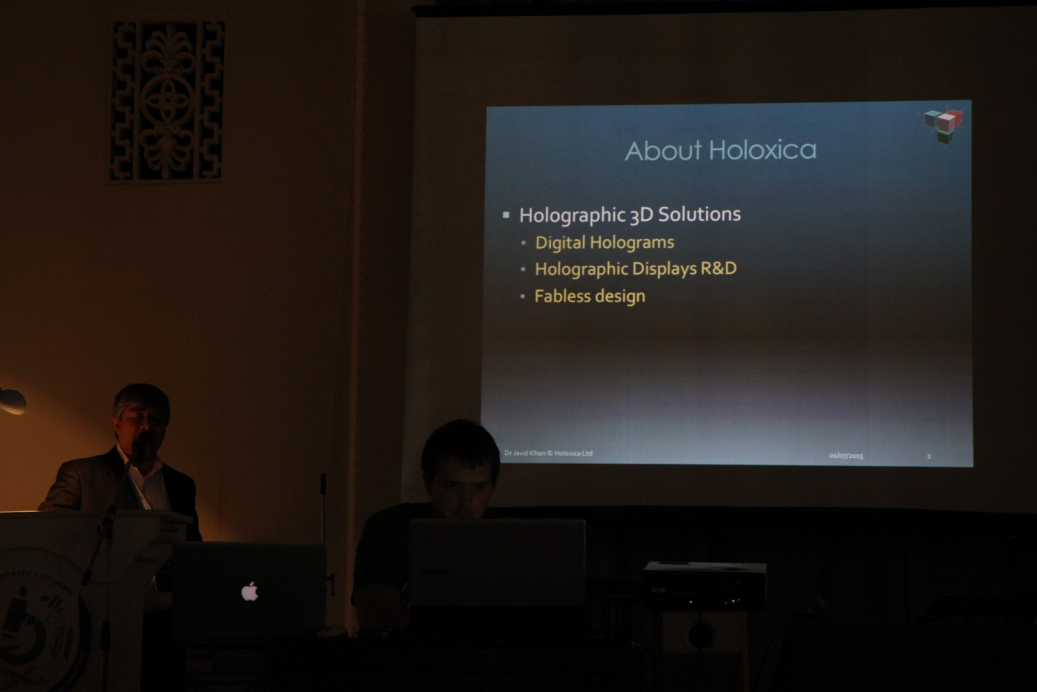

REVIEW OF DESIGN & IMPLEMENTATION OF ELECTRO-HOLOGRAPHIC DISPLAYS
Javid Khan
Holoxica® Ltd
Scottish Microelectronics Centre
Edinburgh
July 1, 2015
United Nations Educational, Scientific and Cultural Organization
International Year of Light 2015


About Holoxica
Holographic 3D Solutions
Digital Holograms
Holographic Displays R&D
Fabless design
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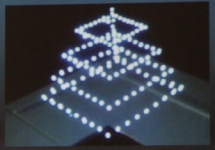
# About Holoxica

- Holographic 3D Solutions
  - Digital Holograms
  - Holographic Displays R&D
  - Fabless design
- Markets
  - Medical Imaging
  - Scientific Visualisation
  - Engineering/Industrial

HOLOXICA

# 3D Technologies

- Classification
  - Stereoscopic
  - Volumetric
  - Integral imaging
  - Holography
  - "Others"
- Commercial focus
  - Viable technologies [1-2]



