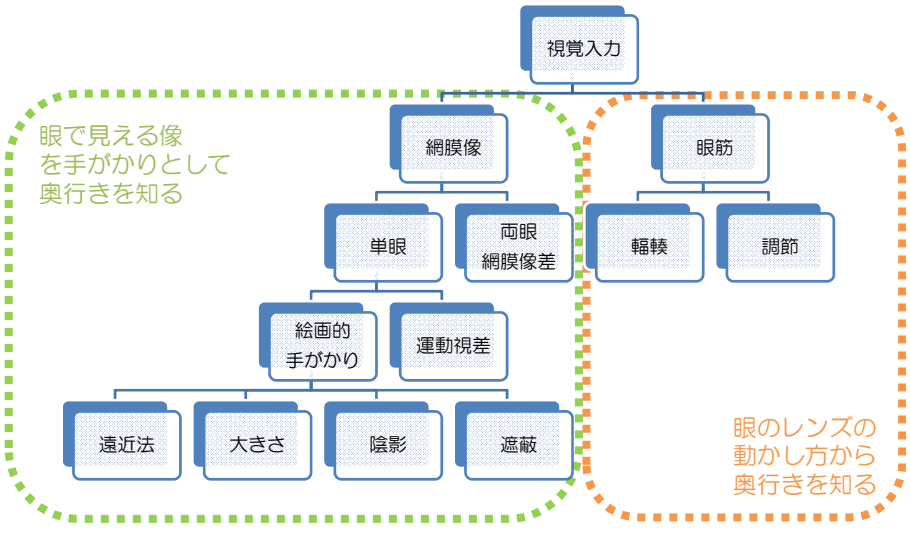


【両眼視差】（左右像の違い）　【輻輳】（眼球の回転）　【ピント調節】（眼のレンズ変化）【運動視差】（運動による像の違い）

4

立体視の心理的要因
（絵画的な奥行手がかり）

奥行き知覚



LEDサインの空中表示

- 光学的特徴：
  - 高い現実感
  - 自由な視点位置
  - 物理的な接触が無い
- 利用分野：
  - 交通標識
  - 非常用表示
  - メッセージ看板
- 求められる点：
  - 広い視野角
  - 文字の可読性
  - 大型化可能な構造

7

空中浮遊映像の表示技術

空中映像は３D像との
インタラクションを可能に.

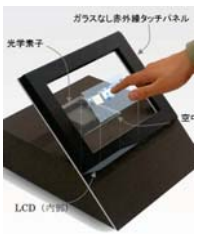
体積型３D表示はCTデータ
や分子構造の可視化に有効.

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

Pioneer

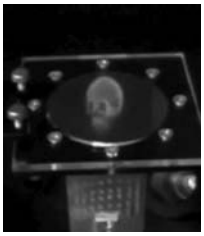
http://provision.tv/

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.

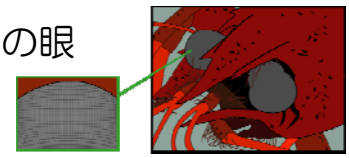
http://aerialimaging.tv/aip_2d_gazoueizou.html

Asuka Net

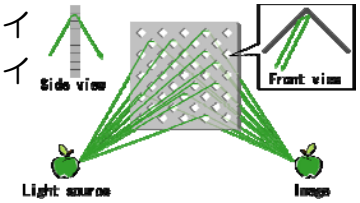
8

反射型結像光学素子の利用

- 自然界のザリガニの眼



- X線用結像素子：Lobster's eye optics[1]
- 2面コーナーリフレクタアレイのディスプレイ応用[2]
  - 微細な開口の高精細なミラーアレイ
  - フローティングタッチディスプレイ



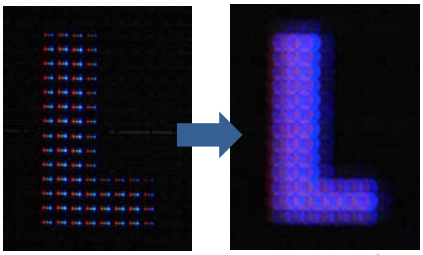
[1] René Hudec： X-Ray Optics and Instrumentation, vol. 2010, 139148 (2010).
[2] S. Maekawa, K. Nitta, and O. Matoba： Proc. SPIE 6392 (2006).

