Non-uniformly Tiled Image Sensors with Built-in Image Compression Capability

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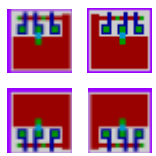
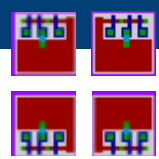


Outline

- Recap of the evaluation platform
- Preliminary test results
- Proposed work
- Qualitative discussion on the modulation transfer function (MTF)



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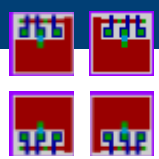


Image sensor evaluation platform architecture

- Provide power and biasing for image sensor
  - User programmable voltage and current
- Hardware interface for address and control
  - Universal connectors
- Mounting for optical system

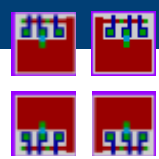
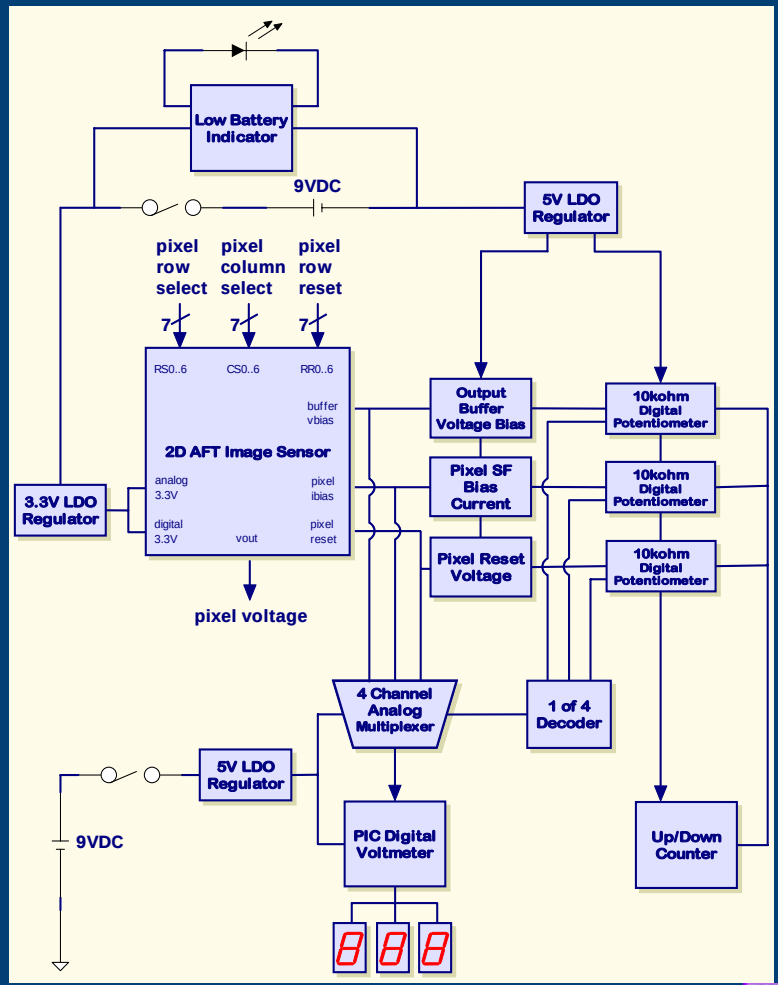


Image sensor evaluation platform block diagram



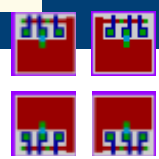


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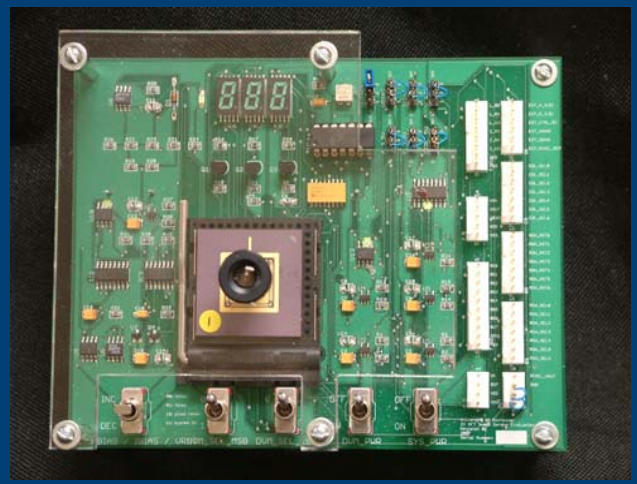
Image sensor evaluation platform (Camera)



