MISC for OST Concept 2

Latest information is available at the following web site on MISC Concept 2:
http://exoplanets.astron.s.u-tokyo.ac.jp/OST/MISC/index_misc_concept_2.html

Itsuki Sakon (University of Tokyo), Tom Roellig (NASA Ames), Kimberly Ennico (NASA Ames)
MISC team

Primary Science Drivers of MISC for Concept 2 OST

Science Objectives	Value of MISC Measurements
(1) Transit spectroscopy of exoplanets	Measurement of biogenic CH_4 7.6μm, CO_2 15μm, O_3 9.6μm, N_2O 17.6μm, and H_2O 17+ μm absorption lines achieving 5ppm (1ppm with a goal) utlra-high sensitivity with R~100 (<15μm) and R~300 (>15μm)
(2) Measurements of mid-infrared lines in Rise of Metals & Black Hole and Feedback programs	Measurement of dust features and [NeII] 12.8μm, [NeIII] 15.6μm, [SIII] 18.7μm, and [SIV]10.5μm lines at z up to ~1 (de-scoped from z~2, lose ability to detect 28 μm H_2 line at any z) with R>300
(3) Direct detecton of Jupiter/Saturn analogues around nearby stars	Detection of Jupiter and Saturn analogs around nearby stars with R~5 in 5 bands in 5-28μm achieving coronagraph blocking capability of 10^{-6} at 2.5λ/D
(4) Engineering objective: provide focal plane pointing and guiding function for observatory by observing star fields	
(5) General objective: Mid-infrared Imaging (not specifically tied to any program but generally agreed that we need it)	

MISC for Concept 2 OST

Configuration:

[1] MISC Camera / Wide Field Imager (WFI-S1, WFI-S2, WFI-L) + Coronagraph (COR)

[2] MISC Transit Spectrometer (TRA)

Detectors:

[1] Si:As (TBD)

Three 2kx2k Detector Arrays [30μm/pix] for WFI-S1, WFI-S2 and WFI-L

One 1kx1k Detector Array [30μm/pix] for COR

[2] super-conducting nano wire detector (TBD)