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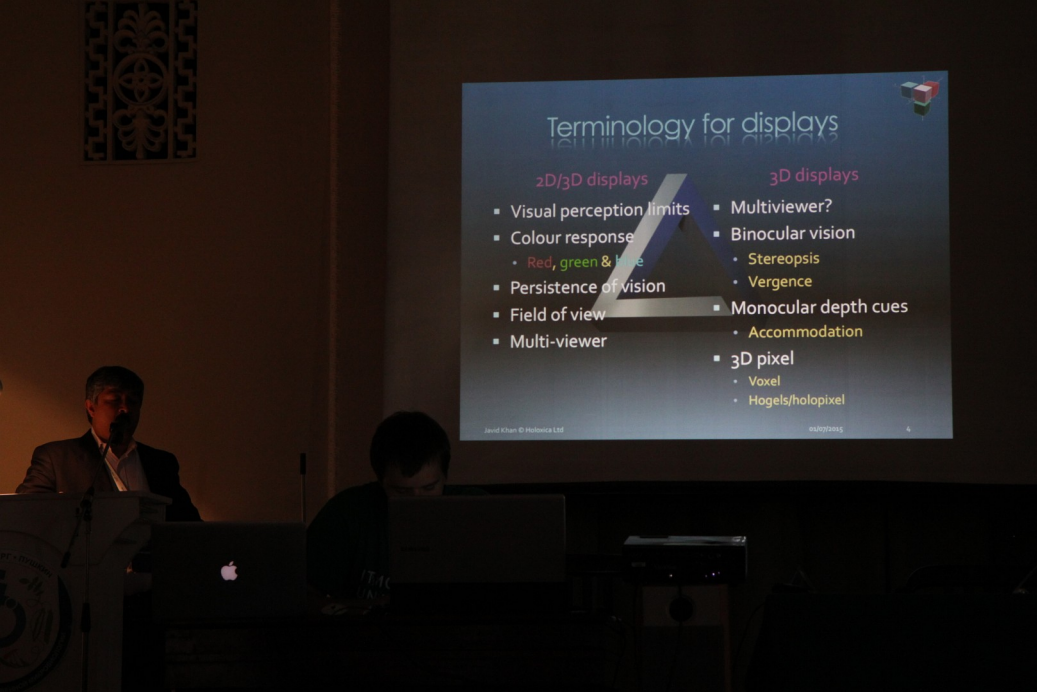
Terminology for displays
2D/3D displays
Visual perception limits
Colour response
Red, green & blue
Persistence of vision
Field of view
Multi-viewer
3D displays
Multiviewer?
Binocular vision
Stereopsis
Vergence
Monocular depth cues
Accommodation
3D pixel
Voxel
Hogels/holopixel
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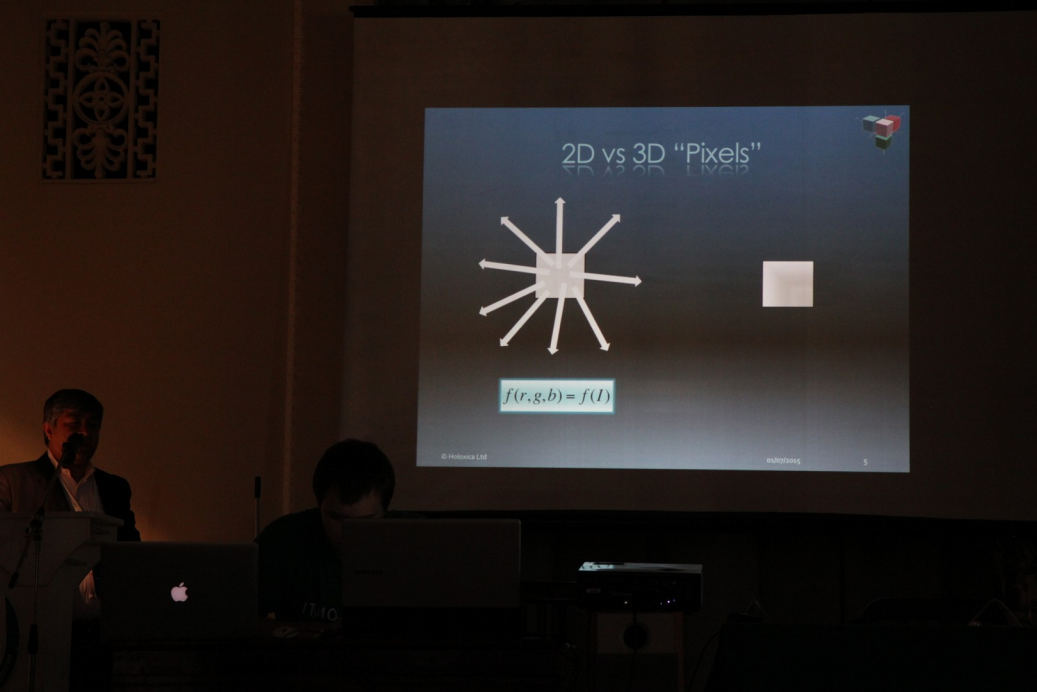
2D vs 3D "Pixels"
$f(r,g,b) = f(I)$
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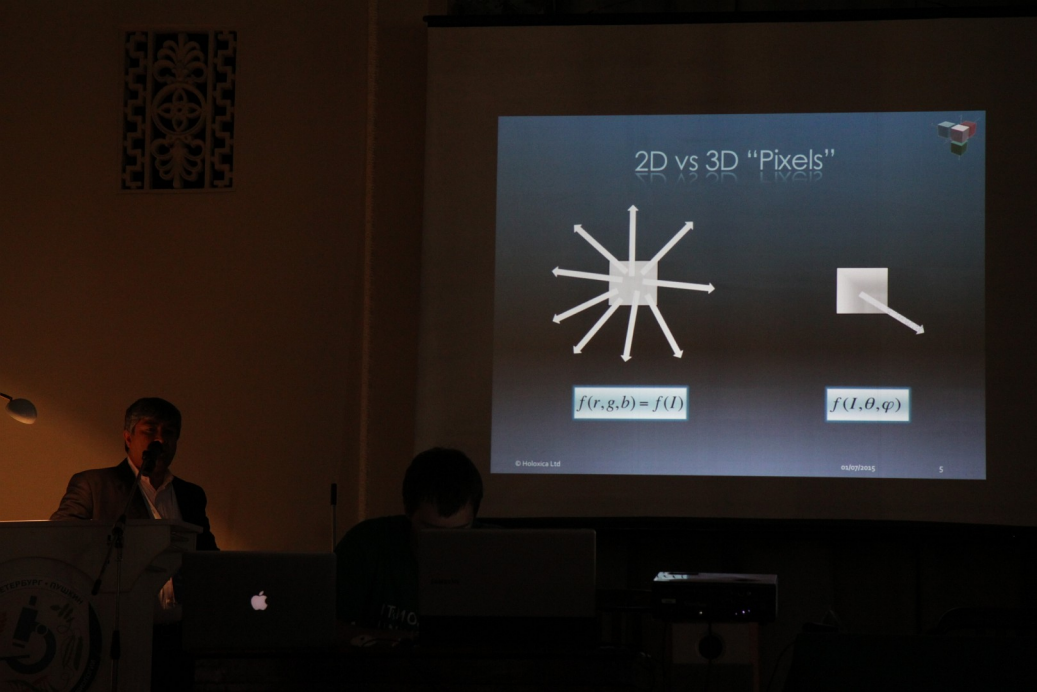
2D vs 3D "Pixels"
$f(r,g,b) = f(l)$
$f(l,\theta,\varphi)$
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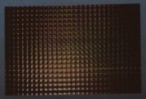
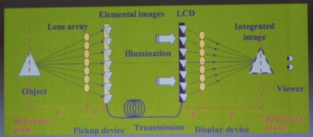
# Integral Imaging

