

Target detection with a low-power holographic detector

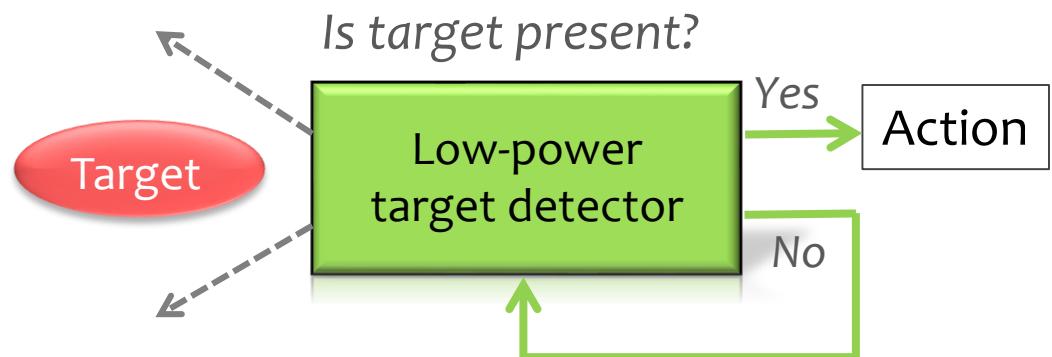
Sri Rama Prasanna Pavani, Lingfei Meng

RICOH INNOVATIONS

Goal: Low-power target detection

- Detect target presence/absence with

- Low power (μW)
- High speed (KHz)
- Wide field (50°)
- Compact size (cm^3)
- Room light



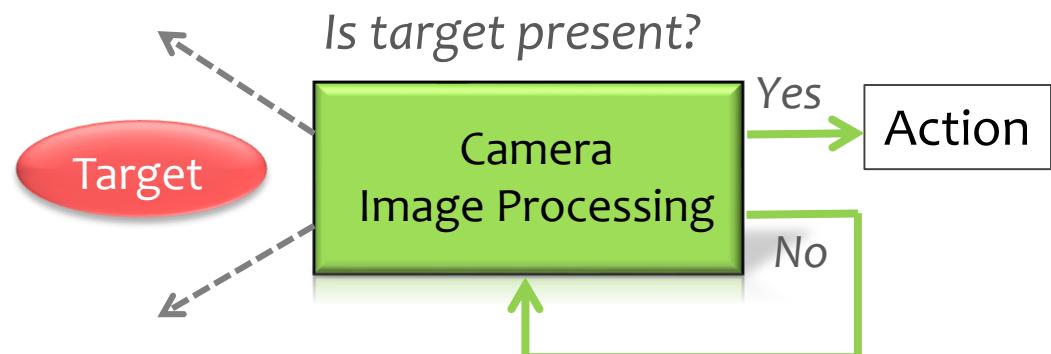
- Applications

- Automotive, Factory Automation, Consumer Electronics

Low-power target detection: Digital Processing

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- Applications

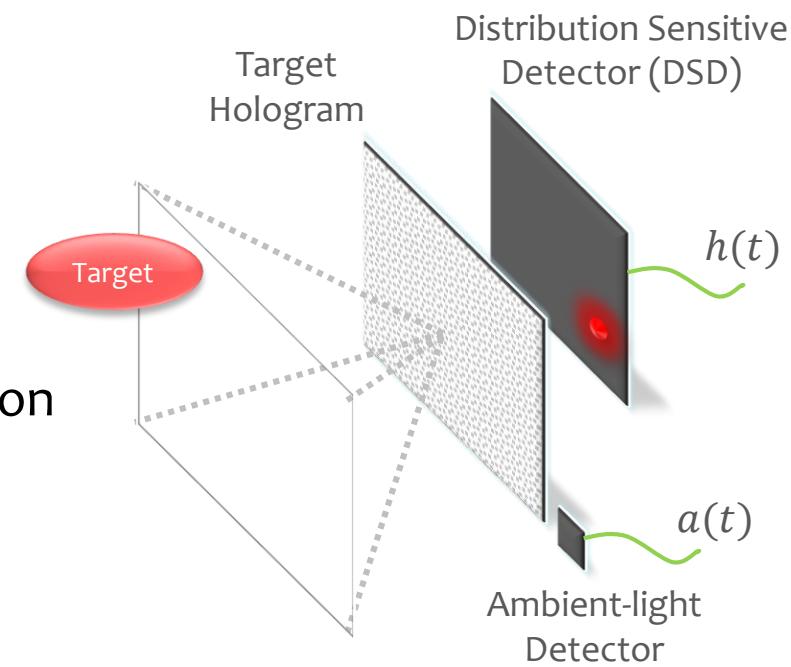
- Automotive, Factory Automation, Consumer Electronics

Digital Processing: High power (mW), Low speed (30Hz)

- J. A. Ratches, Opt. Eng. 50 (2011)

