RICOH
imagine. change.

Low-power sensors for shopper detection

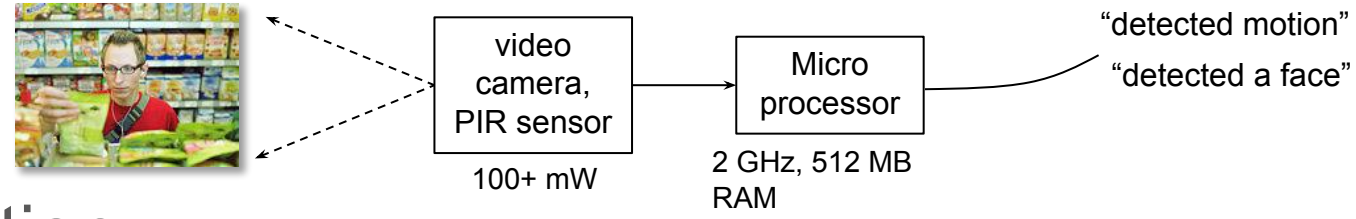
Prasanna Pavani
Ricoh Innovations, Inc.
February 4, 2013

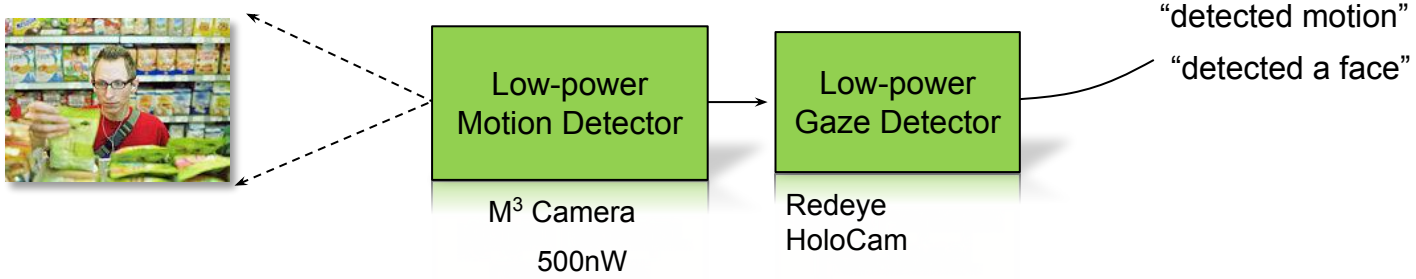
Shopper Detection

- Product need
  - Infosys, Kroger, etc.
- Problem
  - Camera and Passive IR sensors are power hungry
- Solution
  - Low-power sensors for motion and face detection

Shopper walks by product A

Shopper looks at product B



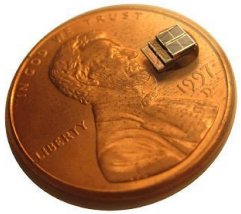


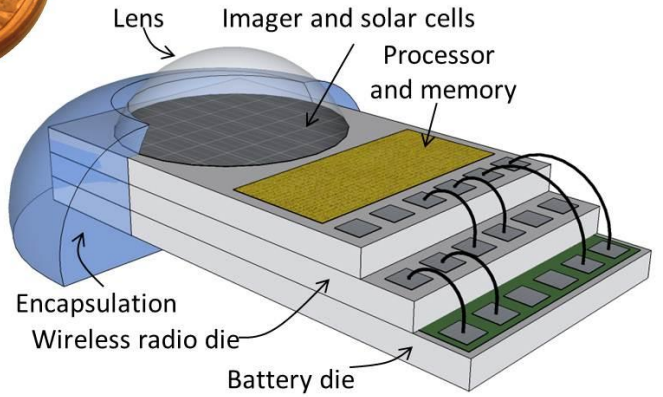
RICOH
imagine. change.