- Proposed by G. Lippmann
- 3D Light Field Synthesis
  - Elemental images
  - Lenslet array: fly's eye
  - Integrate series of 2D images

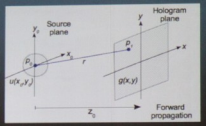





E. Stoykova et al [3]

# Fourier Optics

- Pre-requisites
  - Signal processing
  - Image processing
  - Optics
- Propagation Models
  - Scalar theory
  - Kirchoff diffraction integral



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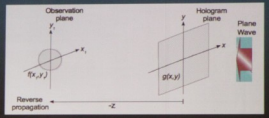


$$g(x,y;z_0) = \frac{1}{j\lambda}\iint_{\rho} u(x_0,y_0;0)\frac{z\exp(jkr)}{r^2}dx_0dy_0$$

$$r = \sqrt{(x-x_0)^2+(y-y_0)^2+z_0^2}$$

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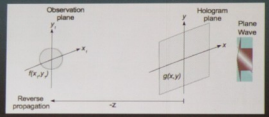



*Fresnel approximation:*

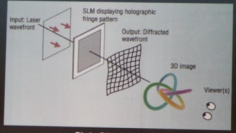
$$r \approx z + \frac{(x-x_0)^2 + (y-y_0)^2}{2z}$$

$$h = \frac{1}{j\lambda z}\exp(-jkz)\exp\left(-\frac{jk(x^2+y^2)}{2z}\right)$$

$$H = \exp(jkz)\exp\left(j\pi\lambda z(f_x^2 + f_y^2)\right)$$

# Holographic display design

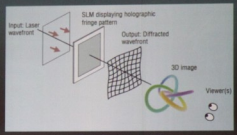
- Display fabrication
  - 1 µm pitch, 5x5cm
  - Diffraction angle: 60 deg
  - 50x50mm = 2.5 Gpixels




Chris Slinger et al [4]