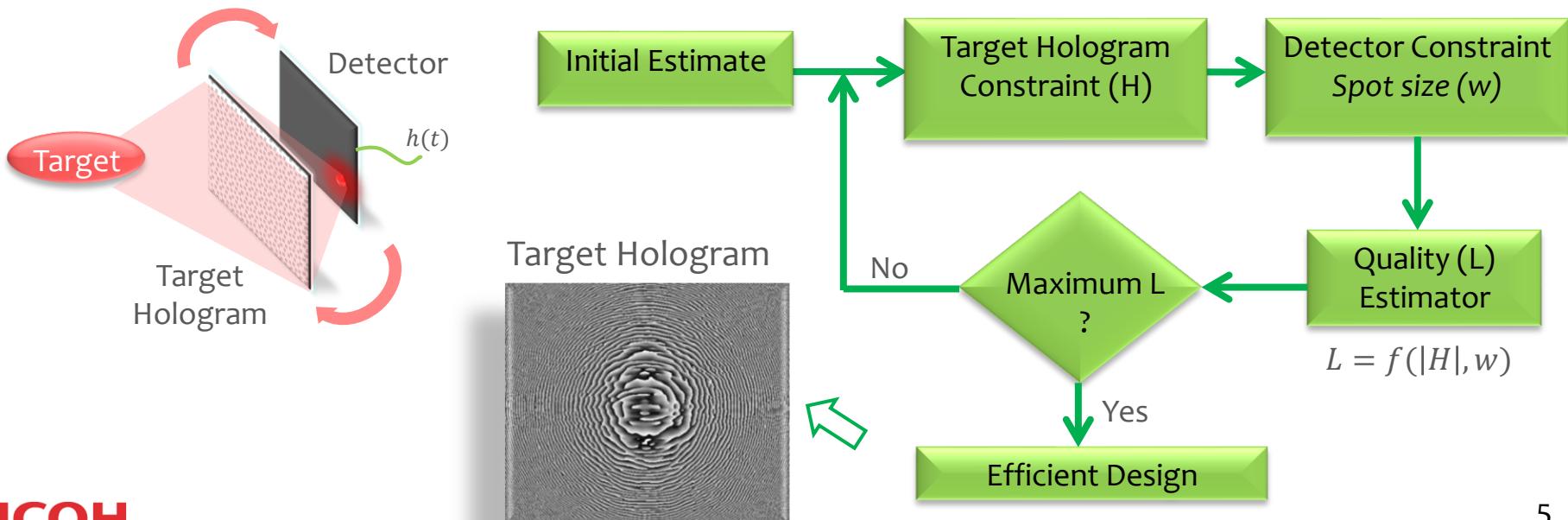
HoloCam: Low-power target detector

- Target Hologram
 - Encodes target features
 - Single-element optical processing
- Distribution Sensitive Detector
 - Single-pixel spot/blur classifier
 - Local-currents in non-uniform illumination
- Features
 - Low power ($<20\mu\text{W}$)
 - High speed (2.5KHz)
 - Wide field, Compact, Room light



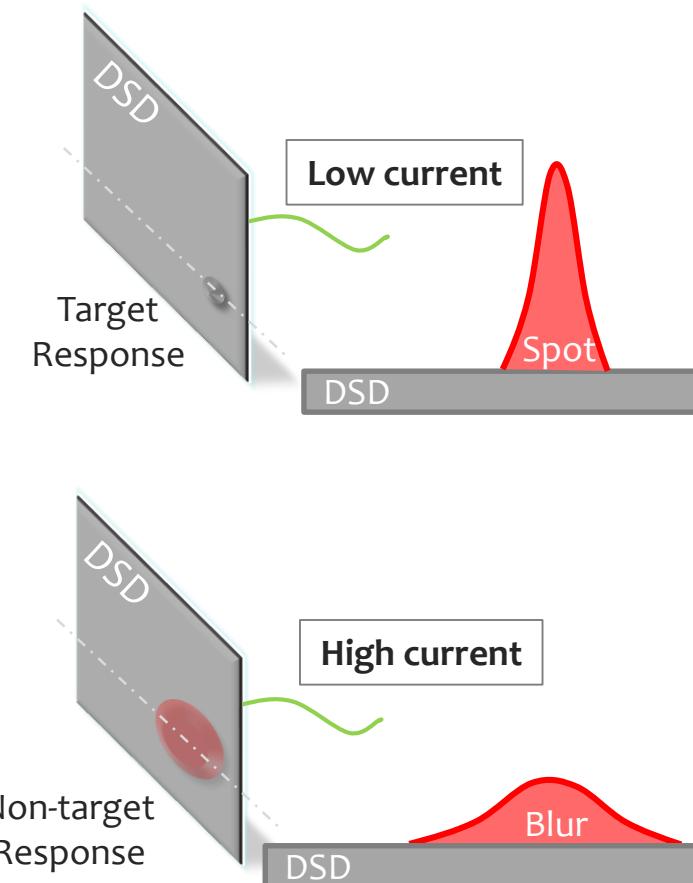
Target Hologram Design

- Computer Generated Hologram Optimization
 - Wavefront control: projections on to convex sets
 - Piestun et al., Opt. Lett. 19, 771 (1994)
 - Initial Estimate: Matched Filter
 - Hologram plane constraint: Phase-only
 - Detector plane constraint: Confine intensity to tight spot