9

LEDサイネージの問題点

- LEDランプ間には，発光しない黒領域が存在する．
- 滑らかな画像のために，大量のLEDランプが必要．

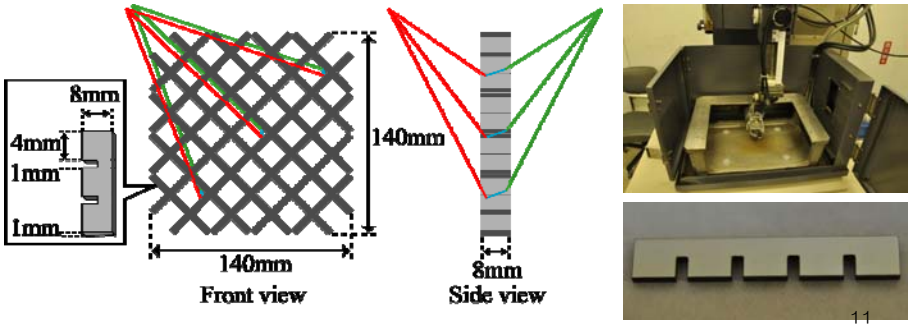
Blurred imaging
- 可読性の向上：
  - 黒領域の塗りつぶし
  - 粒度感の減少
  - 色の混合
- ランプ数の削減



10

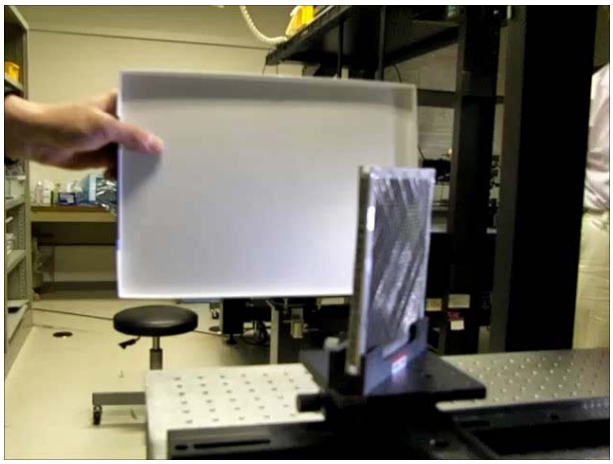
LEDパネル用の反射型結像光学素子を製作

- CMA (Crossed-Mirror Array) を設計.
- 交差ミラー構造による中空開口
  - 広い視野. サーマル3D表示可能.
- 4 mm ×4 mm の開口による Blurred imaging.



11

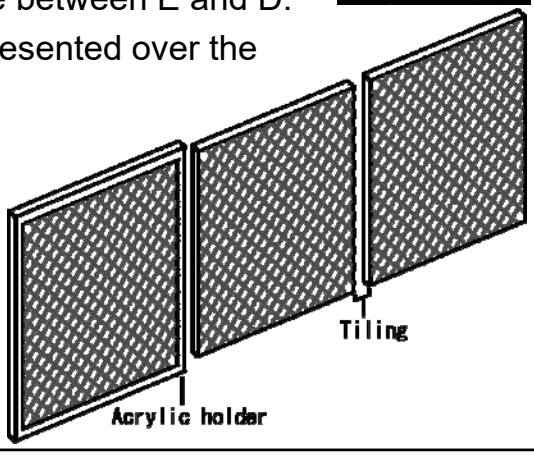
LEDパネルによる空中像の結像位置観察



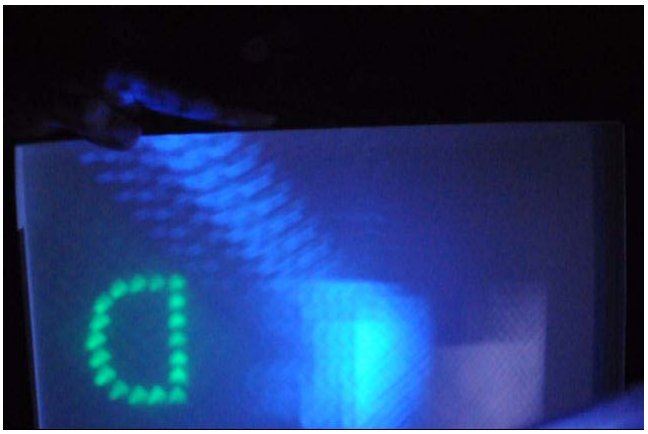
12

Tiling of CMAs

1. A transparent frame was used to indicate the boundary between L and E.
2. There was no frame between E and D.
3. LED signs was represented over the boundaries.