Low-power Motion Detector

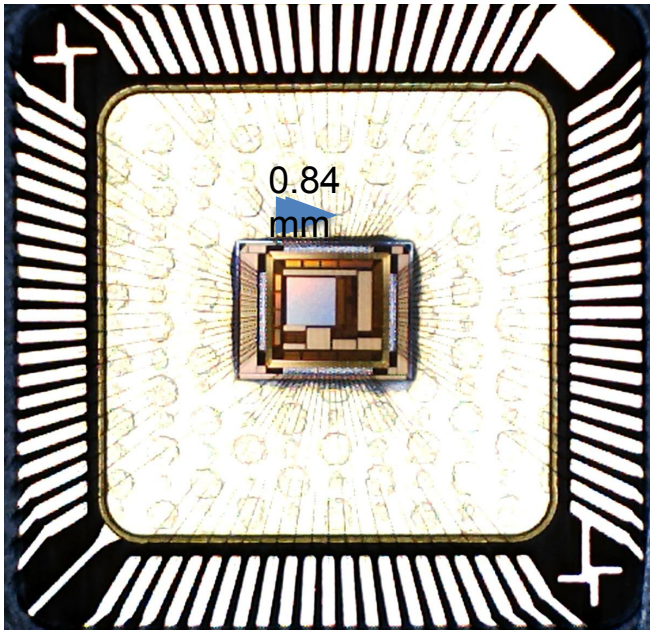
M^3 Camera

M^3 Camera



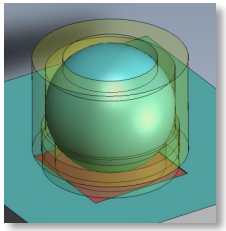


- M^3 Imager: Features
  - Ultra-low power consumption (500nW)
    - Conventional Imagers: 100+mW
  - Ultra-compact (0.84mm)
    - 22x smaller area than iPhone 5 primary camera
  - In-built motion detection hardware
- Optomechanical Challenge
  - Miniature M^3 Optics Design
  - Precision Mounting
  - Compliance with Solar Cells
- RII Solutions for M^3 Optics
  1. Ball Lens: Traditional Mount
  2. GRIN Lens: External Cap Mount
  3. Liquid Drop Lens: External Cap Mount

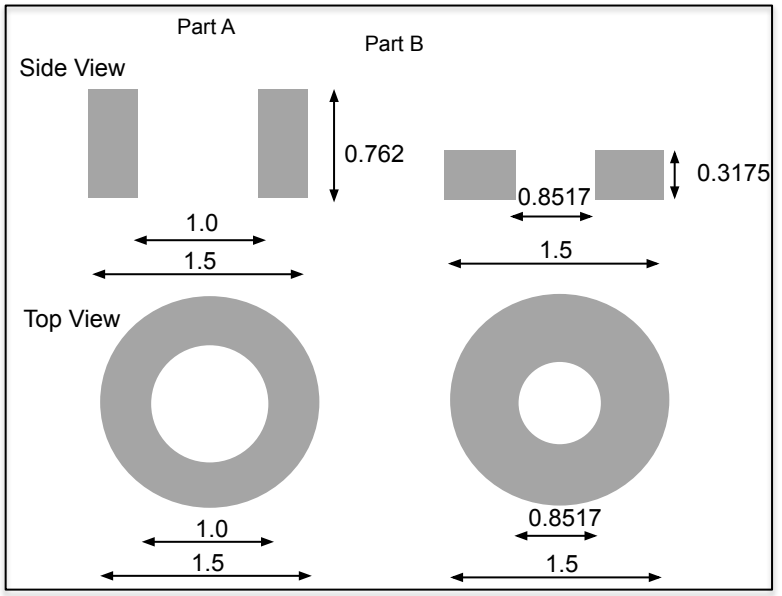


Ball Lens: Mounting and Imaging

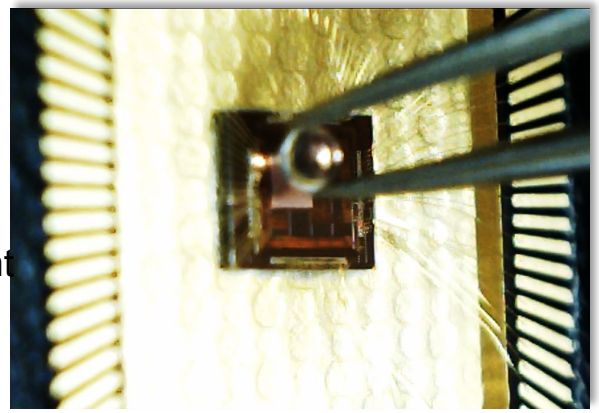
- Features
  - High index (n=2)
  - Diameter: 1 mm
- Advantages
  - No lens-imager gap
  - Orientation independence
- Drawbacks
  - Difficult to handle and mount
  - Image distortion

