FUV Detector System Performance Verification

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FUV PERFORMANCE REQUIREMENTS

- COS FUV Detector performance requirements given in document COS-08-0003 (Statement of Requirements)
  - Quantum Efficiency both in and out of band
  - Spatial Resolution
  - Spatial Linearity
  - Dark Count Rate
  - Maximum Global and Local Count Rate
  - Deadtime Performance
  - Detector Lifetime

- Performance Verification Test Plan in COS-UCB-006
- Verification done with standard and specialized test procedures throughout detector system build.

FUV Performance Requirements (cont)

Item	Performance Requirement	SOR
Image Quality		
Spatial resolution	<(25 μm x 50 μm) FWHM over 80% of active area	3.7
Integral non-linearity (≥ 1mm frequency)	<±100 μm over 80% of active area	3.8.1
Differential non-linearity (<1mm frequency)	Characterize to 3.2% RMS (Flat field at 166 cts /pixel)	3.8.2
Thermal spatial stability	<±3.3 pixels/°C (DVA), ±1.7pixels/°C (DEB)	3.15
Flat field stability	≤1% RMS per resel over ≥ 80 mm by 0.5 mm	3.16
Detection Efficiency		
Quantum efficiency (QDE)	≥ 25% @ 1335Å,19% @ 1463Å, 17% @ 1560Å	3.5
Visible light rejection	QDE<10^{-6} @ 4000Å to 6500Å	3.5.2
Deadtime efficiency loss	10% QDE loss at 10 kcps per segment 60% QDE loss at 100 kcps per segment	3.13
Non Active Area Scatter	No (Ly α) scattered photons from MCP gap	3.6.1
Event Rates		
Dark count rate (at I&T)	<0.5 cps/cm^2	3.9
Maximum global count rate	≥40,000 cps/segment	3.11
Maximum local count rate	5 cps/pore over 10^3 μm^2 (81cps/10^3 μm^2)	3.12
MCP Fluence Life	>10^9 events per mm^2	3.14

COS Detector Performance Verification Test Matrix

Vallerga 10/30/00

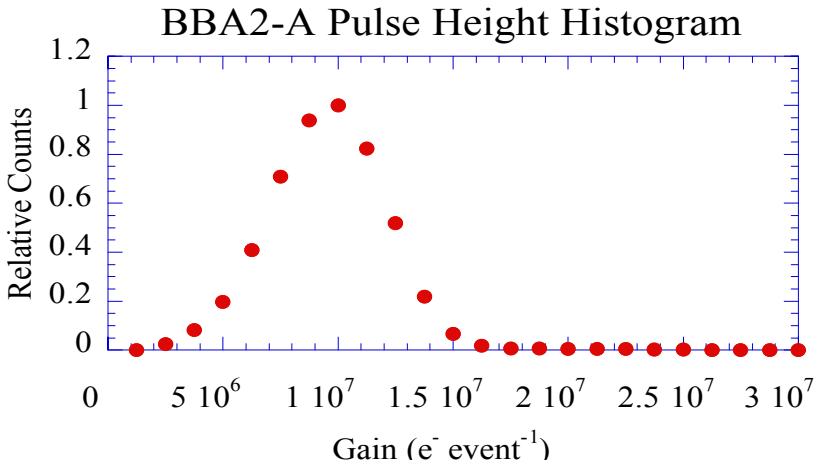
Requirement	Description	Qualified by Analysis	Qualified by Test	After photocathode	Test Procedure: Gain/PHD vs. Voltage	Background rate image	Flat field	Resolution/Linearity Mask	QDE vs l and q	MCP Lifetime test	Deadtime Calibration	Resolution/UV Microscope	Facility: Test Chamber	QE Calib. Tank	DVA	Date passed	Report #
SOR 3.2	Pixel Format	X															
SOR 3.3	Digitized pixel Scale		X		X		X	X					X				
SOR 3.4	Wavelength Range	X															
SOR 3.5	Quantum Efficiency		X	X	X	X	X		X					X			
SOR 3.5.1	Grid Shadowing		X	X			X		X					X			
SOR 3.5.2	Visible Rejection		X	X		X	X		X					X			
SOR 3.6.1	Non-Active Area		X			X	X		X					X			
SOR 3.7	Spatial Resolution		X		X	X		X					X				
SOR 3.8	Spatial Linearity		X		X	X		X					X				
SOR 3.9	Dark Count Rate		X	X	X	X									X		
SOR 3.10.1	Dead spots		X	X			X							X			
SOR 3.10.2	Hot spots		X	X		X	X								X		
SOR 3.11	Max. global rate		X		X		X						X				
SOR 3.12	Max. Local ct. rate		X		X			X					X				
SOR 3.13	Deadtime Performance		X								X		X				
SOR 3.14	MCP Lifetime		X	(Proxy MCPs)						X			X				