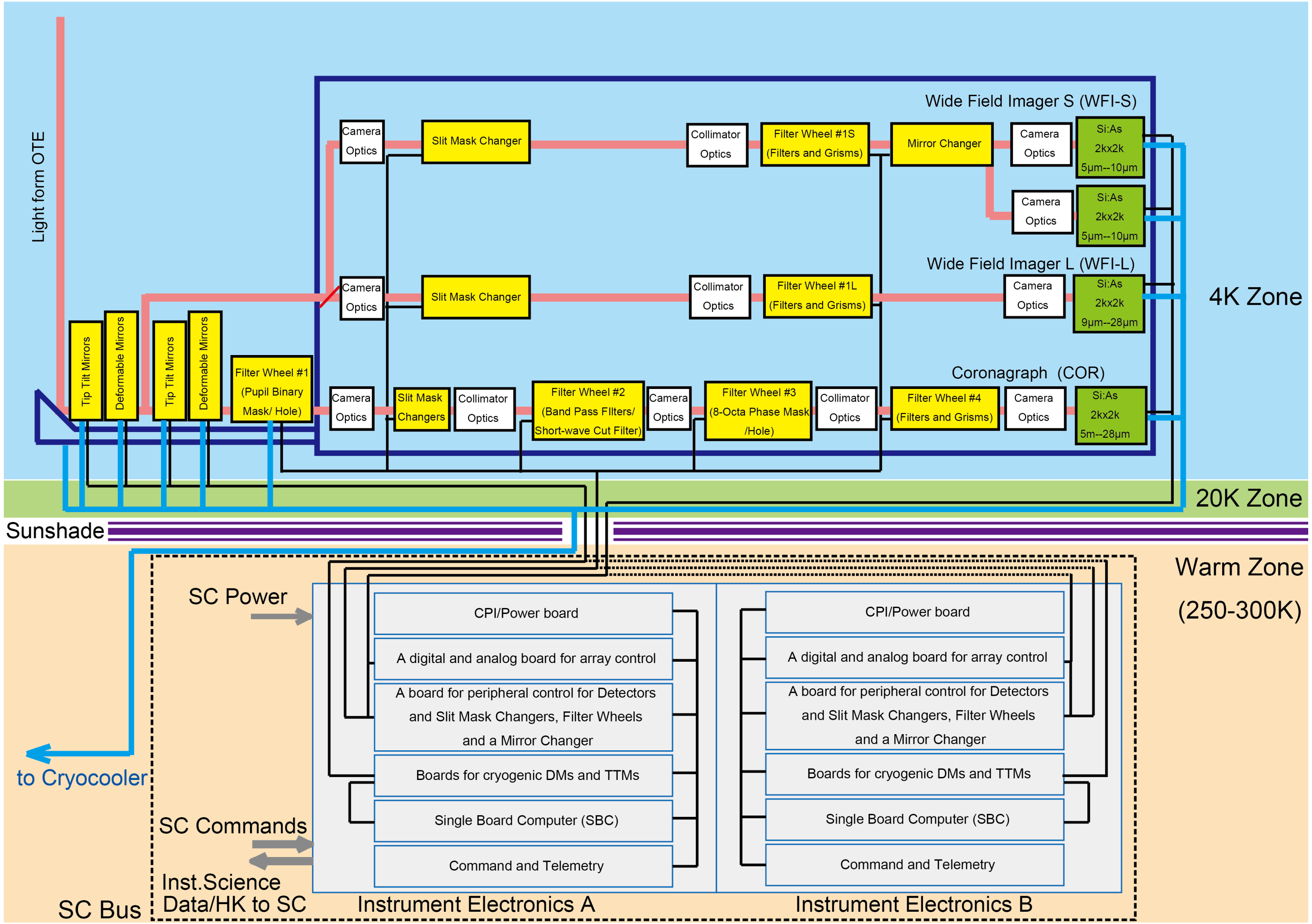
Twelve 5(spatial) x 140(dispersion) Detector Arrays for TRA

Observing Modes of MISC for OST Concept 2

(1) MIR Imaging [WFI-S, WFI-L]
(2) MIR Low-Resolution Spectroscopy (slit) [WFI-S, WFI-L]
(3) MIR Low-Resolution Spectroscopy (slitless) [WFI-S, WFI-L]
(4) MIR Scan [WFI-S, WFI-L]
(5) MIR Coronagraph Imaging [COR]
(6) MIR Coronagraph Spectroscopy [COR]
(7) MIR Ultra Stable Spectroscopy [TRA]

(1) MISC Camera for OST Concept 2

OST/MISC Camera - with coronagraph channel



(1-1) MISC Camera/Imager

- Wide Field Imager-Short 1
- Wide Field Imager-Short 2
- Wide Field Imager-Long

Yuji Ikeda (Photocoding); Optical and structural designing of MISC Camera/Coronagraph
Takehiko Wada (ISAS/JAXA); Detector technology, studies on observing mode 'MISC Scan'
Aoi Takahashi (ISAS/JAXA); Deformable mirror
Itsuki Sakon (U Tokyo), Tom Roellig (NASA Ames), Kimberly Ennico (NASA Ames),
MISC Camera team

MISC Scan (1)

The scan speed for MIR scan is estimated based on the scheme adopted for AKARI/IRC All Sky Survey (Ishihara et al. 2008, SPIE, 7010, 70100B)

- using double lines (2 x 1 pix x 2048 pix) for the purpose of mili-sec confirmation
- reading neighboring 4 lines to avoid unstable behavior of the detector
- Concequently 2 x (4+1+4) = 18 lines are read
- 2lines are downlinked and other 16 lines are discarded
- assuming 4 sec for full readout (2048 lines)
- 4 x 18 / 2048 = 35 msec per double lines
- pixel scale; 0.09 arcsec
- Aopting the nyxist rate of twice for the purpose of imaging reconstruction, the scan speed is 0.09 arcsec / 2 / 35msec ~ 1.5 [arcsec/s].

