SNAP SuperNova Acceleration Probe
at the University of Michigan

Towards High Precision Photometry

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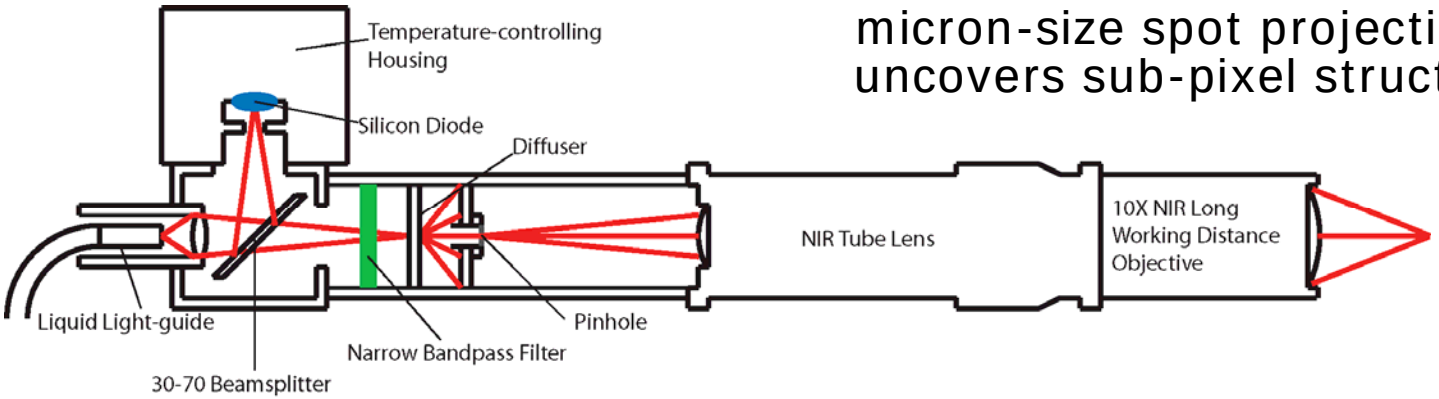
Towards High Precision Photometry



micron-size spot projection system uncovers sub-pixel structure

- Project µm-size NIR spots through dewar window onto detectors
- Measure intra-pixel sensitivity variation
  ⇒ demonstrate required photometric accuracy
- Measure lateral charge diffusion and confirm capacitive coupling measurements

List of NIR sensors

NIR sensor	Manufacturer	Specifications	QE
InGaAs	Raytheon	Virgo 1k	70-80%
HgCdTe	Raytheon	Virgo 598141	80%
HgCdTe	Rockwell	H2RG #102	90-95% w/AR coat
HgCdTe	Rockwell	H2RG # 40	70%
HgCdTe	Rockwell	Banded Array #25	20-30%

Spotomatic

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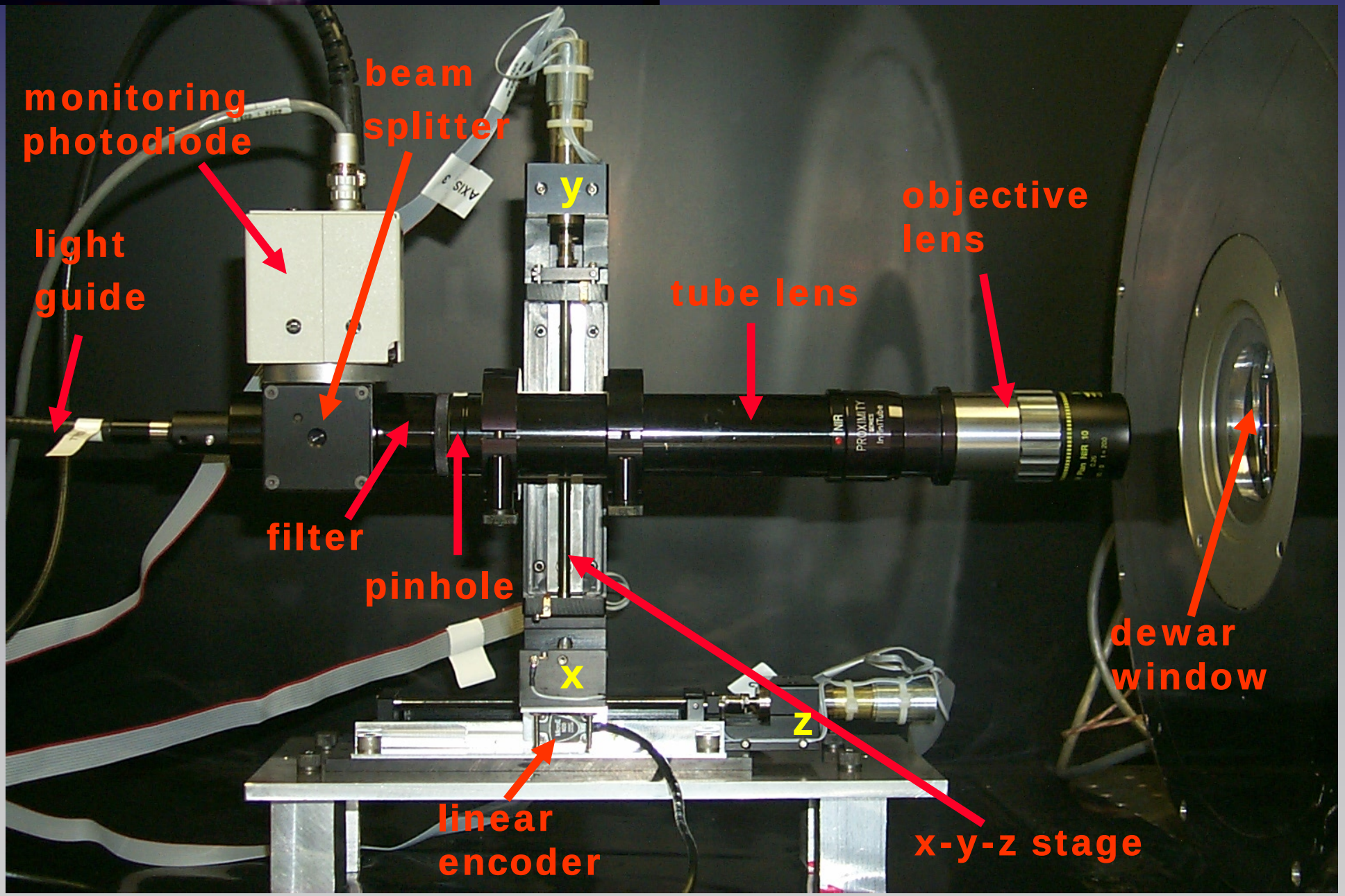


