VIIRS F1 TVAC Crosstalk Testing

VIIRS Calibration Workshop

January 25, 2010

NPP Instrument Calibration Support Team (NICST)
Presented by
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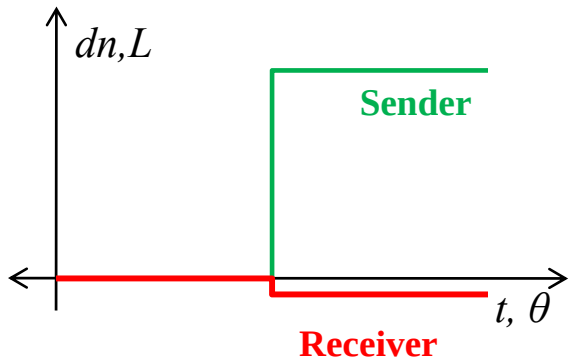
F1 Crosstalk Testing

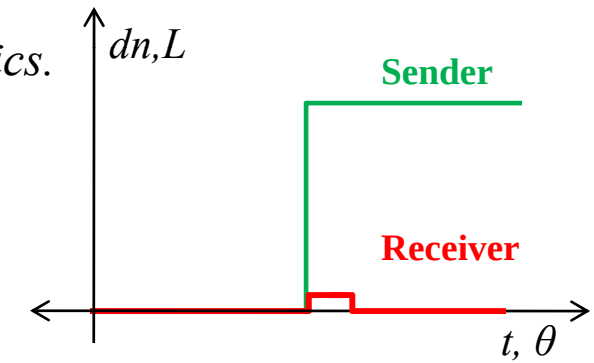
Test	FPA	Test Phase	Static/Scanning	Primary Kind of Crosstalk Measured	Objectives
STR-355	V	Component Level	Static	Dynamic	Evaluate band-to-band optical crosstalk on the Cherry picked IFA - vertical Slit
STR-355a	V	Component Level	Static	Optical	Evaluate band-to-band optical crosstalk on the Cherry picked IFA w/ alternate slit width - Vertical Slit
STR-396	V,S,L	Component Level	Scanning	Dynamic	Examine crosstalk artifacts with a scanning vertical slit
STR-397	V,S,L	Component Level	Scanning	Dynamic	Evaluate crosstalk artifacts present with a scanning vertical knife edge
STR-430	V,S,L	Component Level	Scanning	Dynamic	Evaluate crosstalk artifacts present with a scanning horizontal knife edge
STR-443	V	Component Level	Static	Optical	Evaluate band-to-band optical crosstalk on the baseline IFA - vertical slit
STR-351	V	Ambient	Scanning	Dynamic	Evaluate band-to-band crosstalk - vertical Slit
STR-352	V,S,L	Ambient	Scanning	Dynamic	Evaluate in-band crosstalk with a scanning horizontal Knife-edge
STR-358	V	Ambient	Scanning	Dynamic	Evaluate VisNIR crosstalk artifacts with a vertical knife edge
STR-359	S,L	Ambient	Scanning	Dynamic	Evaluate band-to-band crosstalk - vertical slit
STR-405	S,L	Ambient	Scanning	Dynamic	Evaluate SMWIR and LWIR with scanning vertical knife edge.
STR-406	V	Ambient	Static	Optical	Evaluate VisNIR IFA filter leadage - vertical slit
STR-485	S	Ambient	Scanning	Dynamic	Explore M12 Serial Crosstalk - Spot Illumination
STR-502	V	Ambient	Static	Optical	VisNIR Optical Crosstalk - Test filter Characterization
STR-520	V	Ambient	Scanning	Dynamic	Dual gain band serial crosstalk
STR-527	V	Ambient	Scanning	Dynamic	Dual gain band serial crosstalk - with wide slit and 4 vertical slits
FP-13	V,S,L	Ambient	Static and Scanning	Static Electical & Dynamic	Evaluate dynamic crosstalk with a variety of reticles and Point-to-point in-band static crosstalk
ETP-663	V	Pre-TV	Static	Optical	Band-to-band and point-to-point optical crosstalk with polarized input.
FP-15	V,S,L	TV	Static	Static Electical	In-band band-to-band crosstalk - vertical slit
FP-16 X-talk	V,S,L	TV	Static	Static Electical	In-band band-to-band crosstalk - vertical slit
FP-16 RSR	V,S,L	TV	Static	Optical	In-band and OOB crosstalk - vertical slit
ETP-655	V	TV	Static	Optical	Band-to-band and point-to-point optical crosstalk with polarized input.

Varieties of Crosstalk

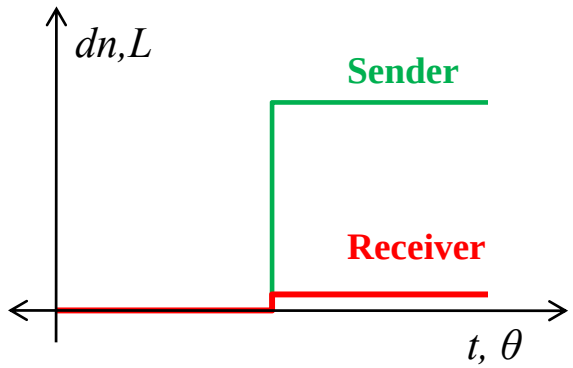
- **Static Electrical Crosstalk**
  - *Characteristic of the electronics - ROIC*
  - *Pathways have been identified on all focal planes*
  - *Effects can be positive or negative*



- **Dynamic Crosstalk**
  - *Also electrical crosstalk – characteristic of the electronics.*
  - *Response to a "knife edge" or sudden change in the illumination/signal.*
  - *Effects mitigated by EDU based rework.*



- **Optical Crosstalk**
  - *A characteristic of the filter/filter assembly*
  - *Wavelength and polarization dependent*
  - *Very narrow (Δλ) features expected.*



NICST Crosstalk Objectives

- **Static Electrical Crosstalk**
  - Characterize crosstalk through the DAWG standardized units
  - Verify compliance with sensor crosstalk requirement, SRV0631
- **Dynamic Crosstalk**
  - Characterize crosstalk through the DAWG standardized units
- **Optical Crosstalk**
  - Characterize crosstalk through spectral crosstalk coefficients
  - Characterize the polarization dependence of optical crosstalk
    - Examine the Filter Spread Function (FSF)
  - Simulate impact of optical crosstalk on SDR products using MODIS granules (VisNIR only – in progress)

Static Electrical Crosstalk

Static Electrical Coefficients

- DN Ratio

$$IC_{dn}(B_s, g_s, B_r, D_r, S_r, g_r) = \frac{dn_r(B_r, D_r, S_r, g_r)}{\sum_{D_S, S_S} dn_s(B_s, g_s)}$$

- Radiance Ratio

$$IC_L(B_s, g_s, B_r, D_r, S_r, g_r) = \frac{L_r(B_r, D_r, S_r, g_r)}{\sum_{D_S, S_S} L_s(B_s, g_s)}$$

Electrical crosstalk measured in both FP-15 and FP-16 has been characterized in tables using this methodology.

VIIRS Crosstalk Requirement

3.1.5.10.4.1 Crosstalk

The receiver is defined as an individual detector element for which crosstalk is being measured. The senders are defined as the set of all other detector elements, including those in other spectral bands, but excluding the nearest neighbor detector elements in the track direction within the same band as the receiver.

Crosstalk is defined as the spurious change in signal on a receiver when the radiance changes on the senders.

SRV0631* For all bands except the DNB, when the steady-state radiance on the senders is changed from 0 to Lmax, the corresponding change in signal on the receiver shall be less than or equal to the larger of 0.002 Ltyp or 0.5 the measured NedL of the receiver when the sender radiance is 0. [AT]

*There is a wavier request for this requirement - W054**.**

This situation is very difficult to create in the lab and does not consider optical crosstalk caused by wide angle scattered light that is out of band.