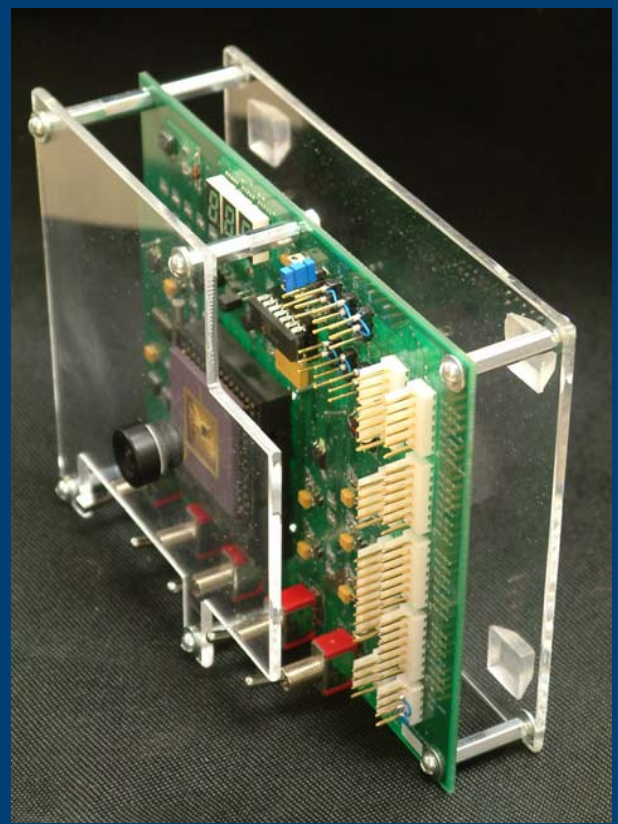


Image sensor evaluation platform (Test & Measurement)