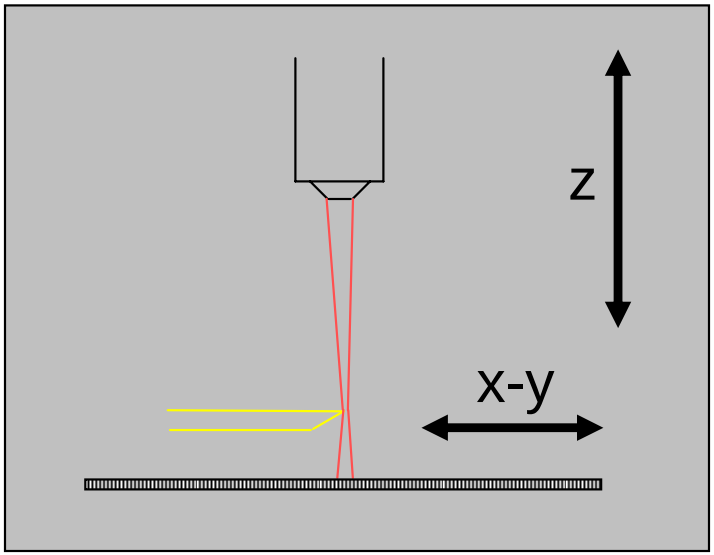
Brief History

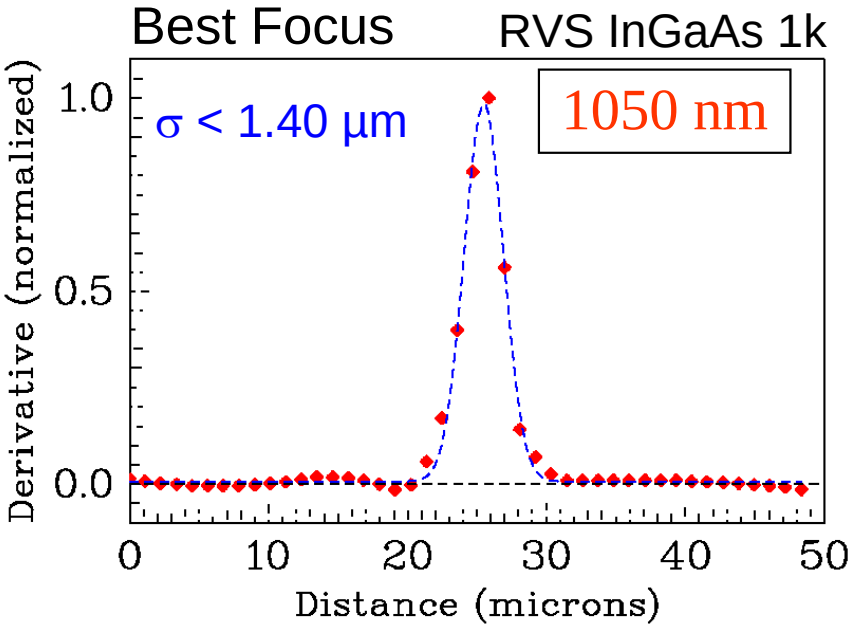
SNAP SuperNova Acceleration Probe at the University of Michigan

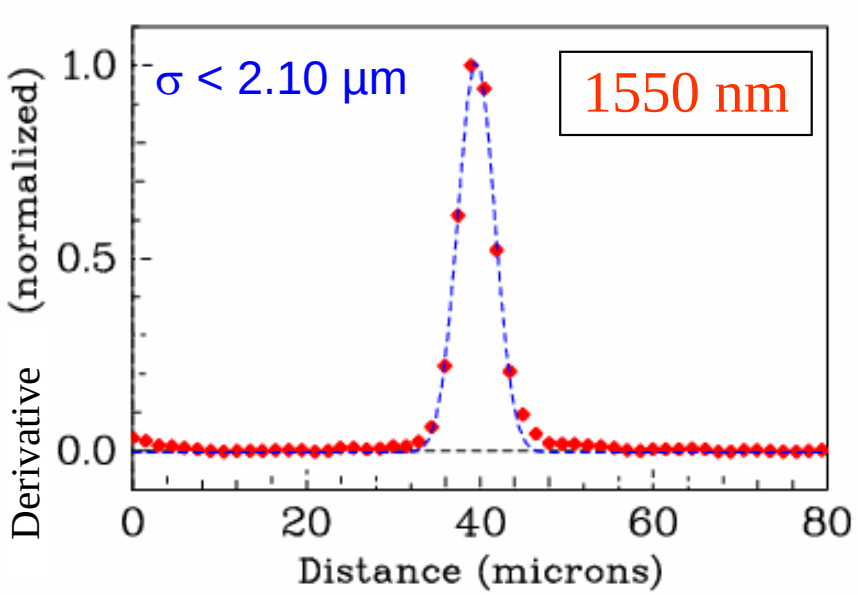
- Start
  - REU Summer 2003 project (M. Borysow)
  - base initial design on LBL pinhole projector (visible)
  - adapt for NIR and improve design (senior thesis project: W2004)
- Improvements
  - REU Summer 2004 project (N. Barron)
  - installed linear encoder on z-axis
  - improve motion control and analysis software (M. Borysow)
- Characterization of NIR devices
  - line-spread functions (LSF)
  - one and two dimensional pixel response functions (PRF)
  - multiple pixel scans (honors thesis project: W2005)
- **Results for RVS and RSC devices**
  - lateral charge diffusion (M. Brown)
  - capacitive coupling
  - photometry simulations (–> publication)

