Holographic display system for photovoltaic retinal prosthesis

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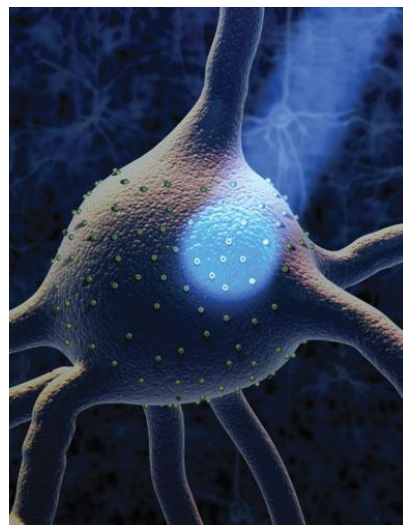
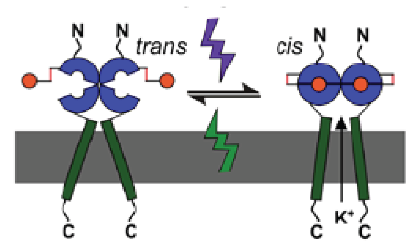
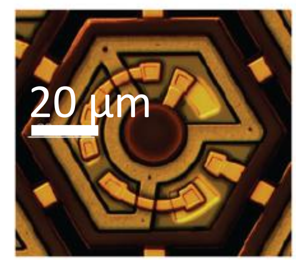
Commercial Disclosure: No Commercial relationships

Context

- Many fully optical approaches to sight restoration are being explored as alternatives to wired implants
  - Optogenetics:
    1 mW/mm^2 at $\lambda \approx 473$nm
  - Photoswitches:
    14µW/mm^2 at $\lambda \approx 380$nm
  - Photovoltaic retinal prosthesis:
    1 mW/mm^2 at $\lambda \approx 905$nm





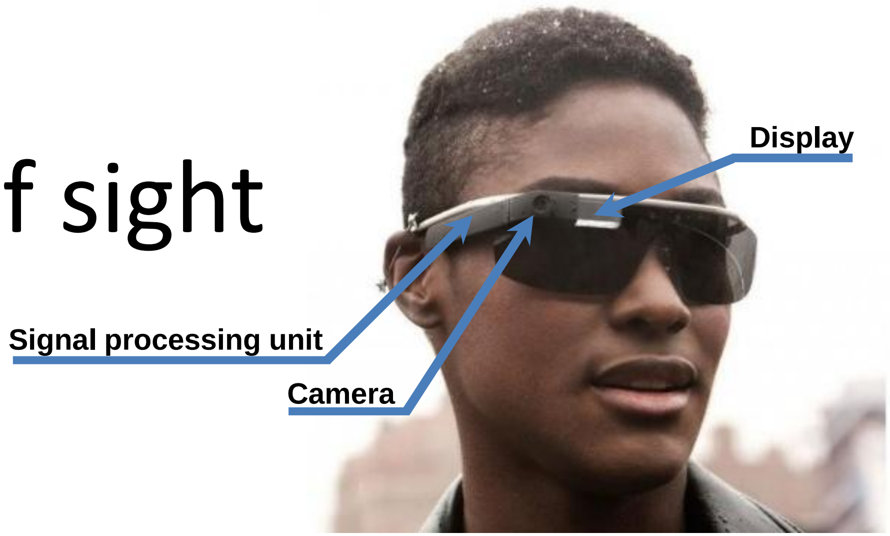


- Ambient light: at most 1µW/mm^2 on the retina

too dim.

Photoswitches illustration by Harald Janovjak. Optogenetics illustration by Ed Boyden.

Video eyewear for optical restoration of sight

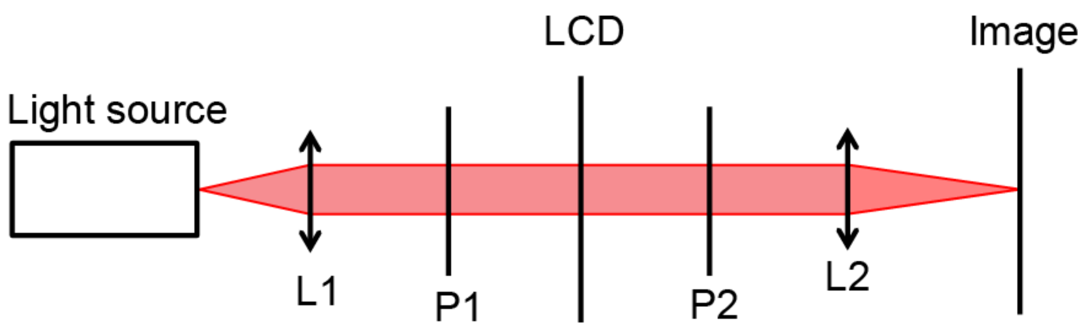


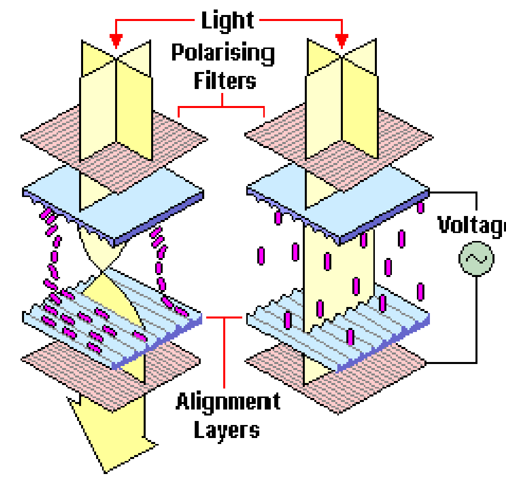
Project Glass, Google Inc.

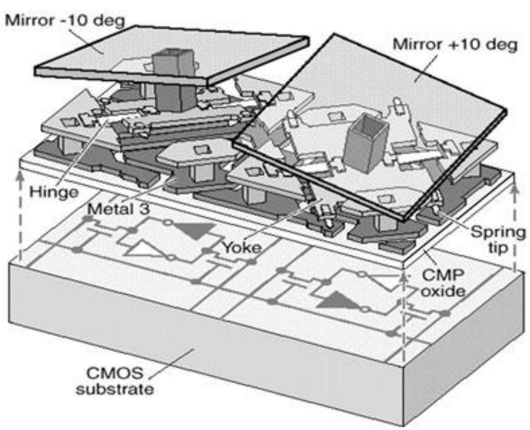
- Requirements:
  1. A camera should capture the visual scene.
  2. Irradiance on the retina has to be orders of magnitude brighter than ambient retinal illumination.
  3. Wavelength should be adapted to the approach.
  4. Safe operation.
- Signal processing unit is between the camera and the display.