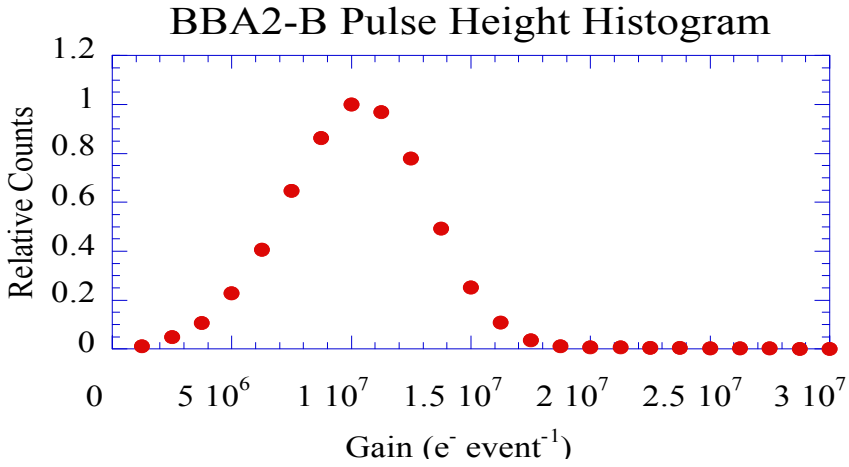
COS Detector Test Flow Plan

- Select MCP stacks
  - Gain uniformity and PHDs *
  - Background and stability *
  - Flat Field response *
  - QE test (bare) *
- Assemble Flight Detector
  - Gain uniformity and background *
- Pinhole Mask tests
  - Set rear field, trim and walk *
  - Resolution test *
  - Spatial linearity test *
  - Local rate test
- Flat Field tests
  - Global rate test *
  - Deadtime test *
  - Dead spot test *
  - Stability test
- Deposit Photocathode
- QE Calibration
  - QE (absolute,angle,position)
  - Visible Rejection test
  - Grid shadow test
  - Non-Active area scattering test
- Final configuration and install in DVA
- Environmental tests (Part 1)
- UV scrub
- Dark rate test/Hot spots *
- Final Flight Config. Flat Field
  - Duration TBD
- Environmental tests (Part 2)

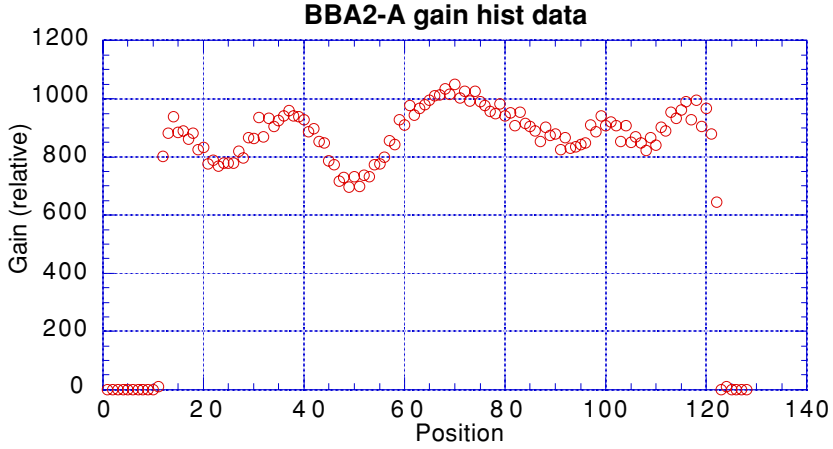
* Denotes tests which have already demonstrated performance using combinations of Flight and ETU components

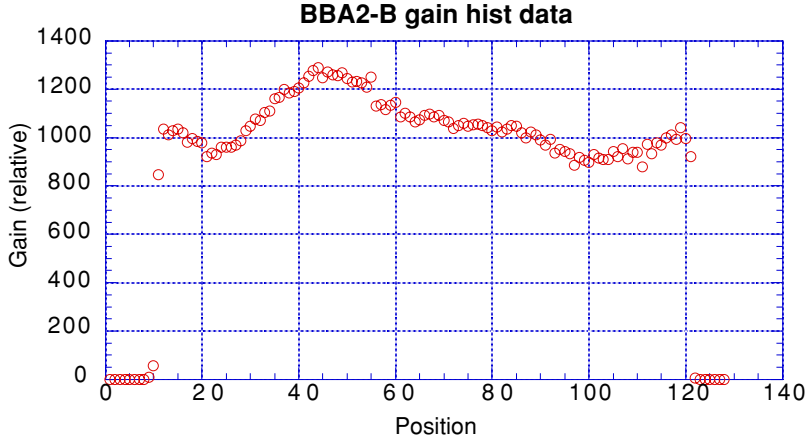
Gain Uniformity





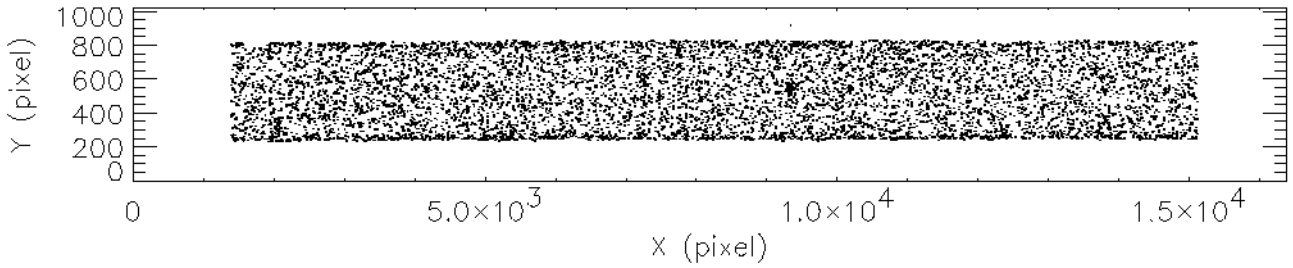
PHDs are all ~ 40-60% FWHM.





Dark Count Rate / Localized Anomalies

- Requirement of <0.5 cts cm^{-2} s^{-1} on the ground (not in-orbit)
- Measured throughout testing, both before and after photocathode, without photon or particle illumination
- Localized Anomalies (hot spots or dead spots) shall not compromise more than 2% of spectrum
- COS P.I. can accept or reject plates during selection process
- Most of the COS MCP stacks have 1-4 cts s^{-1} seg^{-1} (0.1-0.5 cts cm^{-2} s^{-1})