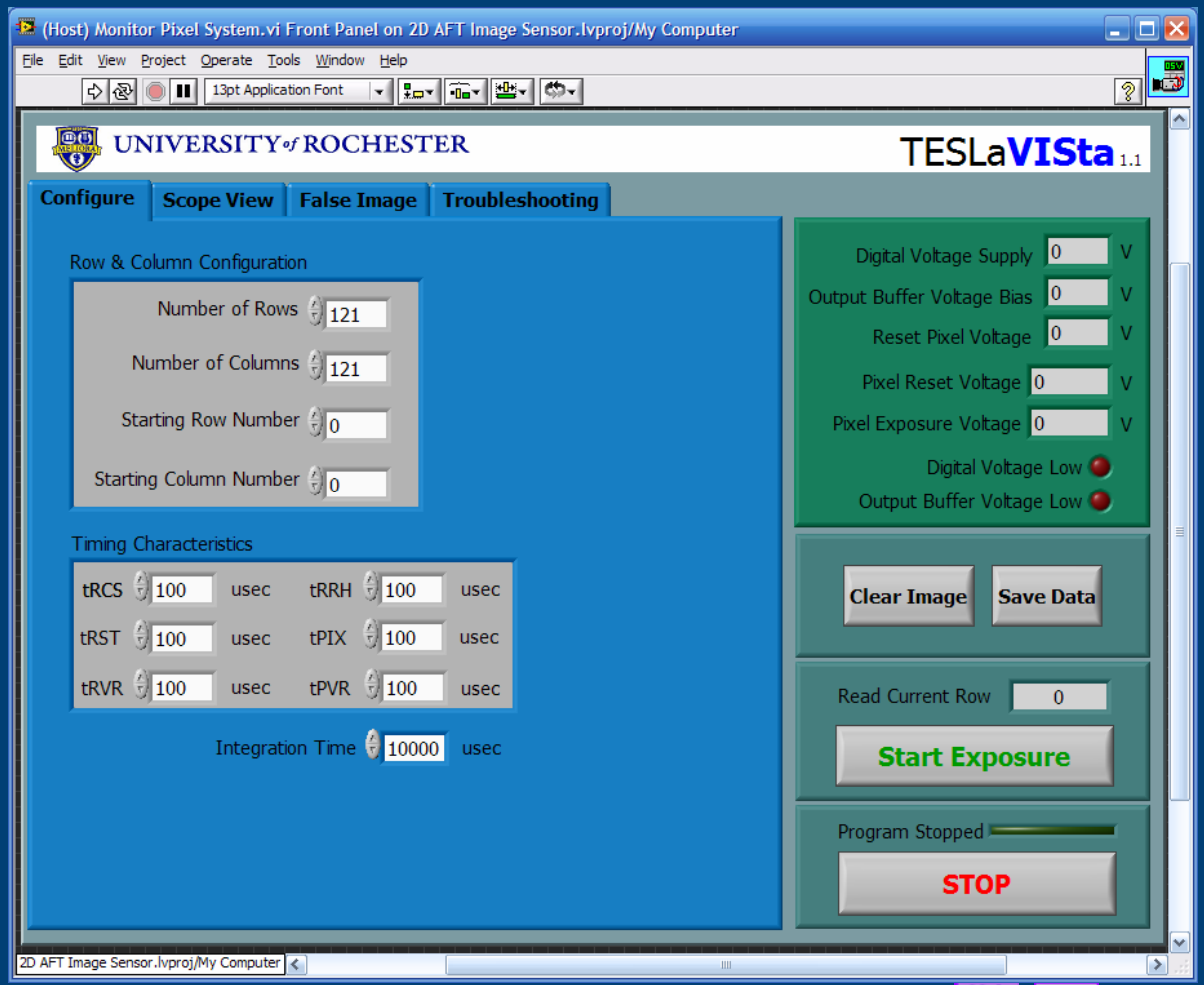