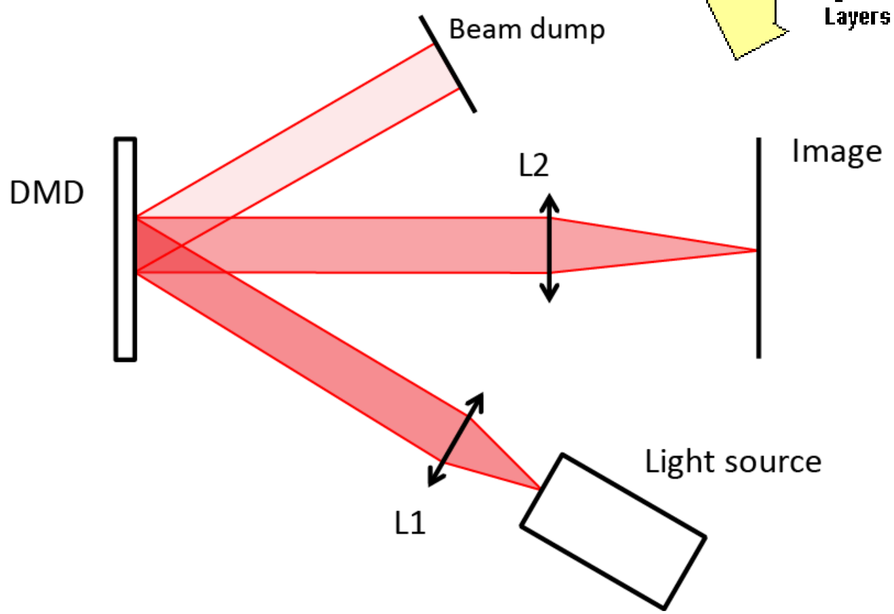
Shaping light: LCD and DMD displays

- LCDs and DMDs shape light by subtraction







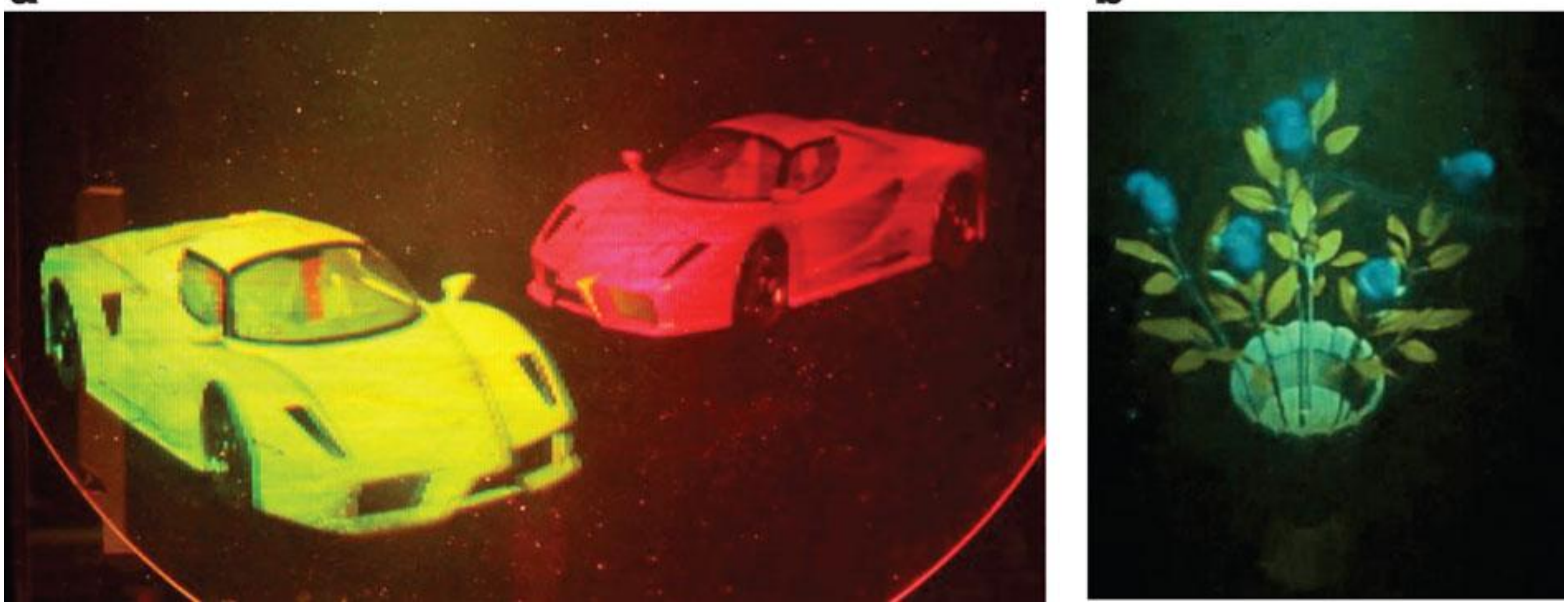


Illustrations by Longtech Optics, NIST.gov.