Characterizing beam spots

- A knife edge is placed ~3 mm above the detector surface
- Spot-O-Matic is scanned across knife edge in x-y while focusing in z to minimize the spot size and determine the line spread function (LSF)

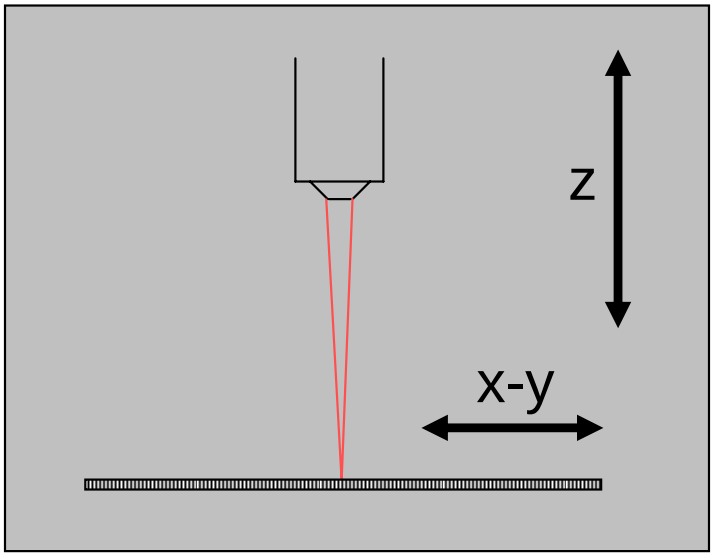




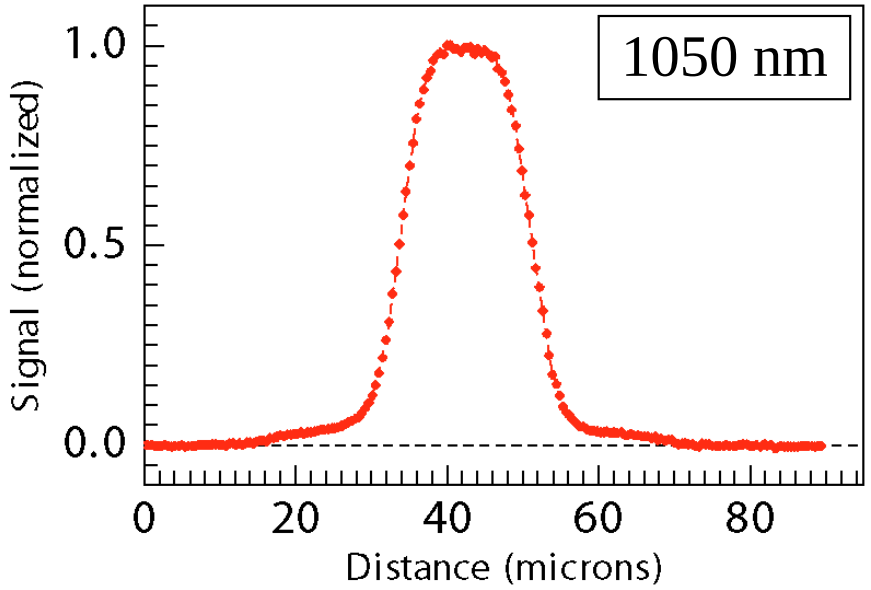


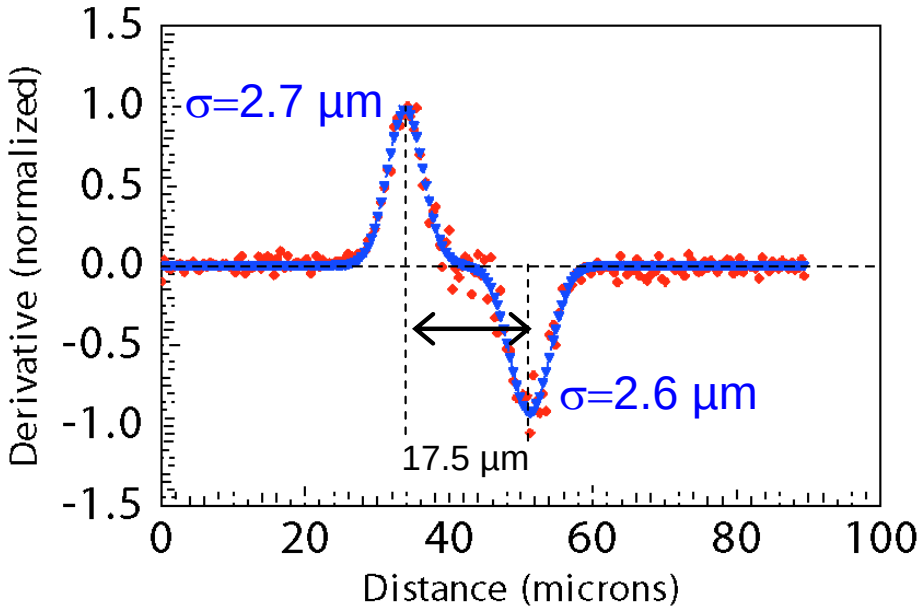
Characterizing pixels

- Virtual knife edge scans (pixel boundary) used to focus Spot-o-Matic onto detector surface
- Intensity profile is a 1-dim convolution of Spot-o-Matic LSF with pixel response function
- Edge transition is increased from the σ = 1.4 μm spot size obtained from the knife-edge scan