Comparison to the Sensor Requirement

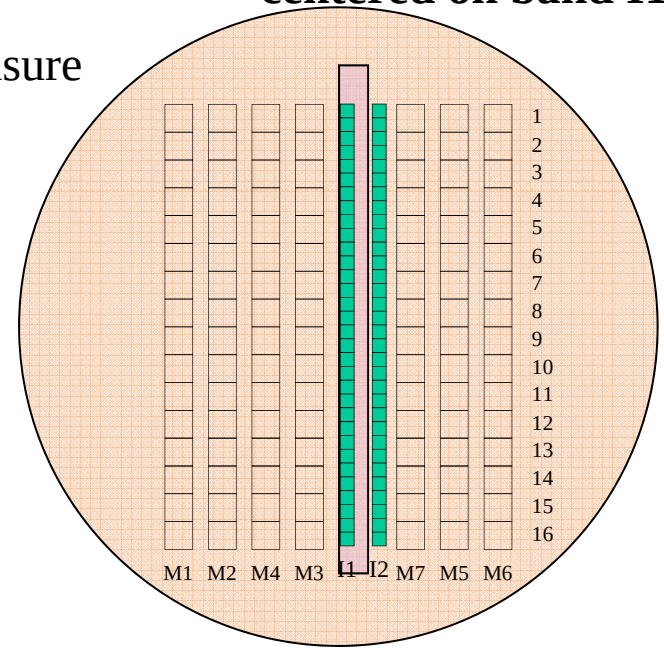
$$dn_{rec}(B_s, g_s, B_r, D_r, S_r, g_r) = IC_{dn}(B_s, g_s, B_r, D_r, S_r, g_r) \sum_{D_s, S_s} L_{\max}(B_s, g_s) g_{B,D,S}$$

- DN ratio influence coefficient is scaled to L_{max} for <u>all senders in the band</u>
- L_{max} for the senders gain state is used
  - Low gain – Specified L_{max}
  - High gain – Specified gain transition point
- Crosstalk is not summed between different sender bands.

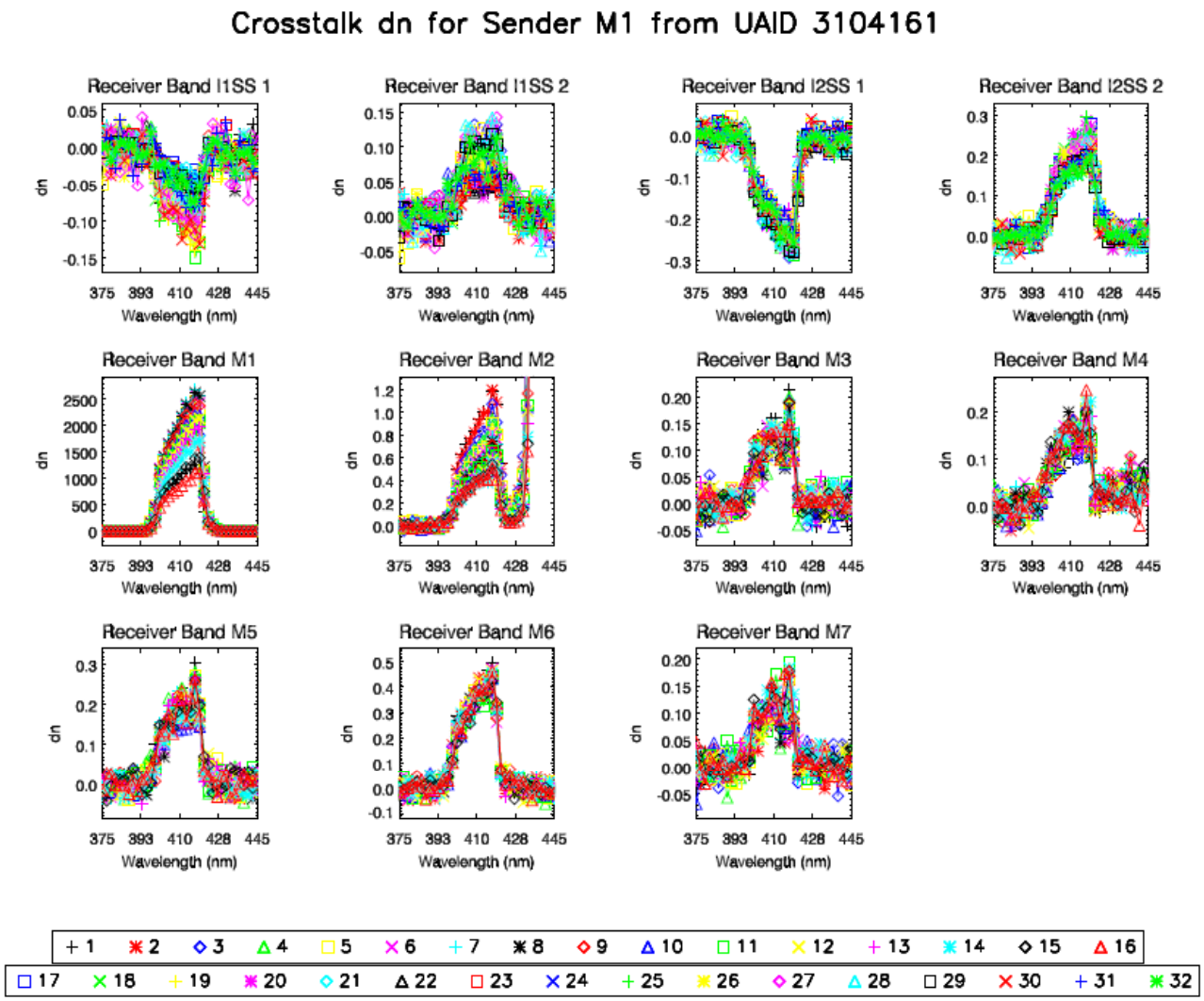
Static Electrical Crosstalk Testing

- **FP-15**
  - Test designed to measure in-band RSR
  - A range of wavelengths covering the extended band pass are used.
    - Subtractive double monochrometer
  - 8-scan staring test
  - Fixed high gain
  - For LWIR and SMWIR bands detector rows are tested separately
- **FP-16 Crosstalk**
  - Test has a special crosstalk part designed to measure static electric crosstalk
  - Same test setup as FP-15 except;
    - Only band center wavelength used
    - 16-scan of data are collected
    - Multiple illumination levels used for Dual Gain bands
      - Low illumination – high gain
      - High Illumination – low gain
    - Multiple Band substitution tables are used.
- **DN Ratio, Radiance Ratio, and Spec. Compliance are computed.**

SpMA exit slit centered on band I1

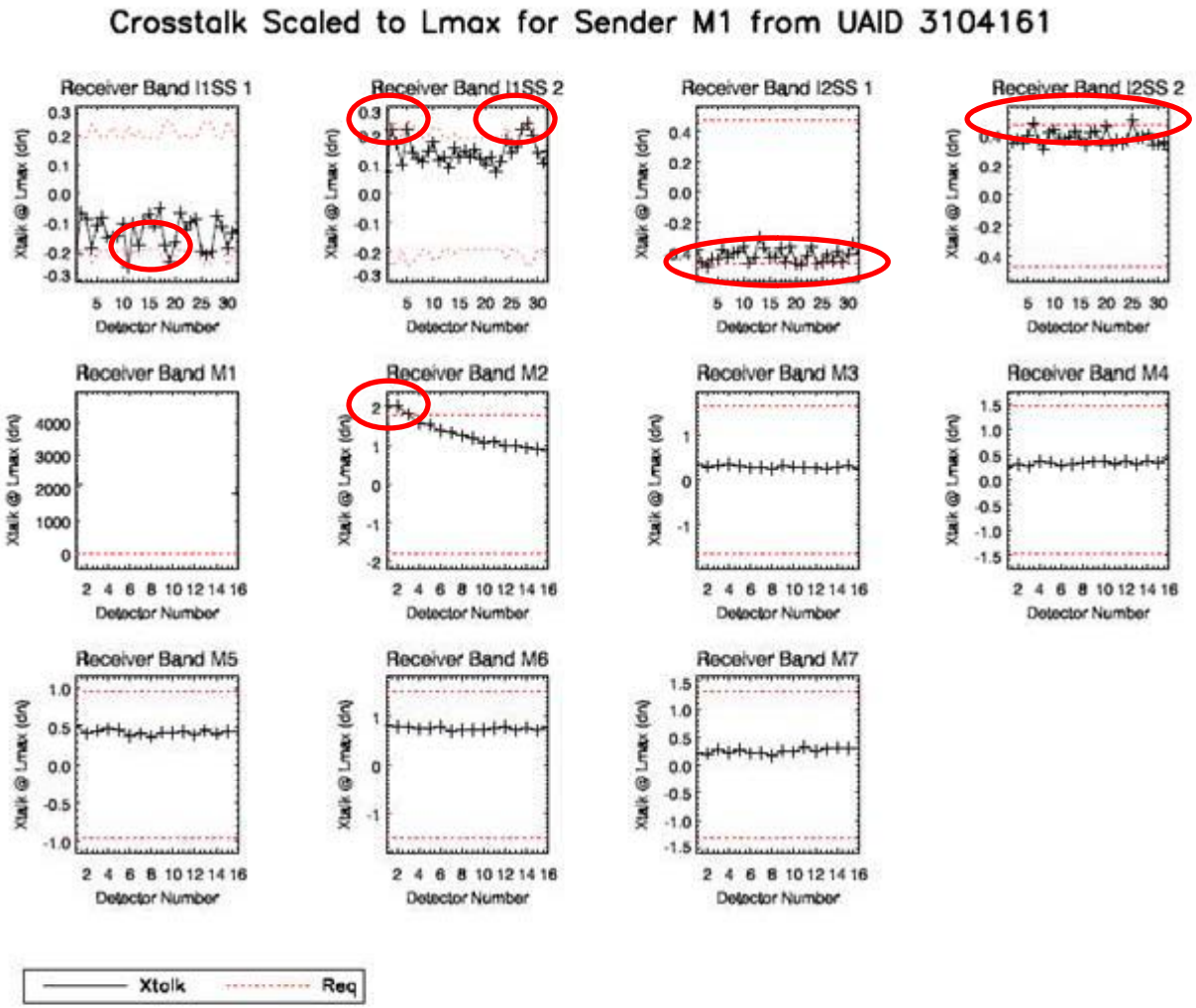


Crosstalk from Band M1 (FP-15)



For specification assessment crosstalk measured at the peak sender signal (417 nm) is used for scaling.