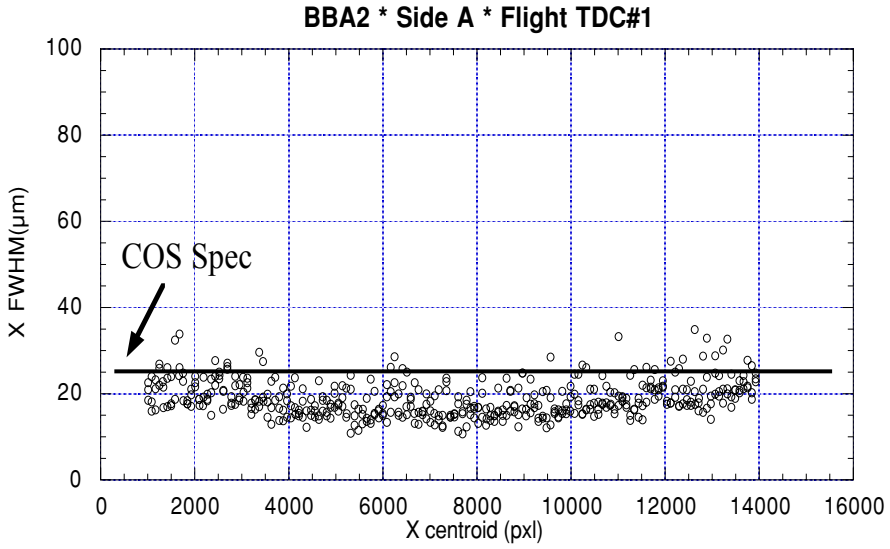


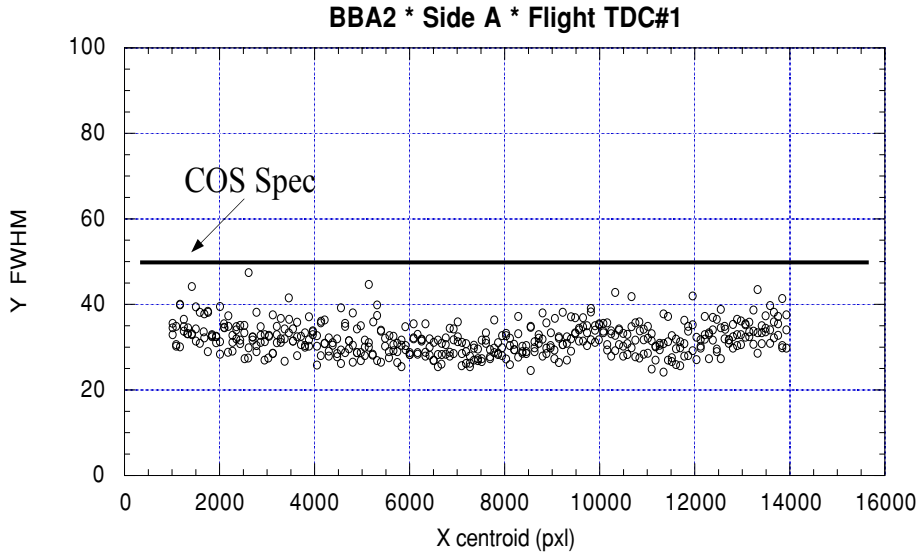
Spatial Resolution

- Pinhole mask (0.5 mm x 0.5 mm grid of 10μm pinholes) placed in contact with top MCP and used to sample spatial resolution over whole detector
- Photon list exposure taken at full resolution to get ~1000 events per pinhole for ~1600 pinholes
- Each spot fit with gaussian and FWHM determined. Systematic scatter in FWHM results is due to illumination of 1, 2 or 3 MCP pores with 10 μm pinholes. Slit mask used in Linearity Tests (see below) can reduce scatter with loss of resolution
- Trimmed flight electronics required for this test
- A second test uses a slit mask (25 μm x 500 μm slits on 200 μm centers) to measure the X resolution. Also useful for linearity testing.

Spatial Resolution (cont'd)

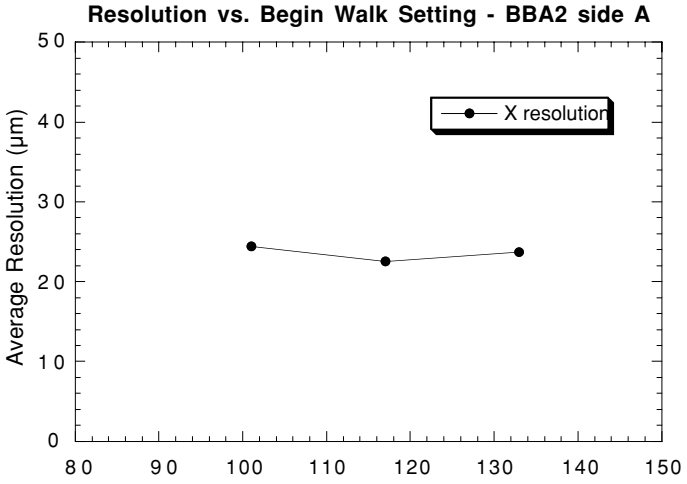
- Test Mask Sub-Image:

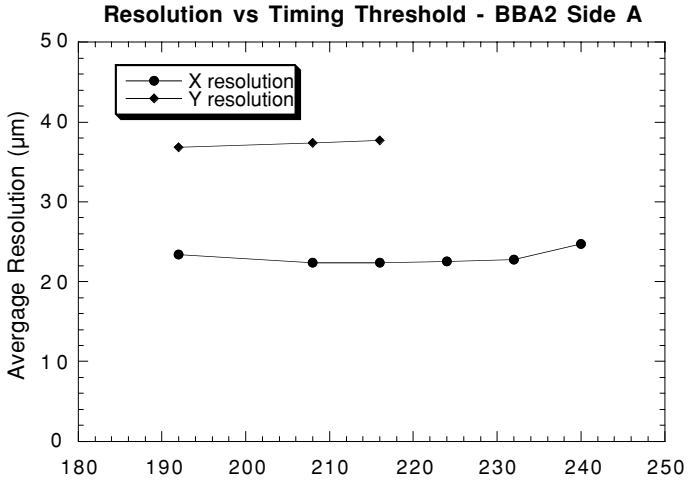


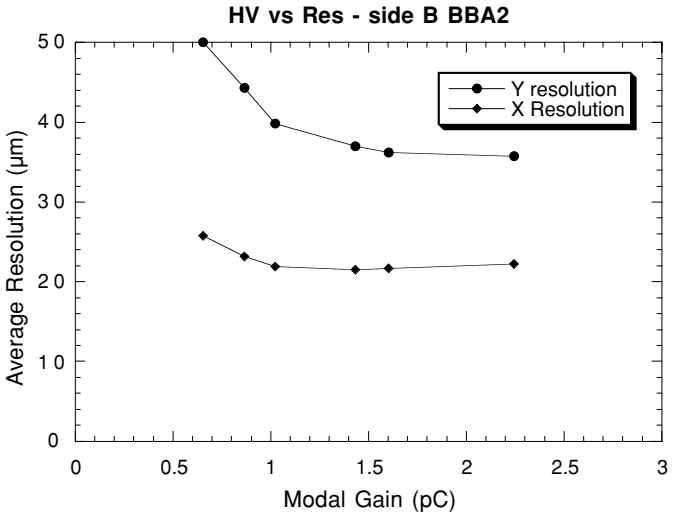


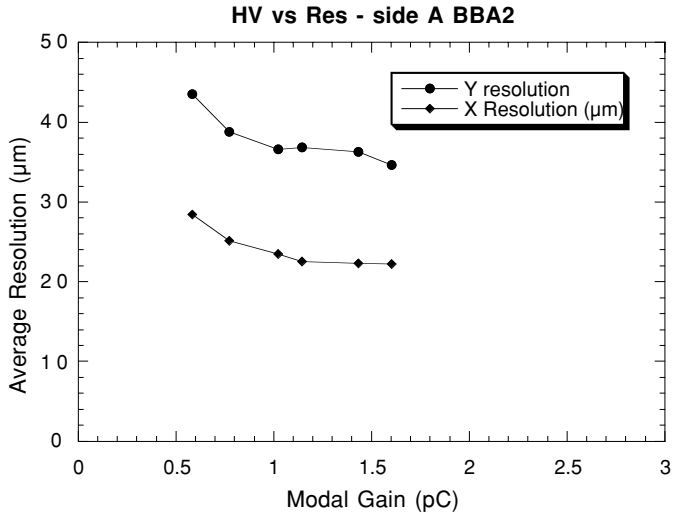
BBA#2 + flight anodes, resolution stability