# Holographic display design

- Display fabrication
  - 1 µm pitch, 5x5cm
  - Diffraction angle: 60 deg
  - 50x50mm = 2.5 Gpixels
- Bandwidth
  - 3bits/pixel=937.5 Mbytes
  - 25fps*3(RGB)~70.3GB/s
- CGH computation
  - 1 mm³ volume
    - 100 µm spacing
    - 1k points/cu mm
    - 10 ops per point
  - 1k*10*2.5G*25*3
    =1.875 Pops/sec




Chris Slinger et al [4]

# Practical Considerations

| Parameter | 4K Display | Design |
|---|---|---|
| Diagonal | 9.6" | 2.8" |
| Resolution px | 24.7M RGB | 2.5G |
| Pixel density ppi | 1.3k (H) | 25.4k (H/V) |
| Pixel size | 18.5µm | 1µm |
| Bandwidth GB/s | 2.25 | 70.3 |
| Computation Pops | - | 1.875 |

- Very challenging
  - Simplifications
  - Optimisations
  - Single parallax
  - Compression
  - Other models

# Academic Displays

- MIT Media Labs
  - AOM
  - Mark1-4
- Rewriteable materials
  - University of Arizona [6]
    - Electrically-erasable
  - Shanghai Jiao Tong Univ. [7]
    - Optically-erasable

# Military Displays

- Qinteq display [4]
  - OA-SLMs
  - Tiled Array
- Zebra Imaging [8]
  - 21" diag
  - Brightness: 200 cd/m²
  - Contrast 70:1
  - Viewing angle: 90 deg
  - 4000 colours
  - ~3Hz refresh rate

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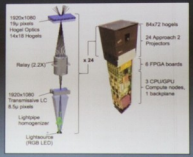
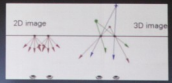


# Semi-holographic

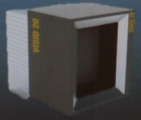
- Holografika, Hungary
  - Light field
    - Multi-projection technology
    - 'Holographic screen'
  - Commercially available
- Ostendo
  - Fine pixels
  - Integral imaging

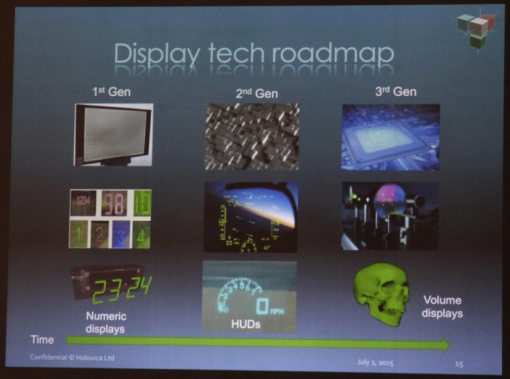
© Holografika, HU

# Constrained Displays

- SeeReal
  - Constrain viewer
  - Simplified SLM
  - Eye tracking
- Leia Inc [9]
  - Directional gratings
  - Edge-lit
- Realview Imaging?
- Holoxica




Display tech roadmap
1st Gen
2nd Gen
3rd Gen
Numeric displays
HUDs
Volume displays
Time
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# 1st Gen Display

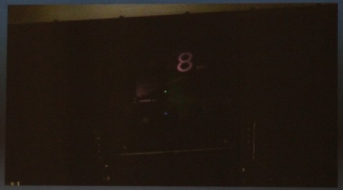
- Holoscreen
  - Multiplexed & interleaved
  - Fixed nr frames
- Proof of concept, 2010
- Real space images
- Easy illumination
- Patented
- Cons
  - Limited resolution
  - Scalability

# 2nd Gen Display

- HOE Display, 2013
- Focal lengths
  - DCG: 22cm @532nm
- Viewing angle
  - 30 deg, before distortion
- Diffraction efficiency
  - 65%
- Image size ~7x7cm
- Distortion
  - Non-paraxial imaging
  - Barrel distortion