Crosstalk Scaled to L_{max} from Band M1 (FP-15)



Non-compliances appear in M2 and both I-bands after the crosstalk is scaled to M1 L_{max}.

Crosstalk Non-Compliances from FP-15

Receiver Band \ Sender Band	M1	M2	M3	M4	M5	M6	M7	M8	M8	M9	M9	M10	M10	M11	M11	M12	M12	M13	M13	M14	M14	M15	M15	M16A	M16A	M16B	M16B	I1	I2	I3	I3	I4	I4	I5	I5
M1	X																																		
M2		X																																	
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M13																		X	X																
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M16A																								X	X										
M16B																										X	X								
I1 S1																												X							
I1 S2																												X							
I2 S1							X																						X						
I2 S2							X																						X						
I3 S1												X	X																	X	X				
I3 S2												X	X																	X	X				
I4 S1																																X	X		
I4 S2																																X	X		
I5 S1																																		X	X
I5 S2																																		X	X

Red = Positive crosstalk exceeding the requirement **White = compliant**

Blue = Negative crosstalk exceeding the requirement

Solid = all detectors, Lines = some detectors

Light Grey = unavailable due to band substitution

Crosstalk Non-Compliances from FP-16

Receiver Band \ Sender Band	M1	M2	M3	M4	M5	M6	M7	M8	M8	M9	M9	M10	M10	M11	M11	M12	M12	M13	M13	M14	M14	M15	M15	M16A	M16A	M16B	M16B	I1	I2	I3	I3	I4	I4	I5	I5
M1	X																																		
M2		X																																	
M3			X																																
M4				X																															
M5					X																							?							
M6						X																													
M7							X																						X						
M8								X	X																										
M9										X	X																								
M10												X	X																	X	X				
M11														X	X																				
M12																X	X																		
M13																		X	X																
M14																				X	X														
M15																						X	X												
M16A																								X	X										
M16B																										X	X								
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I1 S2																												X							
I2 S1							X																						X						
I2 S2							X																						X						
I3 S1												X	X																	X	X				
I3 S2												X	X																	X	X				
I4 S1																																X	X		
I4 S2																																X	X		
I5 S1																																		X	X
I5 S2																																		X	X

Red = Positive crosstalk exceeding the requirement **White = Compliant**

Blue = Negative crosstalk exceeding the requirement

Solid = all detectors, Lines = some detectors

MODIS Crosstalk Requirement

GSFC 422-20-02, 3.4.5.3.3

The response of a detector element in a given spectral band (the sender) shall not cause an apparent change in either the response of another detector element in any band (the receiver) that is greater than one least significant bit (1-sigma) in response to a signal placed on the sender that is equivalent to the Ltypical for the sender and the receiver with zero incident radiance.

Notable Differences

- VIIRS sender is all other detectors – MODIS sender one detector
- VIIRS senders are at L_{max} – MODIS sender is at $L_{typical}$
- VIIRS receiver signal less than $0.002L_{typ}$ or 0.5NedL - MODIS receive signal less than least significant bit (1DN) or 1-sigma

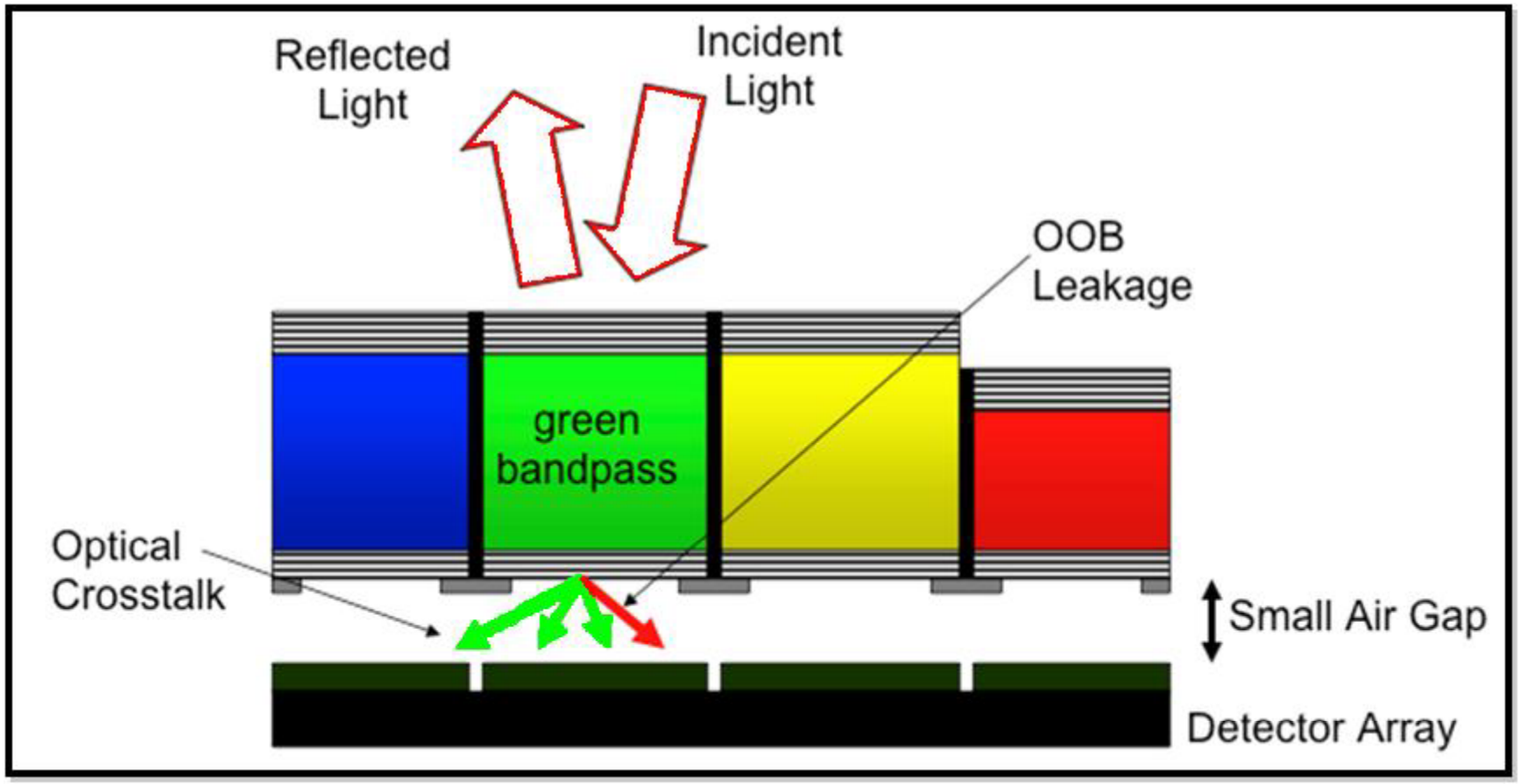
*** The MODIS requirement is generally far less stringent than VIIRS and more easily tested.**

Static Electrical Crosstalk Summary

- Specification non-compliances found both at the band-to-point (FP-15 & FP-16) and point-to-point level (FP-13) on all three focal planes.
  - Non-compliances can be up to 5 times the requirement
    - M3→ I1, M4→M2 & M3, M5→I1 & M6, M7→M5, I2→M5, I2→M6, I2→I1
- VIIRS sensor requirement is *very* strict
  - For some bands I1 and I2 this translates to a fraction of a DN
  - Far stricter than the MODIS requirement - heritage performance or better may be maintained.