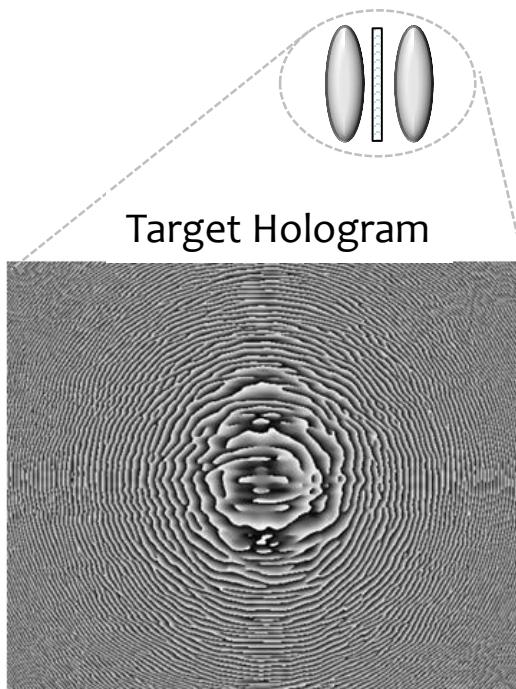


Distribution Sensitive Detector

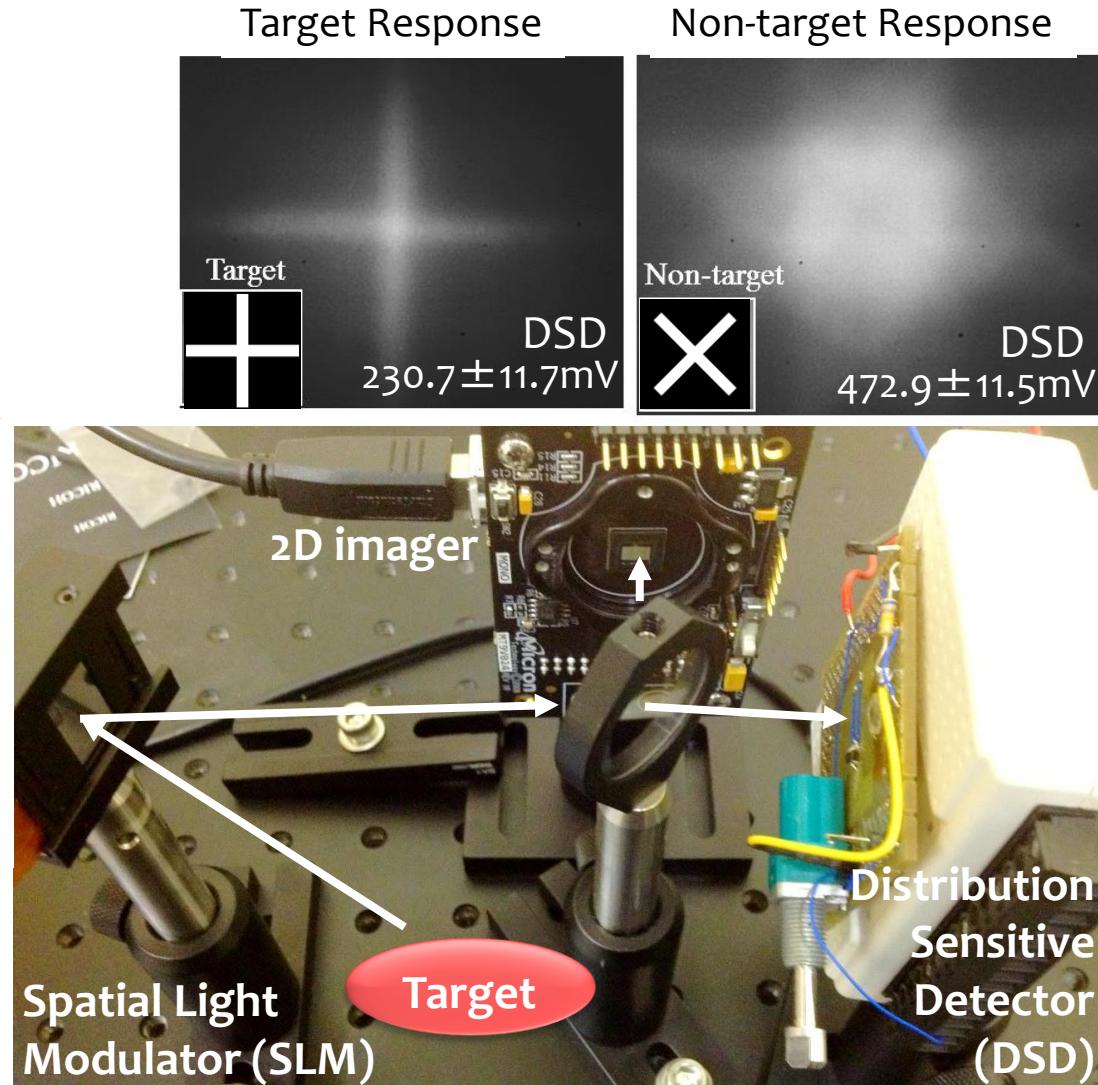
- Single pixel spot/blur classifier
 - Low current for “spot” response
 - High current for “blur” response
- Distribution Sensitivity
 - Sensitive to optical intensity distribution
 - Sensitive to optical power
 - Non-uniform distribution increases losses
 - Increased local currents
 - Homogenizers in Concentrated Photovoltaics