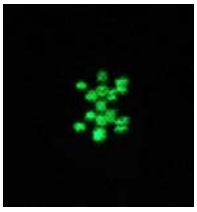
Focusing of light to the different floating position of “LED” by use of tiled CMAs



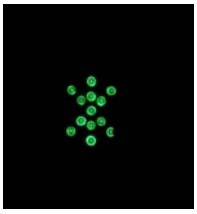
空中LED像とLED像の調節応答

- CMAを用いた空中LED像とLED像の調節応答を像が同じ距離の時と違う距離の時の測定を行った.
- 空中LED像とLEDを10秒ずつ交互に2回表示し測定を行った.

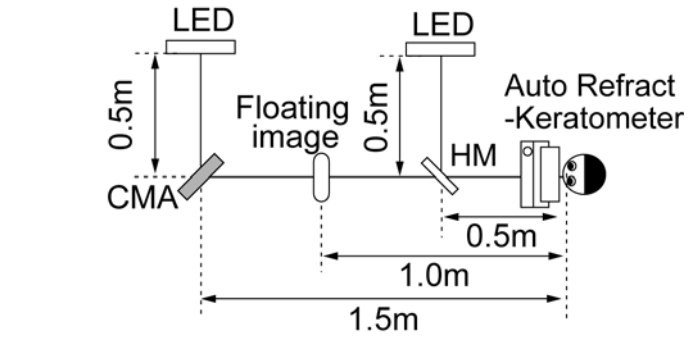
CMAによる空中LED像

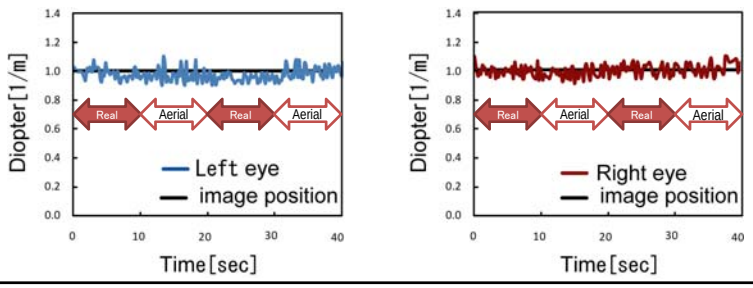


LED像

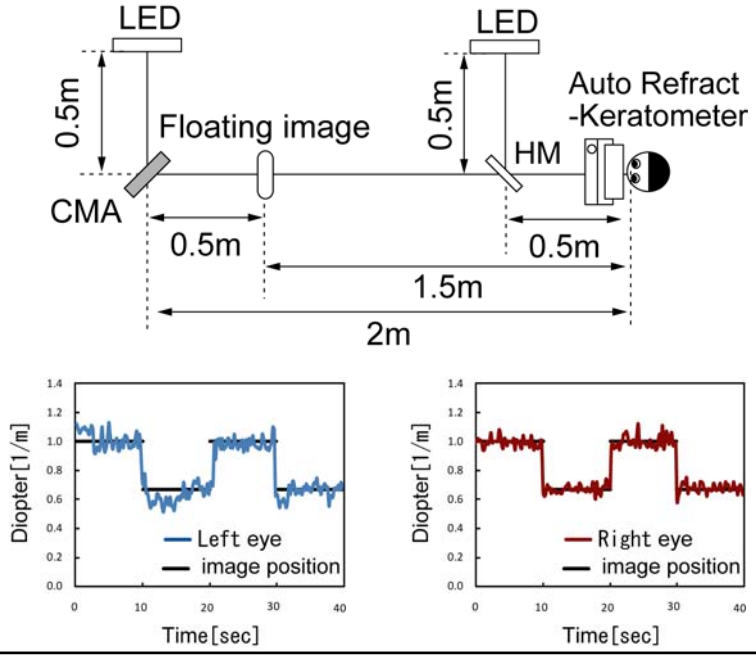


空中LED像とLED像が等距離 1.0m にあるとき

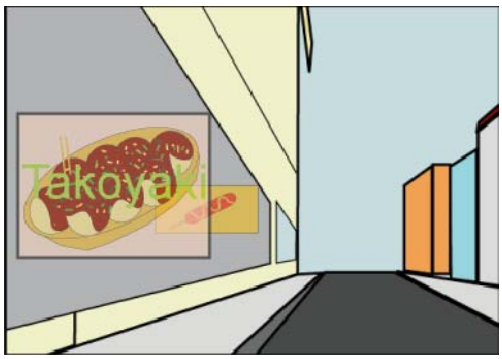




被験者から空中LED像1.5m, 実LED1m



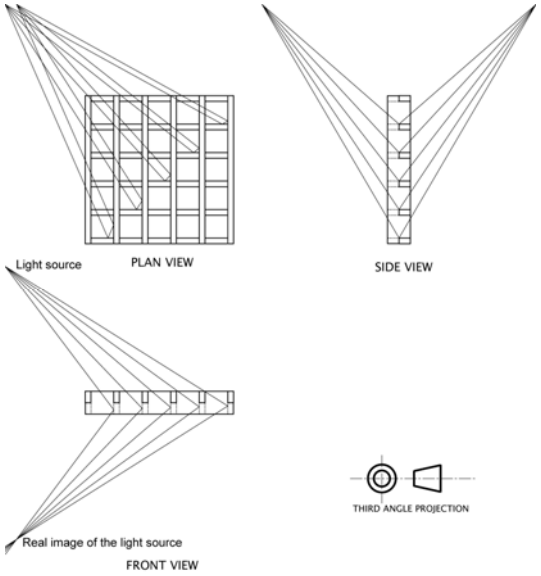
光と熱の空中フローティング表示のねらい



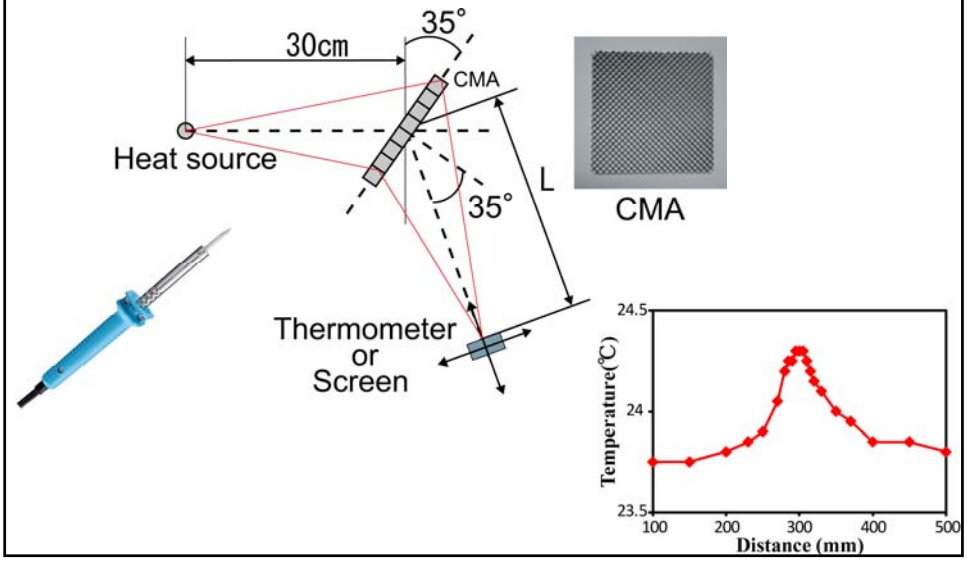
- 空中像なので，目の前に提示可能
- 温かさで注意を引く
- 視覚障害者へのサインにも使えないか？

18

CMA can focus far infrared radiations.



Experimental setups for thermal display



「ミラーアレイがオクルージョン矛盾を発生させている。」（IDW'12にて展示をご覧になった阿山みよし先生の感想）

CMA unit

Viewed image

•CMA is made of stainless mirrors.
•Mirror thickness: 1mm
•Mirror height: 8 mm
•Aperture size: 4 mm × 4 mm

LED signs are overlaid with crossed mesh

21

Aerial Imaging by Retro-Reflection (AIRR)

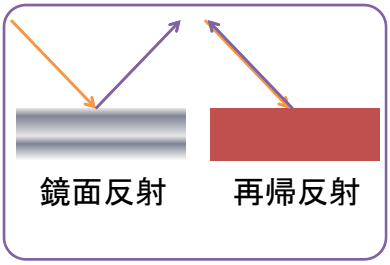
To realize a new aerial 3D LED display that overcomes the three problems.

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.