Alternative approach: holography

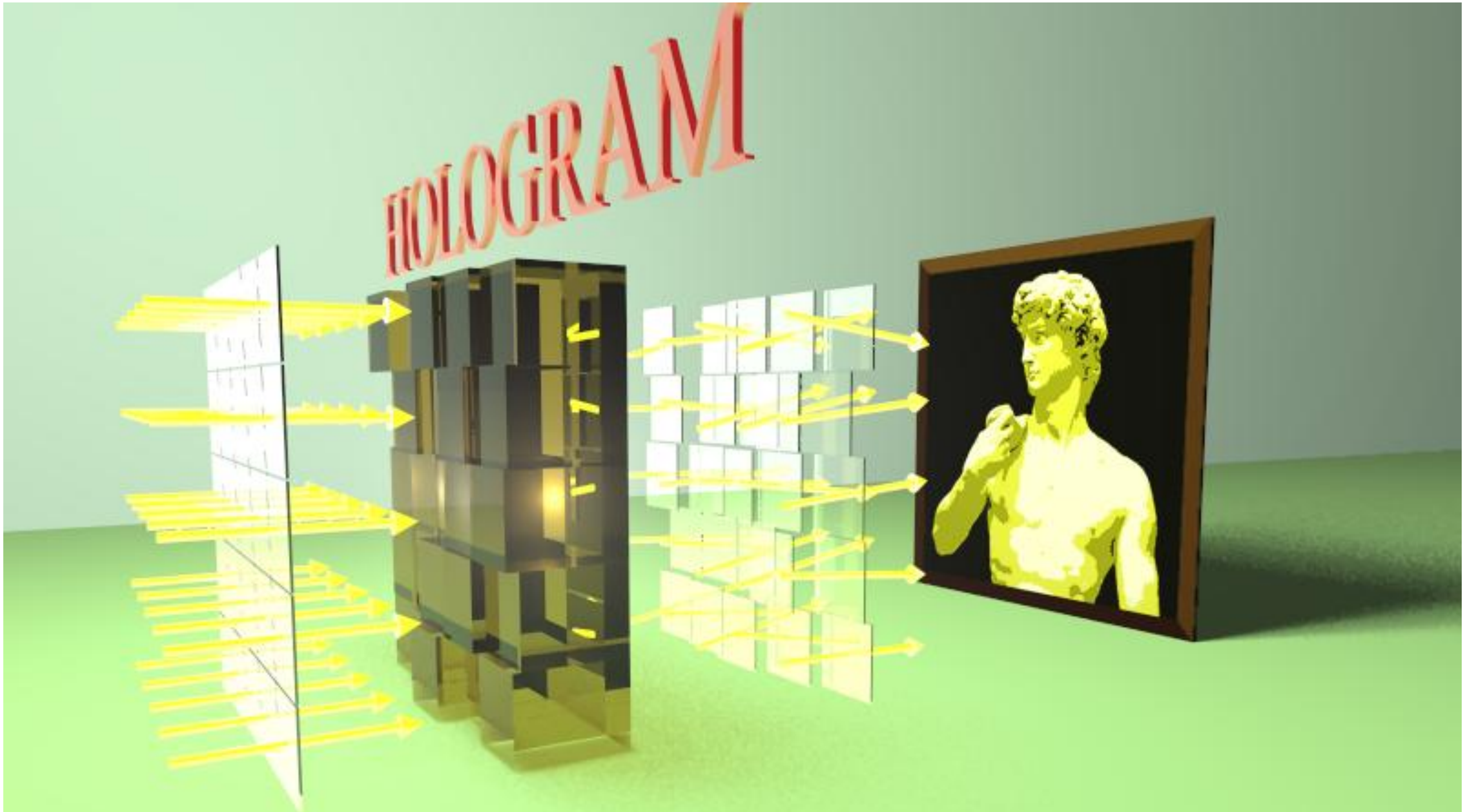
- Holographic techniques shape light by redistribution

a b

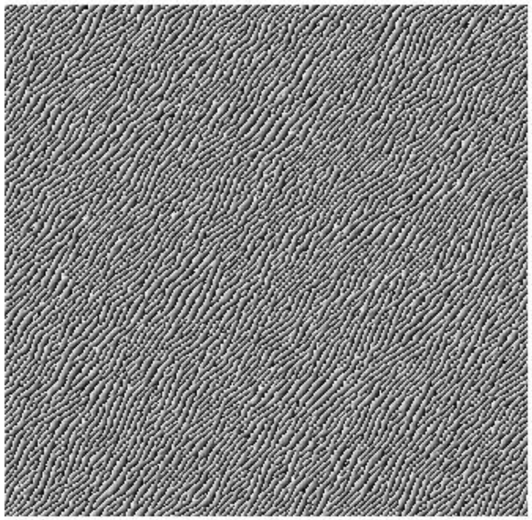


Blanche et al., *Nature* 2010;468:80-83

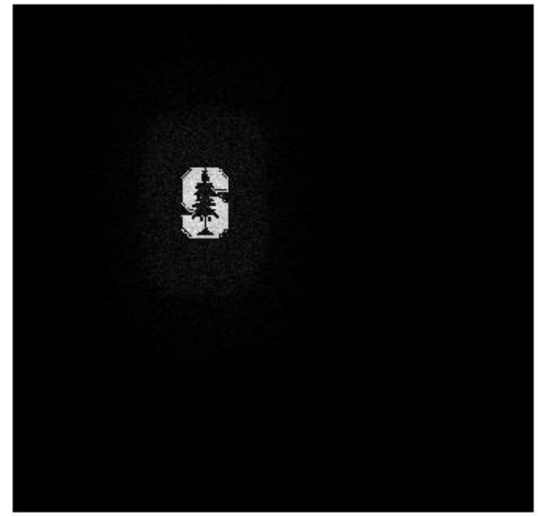
Holography: how does it work?



Hologram computation



Hologram

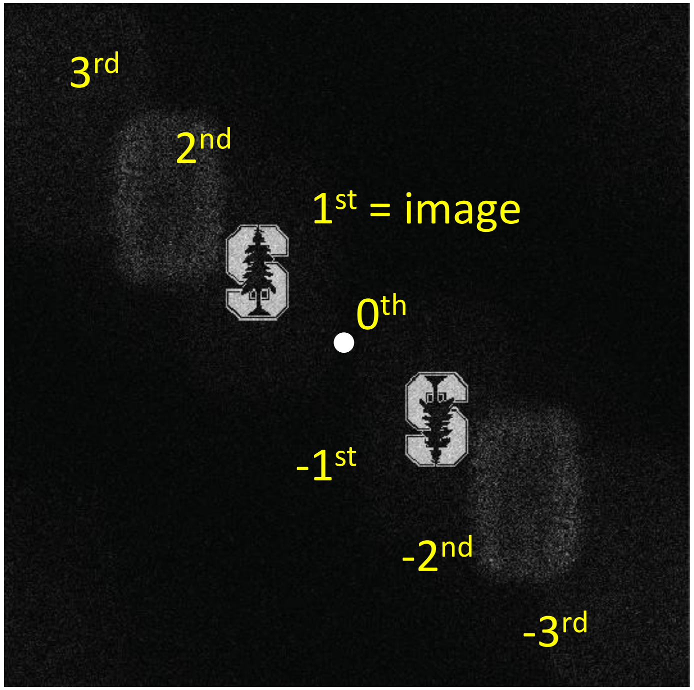


Resulting image

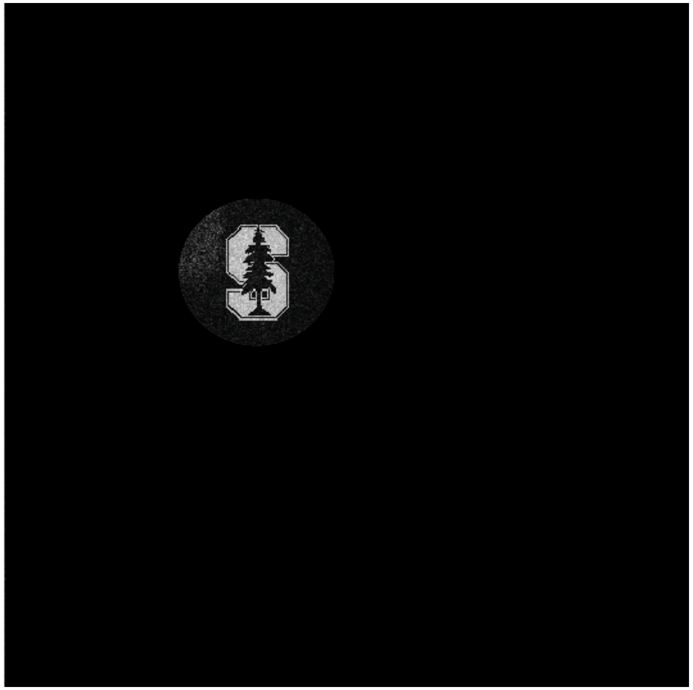
- A well-studied problem
  - We use the Gerchberg-Saxton algorithm
  - Hologram computation can be done efficiently on GPUs
  - iPhones have GPUs