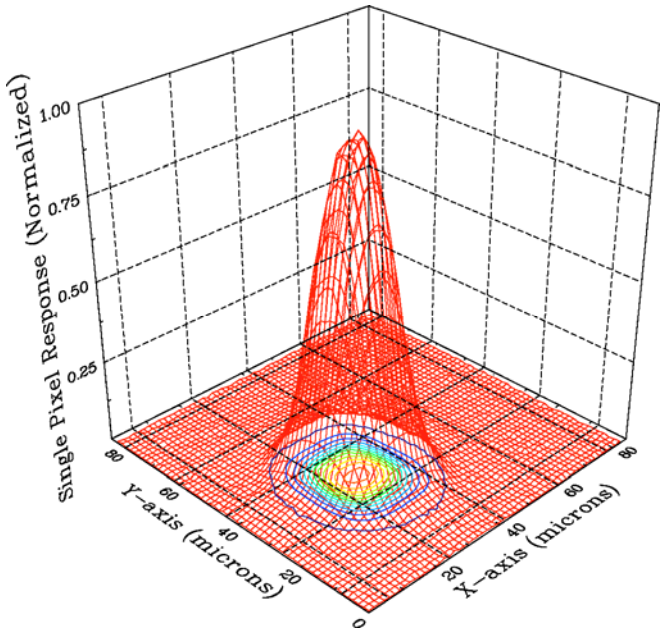


RSC H2RG #102





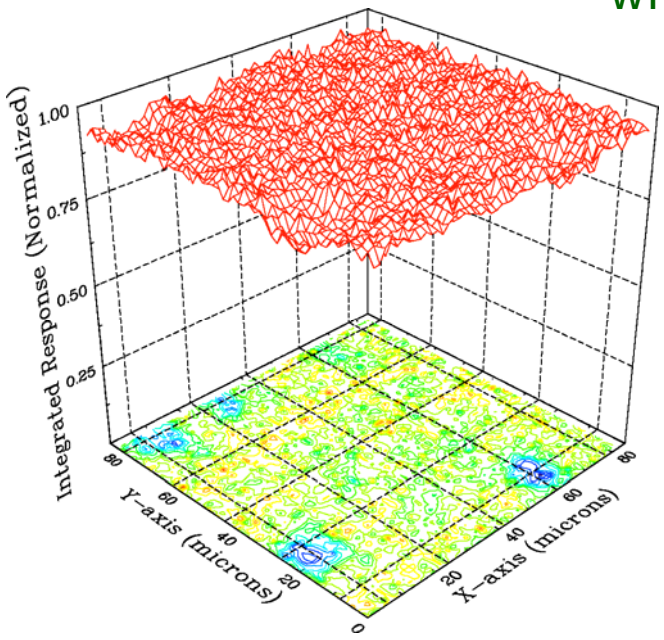
Pixel Response Profile (RSC H2RG #102)

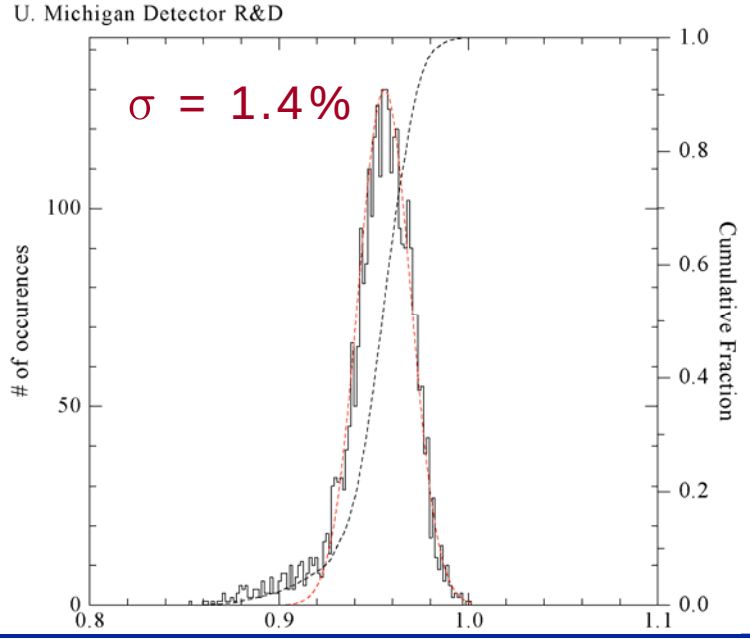


2D scan at best focus. Pixel scan is convolution of the PRF with the PSF of the spot

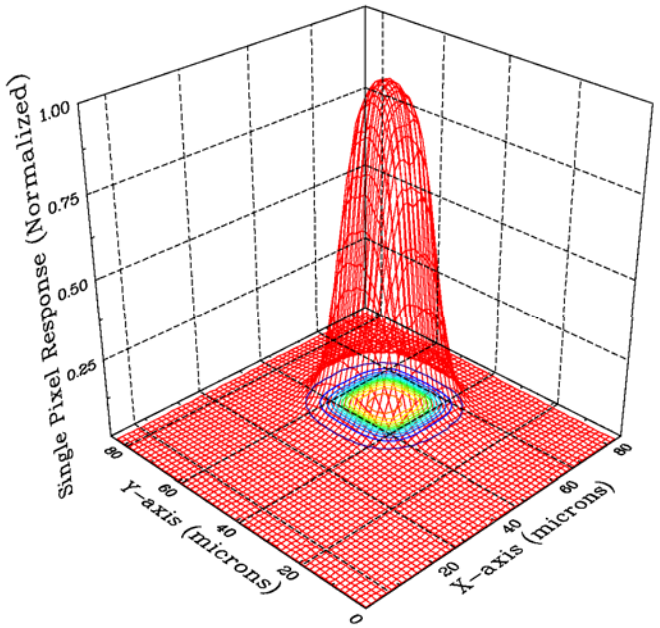
single pixel response is generally very uniform

summing pixels gives a smooth response, with dips tending to fall on pixel boundaries