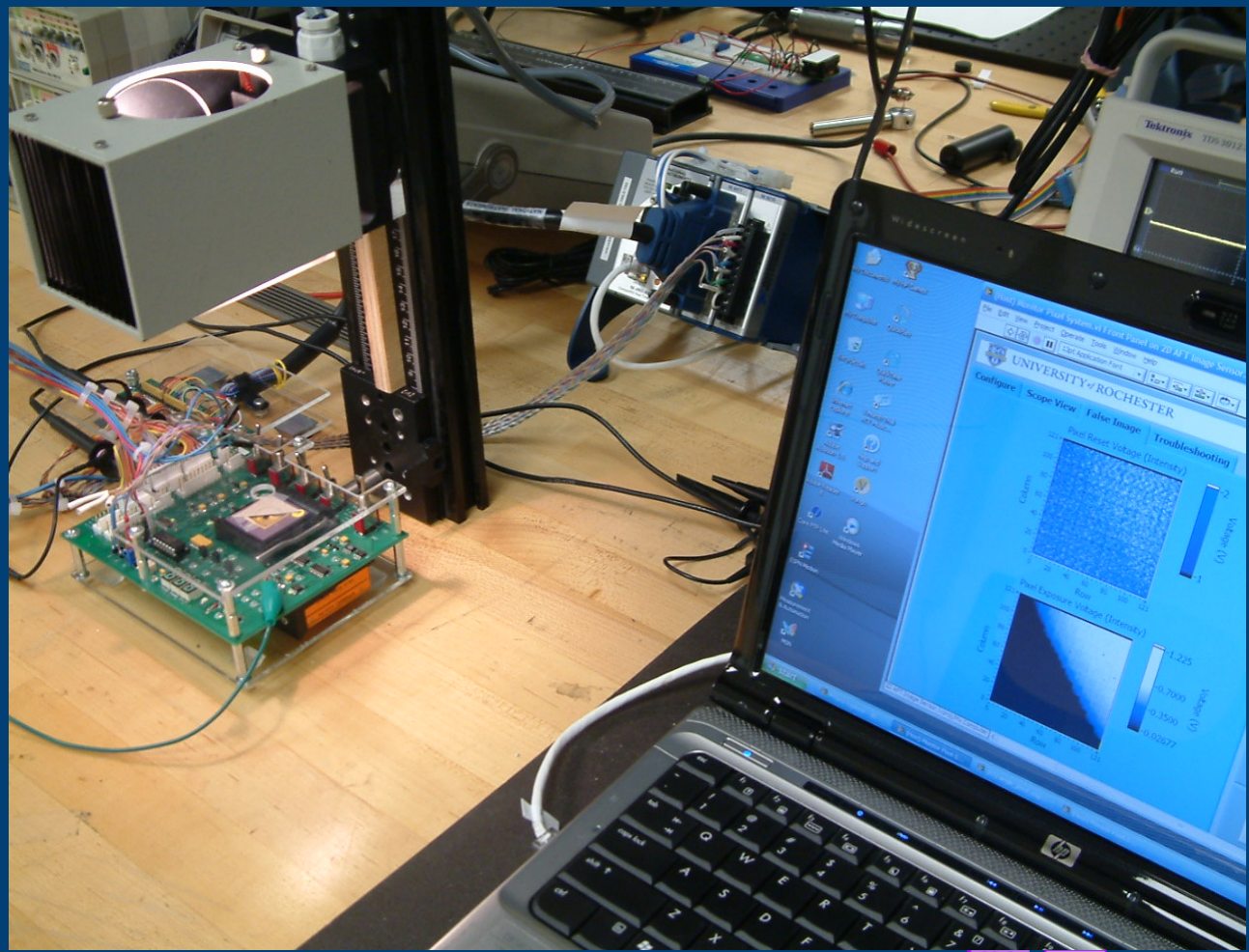