Influence of unwanted diffraction orders

- Unwanted diffraction orders are traditionally discarded by the spatial filter



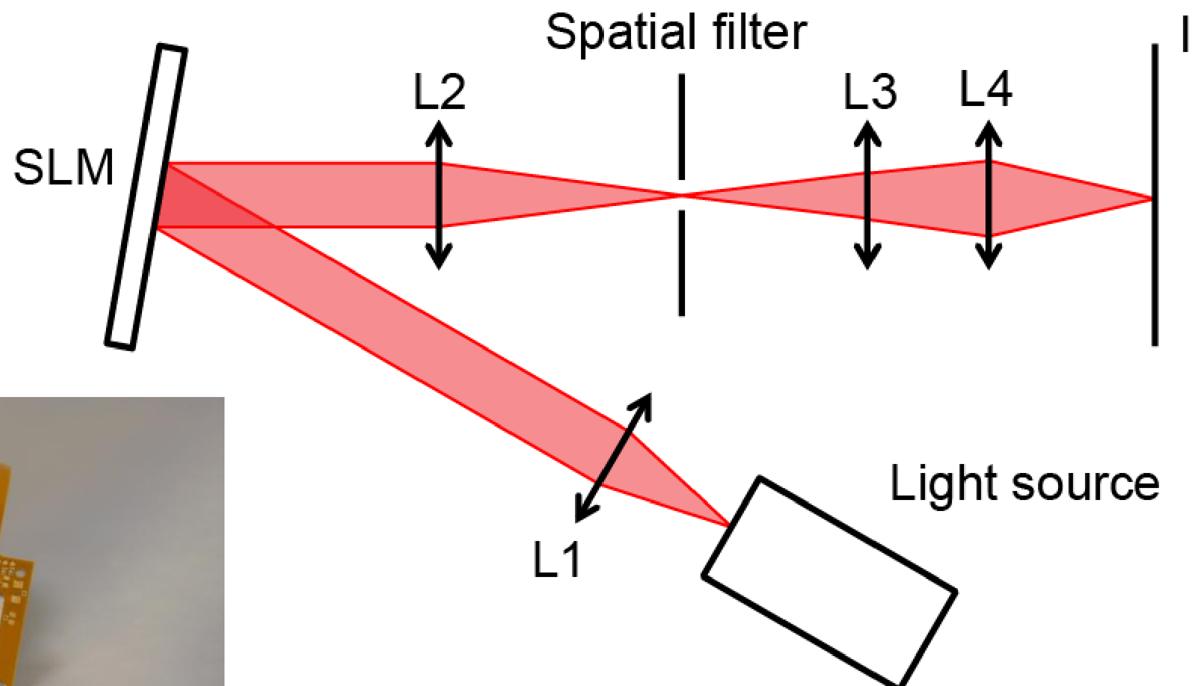
Unfiltered image

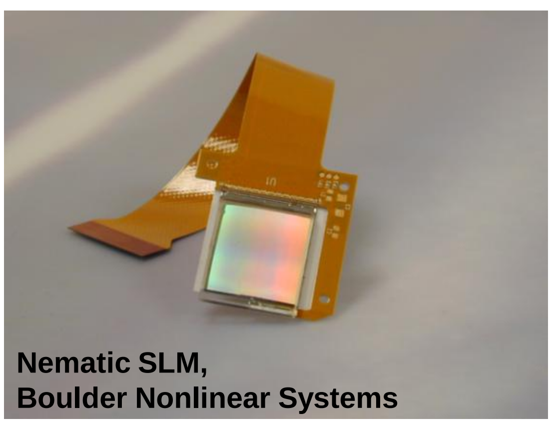


Filtered image

Holography: how does it work?

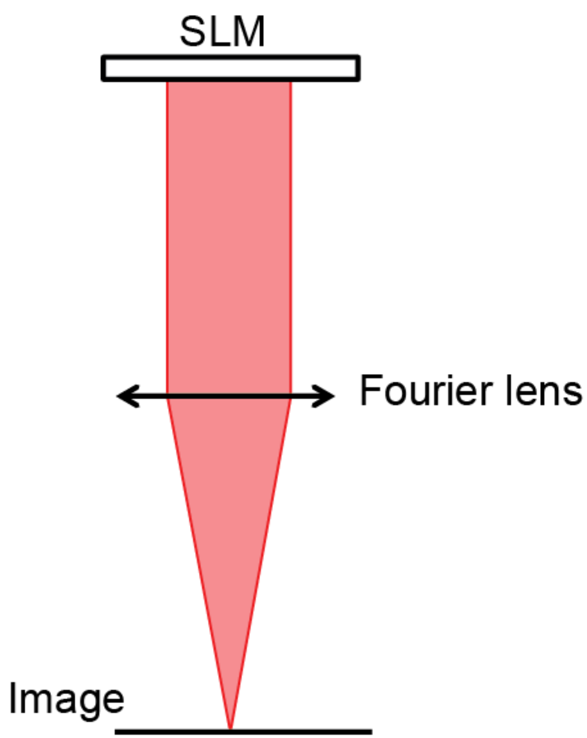
- Relies on Fourier transforming properties of lenses

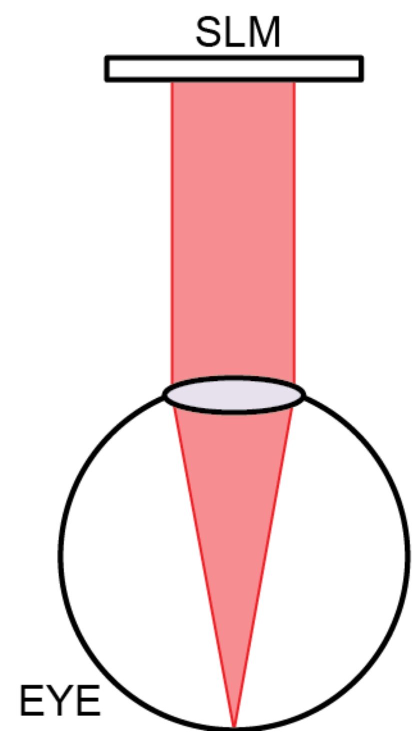




Towards holographic eyewear

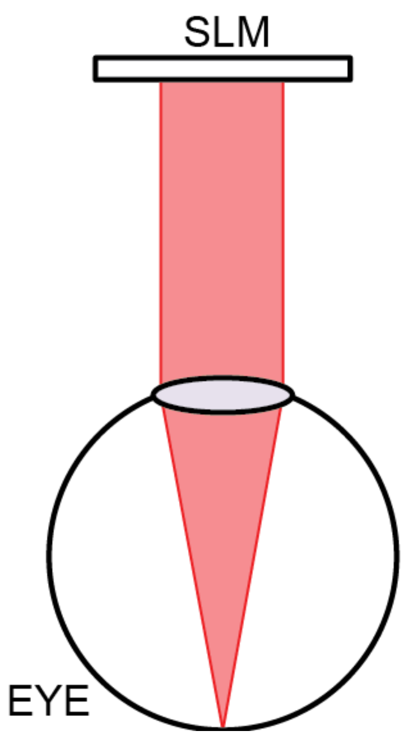
- The essential components in the system are the SLM and the Fourier lens