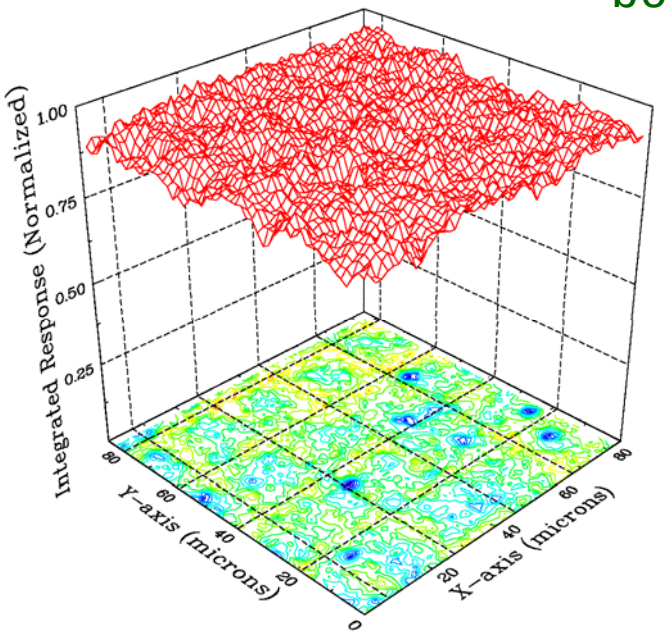
Pixel Response Profile (RVS 141SR)

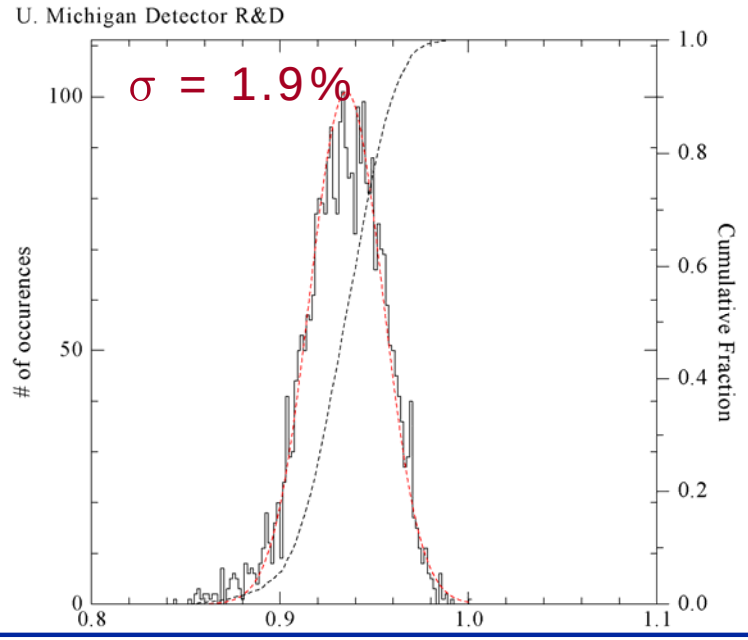


2D scan at best focus.

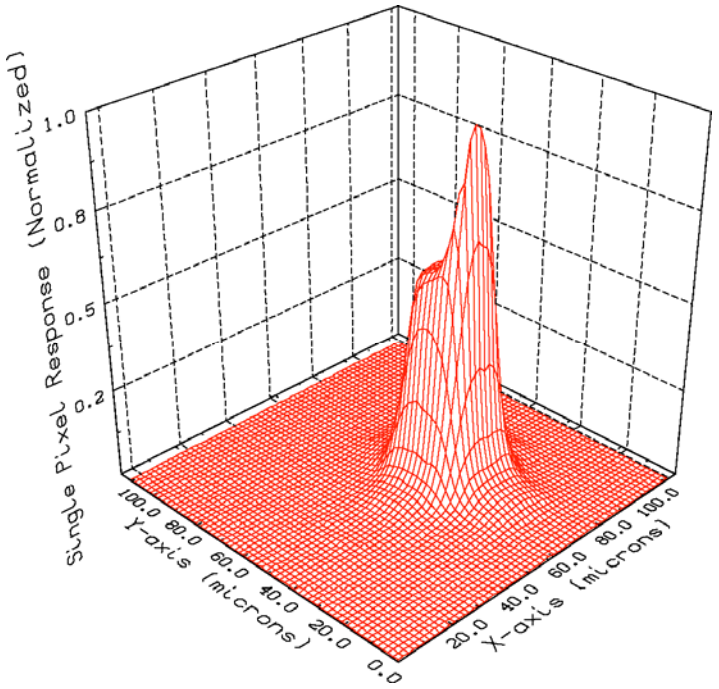
single pixel response is very uniform

summed pixels also gives a smooth response, with dips tending to fall close to pixel boundaries