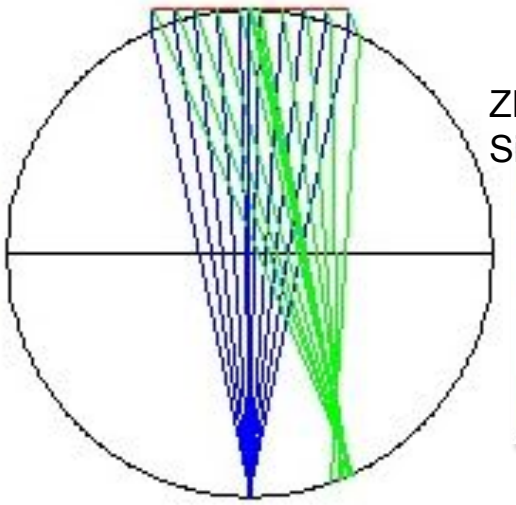


3D Model of Ball Mount



Ball Lens Mounting Experiment





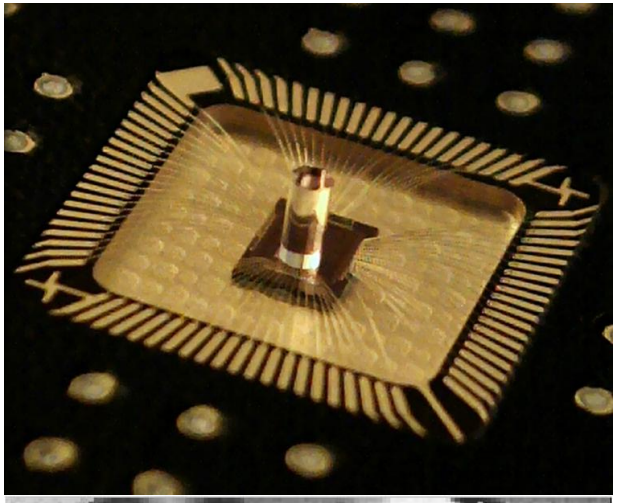
ZEMAX Design & Simulation

Distortion

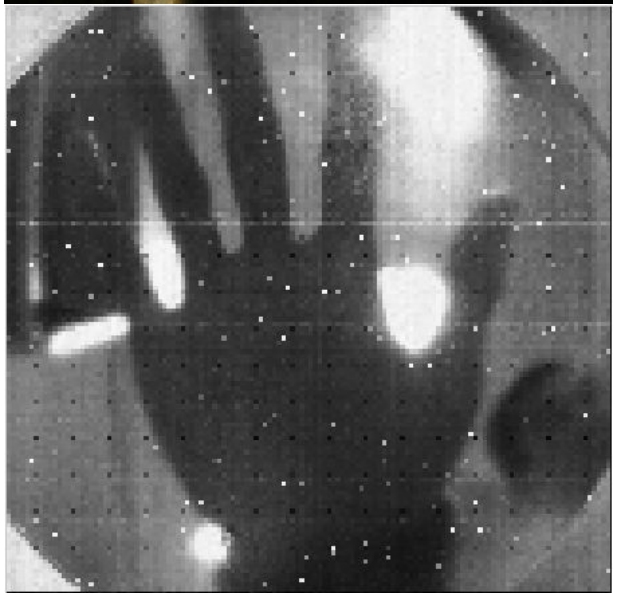
RICOH
imagine. change.

GRIN Lens: Direct Mounting and Imaging

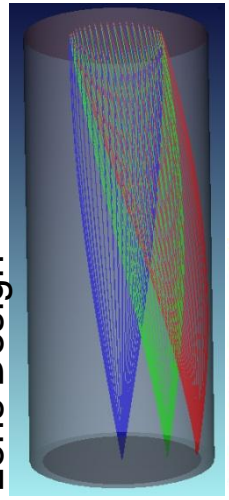
- Features
  - Gradient Index Cylinder
  - Diameter: 1 mm; Height: 2.4 mm
- Advantages
  - No lens-imager gap
  - Less difficult to handle & mount
- Drawback of Direct Mounting
  - Low yield
    - Twisted wirebonds
    - Glue-imager interaction



GRIN on M^3 imager



128x128 Lingfei Image



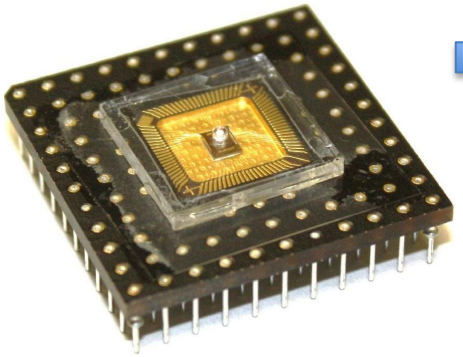
Lens Design

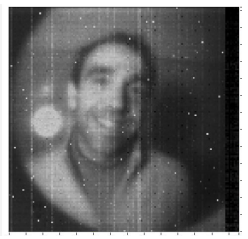
ZEMAX simulation

GRIN Lens: External Cap Mounting and Imaging

RICOH
imagine. change.

- Features
  - Acrylic Cap with 1mm hole
  - Lens attached to cap
  - Imager is glue-free
  - Wirebonds are untouched



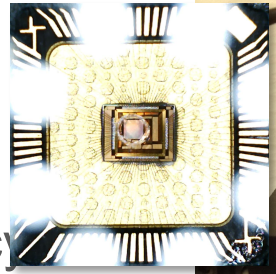


Visible light image

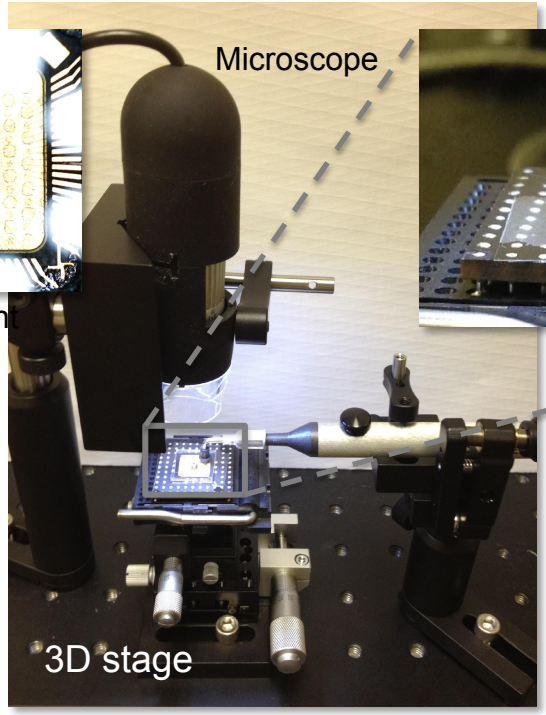
NIR image

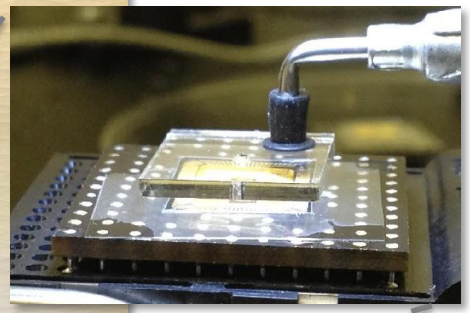
Vacuum tweezer

- Process Protocol
  1. Transparency on M^3
  2. Ext. Cap on transparency
  3. Lens in Cap