MISC Scan (2)

There is an alternate way of doing scanning with MISC for imaging or slit-less grism spectroscopy, which is to use the tip-tilt mirror in the front of the MISC imager moving in a "freeze-frame". Sawtooth pattern.

This has the advantage of achieving higher sensitivity, but limits the maximum scan rate.

If we assume that we can read out one of the MISC 2k x 2k arrays at 0.25 Hz, and we further assume that we only can read out a maximum of half the imager FOV (because otherwise we would need to increase the 3' x 3' FOV), then we could handle a maximum scan rate of roughly 22.5 [arcsec/sec].

(1-2) MISC Camera/Coronagraph

- 8OPM Coronagraph

Jun Nishikawa (NAOJ); Simulation studies of 8OPM Coronagraph for MISC Concept 2
Naoshi Murakami (Hokkaido Univ.); development of 8OPM Coronagraph
Aoi Takahashi (ISAS/JAXA); WFE correction system (deformable mirror)
Keigo Enya (ISAS/JAXA); 8OPM coronagraph, TTM, DM
Yuji Ikeda (Photocoding); Optical and structural designing of MISC Camera/Coronagraph
Itsuki Sakon (U Tokyo), Tom Roellig (NASA Ames), Kimberly Ennico (NASA Ames)
MISC Camera team

OST(2) + Shaped Pupil + 8OPM

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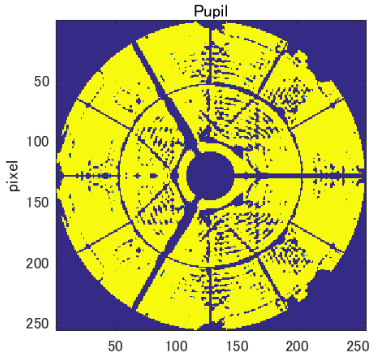
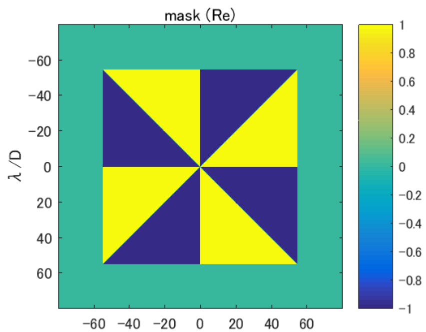
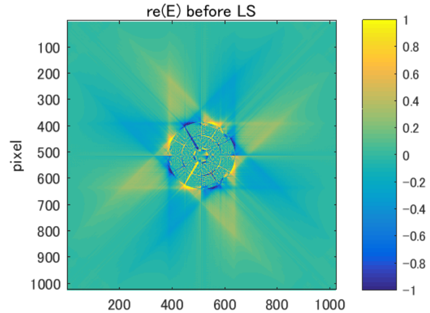
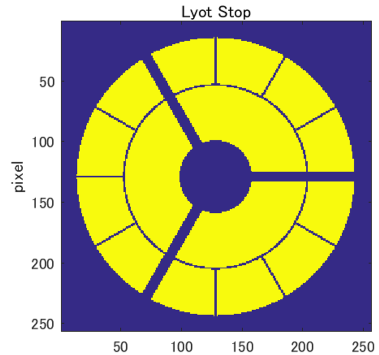