Optical Crosstalk

Optical Crosstalk Background

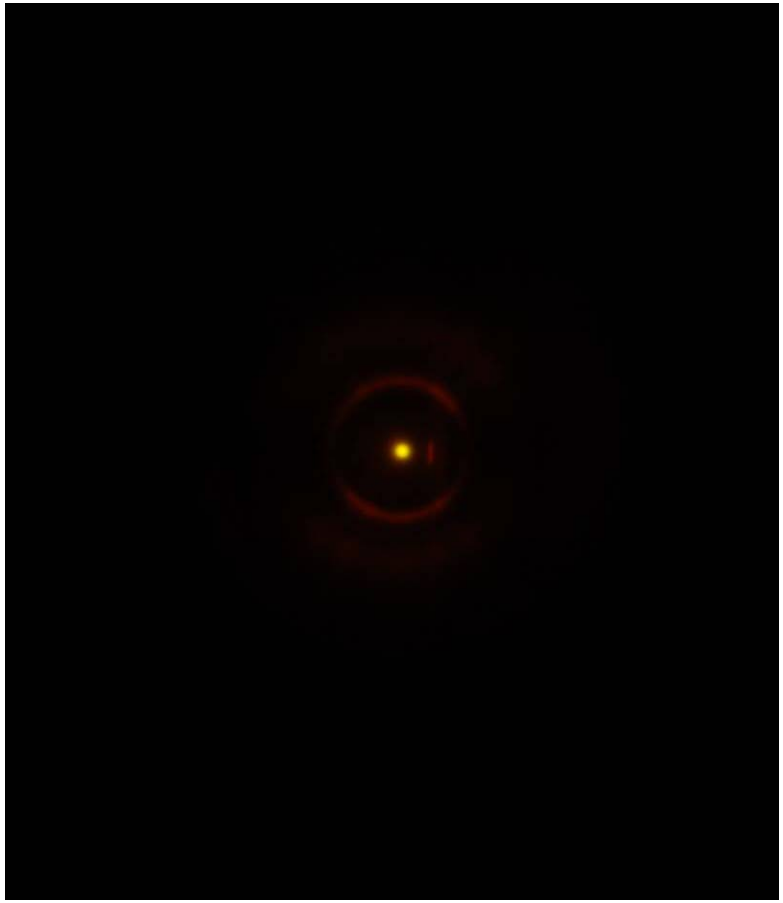


- Magnitude is dependent on polarization of the incident light
- Wavelength dependent – typically features have small bandwidth

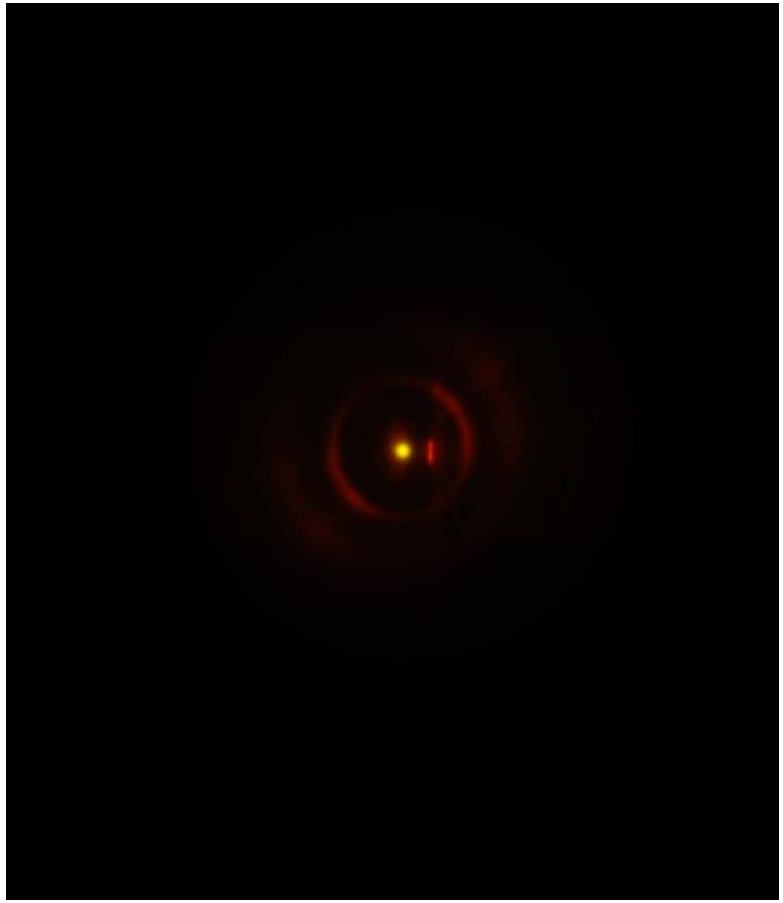
Image Courtesy Peter Fuqua, et. al. (from Calibration Conference 2007)

Optical Crosstalk Background Cont.

96 deg (90 Deg is vertical)



36 deg



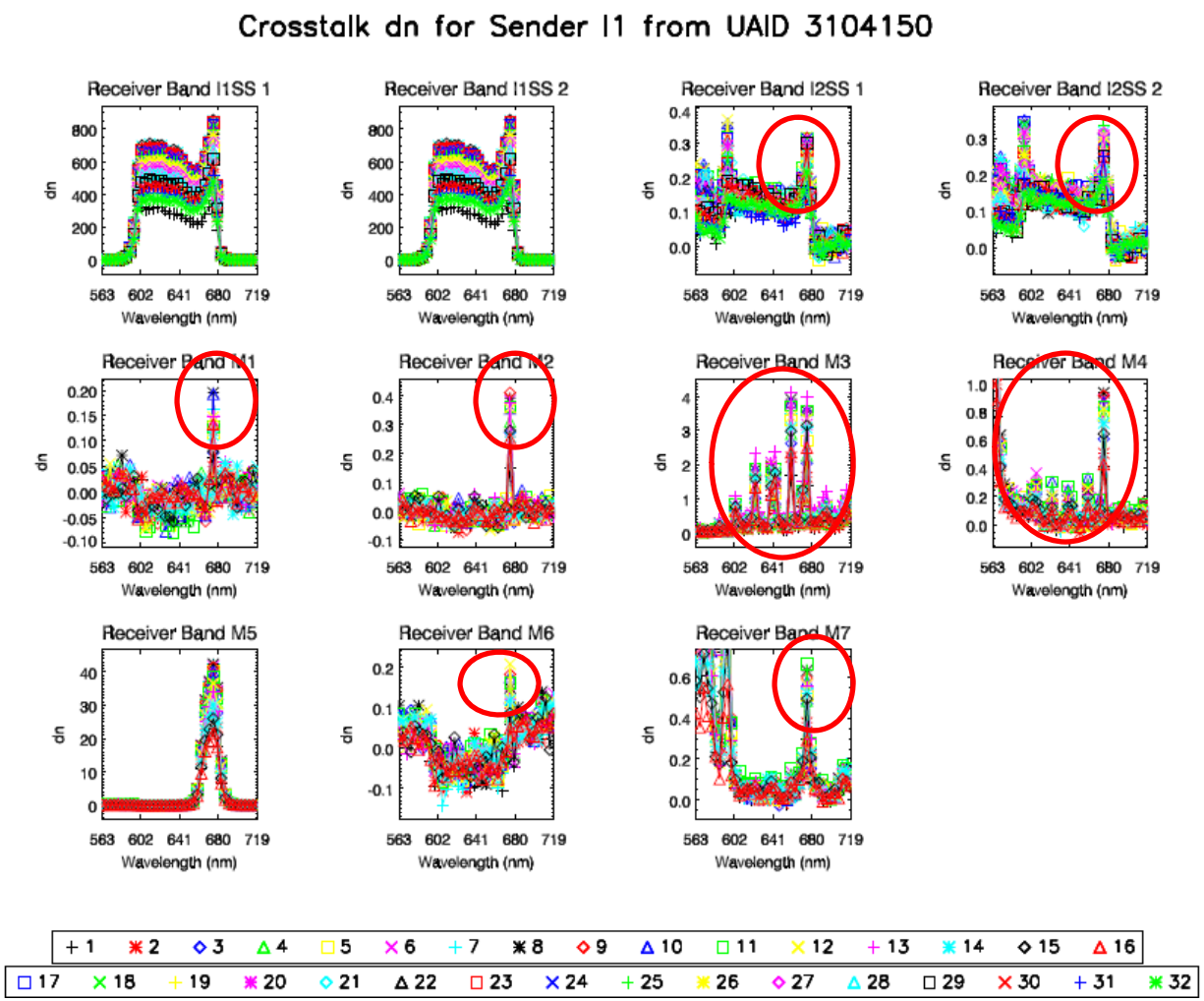
- Optical Crosstalk from Angle Resolved Scatter is expected to be polarization dependent – similar filter to M4 used.