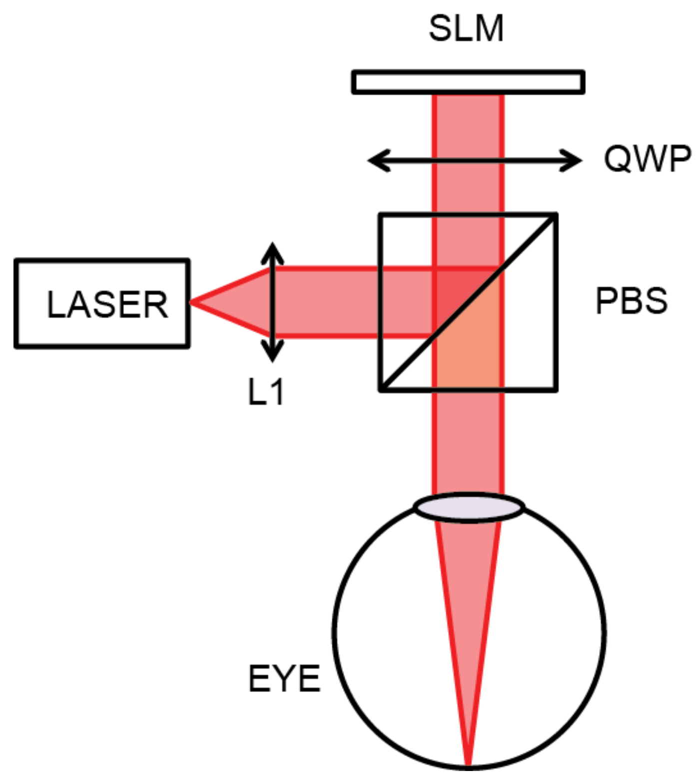




Holographic eyewear

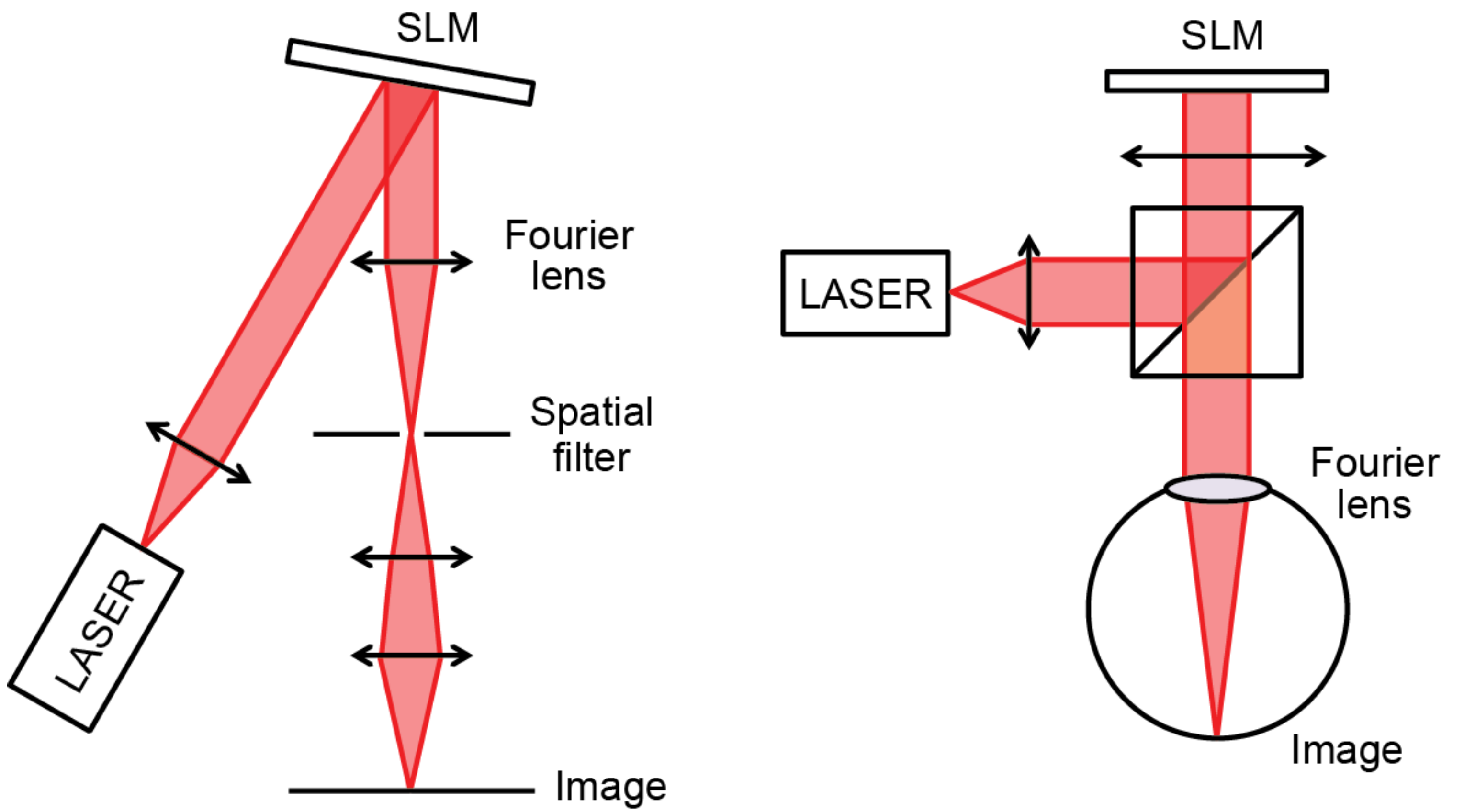
- How to deliver the light to the SLM