HoloCam Experiment

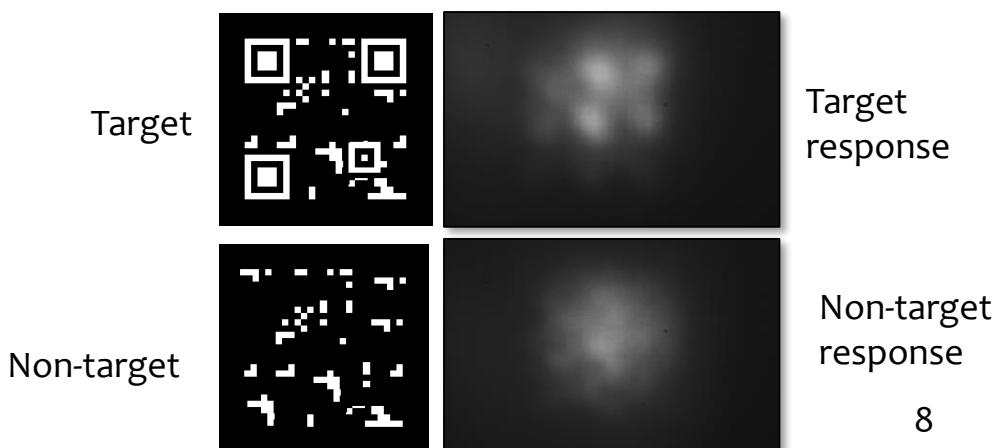
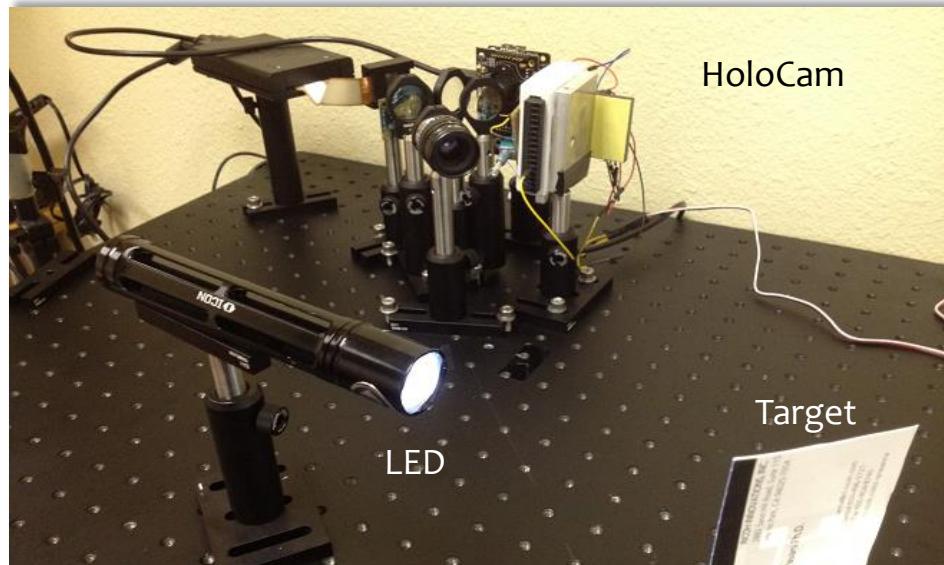