Images Courtesy Peter Fuqua (Polarization Sensitivity of Angle Resolved Scatter (ARS), 2009)

F1 TVAC Optical Crosstalk Tests

- FP-16 RSR
  - OOB RSR test
  - Band-to-point
  - Uses SpMA – partially polarized
  - All three focal planes tested over full OOB range
    - 360-1100 nm – VisNIR
    - 990-7000nm - SMWIR
    - 2200-16000nm – LWIR
  - Test setup as described earlier (FP-15 and FP-16 Crosstalk)
- ETP-655 & ETP-663
  - Select VisNIR bands tested (M1, M3, M4, M6)
  - SpMA used in combination with a wire grid polarizer
  - Band-to-point and point-to-point measurements
- Optical crosstalk effects present in other tests as well
  - FP-15 & FP-16 Crosstalk specific testing

Optical Crosstalk from I1 (FP-15)



- Large ARS peak ~680 nm show up across all bands in the focal plane.
- Several smaller peaks seen in M3 and M4

Optical Crosstalk Analysis

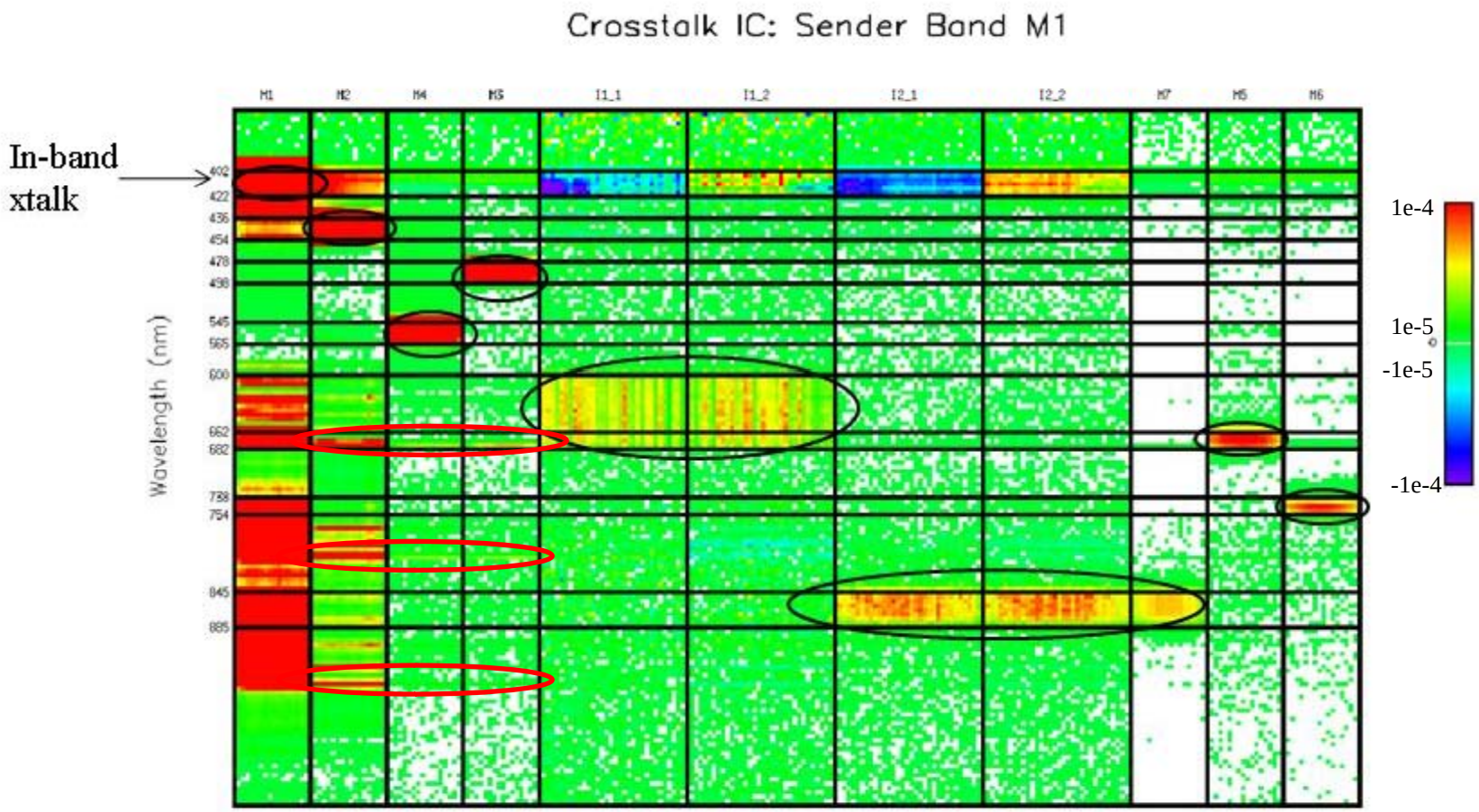
$$IC(B_S, D_R, S_R, \lambda) = \frac{L_R(B_S, D_R, S_R, \lambda)}{L_{Source}(\lambda)}$$

- Influence coefficients are integrated into bins matching the VIIRS bandpasses (VisNIR shown)
  - Near-field scattered light removed prior to binning or marked
  - **Made for use in NICST SDR impact modeling tool.**
  - Band average and band-to-detector coefficients have been delivered.

$$IC(B_S, D_R, \lambda_{bin}) = \int_{\lambda_{bin_\min}}^{\lambda_{bin_\max}} \frac{\langle IC(B_S, D_R, SF_R, \lambda_{SpMA}) \rangle_{SF}}{BW_{SpMA}} d\lambda$$

Wavelength Range	VIIRS Band
370-402	
402-422	M1
422-436	
436-454	M2
454-478	
478-498	M3
498-545	
545-565	M4
565-600	
600-662	I1
662-682	I1/M5
682-738	
738-754	M6
754-845	
845-885	M7/I2
885-1050	

Optical Crosstalk from FP-16



- Large ICs
  - Wavelengths in-band for the sender (possible electrical)
  - Wavelengths in-band for the receiver (possible near field scatter)
  - ARS "tall poles" – Optical Crosstalk (red circles)
    - Most seen in M2 (its nearest neightbor)

Binned Optical Crosstalk Coefficients

M1

	M1	M2	M4	M3	I1	I2	M7	M5	M6
370-402	4.28E-02	1.62E-04	6.86E-05	1.83E-05	-9.11E-08	1.62E-06	2.12E-06	9.38E-06	6.86E-06
402-422	8.66E-01	3.98E-03	1.03E-03	6.28E-04	3.42E-04	2.11E-04	1.77E-04	1.69E-04	1.37E-04
422-436	5.82E-03	5.50E-05	4.77E-05	3.41E-05	7.32E-06	2.63E-06	2.69E-07	8.44E-06	6.88E-06
436-454	2.48E-04	1.07E-04	3.91E-06	2.63E-06	3.13E-07	1.20E-06	6.44E-07	3.28E-07	7.00E-07
454-478	6.10E-05	1.49E-05	5.10E-06	-8.83E-07	2.03E-07	-3.45E-07	2.25E-07	-4.29E-07	2.86E-08
478-498	1.92E-05	5.98E-06	5.15E-06	-1.06E-05	9.42E-07	-6.84E-07	1.41E-07	4.44E-07	1.17E-07
498-545	2.58E-05	1.48E-05	3.72E-05	1.69E-06	8.12E-07	4.59E-07	-6.94E-08	-3.74E-07	9.20E-07
545-565	3.29E-06	1.13E-05	4.97E-05	1.90E-06	9.43E-07	5.56E-07	-2.10E-08	5.58E-07	3.26E-07
565-600	1.11E-04	6.88E-06	4.89E-05	2.20E-06	-4.35E-07	-1.36E-06	-4.35E-07	-1.38E-07	5.24E-07
600-662	2.26E-03	6.25E-05	8.94E-05	1.60E-05	-8.43E-06	-1.07E-05	-4.83E-07	1.13E-06	1.66E-06
662-682	2.83E-03	7.10E-05	2.68E-06	1.40E-05	-3.02E-07	-1.87E-06	2.11E-07	-1.40E-05	8.21E-07
682-738	4.39E-04	1.10E-05	7.88E-06	9.79E-07	1.06E-06	-4.23E-07	-2.61E-07	-4.07E-07	9.81E-06
738-754	6.58E-04	1.53E-05	1.25E-06	1.87E-07	1.37E-06	6.93E-07	5.50E-07	1.55E-06	-4.31E-05
754-845	1.40E-02	3.26E-04	1.00E-05	1.91E-05	1.16E-06	3.32E-05	5.30E-05	2.22E-06	8.78E-06
845-885	2.27E-03	6.37E-05	3.91E-06	3.08E-06	-4.05E-06	2.95E-04	1.71E-04	4.33E-06	-1.07E-06
885-1050	6.73E-03	1.90E-04	5.63E-06	1.38E-05	3.07E-06	9.21E-06	2.12E-05	1.88E-06	5.90E-07