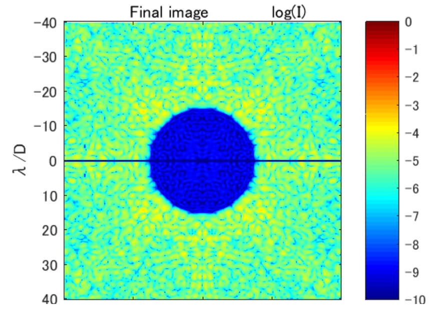
8OPM ±55λ/D



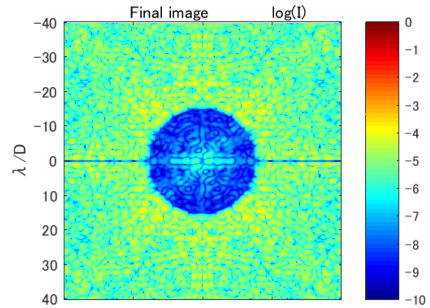


Lyot Stop

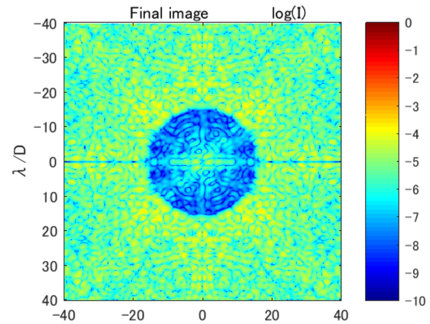
Primary Diameter x0.9
Secondary Diameter x1.5
Spider width x2.0



θin = 0.00λ/D



0.02λ/D



0.05λ/D

OST(2) + Shaped Pupil + 8OPM

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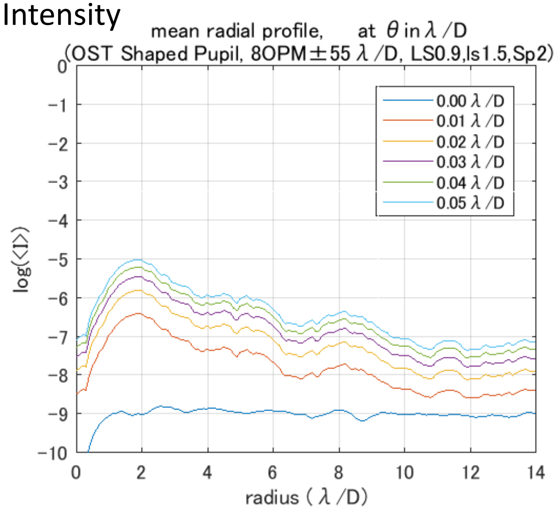
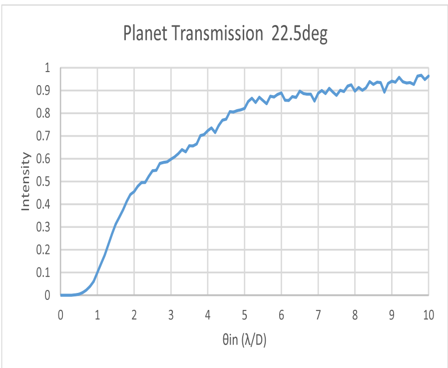
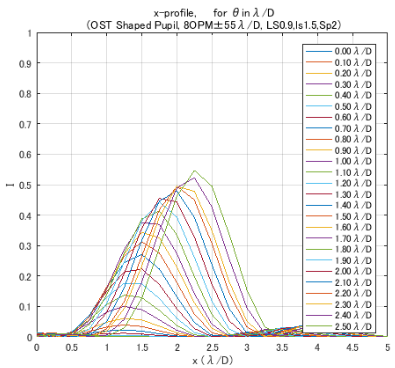
Leak Intensity



Planet transmission @22.5deg (best direction)