22

キーデバイス「再帰反射シート」



救命胴衣

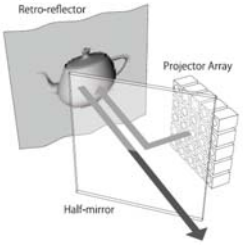


http://www.kiwa-chemical.co.jp/film/reflection/capsule_lens/capsule_lens-index-j.html

道路標識

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

立体表示

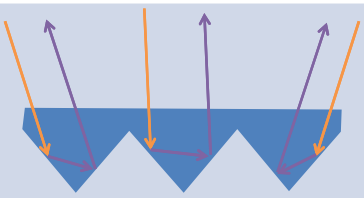
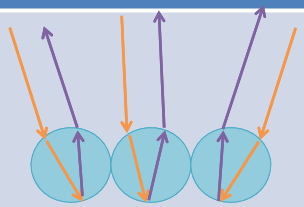


Yoshida et al., J. ITE 66 (2012) 1.

光学迷彩

http://tachilab.org/

Feature (B) Blurred imaging with a retro-reflective material

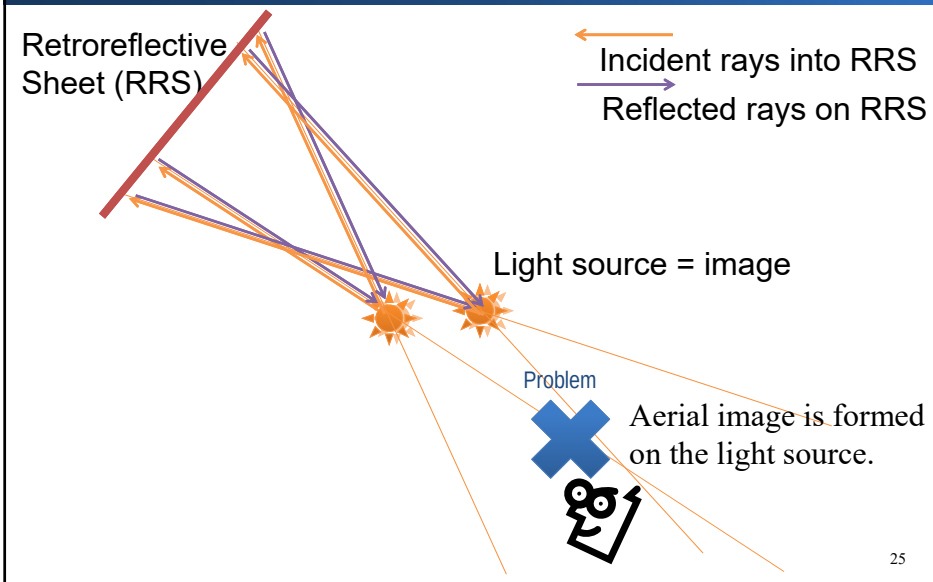
Retro-reflective material	Corner-cube type	Micro-beads type
Structure		
Advantages	Precise reflected angle High reflectance	Wide viewing angle Freedom in shape Flexible
Problems	Narrow viewing angle Only flat shape Thermal stability	Not precise reflected angle A little scattering

24

Good for blurred imaging

Trivial case

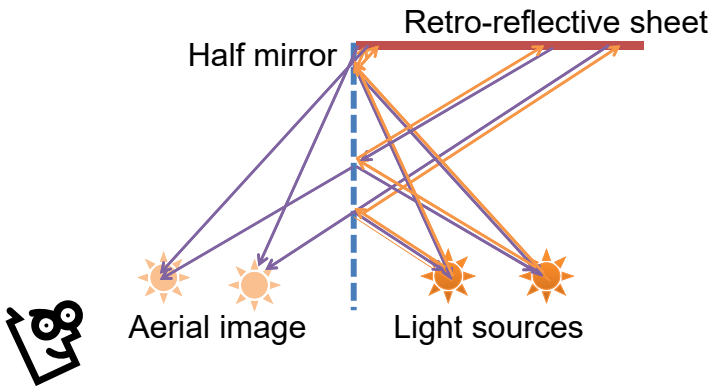
Light source and retroreflective sheet



25

This work

(A) Forming an aerial image



Aerial image is separated from the light source
at the plane-symmetrical position of the light sources
regarding to the half mirror.