Image sensor evaluation platform (Putting it all together…)



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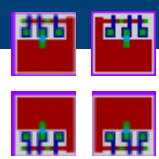
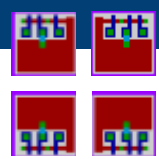


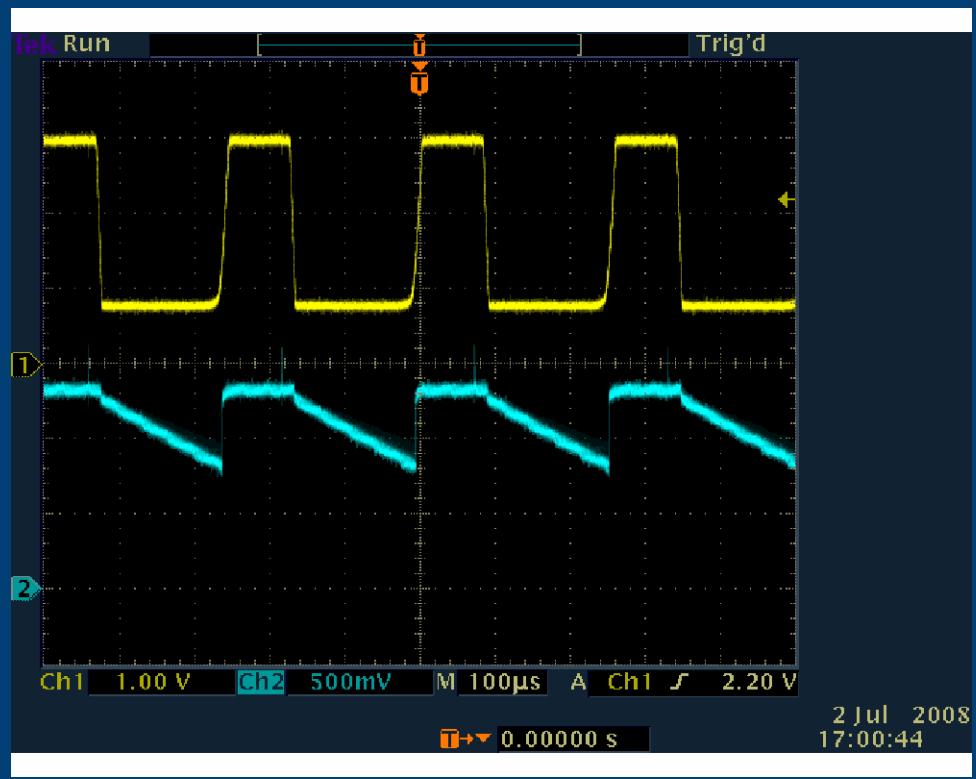
Ongoing verification results

- Fabricated silicon tests
  - Verify silicon die
  - Verify evaluation platform

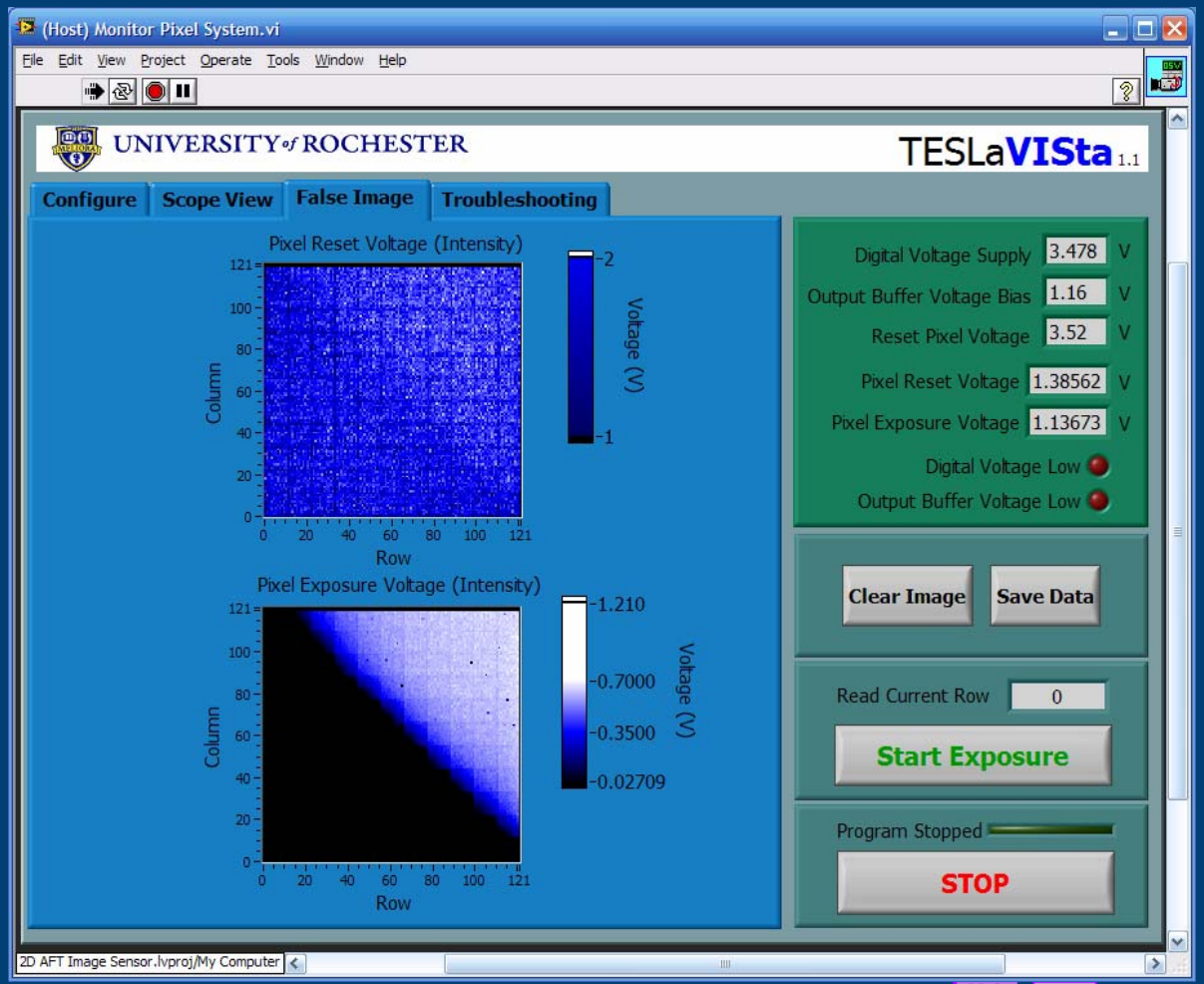


Single pixel operation cycle

- “smoke test”
- Pixel (60,60) reset and integrated
- Verify decoders, output multiplexer, output buffer and pad frame



2D AFT image sensor “raw” image



Proposed work

- Conduct in-depth testing of the image sensor
  - Images, noise, QE, MTF
- Gain better understanding of the MTF
  - Background reading
- MTF model for non-uniformed pixel array

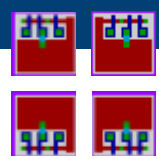