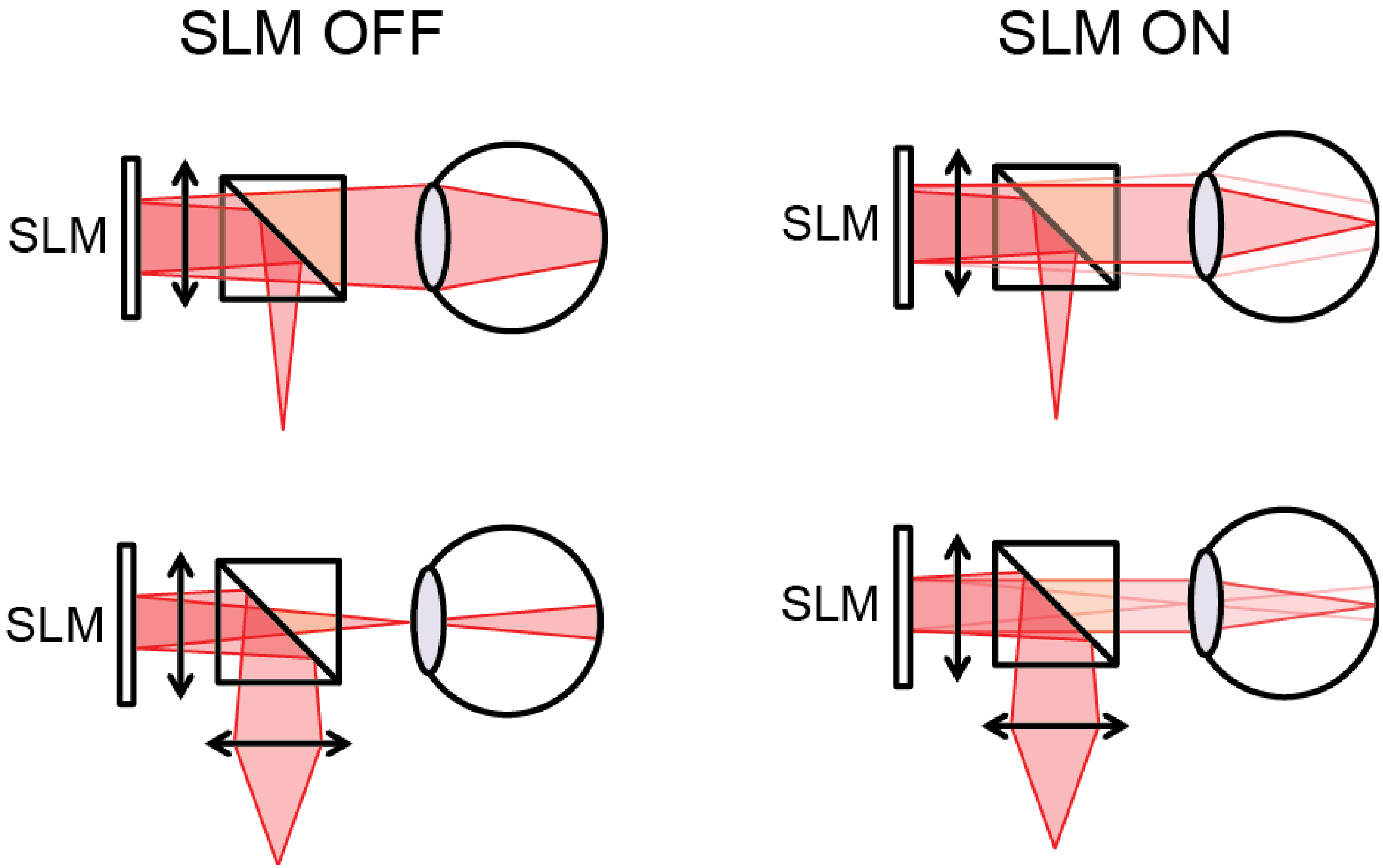


Comparison with traditional holographic systems

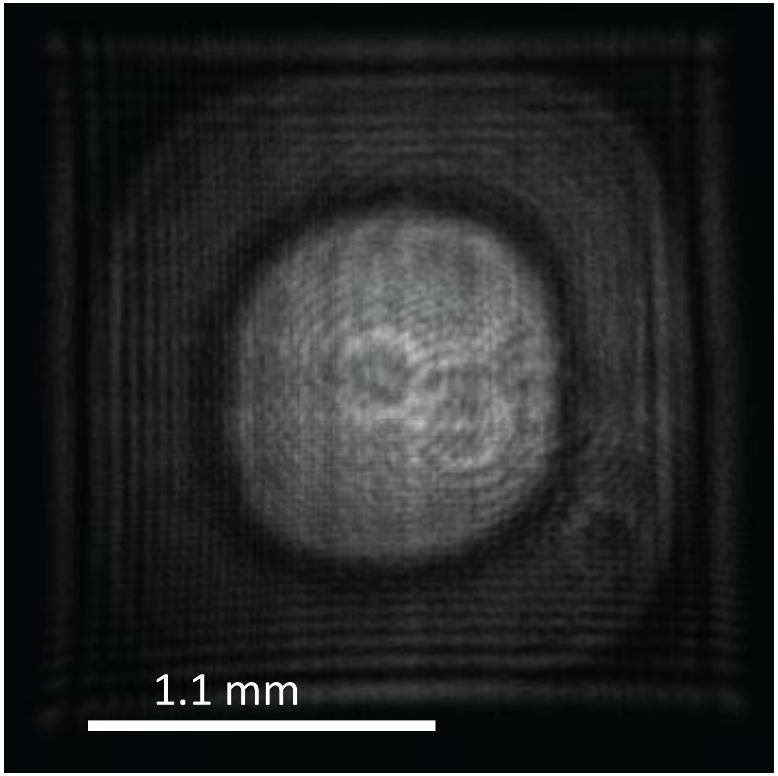
- No spatial filter in the wearable layout.