# Apps

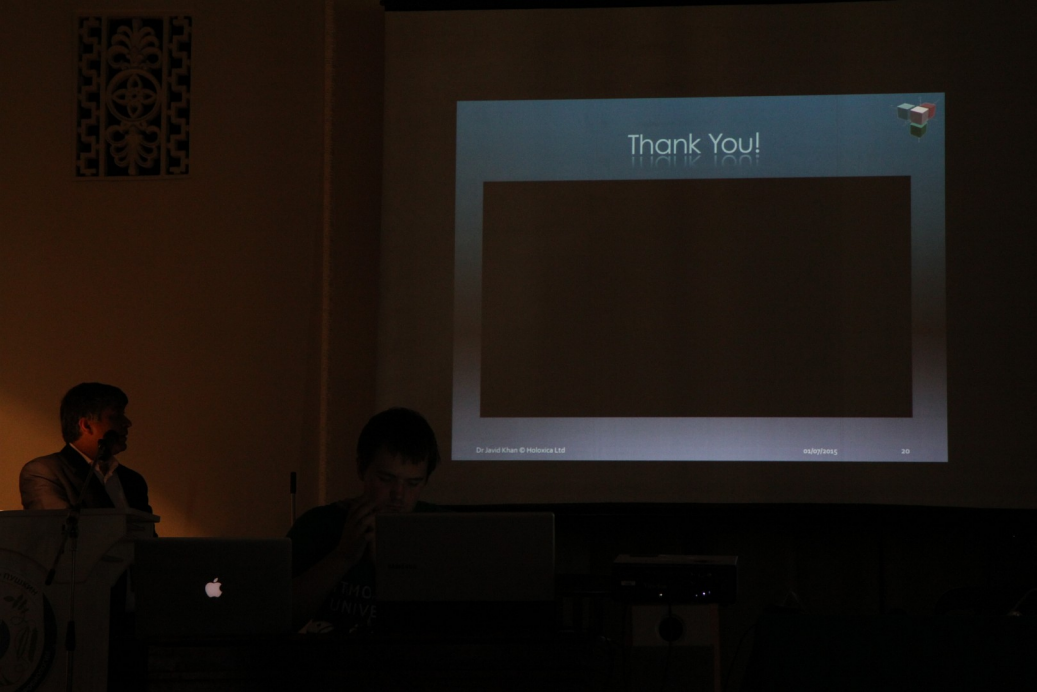
- HUD main
- Counter
- AirDraw
- Keypad
- Meter
- Ball



# Next steps: volume display

- 3rd Generation display
- Real space
- Volume slices
  - CT/MRI scanners
- Advanced components
  - Lasers
  - Optical elements

Artist's impression


Thank You!
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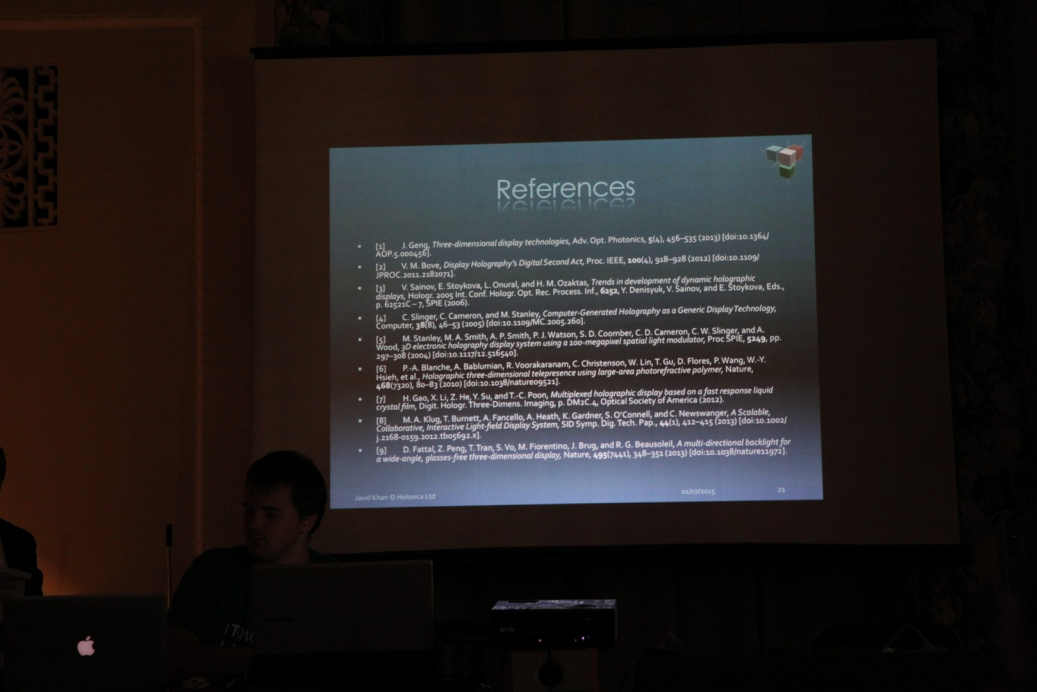
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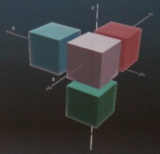

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