- Resolution very stable to electronics settings, and over wide gain range







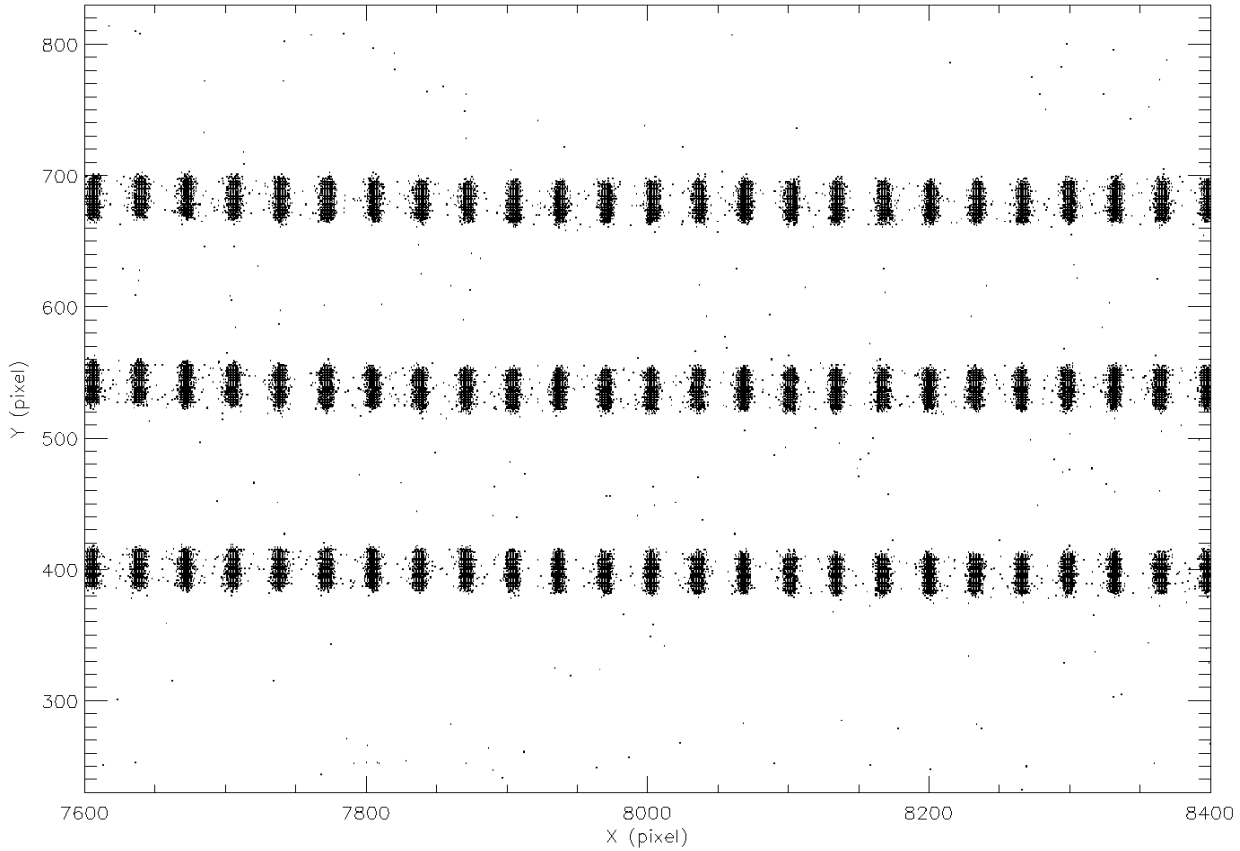


Spatial Linearity

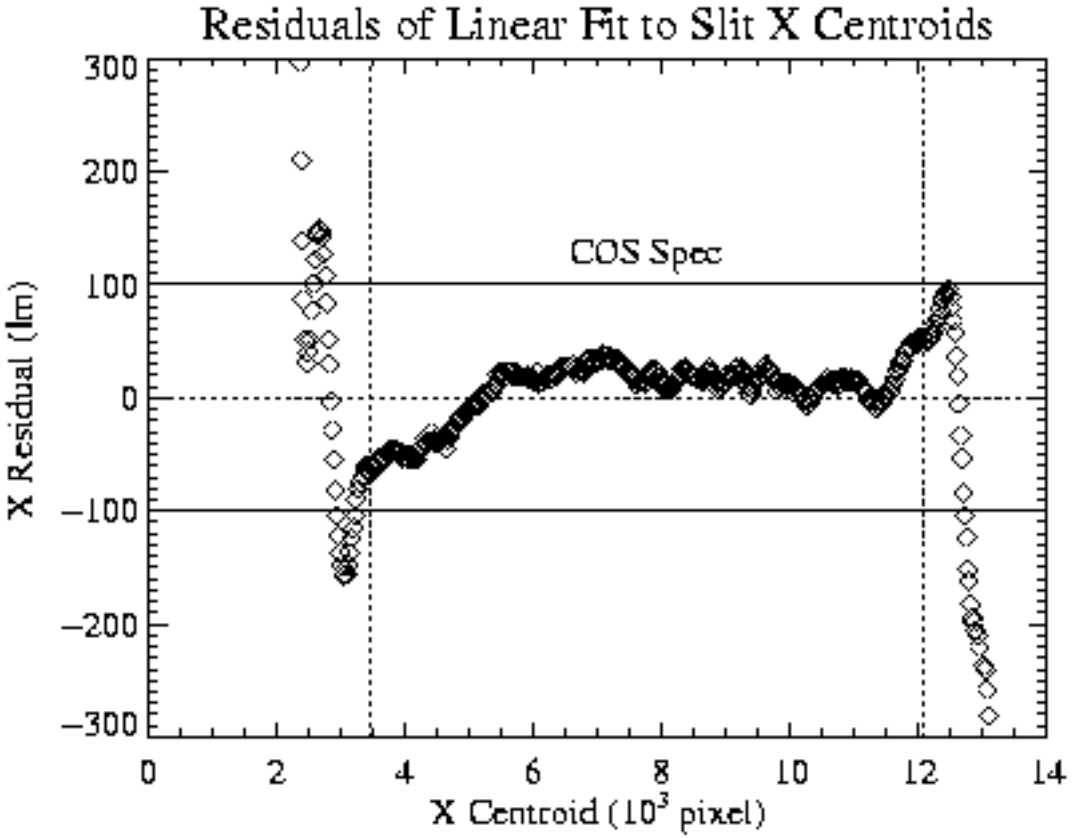
- XDL anodes have "analog" pixels; X(cm) ⇒ X(pixel) to first order is a linear mapping dependent on MCPs, anodes and electronics
- Non-linearity can result in incorrect wavelength and flux density
- Separate into two types requiring different measuring techniques
  - "**Integral**" or slowly varying in spatial dimension (> 1 mm)
  - "**Differential**" at the highest spatial frequencies
- Requirement
  - Integral non-linearity (true location-measured) shall not exceed 100µm and be measured every 1 mm over 80% of the active area.
  - Differential must be characterized by a uniform flat field with 10000 cts/resel to achieve a S/N ratio of > 100:1 per resel (35µm x 200µm).
  - This corresponds to a flat field of ~ 1 billion cts or 8 hours at 40,000 cps

Spatial Linearity (cont'd)

- Use "slit mask": 3 rows of 25µm x 500µm slits spaced on 200µm centers
- Oversamples > 1 mm non-linearities by a factor of 5



Spatial Linearity (cont'd)



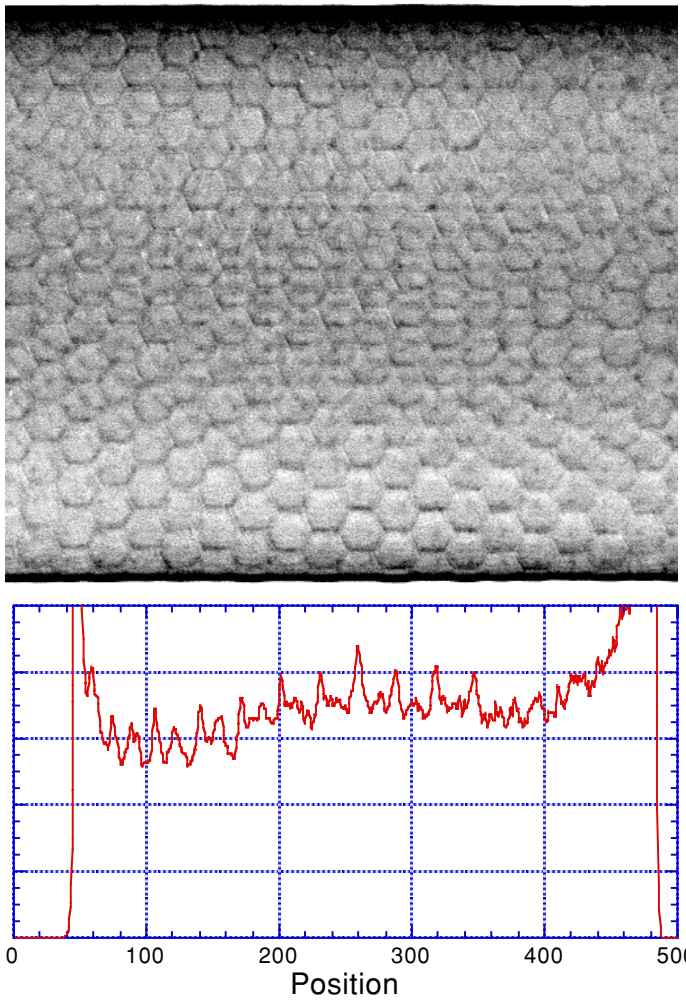
±100 µm achieved over > 80% of the detector