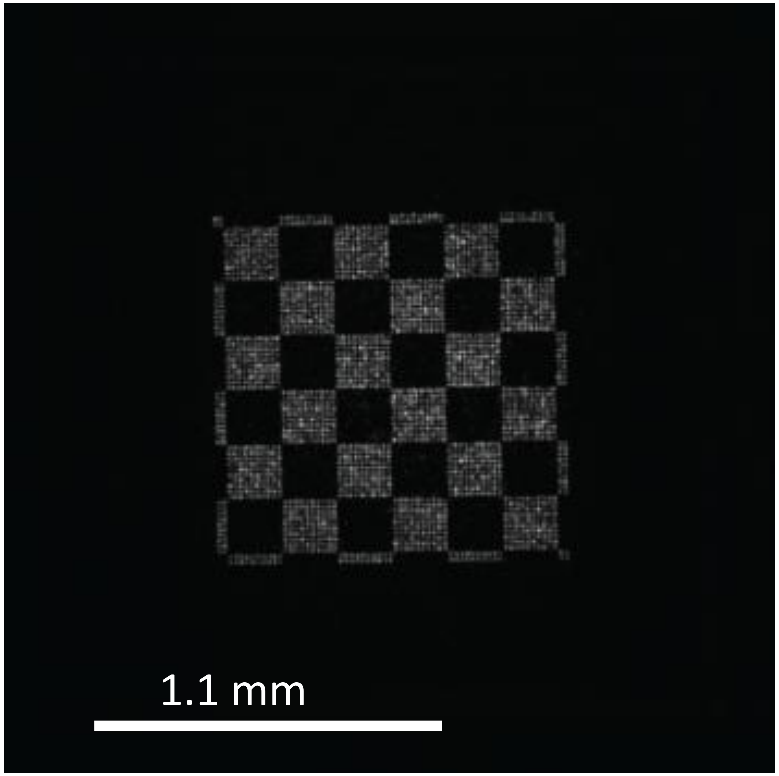
Defocusing of the zero order



Defocusing of the zero order

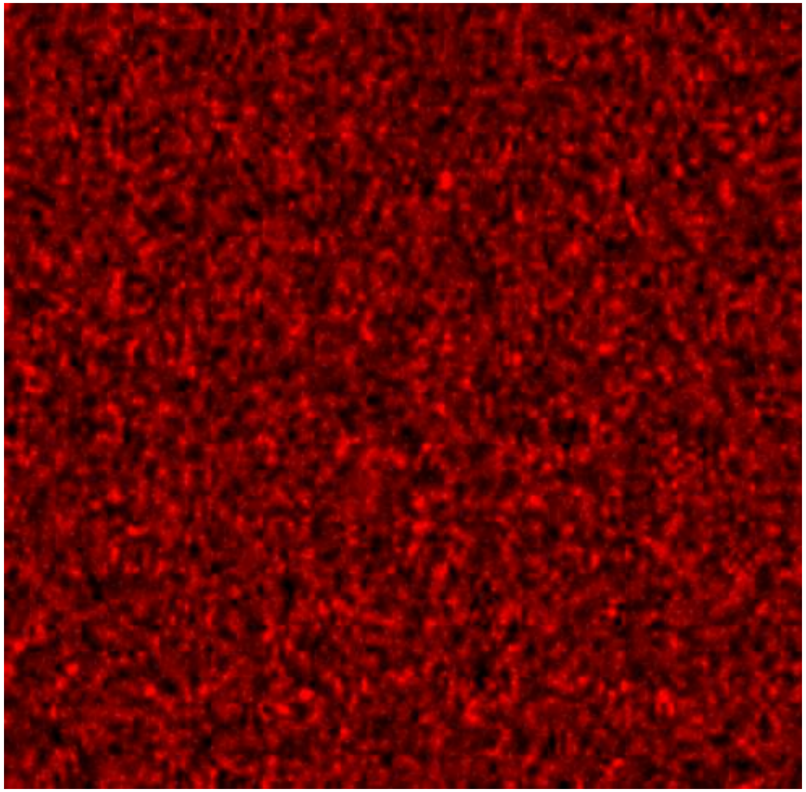


SLM OFF: all the light to the zero order

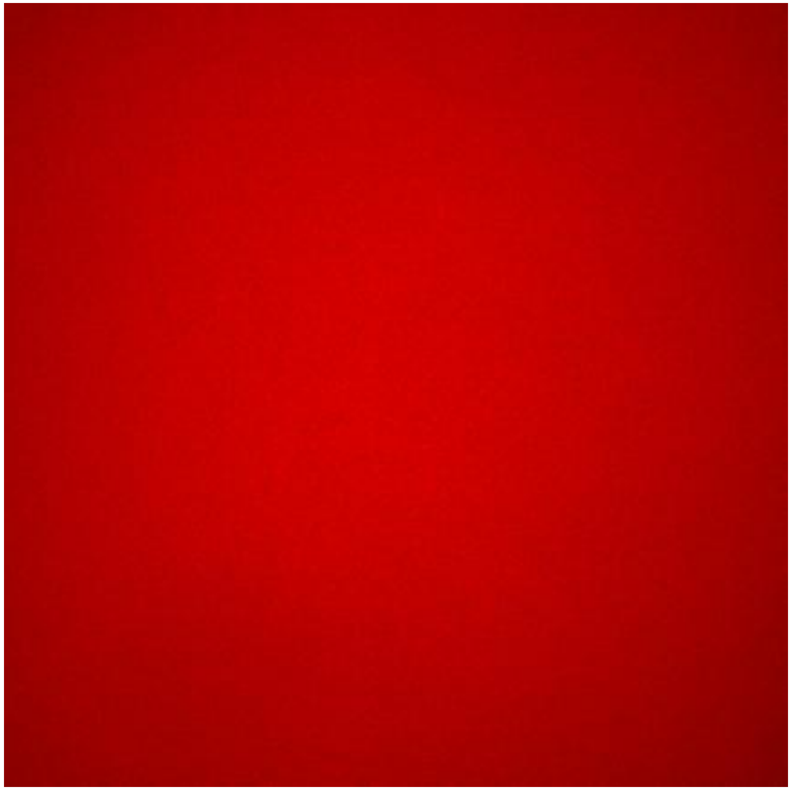


SLM ON: zero order and modulation

Speckling



Illumination with a coherent source

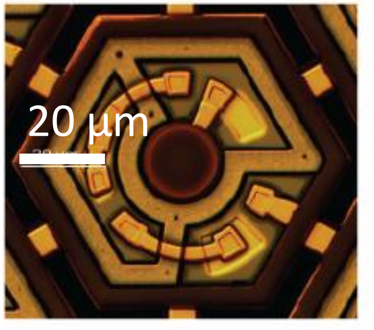


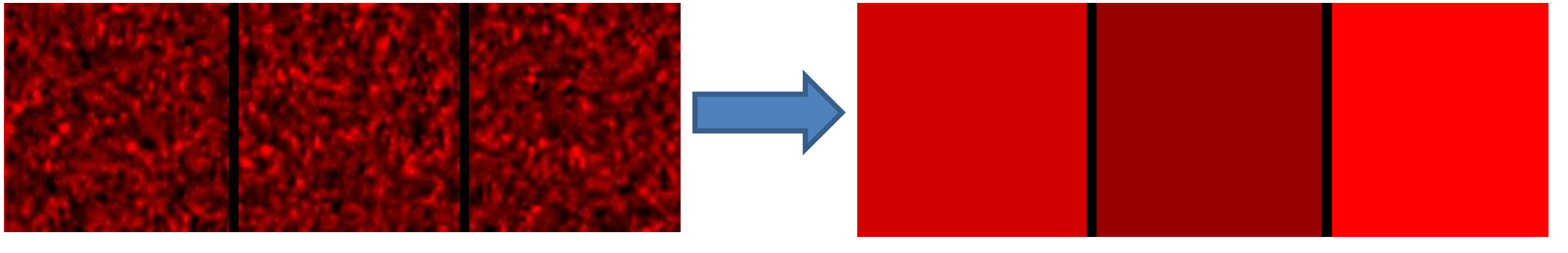
Illumination with a low-coherence source