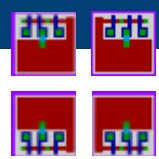


Image generation

- Implement AFT algorithm
  - MATLAB, LabVIEW
- Vary imaging parameters
  - Integration time, bias current, waveform characteristics



Noise testing

- Fixed pattern noise (FPN)
  - Illuminated: shot noise, pixel gain
  - Dark: device offset mismatches

$$FPN_{frame} = \sigma_{frame} = \sqrt{\frac{\sum_{i=1}^{M} (Pixel_i - \overline{Pixel})^2}{M-1}}$$

$$FPN_{overall} = \frac{\sum_{frame=1}^{N} \sigma_{frame}}{N}$$

Noise testing

- Read noise
  - Variation of pixel output with each readout

$$RN_{pixel} = \sigma_{RN} = \sqrt{\frac{\sum_{frame=1}^{N} (Pixel - \overline{Pixel})^2}{N-1}}$$

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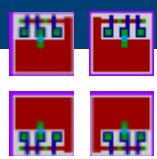
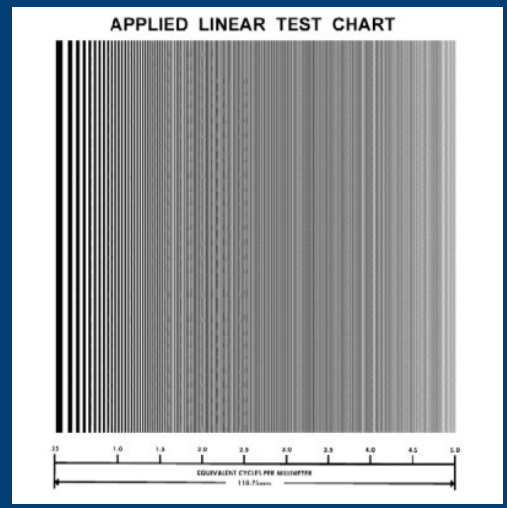
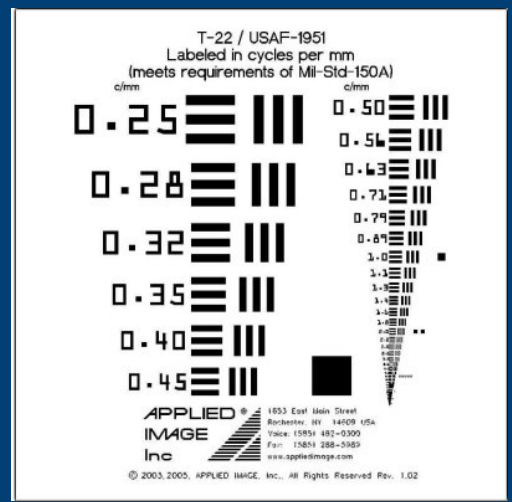