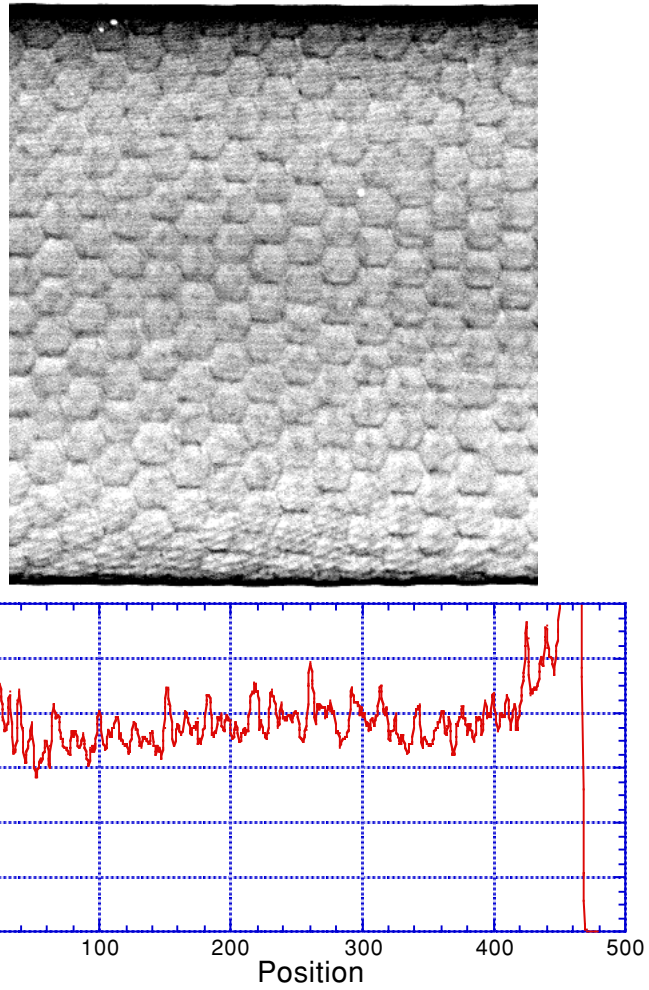
Spatial Linearity - Differential

- Small scale distortions cannot be sampled by pinhole grids
  - Multi-fiber boundaries
  - Moiré
- Distortions cause fixed pattern noise since pixels have different effective areas
- Deep, uniform flat fields can characterize pixel size

COS BBA#2-B UV full field illumination with Flight TDC

Flight BBA#2-B MCP Stack Fixed Pattern Noise





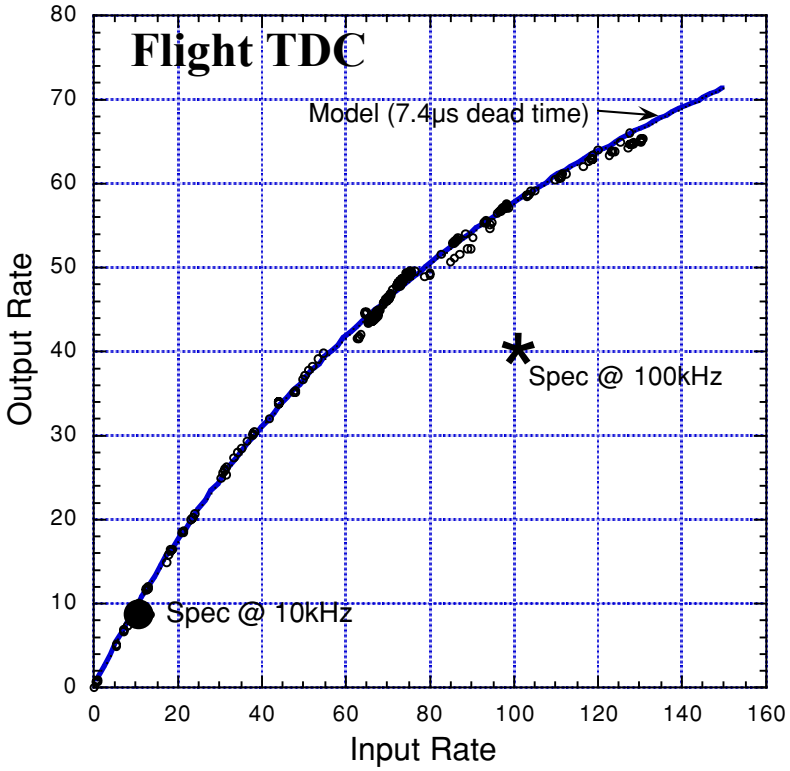
•Multifiber modulation dominates, small Moiré at some edges

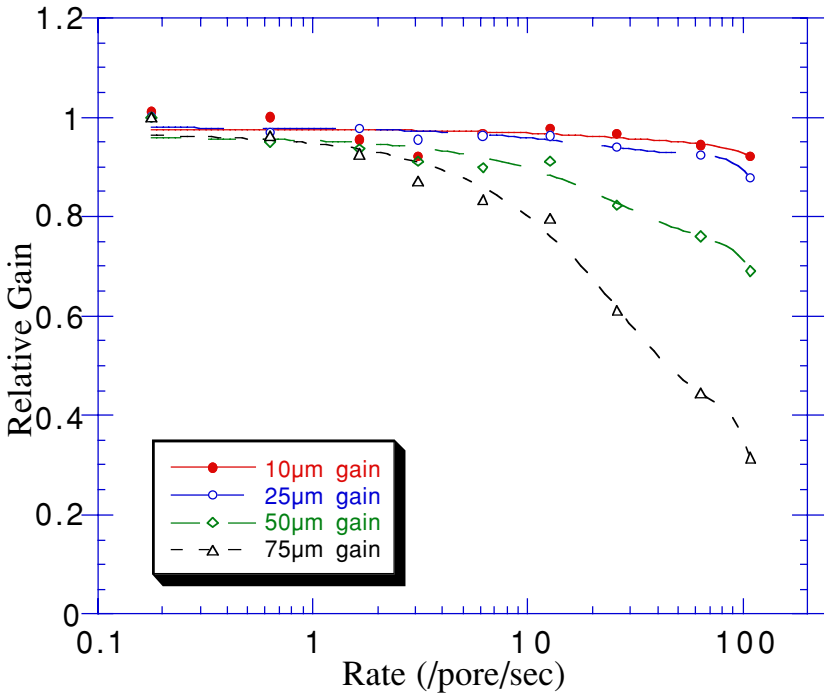
Flat Field Image Stability Test

- A flat field will be taken over at least an area of 80 mm x 0.5mm with 14100 cts per resolution element (35µm x 200µm)
- The backplate and TDC will be raised in temperature by ≥ 5 deg. C
- Another flat field will be collected.
- The RMS deviation between these flats must not exceed 1% after correcting for thermal distortions using the centroids of the electronic stims.