26

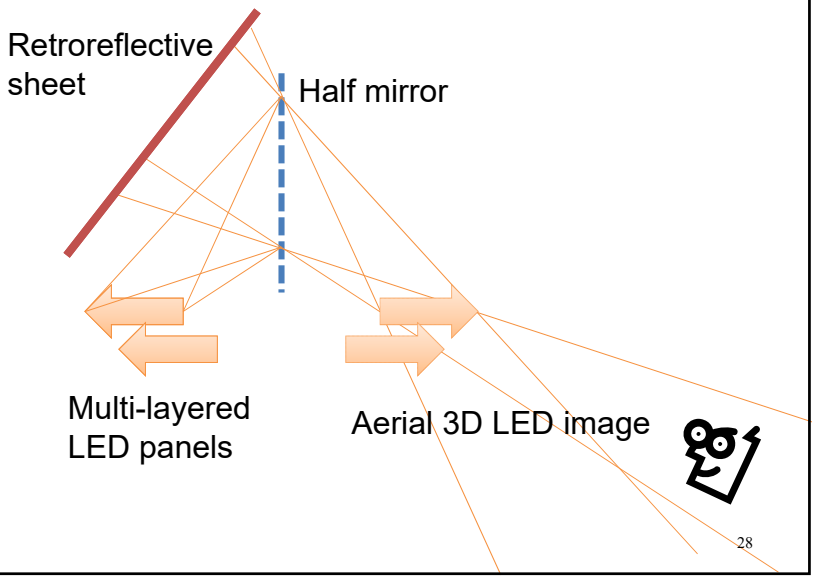
Result

(B) Smoothing LED gaps

27

Feature

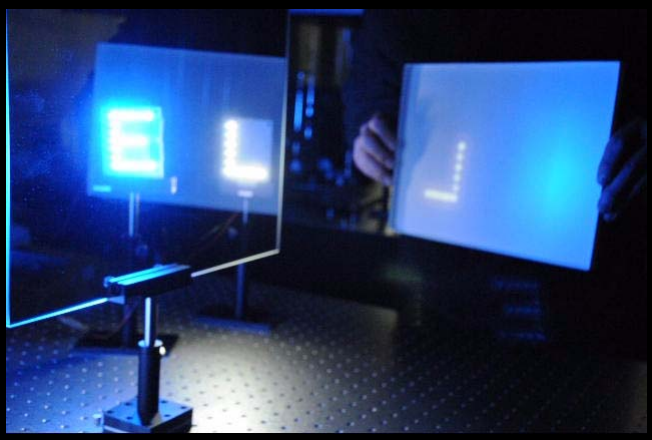
(C) Aerial 3D LED display



28

Result

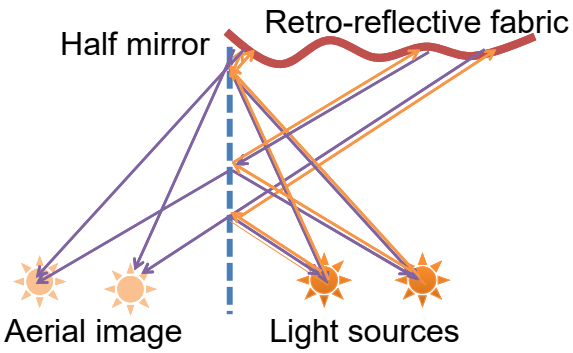
(C2) Forming multi-layered LED signs



29

Feature

(D) Alignment tolerance

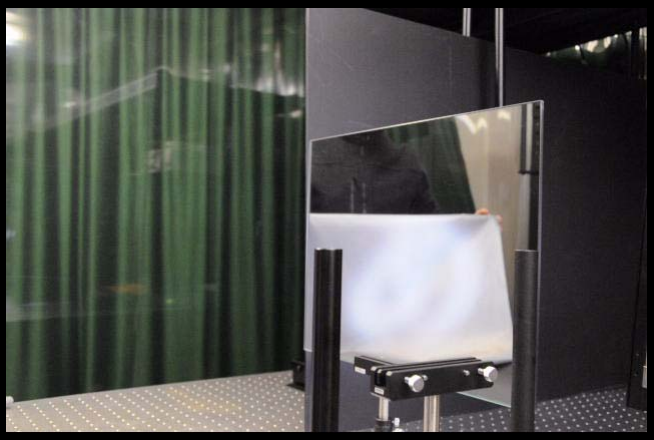


Aerial image is independent from waves of retro-reflective fabric.
No precise alignment is needed to form aerial image.