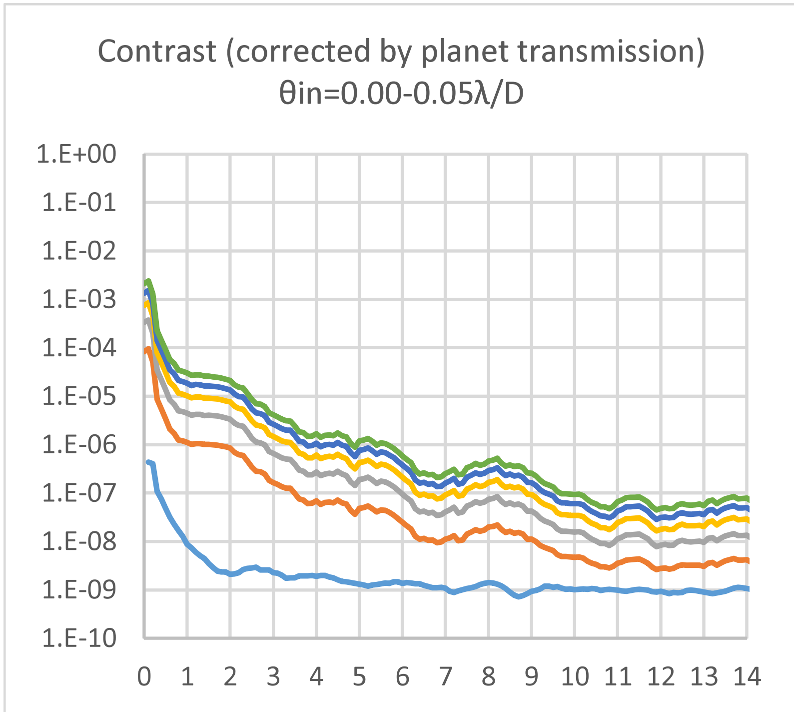
IWA(50%) ~2.2λ/D @22.5deg (best direction)

Achievable Contrast (without wavefront error)

θin=0.01λ/D ~ 1E-6@(1-)2λ/D, 1E-7@5λ/D , 1E-7@10λ/D

θin=0.02λ/D ~ 3E-6@(1-)2λ/D, 2E-7@5λ/D , 2E-8@10λ/D

θin=0.05λ/D ~ 2E-5@(1-)2λ/D, 1E-6@5λ/D , 4E-8@10λ/D



OST(2) + 8OPM + Lyot Stop (Block >=1%)

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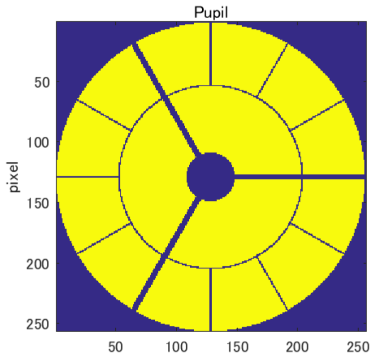
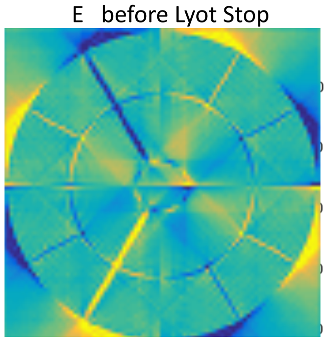
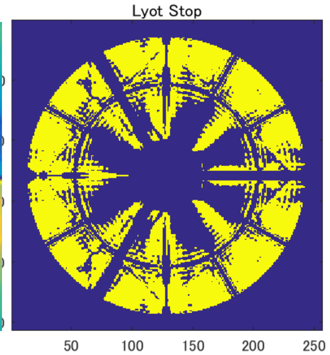
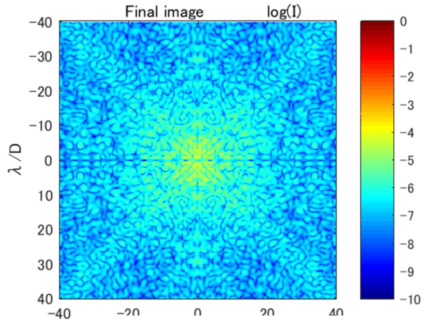






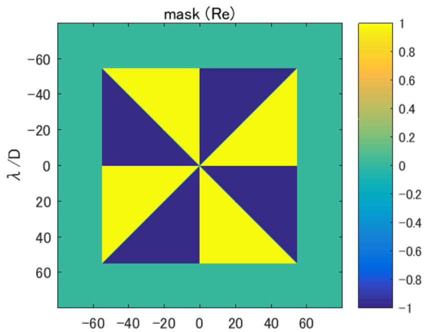


Leak Intensity (θin=0~0.1λ/D)