Cap alignment

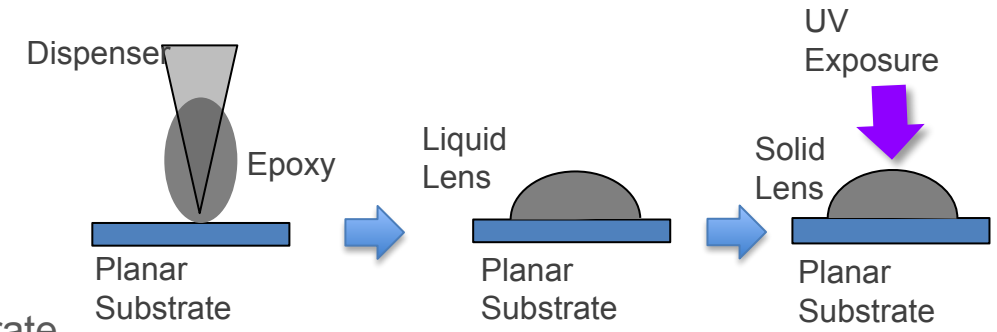


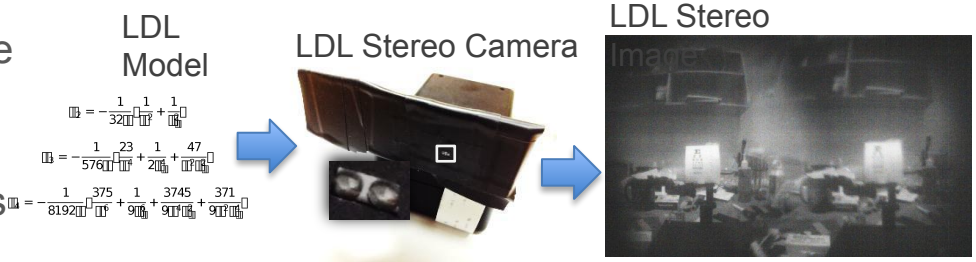


- Advantages
  - High yield
  - Automated mounting possible

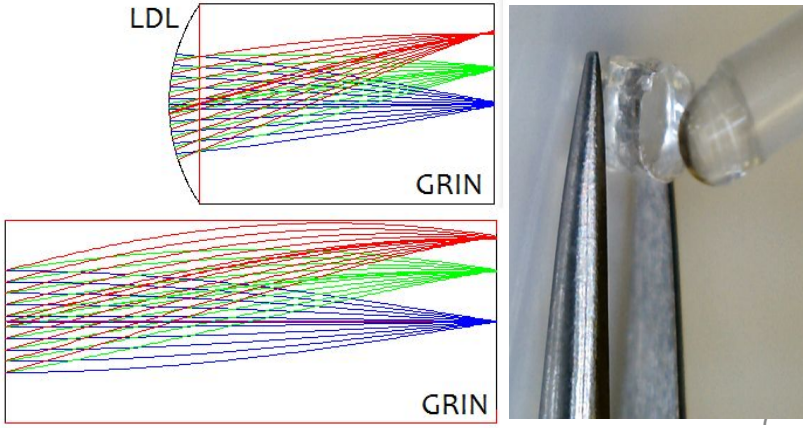
Liquid Drop Lenses (LDL)

- LDL Protocol
  - RII proprietary technology
    1. High-viscous liquid epoxy is dispensed on a planar substrate
    2. Surface tension minimizes surface area of the epoxy to a spherical lens
    3. Exposure to ultra-violet light cures the epoxy to a solid





- Advantages
  - LDL+GRIN offers 33% reduction in lens height over GRIN
  - 8 degree improvement in field of view
- LDL+GRIN can be mounted with an External Cap Mount