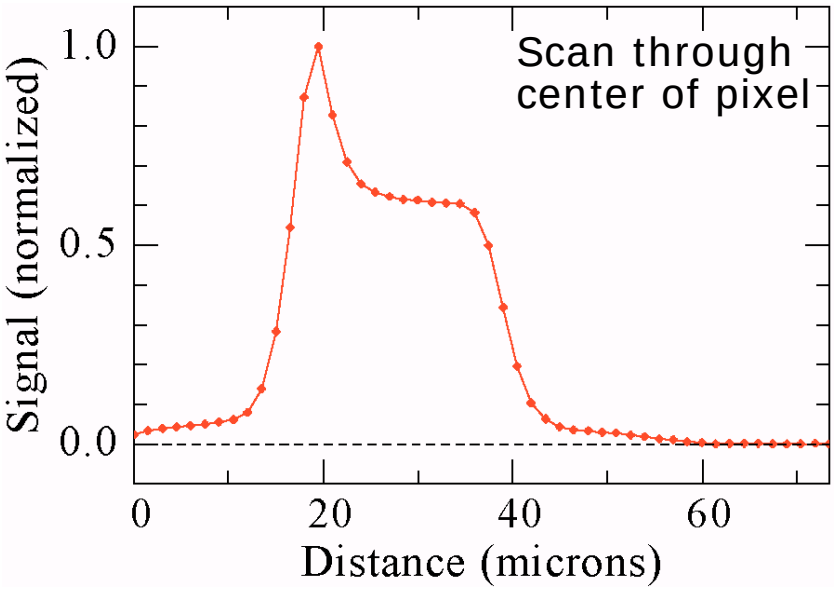
Intra-Pixel Variation

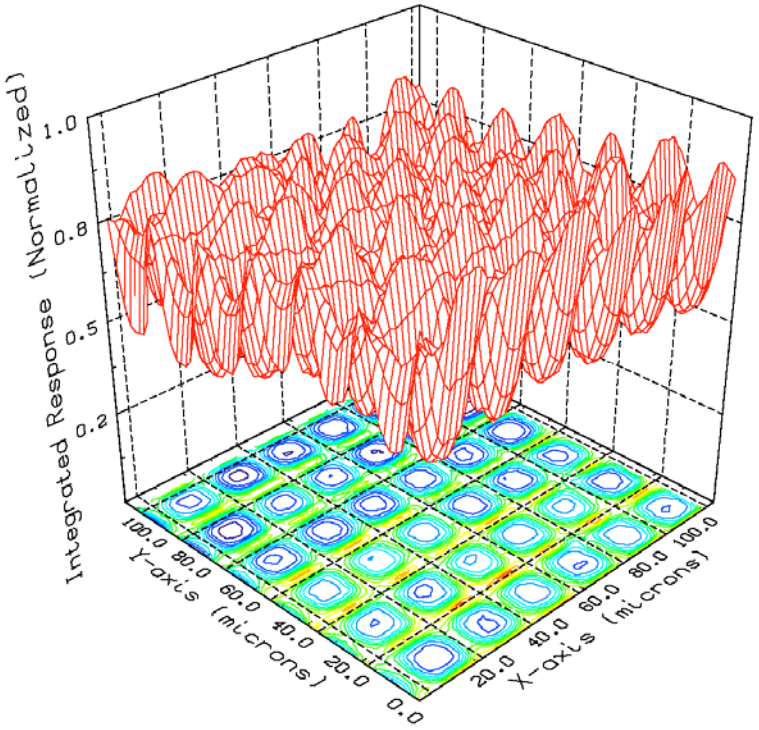


H2RG #40 (RSC) with anomalous substructure

appeared to be perfectly fine detector:

- 70% QE, 35 e^- read noise, 0.05 e^-/px/s DC

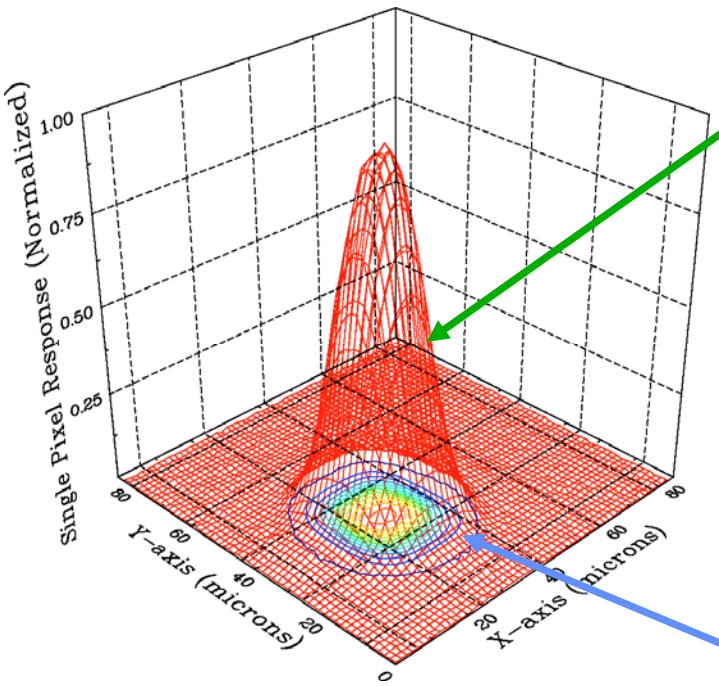




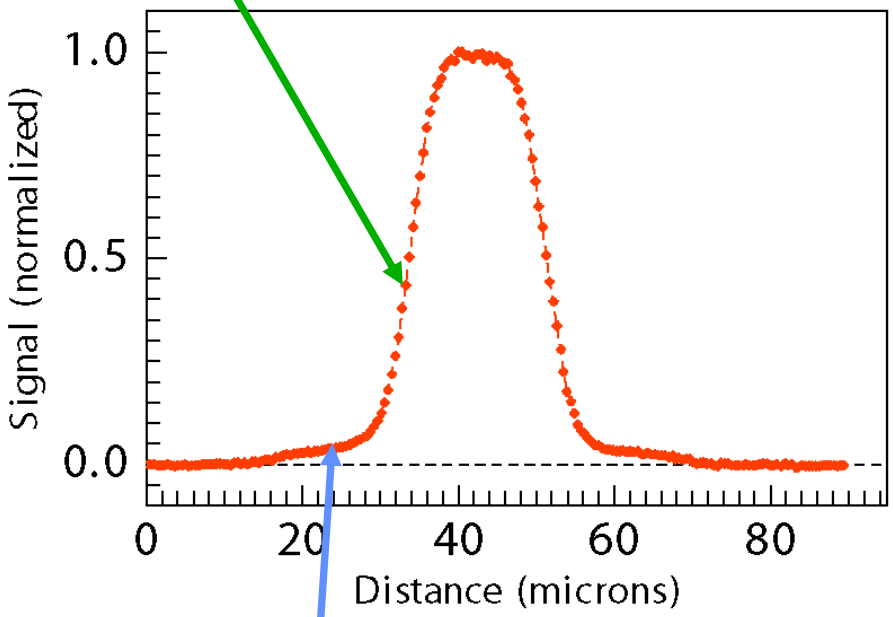
Effect on photometry under study!