Count Rates: Global, Local and Deadtime

- Requirements
  - Global Output rates of >40,000 cts s^{-1} per segment output
  - Local Input rates of >5 cts s^{-1} per microchannel
  - Deadtime <10% at input rate of 10,000 cts s^{-1} & <60% at 100,000 cts s^{-1}





QDE Calibration

- DQE specified at 6 wavelengths:

Wavelength (Å)	SoR DQE (%)	Measured (%)
1152	44	49
1216	32	36
1335	25	26
1463	19	21
1560	17	16
1710	11	10

- Measured *after* CsI photocathode deposition
- Absolute calibration measured in center of detector and traceable to NIST calibrated photodiode
- Measured at input angle appropriate for wavelength
- Relative DQE vs. X position performed with detector translation
- Test setup is a flight BBA with QE enhancement grid in place on a test detector.

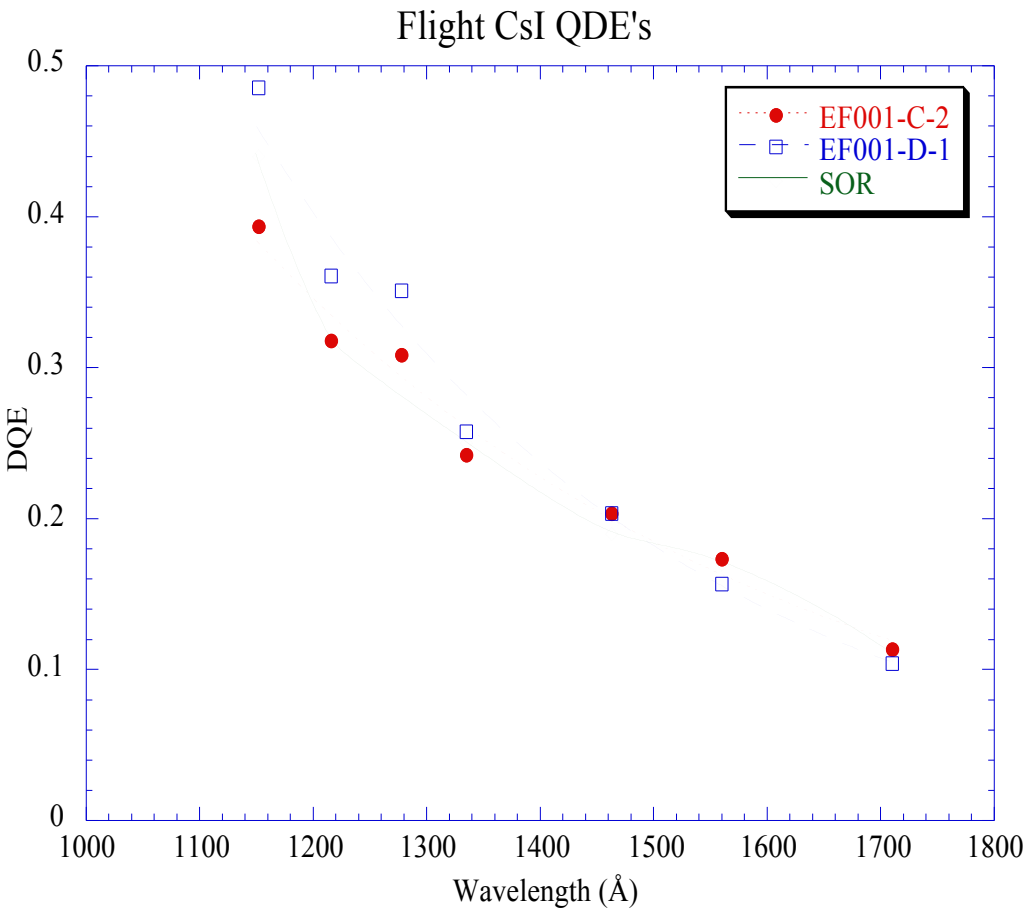
QDE Calibration (cont'd)

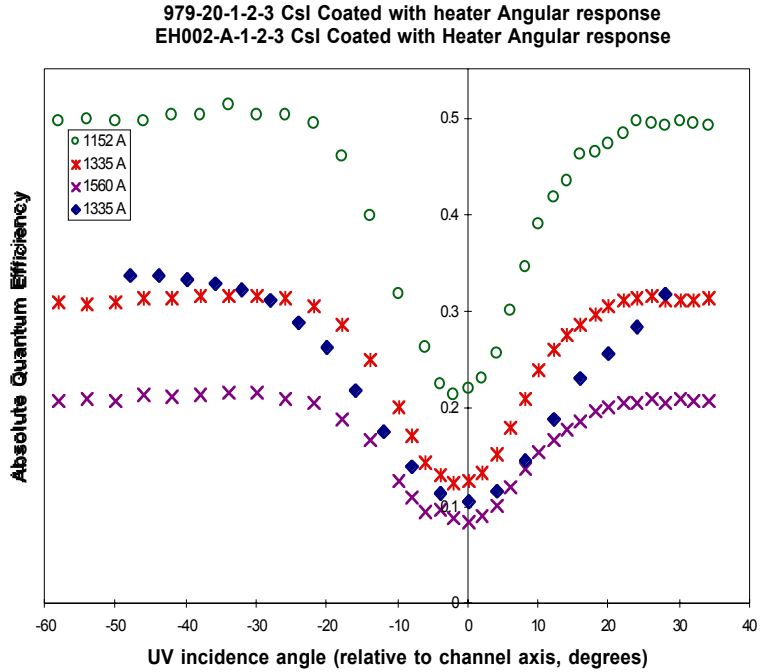
- Grid Shadows
  - measured with collimated light flat field.
  - Effect of f/24 input beam then determined by analysis