~ 3E-5@2λ/D,

~ 1E-5@5λ/D,

~ 3E-6@10λ/D



Lyot Stop

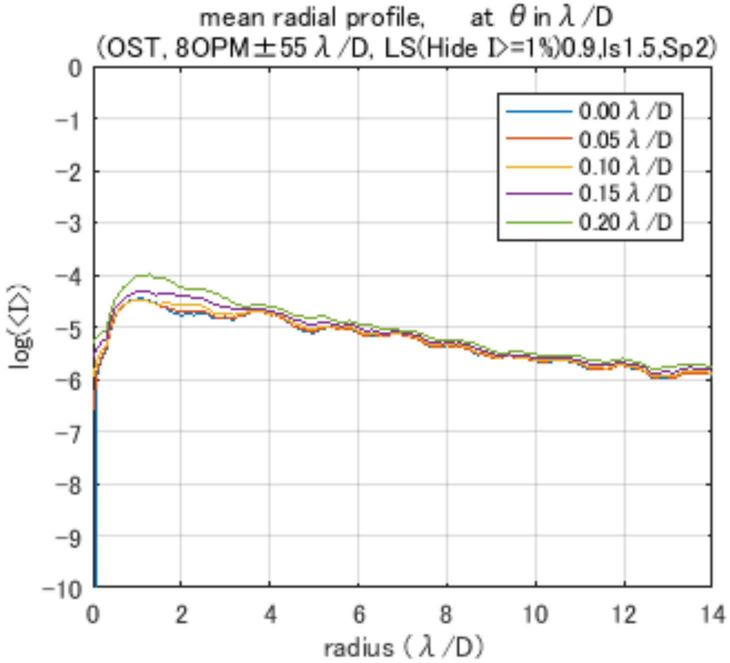
Primary Diameter x0.9

Secondary Diameter x1.5

Spider width x2.0

Block Bright Area

(|E|>=0.1, Intensity >=1%)



Summary of simulation for the Concept 2 MISC Camera/Coronagraph capability

OST(2) + Shaped Pupil + 8OPM (**WITH** WFE correction using internal DM + TTM)

Achievable Contrast (without wavefront error)
θin=0.01λ/D ~ 1E-6@(1-)2λ/D, 1E-7@5λ/D , 1E-7@10λ/D
θin=0.02λ/D ~ 3E-6@(1-)2λ/D, 2E-7@5λ/D , 2E-8@10λ/D
θin=0.05λ/D ~ 2E-5@(1-)2λ/D, 1E-6@5λ/D , 4E-8@10λ/D