Target Hologram



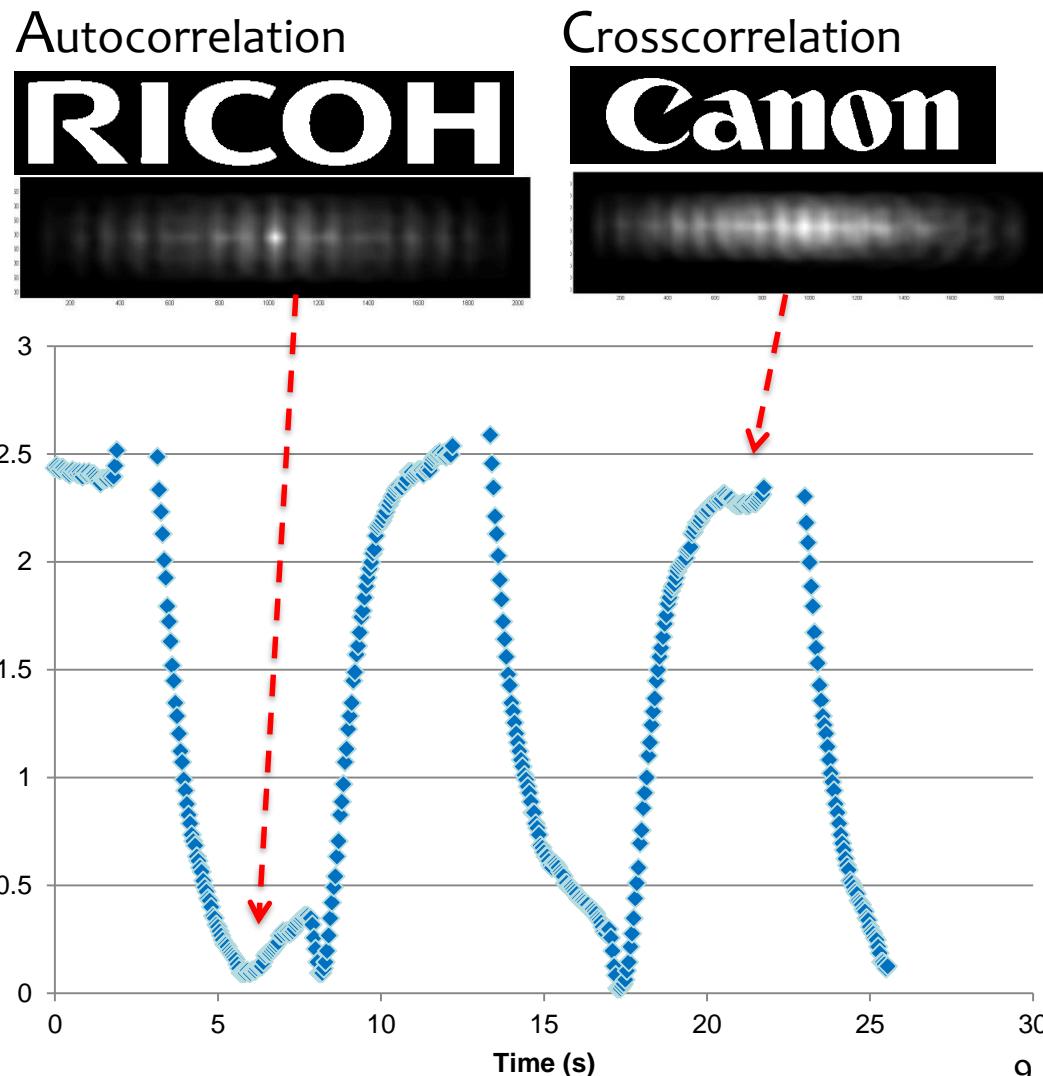
Upgraded HoloCam

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



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

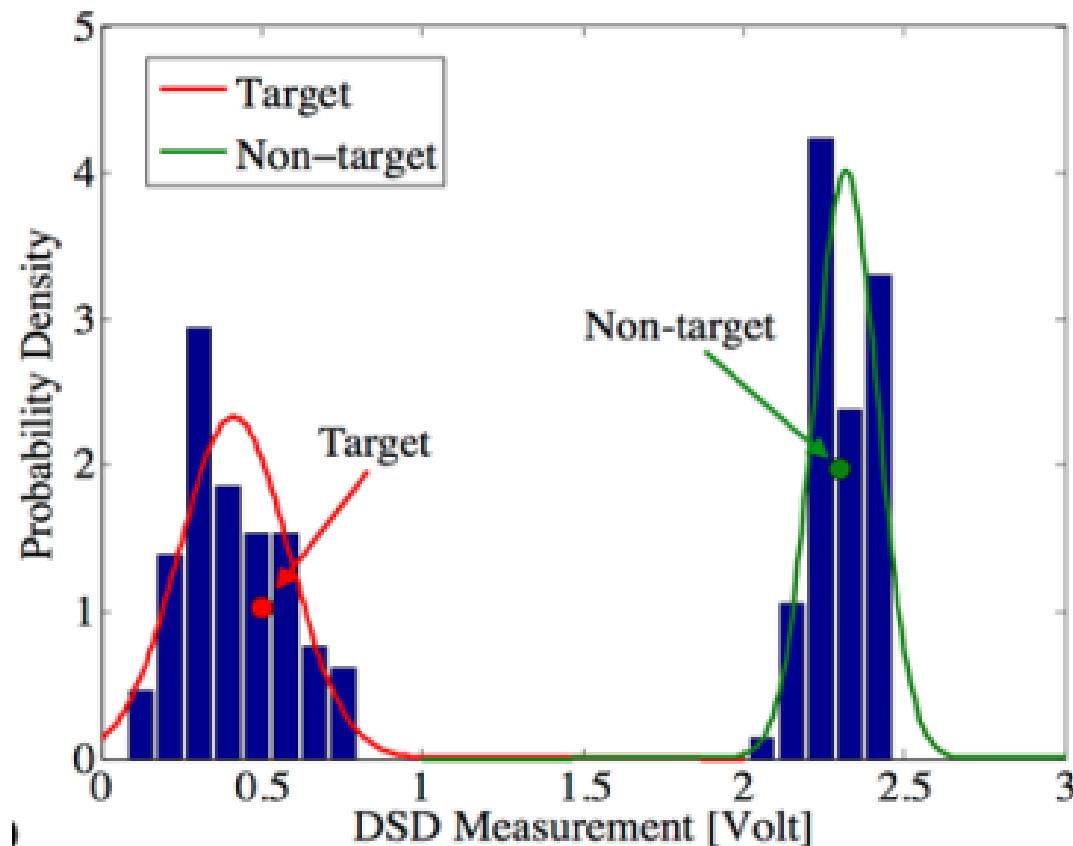


Detection Method

- Bayes decision theory
 - Two class classification problem
 - Target: Class w_1
 - Non-target: Class w_2