30

Result

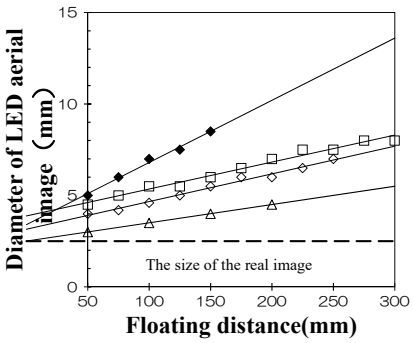
(D2) Alignment tolerance
— Putting a retro-reflective fabric —



31

Comparison of Prism type with beads types

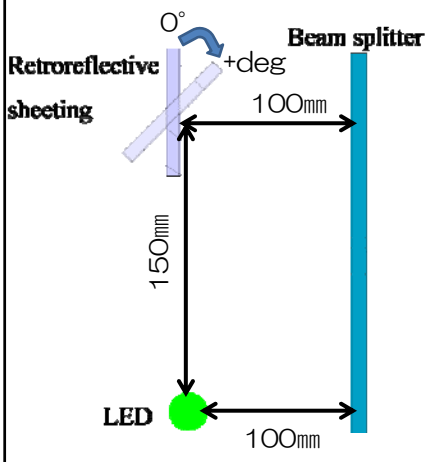
Experimental results on aerial-image size by AIRR (aerial imaging by retro-reflection) suggest that prism type forms a fine aerial image rather than micro-beads type.

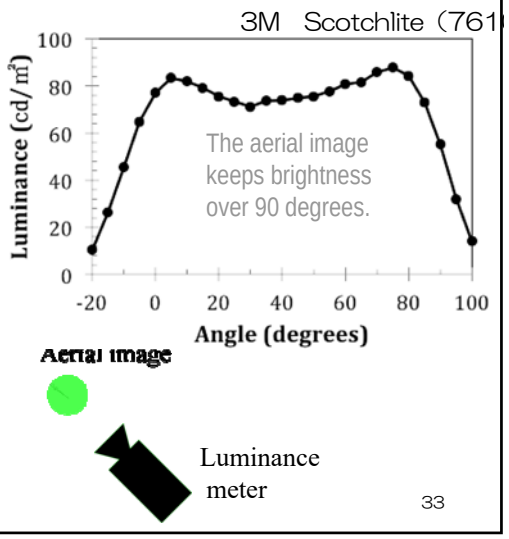


◆	A	Enclosed type of micro-beads (black)
□	B	Exposed type of micro-beads (white)
◇	C	Enclosed type of micro-beads (white)
△	D	Prism type

(Reference) Y. Tomiyama, H. Yamamoto, and S. Suyama, "LED Aerial-Image Size Dependence on Floating Distance by Retro-Reflection," IMID 2014, 6-1 (2014).