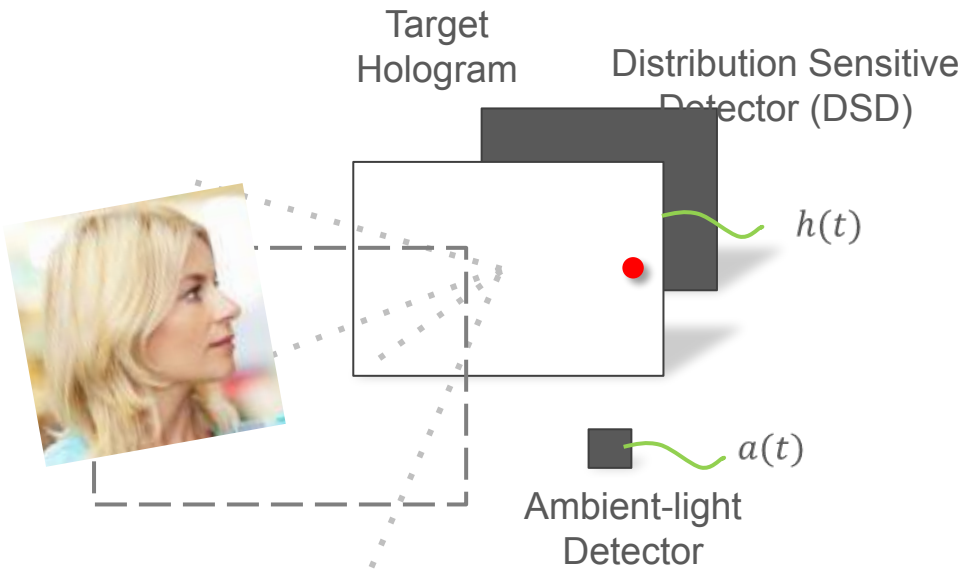
RICOH
imagine. change.

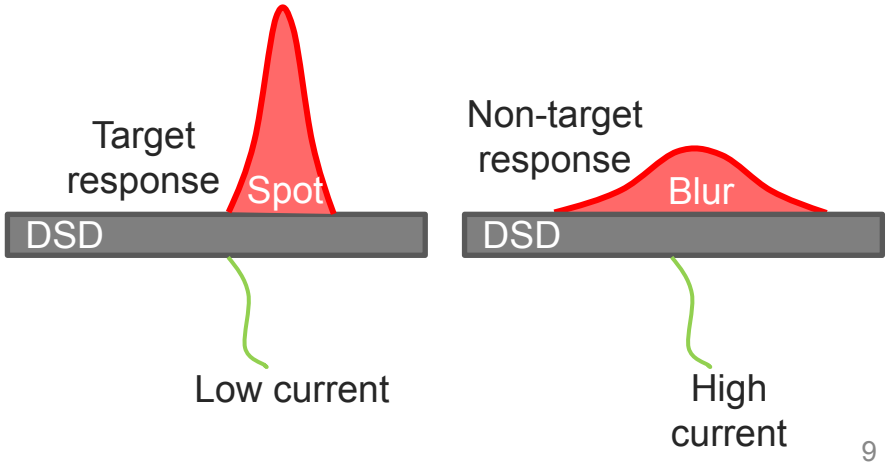
Low-power Gaze Detector

HoloCam

HoloCam: Technology

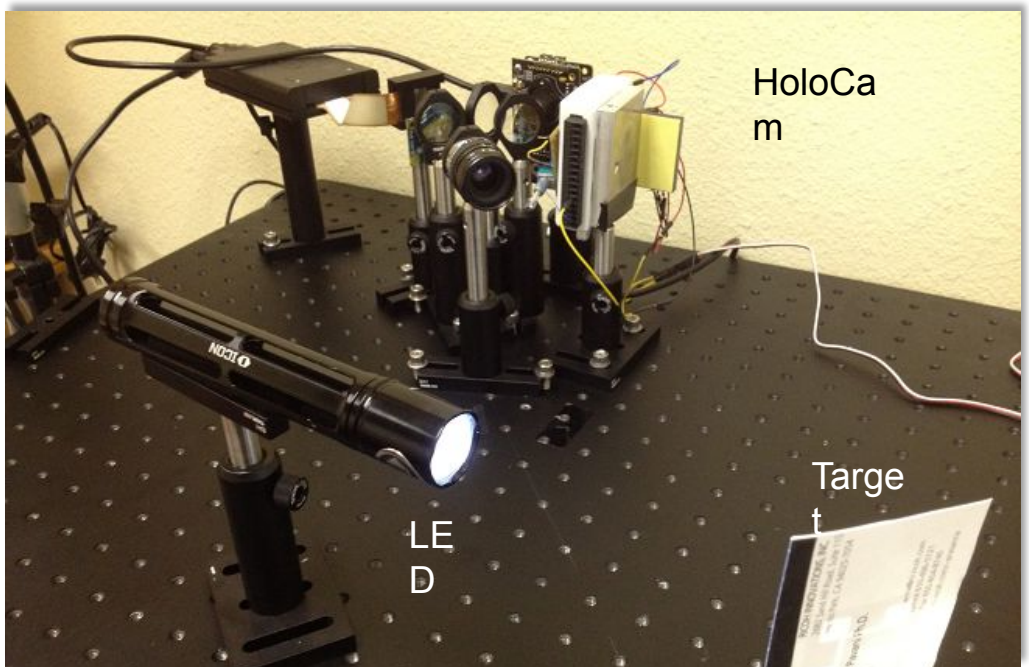
- Compact target detector
  - Target Hologram
  - Single-element optical processing
- Distribution Sensitive Detector
  - Novel single-pixel spot vs. blur classifier
  - Leverages local-currents in non-uniform illumination
- Features
  - Low power consumption
  - High speed
  - Wide field of view
  - Room light operation