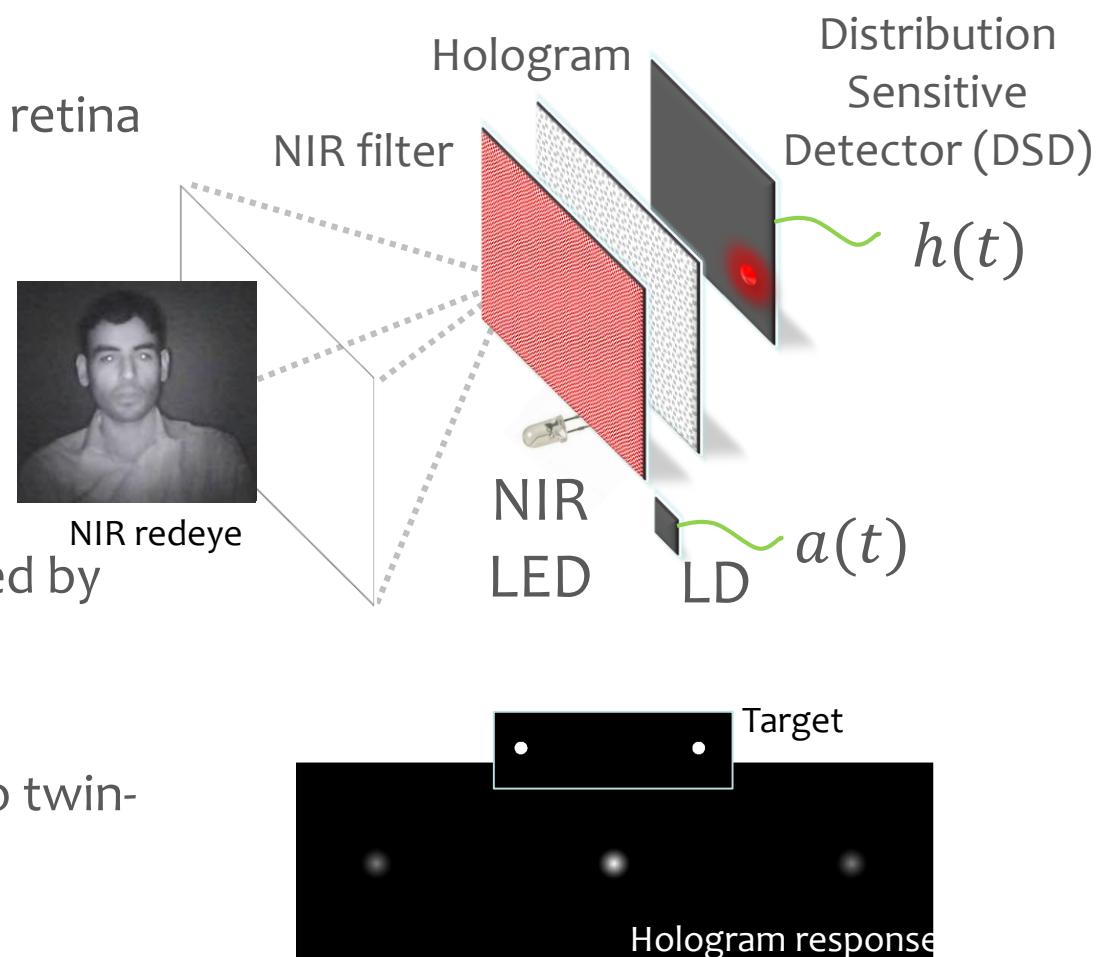
$$P(x|w_1)P(w_1) > P(x|w_2)P(w_2)$$

- x : DSD measurement
- $P(x|w_i)$ Conditional probability
- $P(w_i)$ Probability of class w_i



Eye Detection with Red-eye HoloCam

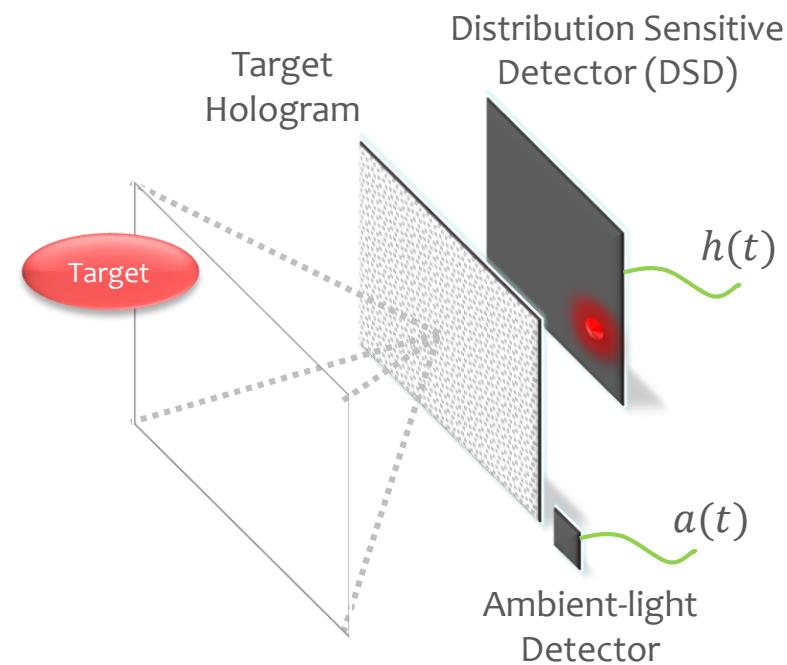
- Red-eye effect
 - Prominent appearance of retina
 - Flash close to lens
 - Most prominent in dark
 - Expanded pupil



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

Conclusion

- HoloCam: low-power target detector
 - Target Hologram
 - Distribution Sensitive Detector
 - Low-power and high speed
- Improved HoloCam to have wide field and better low-light sensitivity
- Demonstrated QR code and logo detection





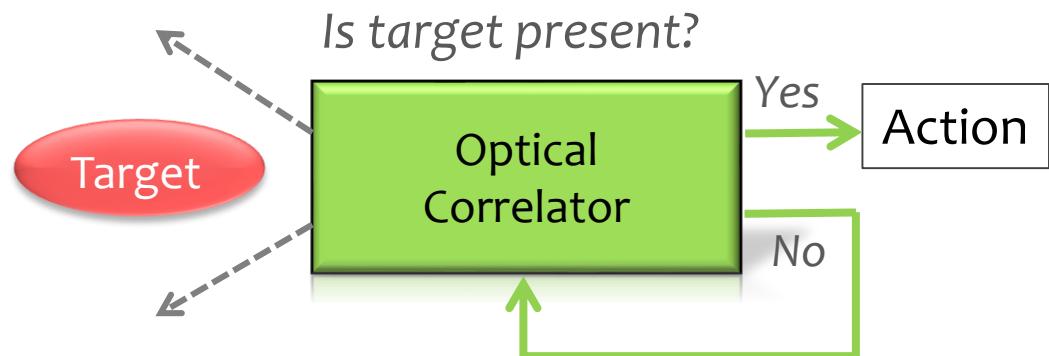
RICOH
imagine. change.

Details

Low-power target detection: Optical Correlator

- Detect target presence/absence with

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- Compact size (cm^3)
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- Applications