- Visible Light Rejection
  - Use two monochromatic He-Ne laser lines (632nm and 543 nm)
  - Calibrated optical (Si) photodiode to measure beam flux
  - All previous tests show that visible QDE to be orders of magnitude below requirement and therefore do not need to characterize QDE curve in visible regime

QDE Calibration (cont'd)

- Sample QDE plot

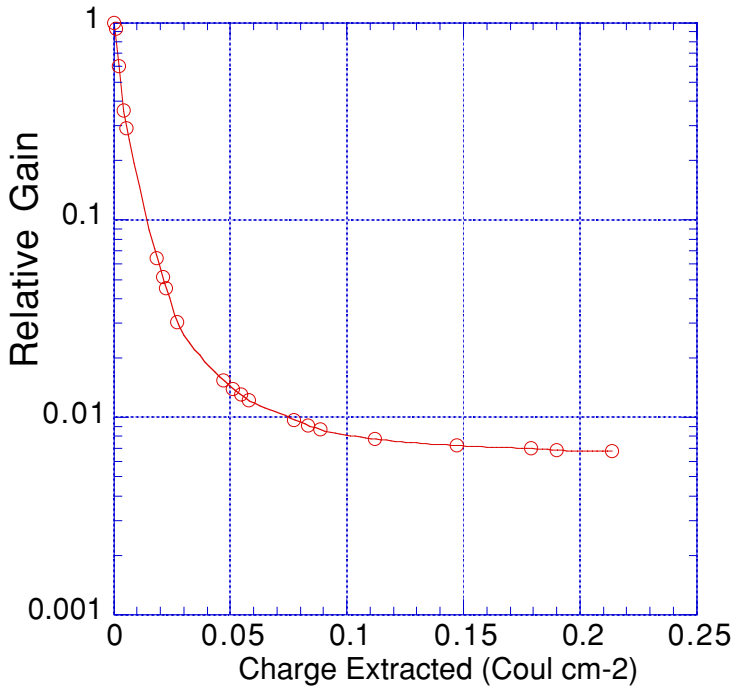




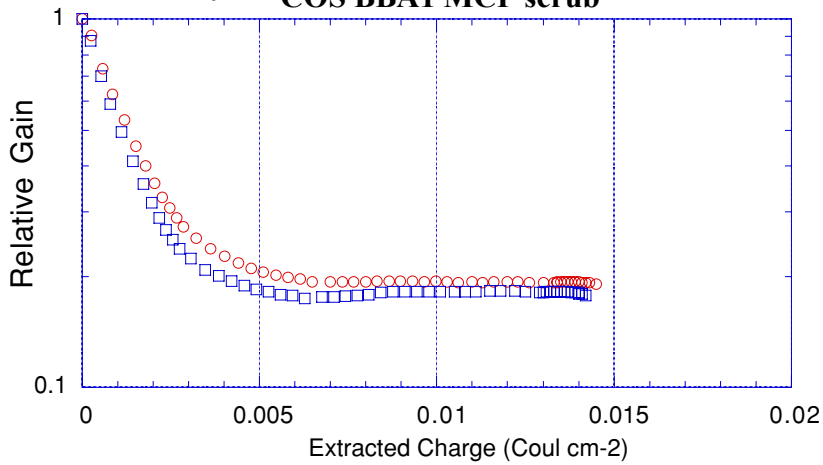
MCP Conditioning (UV Scrub)

Both pre-scrubs on BBA's #1 and #2 show gain stabilization

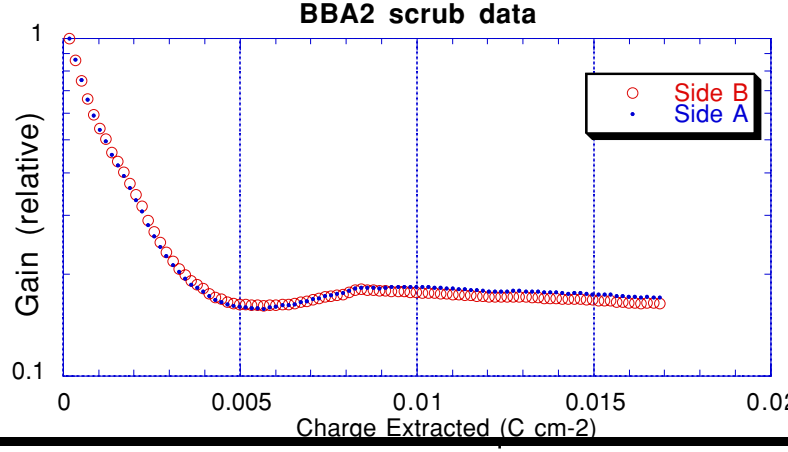
- COS sample MCP scrub



- COS BBA1 MCP scrub



BBA2 scrub data



BBA to Backplate Metrology Plan / Status

•To maintain focus, the MCP's input surface must match the optical focal surface (R= 826 mm) to ±100 μm (SoR 7.1.1)

•Since there is ±0.5 mm of focus adjustment in X, Y, and Z the primary constraint is on the knowledge of the orientation of the MCP surface relative to the backplate surface.

•A CMM with a camera and microscope objective will be used to measure the MCP surface relative to the backplate surface and optical cube to ±30 μm .

•The BBA will be shimmed such that the vertex of the MCP radius will be 10.4 mm above the backplate surface.

•The flight and spare detectors will be shimmed to within ±50 μm of the same height.

•The MCP surfaces will be characterized in about 40 locations per segment in two stripes in Y once final MCP and BBA shimming has been performed.

•Procedures are in place (UCB-COS-PRO-1132 and UCB-COS-PRO-1133) and measurements are in progress.