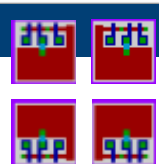
Modulation in an imaging context

- Black and white bars
- Light fully absorbed or reflected
- Square wave light waves degrade to sine waves

$$M = \frac{AC_{amplitude}}{DC_{level}} = \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}}$$



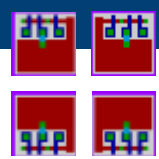




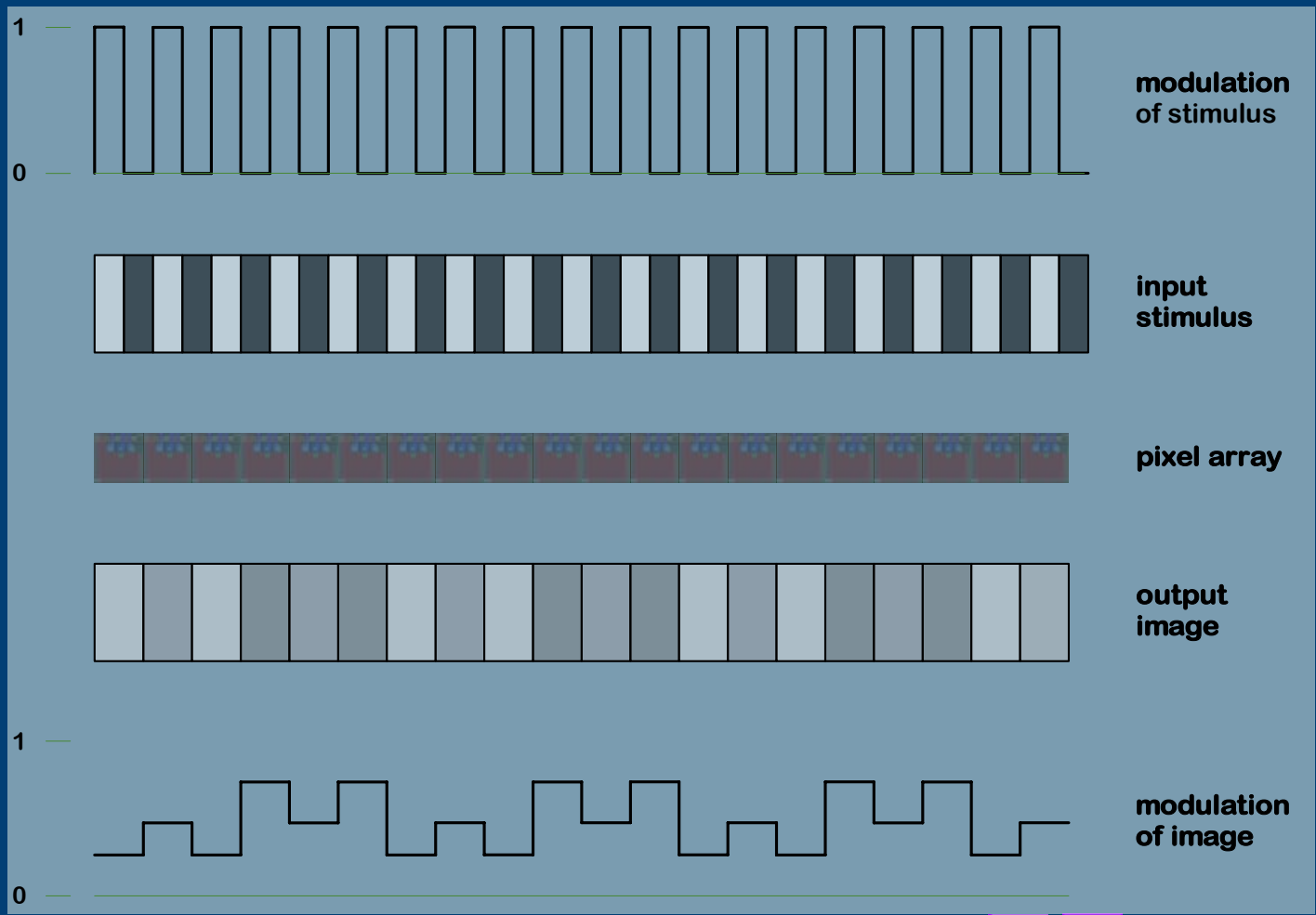
MTF

- Modulation of the stimulus and image
- Imaging a spatial frequency onto a FPA and measuring its response