Speckling

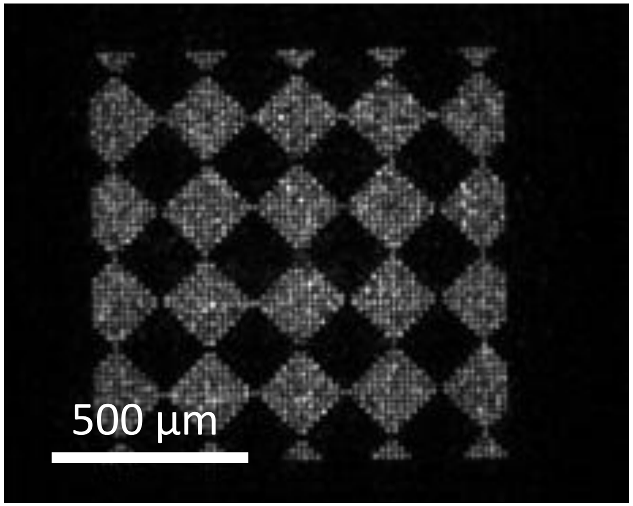
- For systems with slow response times, time-averaging of the speckles works well.
- Does not work with photodiodes…

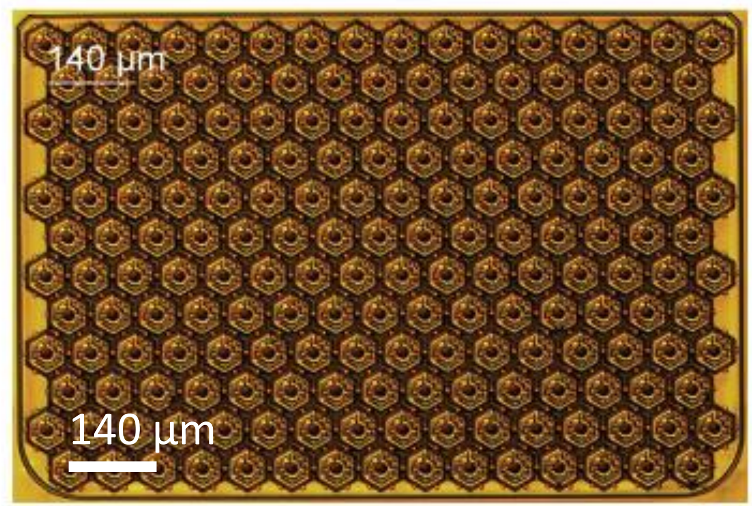
- Shadowing a diode blocks the whole pixel.
- We have to rely on spatial averaging instead

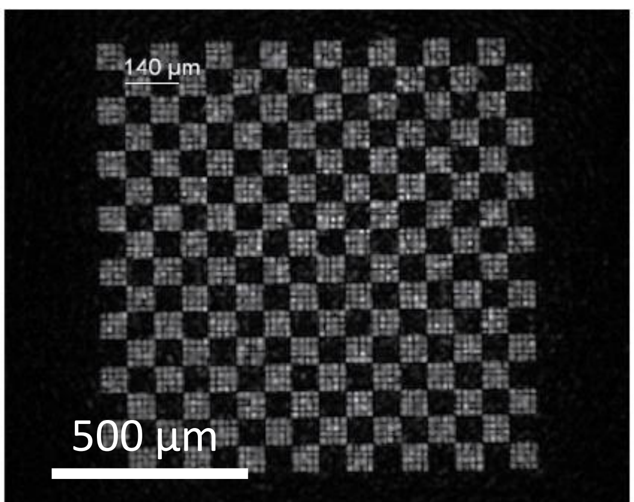


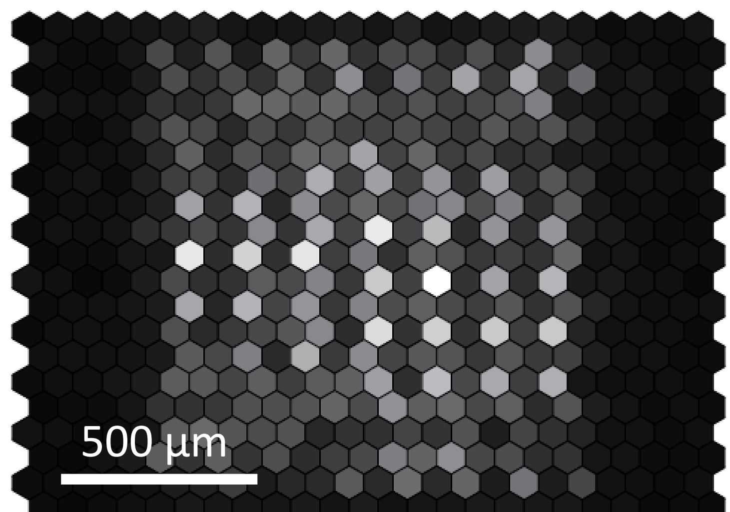


Sampling of the image by the implant









Conclusions

	Holography	LCD	DMD ★
Pros	• Very efficient • Simplest layout • Safer than other approaches	• Mature technology • Cheap • No speckling if right light source	• Less lossy than LCD • Mature technology • Cheap • No speckling if right light source
Cons	• Speckling • Hologram computation • Expensive and not really mature	• Very lossy • Requires polarizing optics • Köhler illumination can be dangerous	• Lossy • Köhler illumination can be dangerous

Current team

1 – Hansen Experimental Physics Laboratory
2 – Department of Ophthalmology
3 – Department of Electrical Engineering
4 – Dept. of Physics, UC Santa Cruz
5 – Department of Medicine, St Andrews
6 – Institute of Photonics, Strathclyde

Daniel Palanker, PhD	*principal investigator*	*1,2*
Keith Mathieson, PhD	*fabrication, electrophysiology*	*6*
Philip Huie, MSc	*cell biology*	*1,2*
Yossi Mandel, MD, PhD	*in-vivo electrophysiology*	*1*
Henri Lorach, PhD	*in-vivo electrophysiology*	*1*
Daniel Lavinsky, MD, PhD	*in-vivo imaging*	*1,2*
David Boinagrov	*electrophysiology*	*1*
Alexander Sher, PhD	*electrophysiology*	*4*
Richard Smith	*electrophysiology*	*4*
Georges Goetz	*electrophysiology, optics*	*1,3*
Ted Kamins, PhD	*chip fabrication*	*3*
Lele Wang	*chip fabrication*	*3*
Ludwig Galambos	*chip fabrication*	*SNF*
Stuart Cogan, PhD	*SIROF electrodes*	*EIC Labs*
James Harris, PhD	*chipfabrication*	*3*
Tomas Cizmar, PhD	*optics*	*5*

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