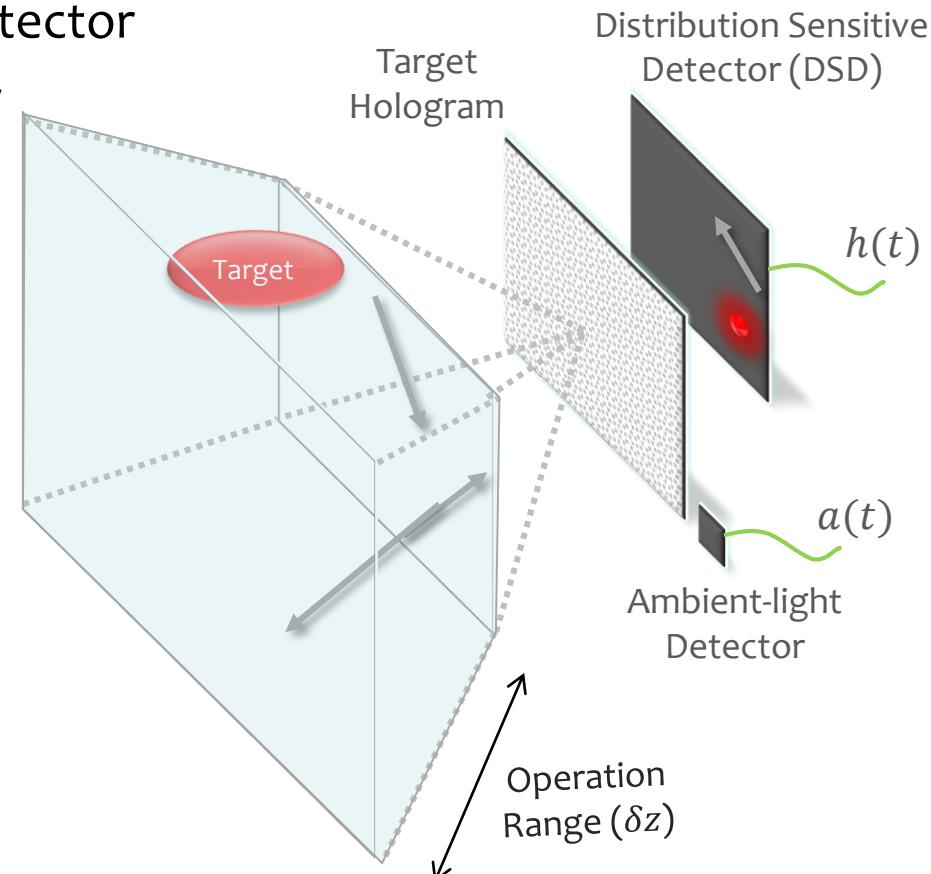
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Optical Correlator: Bulky, Alignment sensitive, Lasers

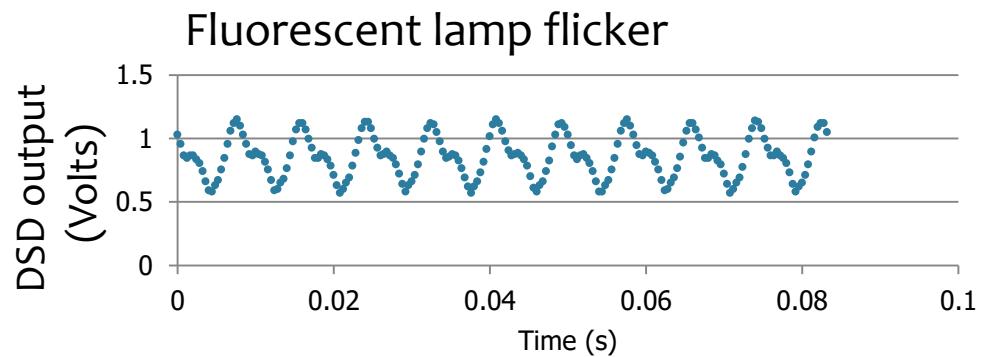
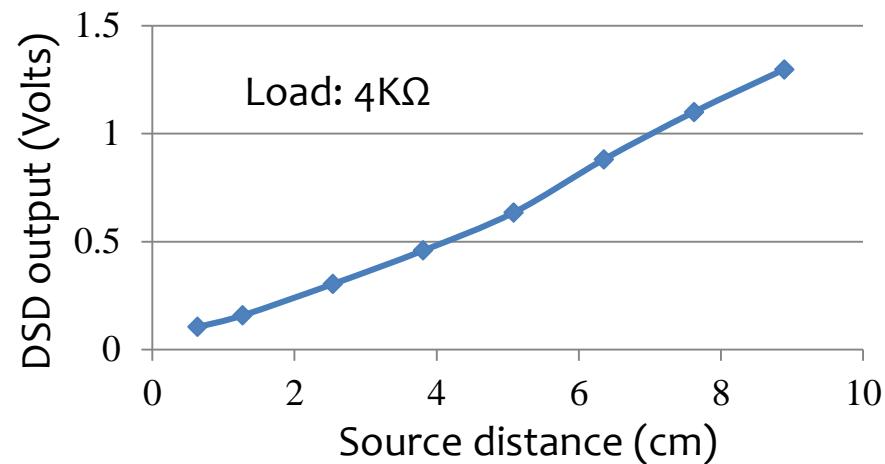
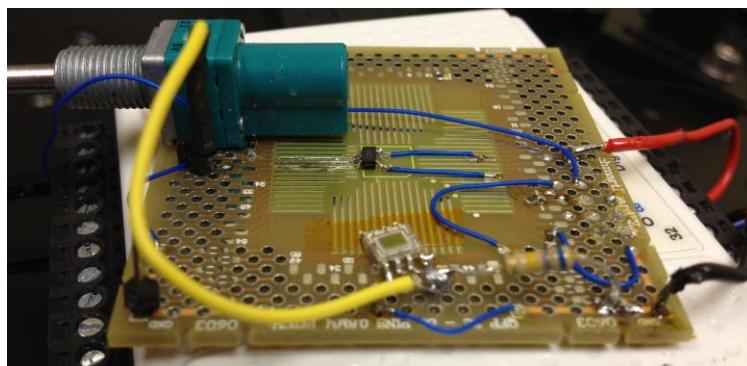
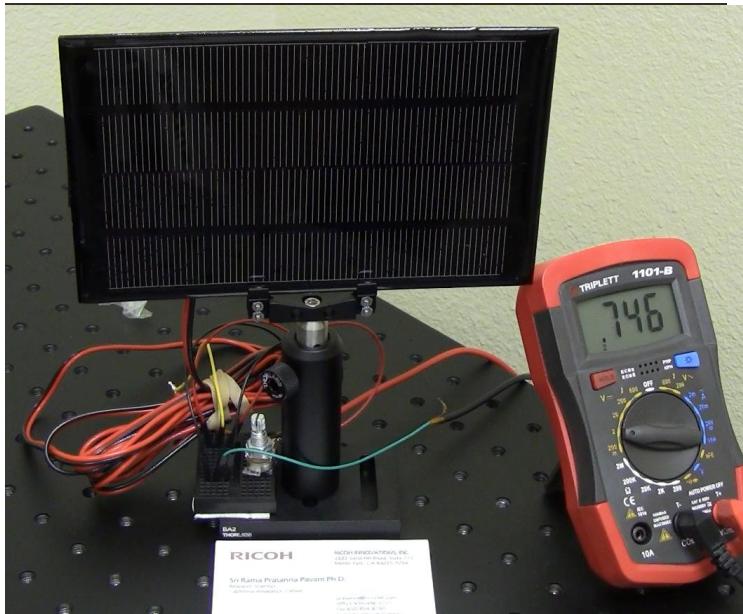
- J. D. Armitage et al., Appl. Optics 4, 461 (1965)
- Avi Pe'er et al., Optics Letters 24, 1469 (1999)
- Pierre Ambs, Adv. in Opt. Tech., 372652 (2010)