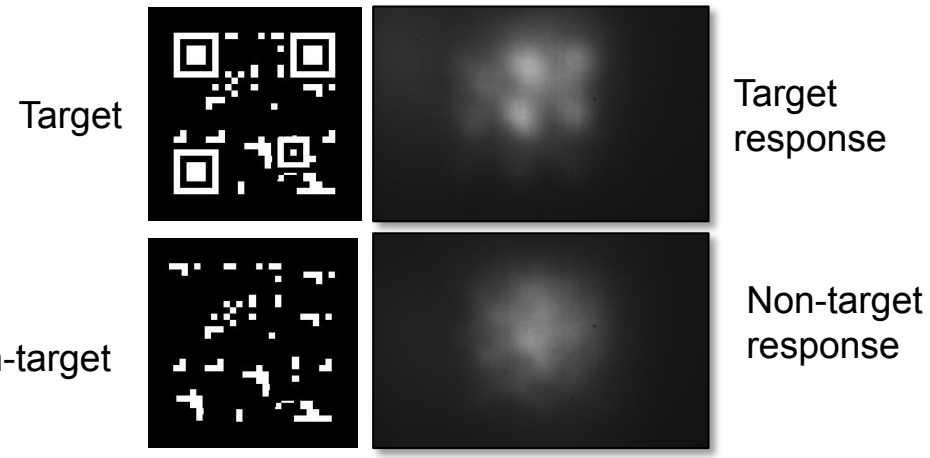




Upgraded HoloCam (since June ‘12)

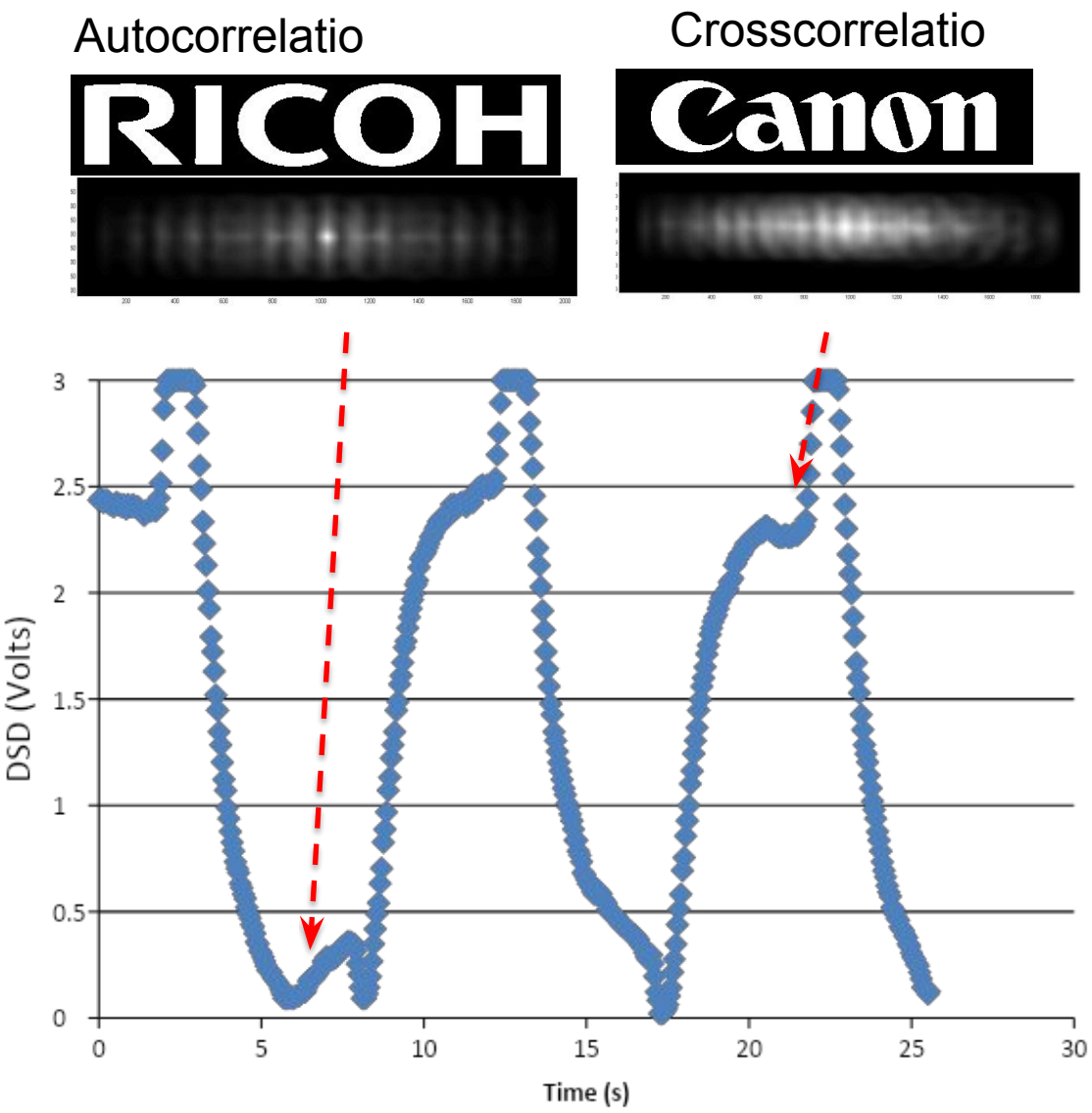
- Realistic Targets
  - QR codes
  - Logos
  - Eyes
- Realistic illumination
  - Scattered LED white light
- Improved optics
  - Low light operation
- Improved detector
  - Lower noise
  - Higher amplification
  - Low power ambient detector
  - Holoboard