Pixel Response

RSC H2RG #102



lateral charge diffusion
random, occurring prior to charge collection



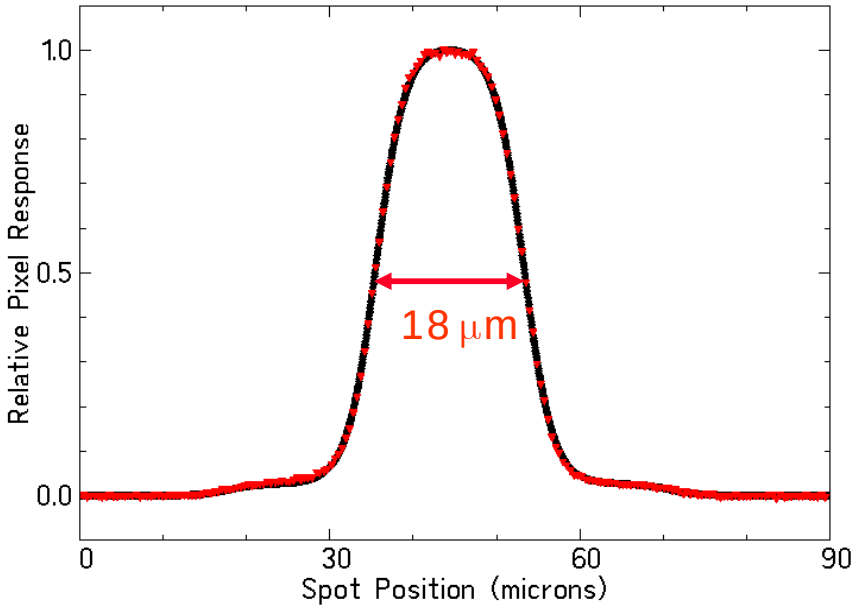
- PRF is uniform over pixel surface
- PRF extends beyond pixel boundary
  - lateral charge diffusion
  - capacitive coupling
  - higher order rings of Airy disk (~0.25% contribution)

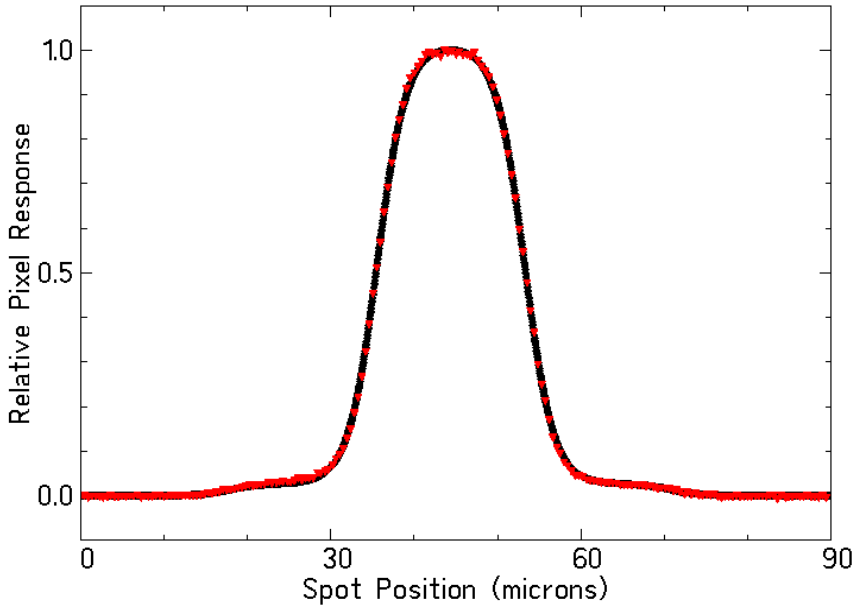
capacitive coupling
deterministically moves charge after charge collection

de-convolution necessary to determine PRF, charge diffusion, capacitive coupling

“De-convolution”

RSC H2RG #102





start with square PRF (18 μm)

convolve with PSF (1.4 μm)

add charge diffusion (1.7±.02 μm)

add capacitive coupling (2.2 ±.1%)

compare to data

let’s fit also the pixel width:

square PRF (17.8 ± .1 μm)

PSF (1.4 μm)

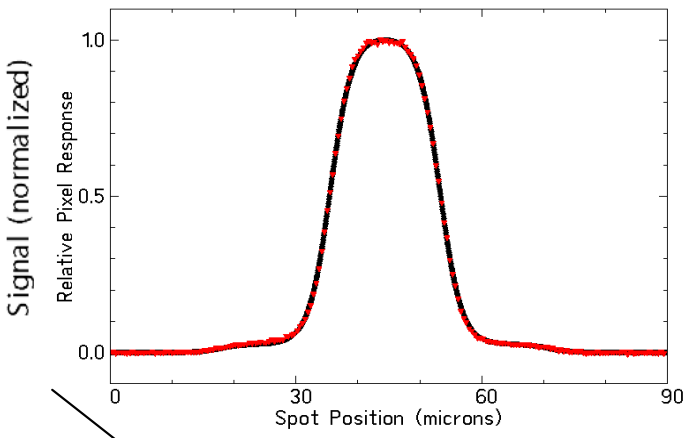
charge diffusion (1.7 ± .02 μm)

capacitive coupling (2.4 ± .1%)

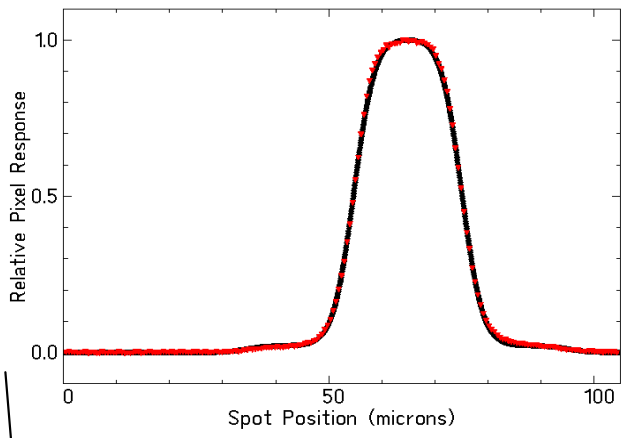
published value: 2.2 ± .1%

Comparison of NIR sensors

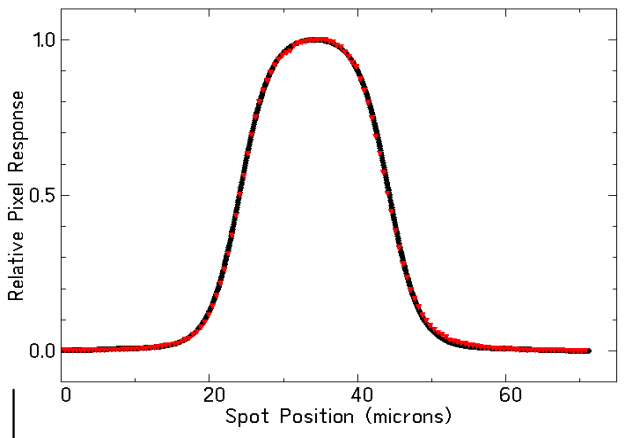
RSC H2RG #102 (1050 nm)