Target Detection: Wide Field of View

- Transverse space **invariance**
 - Hologram response moves on detector
 - 1cm^3 device has $\sim 50^\circ$ field of view
- Axial space **variance**
 - Change in scale and defocus
 - Operation range (δz) = kZ^2
 - $\delta z = 50\text{cm}$ for $Z = 1\text{m}$
- Multiplexed holograms
 - For scale and rotation invariance
 - For multiple targets

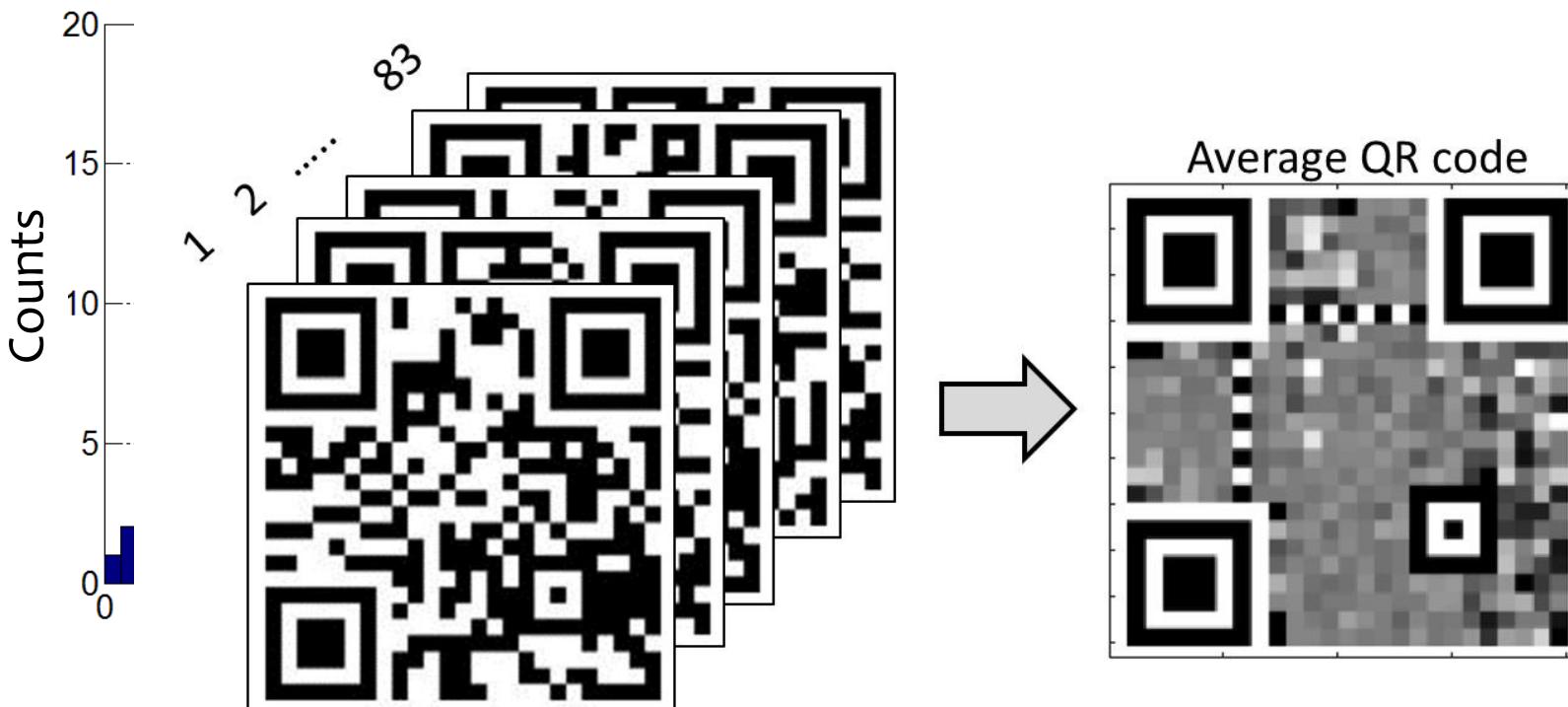


Results: Distribution Sensitive Detector



QR Code Detection (simulation)

- Detection model: $c = [1 - n \sum_x \sum_y [i(x, y) - f(x, y)]^2]$
(Normalized voltage response)



- QR code targets have c values between 0 - 0.15
- Fisher linear discriminant based classification