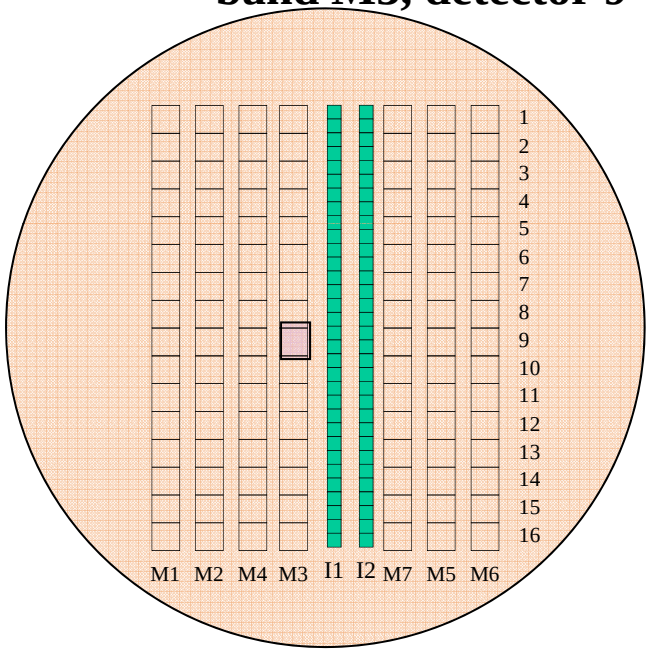
- Integrated band-to-band influence coefficients
- Will be used in NICST SDR Optical Crosstalk impact assessment
  - Cells containing possible near field scattered light and/or static electrical coefficients may be zeroed (shaded cells).

Optical Crosstalk from ETP-655

Test designed to measure polarization dependent crosstalk and filter spread function (FSF).

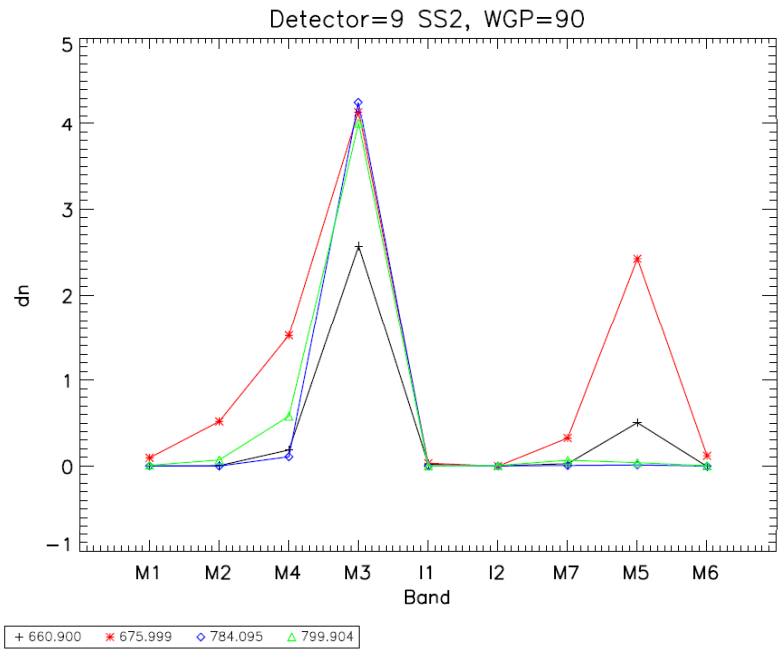
- Limited number of sender bands and wavelengths are tested
  - M1: **411, 415**, 624, 645, 662, 676, 786, 803
  - M3: **481, 487**, 661, 676, 784, 800
  - M4: **553, 555**, 596, 607, 733
  - M6: 447, 640, **744, 745**, 834
- SpMA Wavelength set to crosstalk "tall poles"
  - Identified in STR-443 and other component level testing by Vijay Murgai
  - Wire grid polarizer used at SpMA exit
    - Angles of 0, 45, 90, and 135 for OOB
    - No polarizer IB measurements
  - Cross-slit used for point to point results – FSF
    - Detectors 4, 9, 14
- Spectral output of SpMA measured in separate test
  - Measured with and w/o polarizer