$$MTF = \frac{M_{image}}{M_{stimulus}}$$

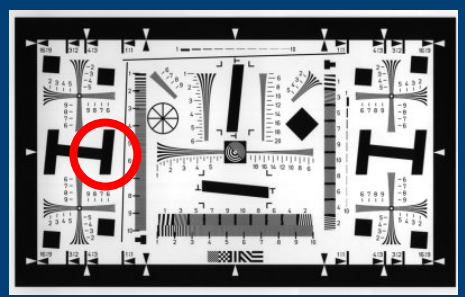


Qualitative approach to the MTF (for regularly spaced pixels)

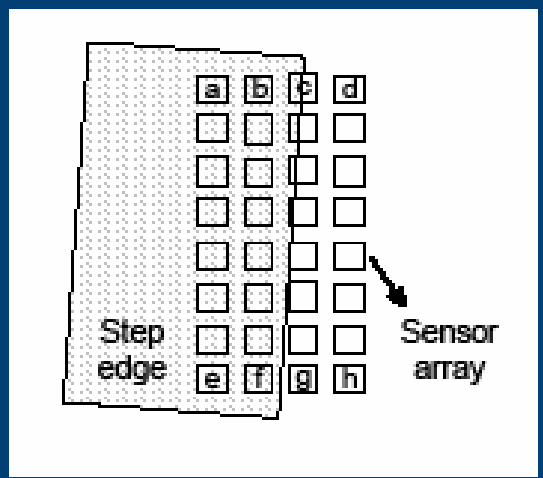


Slanted-edge method for MTF derivation

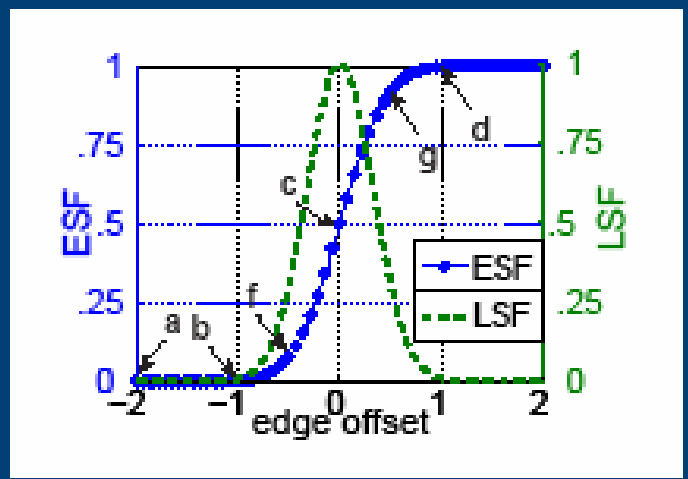
- Use of a slightly tilted knife-edge imaged onto FPA
  - Pick region of interest
  - Compute edge spread function, line spread function



ISO 12233 resolution chart



slanted edge seen by sensor



super resolved edge profile

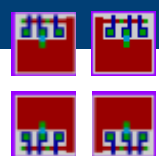
Transforming ESF to MTF

$$LSF = \frac{d}{dx} ESF$$

$$OTF = \Im\{LSF\}$$

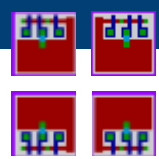
- and since $OTF = MTF e^{i\phi(f)}$
- then

$$MTF = |OTF|$$



Advantages of the slanted-edge method

- Single image is sufficient to compute entire MTF
- Optics not necessary if an edge can be placed on silicon substrate
- Reduced constraints on vertical and horizontal pattern alignments
- Fewer number of pixels required as compared to sine target method



Issue(s) still to be resolved

- How will irregularly spaced pixels respond to a slanted-edge?