Logo Detection

- Objects
  - Target: RICOH
  - Non-target: Canon
- Target hologram
  - Designed for RICOH
- DSD Results
  - Lower voltage for RICOH
  - Higher voltage for Canon
  - Clear separation of levels
- Low-power ALD necessary for detection
- Lingfei: Classifier design

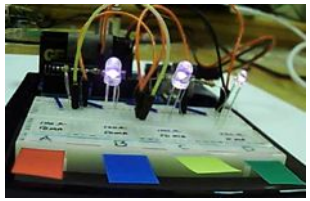


Gaze Detection with Red-eye HoloCam

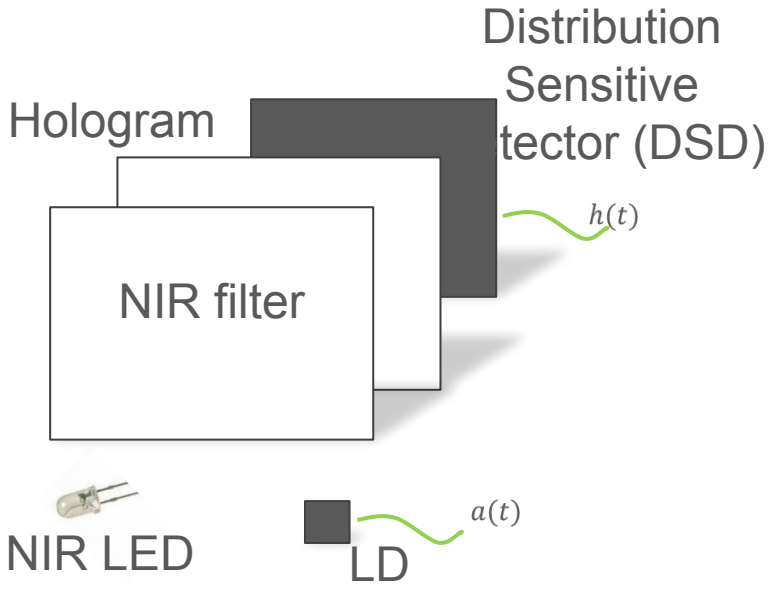
- Red-eye effect
  - Prominent appearance of retina
  - Flash close to lens
  - Most prominent in dark
    - Expanded pupil

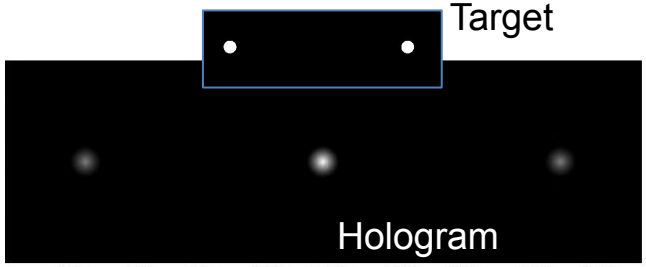
NIR redeye

- Red-eye HoloCam
  - NIR (850nm) LED triggered by M3 motion detector
  - NIR filter
  - Reduces face detection to twin-disc detection
  - Low-power IR LED