RVS Virgo 598141SR (1550 nm)



RVS InGaAs (1050 nm)



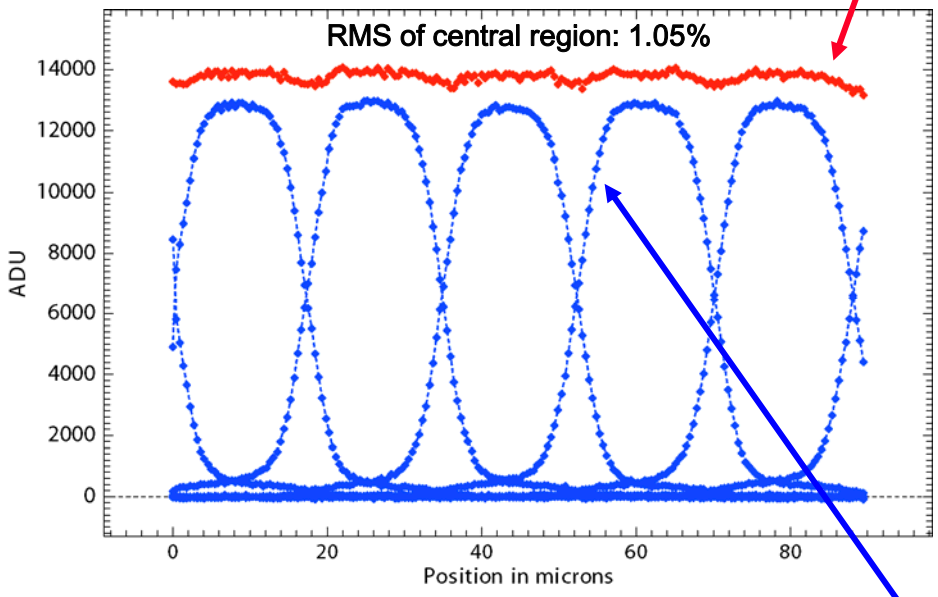
Pixel size	**18 μm** (17.8±0.1 μm)	**20 μm** (20.3±0.1 μm)	**20 μm** (20.0±0.1 μm)
LSF	**1.4 μm**	**2.1 μm**	**1.4 μm**
diffusion	**1.68±0.02 μm** (1.71±0.02 μm)	**1.69±0.05 μm** (1.62±0.04 μm)	**2.26±0.02 μm** (2.3±0.02 μm)
capacitive coupling (published)	**2.24±0.1%** (2.38±0.1%) 2.2±.1%	**2.09±0.1%** (1.96±0.1%) 1.25±.1%	**0.7±0.1%** (0.7±0.1%) 0.5±.1%

Intra-Pixel Variation in 1D

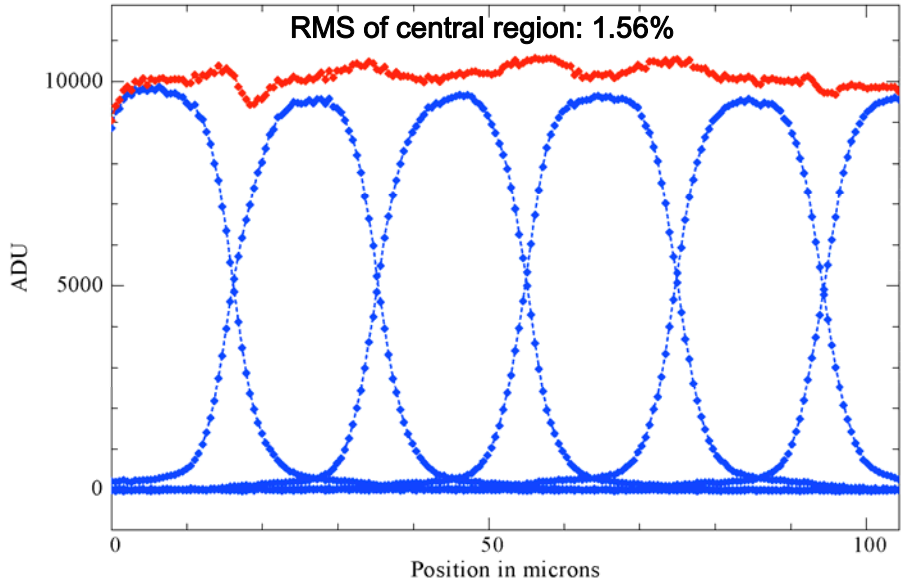
scan over 7 adjacent pixels

summed response of inner 5 pixels

RSC H2RG #102 (1050 nm)



RVS Virgo 598141SR (1550 nm)



response of individual pixels

- simple addition of adjacent pixels restores photometry to better than 2%
- Spot-o-matic can detect sensitivity variations at percent level or below

Conclusions

- Spot-o-Matic has turned into a reliable tool
- Detailed comparison among two vendors now possible
- InGaAs and HgCdTe devices show a very flat pixel response with ~2-3 μm edge effects dominated by diffusion
- A simple addition of adjacent pixels restores photometry to better than ~2%
- Will turn our attention to
  - effect of intra-pixel variations on photometry
  - publish Spot-o-Matic paper this summer