Cross-slit centered on band M3, detector 9

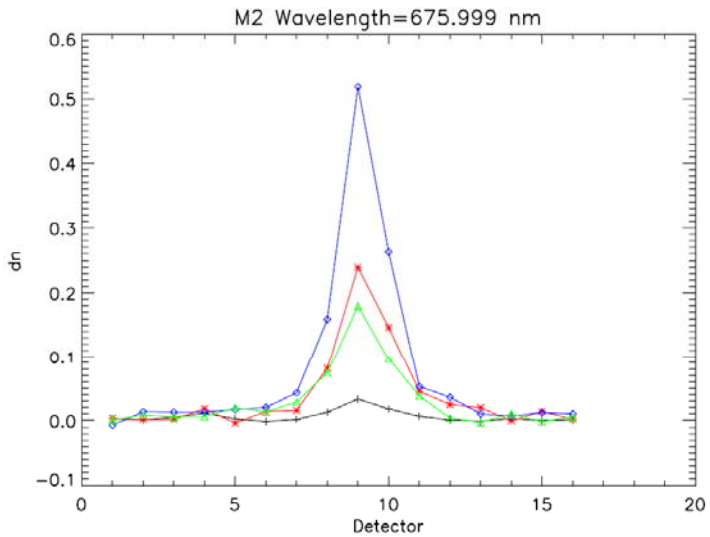


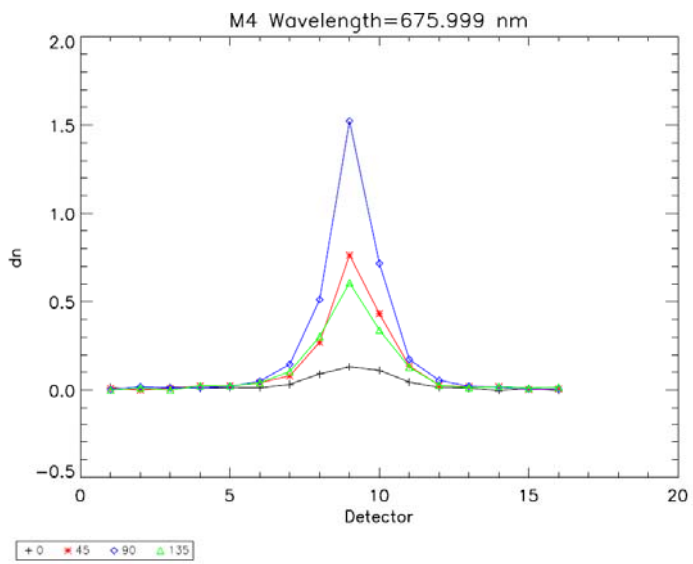
M3 Cross slit on Detector 9

Along-Scan FSF



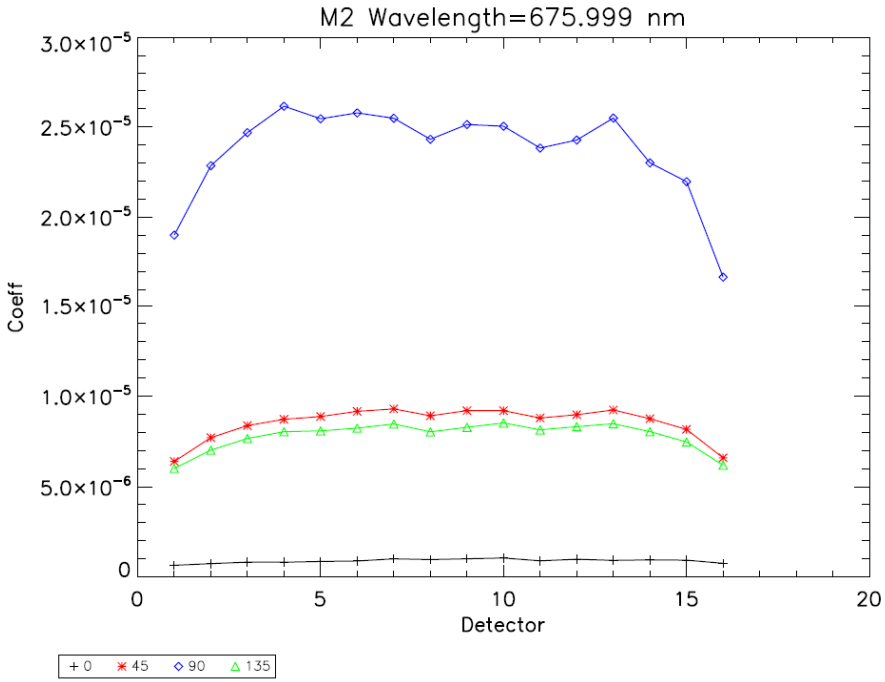
Along-Track FSF

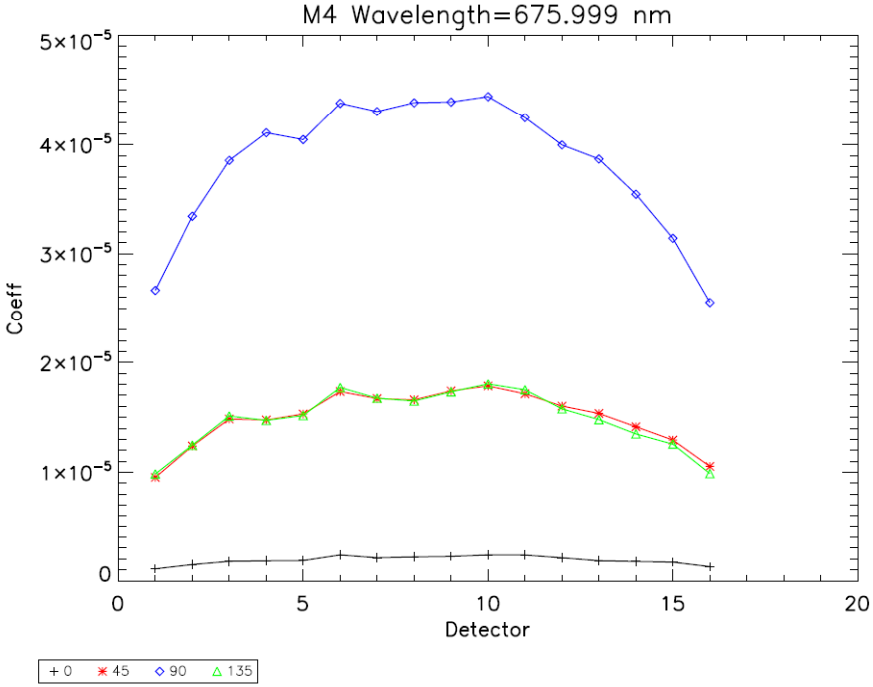




- Signal is strongest in M1, M2, M4 and M7 at 676 nm
- 660 and 676 nm are IB for M5
- Large difference between different polarization angles
- WGP=90 dominates for all wavelengths (fits two-cycle harmonic)

M3 Long Slit ICs





- M2 and M4 IC vs detector for the WGP angles at 676 nm using vertical slit
- WGP=90 has largest coefficient
- IC > 1.0E-5 for M2 (676 nm) and M4 (676 and 799 nm) – excluding receivers where wavelengths are IB.
- **ICs have been Characterized for all measured bands**

Crosstalk Uncertainty

- All the crosstalk tests have in common that more than one scan of data is collected .
  - Calculate an IC for each scan
  - Take the median as the IC and the Max-Min as the dispersion
    - This measure of repeatability takes into account part of the uncertainty.

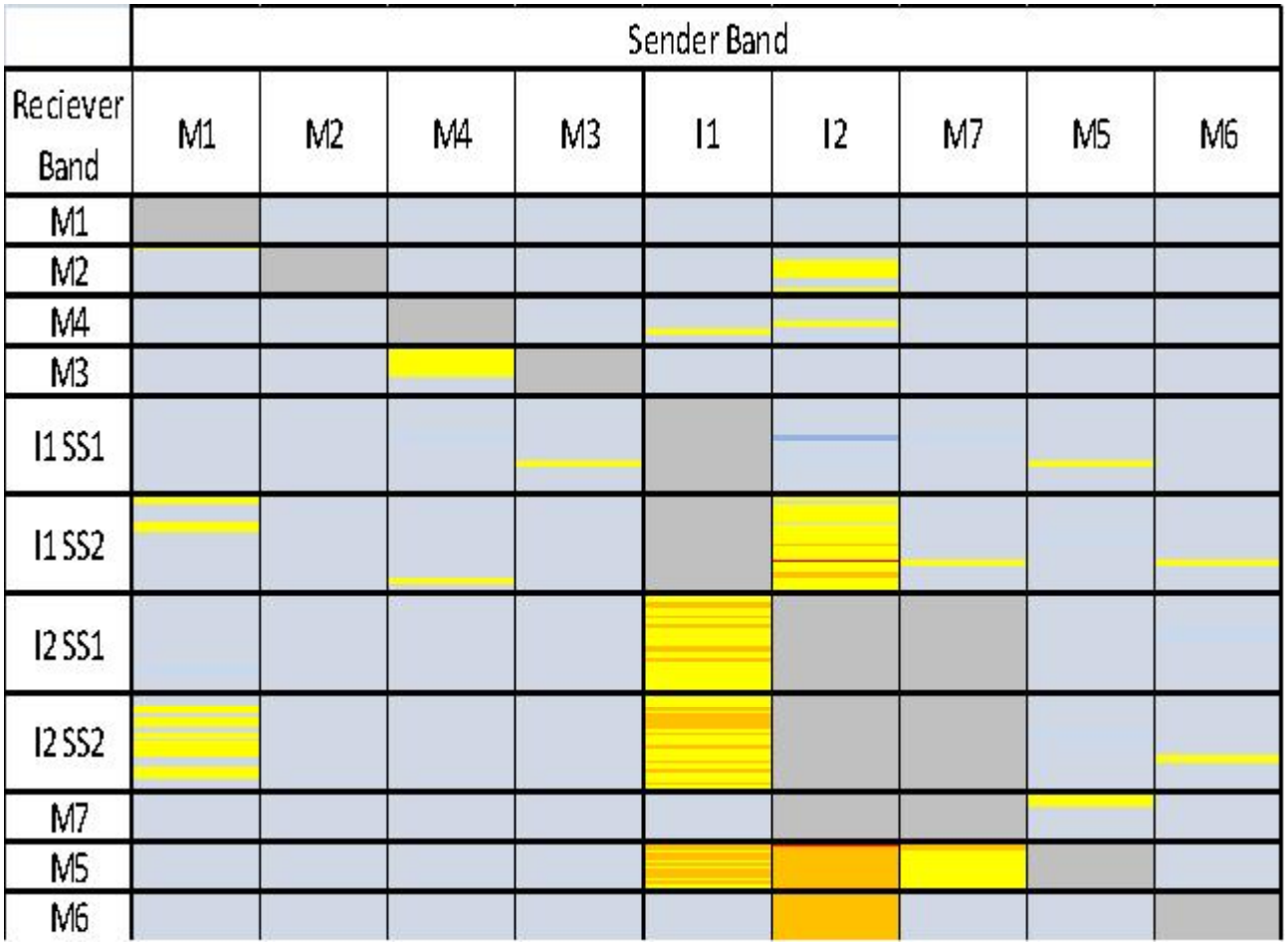
8-Scan Static Electric Dispersion example

	OA	OB	CA	CB	OA	OB	CA	CB
$J =$	1	2	1	2	3	4	3	4

$$IC(B_S, g_s, B_r, D_R, S_R, g_r) = median_J \; IC_J(B_S, g_s, B_r, D_R, S_R, g_r)$$

$$IC_{disp}(B_S, g_s, B_r, D_R, S_R, g_r) =$$
$$\max_J \; IC_J(B_S, g_s, B_r, D_R, S_R, g_r) - \min_J \; IC_J(B_S, g_s, B_r, D_R, S_R, g_r)$$