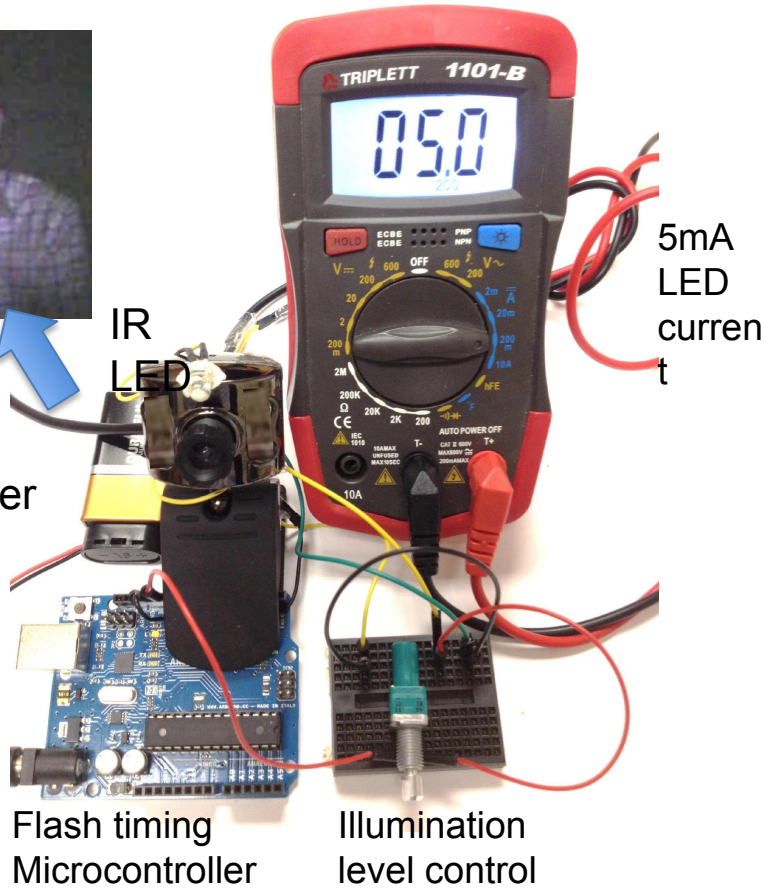
IR LED power characterization





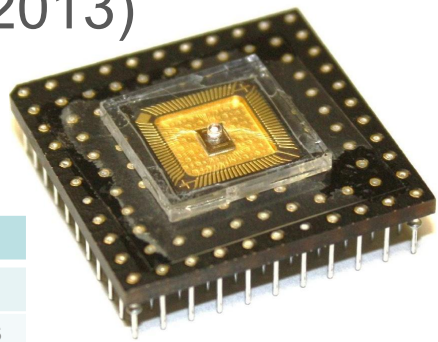
Battery lifetime for low-power Red-eye

- Low-power Infra-red LED
  - Draws 5mA@5V
  - 30 fps camera
  - Exp. time ≤ 33 ms
  - Energy per flash: 825 µJ
- AA battery capacity
  - 1200mAhr@1.5V
  - 6.5 x 10^9 µJ
- Battery Lifetime (no energy harnessing)
  - IR flashes at 1Hz
  - Motion trigger activation
    - 10% of store time (~2 hrs)
  - Lifetime: 2.5 years
- *Single AA battery can power IR LED for years*



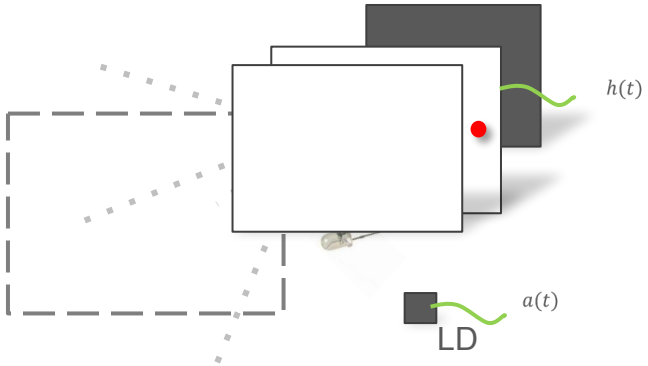
Future steps

- Motion Detection
  - Shipment of 2 M^3 cameras for U. Michigan (1/2013)
  - Automated motion detection prototype
    - In collaboration with U. Michigan



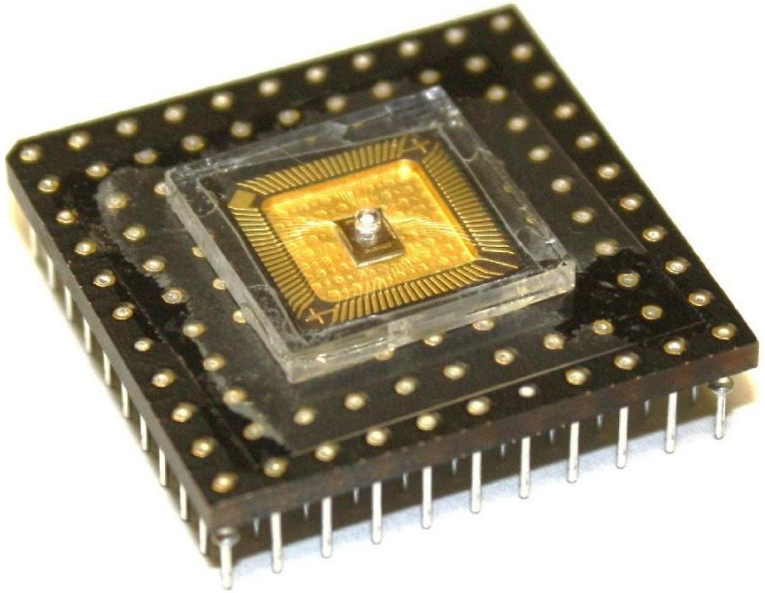
When?	Who?	What?
10/10/2012	U. Michigan to Ricoh	2 Standalone Imager Chips
10/31/2012	Consultant to Ricoh	Time/cost Estimate for Ball Lens Mounting on 2 Imagers
11/30/2012	U. Michigan to Ricoh	Test-bed for standalone imager (Gyouho visit)
1/31/2013	**Ricoh to U. Michigan**	**2 M^3 cameras with External Cap Mounts**
3/31/2013	Ricoh to U. Michigan	Scalable method for mounting lenses on 100 M^3 imagers
Fall 2013	U. Michigan	Release of 100 M^3 systems with lenses

- Gaze Detection
  - Red-eye HoloCam
  - NIR filter integration
  - Prototype



Demo

M^3 camera



Red-eye camera