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

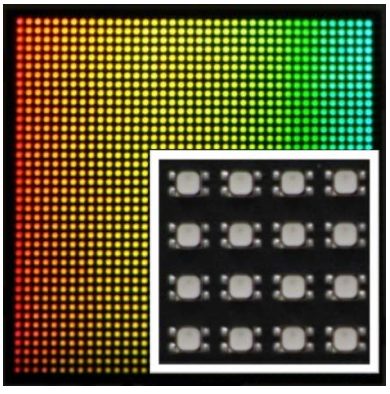


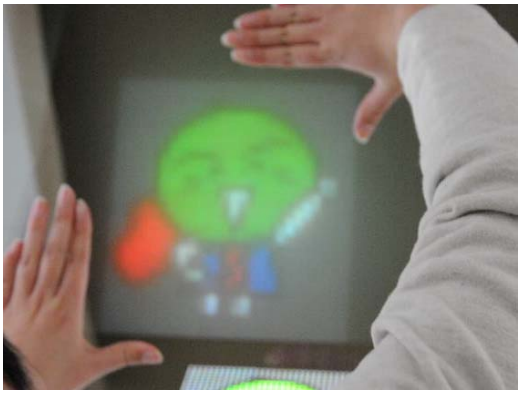


33

Tabletop AIRR 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/m²

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

3434

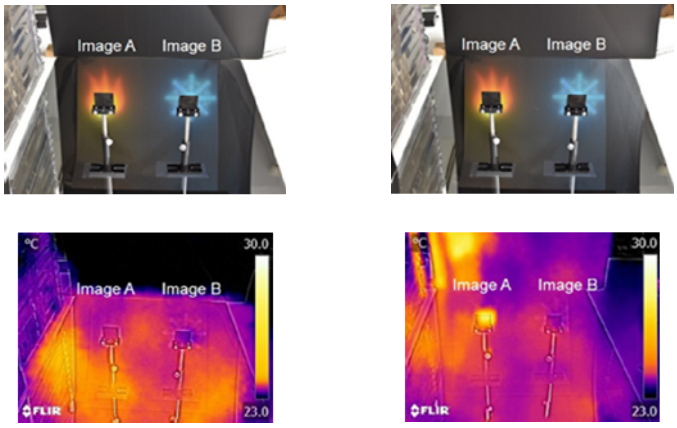
Summary of proposed technique

Aerial imaging method	CMA	AIRR
Scalability	**Fair** CMAs need to be precisely aligned.	**Excellent** AIRR is free from alignment problems.
Cost	**Problem** Fabrication of special optics costs high.	**Effective** Large optics is commercially available at reasonable cost.
Multimodal display	**Excellent** Visual, thermal, and another multimodal display are investigated.	**Challenging**
Stray lights	**Problem** Transmitted and single reflected lights spoil viewing.	**No problem** There is no stray light.
Image blur at long floating distance	**Controllable** Point-spread function (PSF) depends on the aperture shape.	**Problem** PSF increases linearly with floating distance in case of using conventional retro-reflector.
Viewing angle	**Limited** Full-width half-maximum (FWHM) is about 40 degrees.	**Wide** FWHM is more than 90 degrees.

35

Visual and Thermal Display

Power off　　Power on



When the heater was powered on,
the temperature at image A increased.

T. Okamoto, et al., Proc. IDW/AD16, 3D6_3DSA7-4(2016).

36

背景から浮き出す空中表示

https://www.youtube.com/watch?v=TPH35eVDbFY

37

Human-size aerial display (movies)

むすび

1. 奥行き知覚の原理を解説し，実像の形成による3D表示は奥行き知覚の生理的手がかりを満たすことを述べた.
2. 直交ミラーアレイを用いたLEDパネルの映像を空中表示ならびに空中の熱結像について紹介した.
3. 再帰反射シートを用いた空中結像法（AIRR）による空中LEDサインについて紹介した.

空中表示のディスプレイ（ハードウェア）としての普及は将来の姿として，近未来には，誰でも自由空間における情報インタフェース「エアウェア」による産業振興と学術発展を期待している.

39

参考資料

1. H. Yamamoto, M. Kouno, S. Muguruma, Y. Hayasaki, Y. Nagai, Y. Shimizu, and N. Nishida, “Enlargement of viewing area of stereoscopic full-color LED display by use of a parallax barrier,” Appl. Opt., Vol. 41, pp. 6907-6919, 2002.
2. H. Yamamoto, H. Nishimura, T. Abe, and Y. Hayasaki, “Large stereoscopic LED display by use of parallax barrier of aperture grille type (Invited Paper),” Chinese Optics Letters, Vol. 12, 060006, 2014.
3. H. Yamamoto, H. Bando, R. Kujime, and S. Suyama, “Design of crossed-mirror array to form floating 3D LED signs,” Proc. SPIE, Vol. 8288, 828820, 2012.
4. R. Kujime, S. Suyama, and H. Yamamoto, “Thermal and visual 3D display by use of crossed-mirror array,” Proc. IDW/AD'12 (The 19th International Display Workshops in conjunction with Asia Display 2012), pages 1243-1246, 2012.
5. R. Kujime, K. Miyamoto, S. Suyama, and H. Yamamoto, “Crossed-Mirror Array (CMA) converges sound wave in 3D space,” Proc. IDW, vol. 21, pp. 906-909, 2014.
6. H. Yamamoto and S. Suyama, “Aerial 3D LED display by use of retroreflective sheeting,” Proc. SPIE, Vol. 8648, 86480Q, 2013.
7. H. Yamamoto, Y. Tomiyama, and S. Suyama, “Floating aerial LED signage based on aerial imaging by retro-reflection (AIRR),” Optics Express, Vol. 22, pp. 26919-26924, 2014.
8. http://youtu.be/chxJgC1lzt4 Aerial color display between hands formed by AIRR.
9. http://youtu.be/9qOtrVXVieA Quick and easy setup for AIRR.
10. http://youtu.be/iJd7fpH8n6M AIRR Tablet: Floating Display with High-Speed Gesture UI.

40