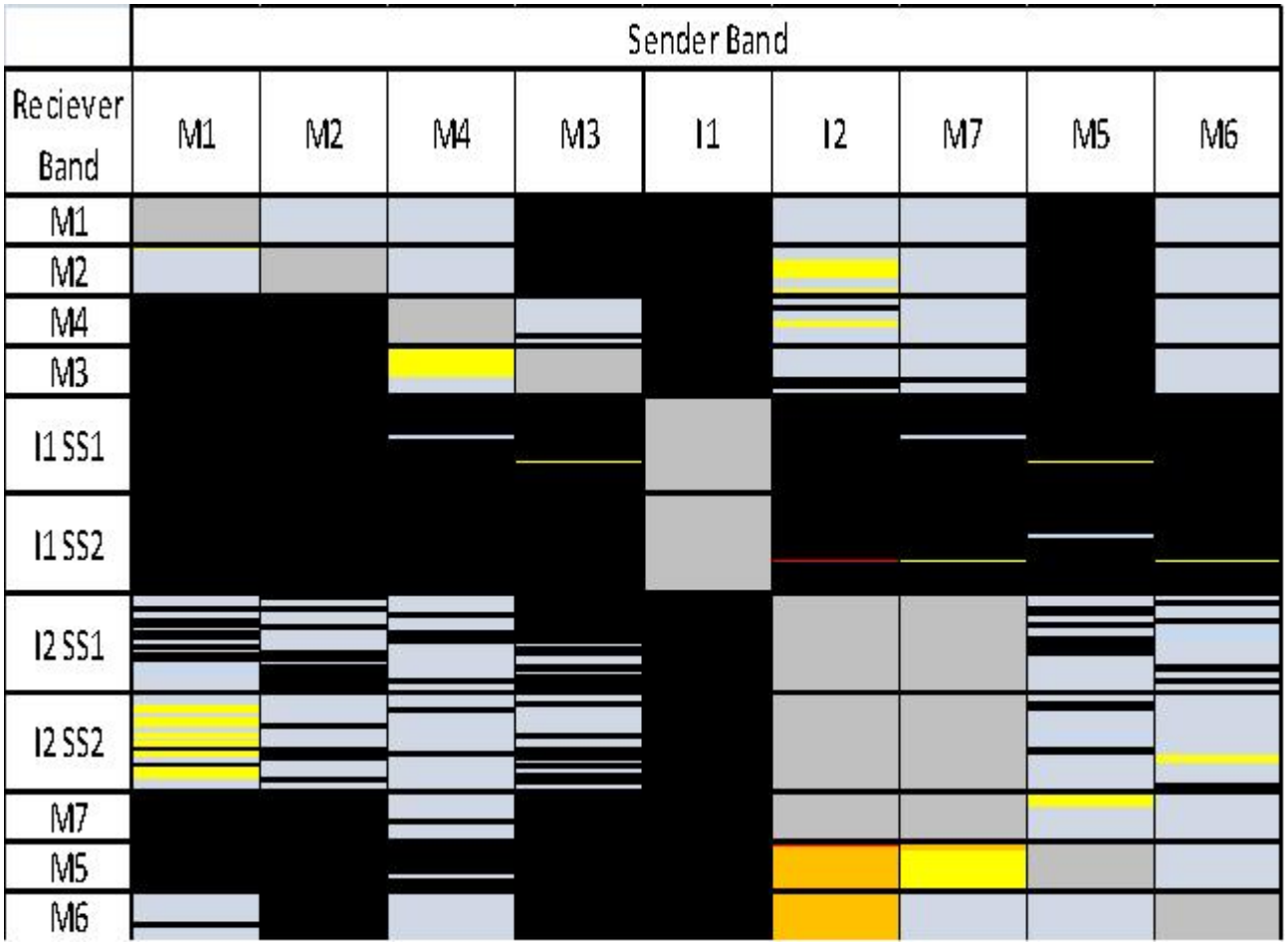
Dispersion Results from FP-16 (Electrical)



- Median xtalk compared to the specification
- Only auto-high gain data shown (low illumination)

Legend	
	xtalk_spec > 0.02
	0.02 > xtalk_spec > 0.01
	0.01 > xtalk_spec > 0.004
	0.004 > xtalk_spec > 0.002
	0.002 > xtalk_spec > -0.002
	-0.002 > xtalk_spec > -0.004
	-0.004 > xtalk_spec > -0.01
	-0.01 > xtalk_spec > -0.02
	-0.02 > xtalk_spec

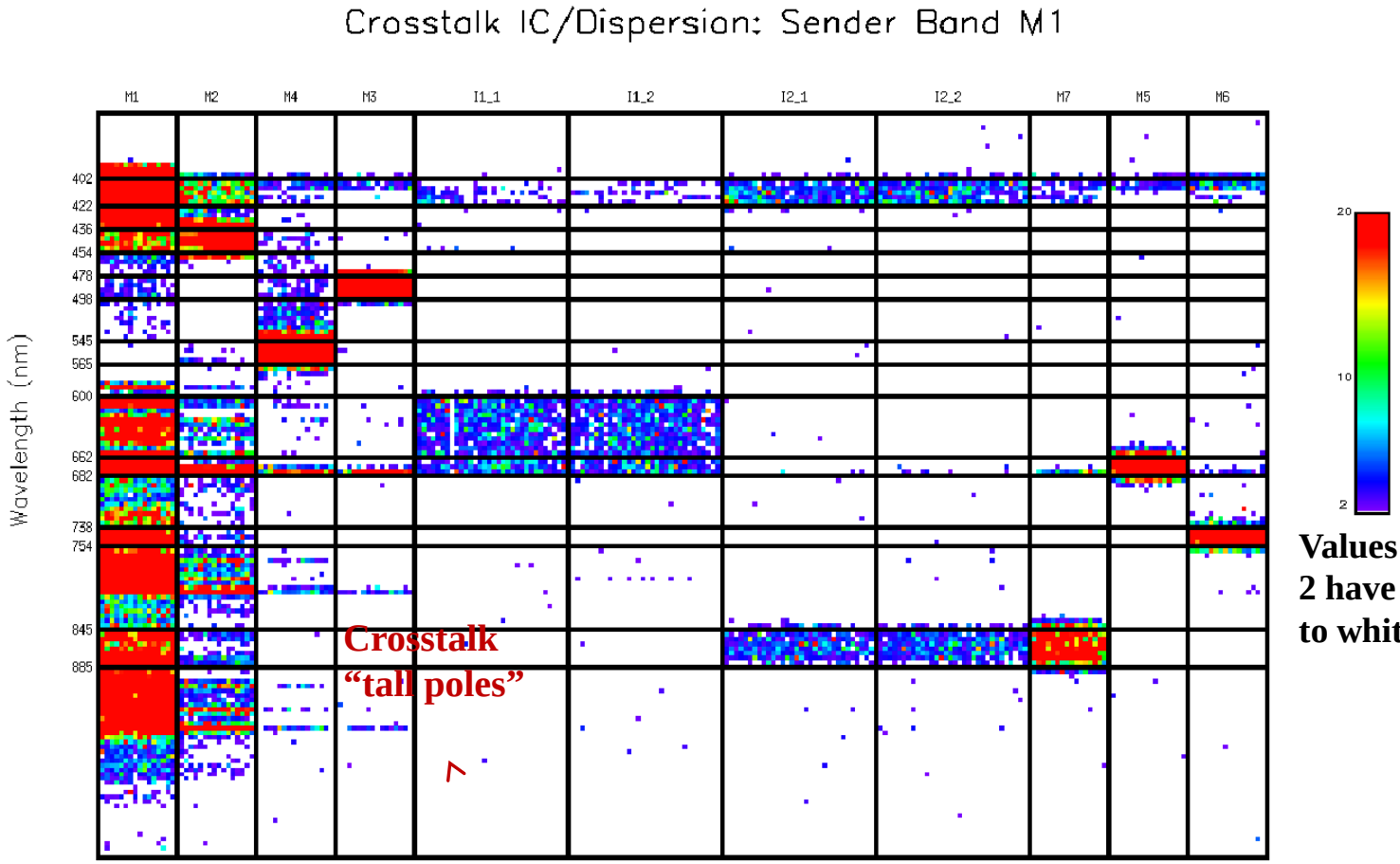
Dispersion Results from FP-16 (Electrical)



- Median xtalk compared to the specification
- Only auto-high gain data shown (low illumination)
- Dispersion > IC/2 blacked out

Legend	
	xtalk_spec > 0.02
	0.02 > xtalk_spec > 0.01
	0.01 > xtalk_spec > 0.004
	0.004 > xtalk_spec > 0.002
	0.002 > xtalk_spec > -0.002
	-0.002 > xtalk_spec > -0.004
	-0.004 > xtalk_spec > -0.01
	-0.01 > xtalk_spec > -0.02
	-0.02 > xtalk_spec

Dispersion Results from FP-16 (Optical)



Values less than 2 have been set to white.

- Most ICs have been set to white. Exceptions include;
  - In-band wavelengths for the Sender (Possibly Electrical)
  - In-band wavelengths for the receiver (Possible Near-Field Scatter)
  - M1 OOB response
  - ARS Tall Poles

Summary and Path Forward

- **VIIRS does not meet the crosstalk requirement - SRV0631**
  - Both at Band-to-point and point-to-point (earlier FP-13) level noncompliance's have been found on all three focal planes.
  - Heritage performance is still possible – MODIS specification was far more lenient than VIIRS
  - Crosstalk measurement shows uncertainties on the order of the requirement for some bands (I1, I2, M5).
    - More thorough uncertainty analysis is needed.
- **Optical and Static electrical crosstalk has been characterized extensively through tables of influence coefficients.**
  - On-orbit impact assessment is in progress for the VisNIR focal plane.
- **Polarization dependence has been characterized for about half the VisNIR bands which shows the FSF.**
  - Many ARS tall poles are heavily polarization dependent – effects disappear at certain polarization angles.
- **Dynamic crosstalk is present in the flight unit though much reduced in magnitude after rework.**

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