note; 0.01λ/D

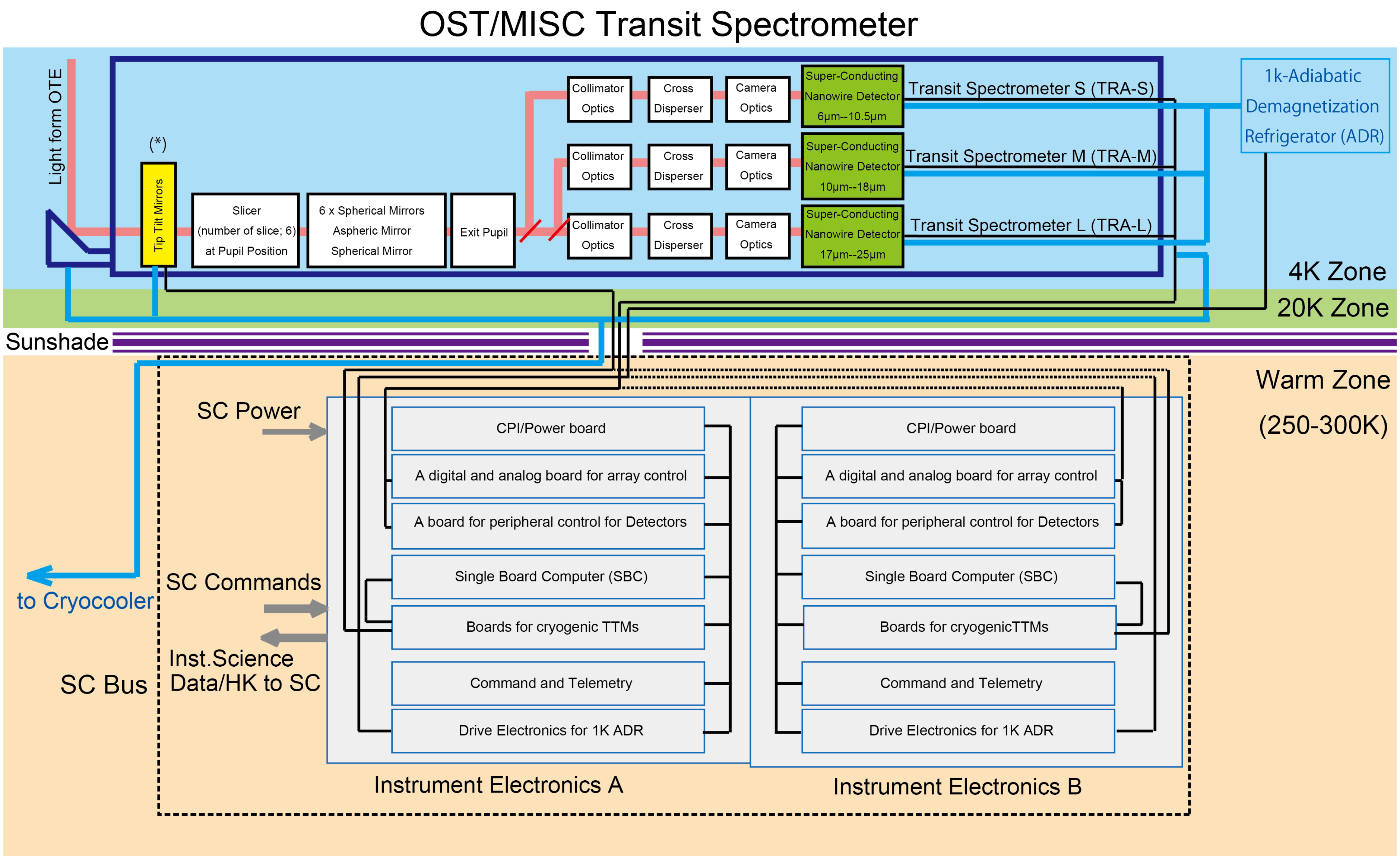
OST(2) + 8OPM + Lyot Stop (Block >=1%) (**WITHOUT** WFE correction using internal DM + TTM)

Leak Intensity (θin=0~0.1λ/D)
~ 3E-5@2λ/D, ~ 1E-5@5λ/D, ~ 3E-6@10λ/D

In the case of the 8OPM, the peak of the leak comes at 1.8λ/D and nearly constant contrast is achieved in 1-2λ/D
→ ~1λ/D can be aimed, although the leak value is very sensitive to the pointing jitter.

1-3E-6 @1-2λ/D can be achieved If the pointing jitter is reduced down to the 2-4mas level
with a help of the WFE correction using internal DM + TTM for the MISC Camera/Coronagraph.

(2) MISC Transit Spectrometer for OST Concept 2



OST/MISC Transit Spectrometer
Light form OTE
(*)
Tip Tilt Mirrors
Slicer
(number of slice; 6)
at Pupil Position
6 x Spherical Mirrors
Aspheric Mirror
Spherical Mirror
Exit Pupil
Collimator Optics
Cross Disperser
Camera Optics
Super-Conducting Nanowire Detector 6μm--10.5μm
Transit Spectrometer S (TRA-S)
Collimator Optics
Cross Disperser
Camera Optics
Super-Conducting Nanowire Detector 10μm--18μm
Transit Spectrometer M (TRA-M)
Collimator Optics
Cross Disperser
Camera Optics
Super-Conducting Nanowire Detector 17μm--25μm
Transit Spectrometer L (TRA-L)
1k-Adiabatic Demagnetization Refrigerator (ADR)
4K Zone
20K Zone
Sunshade
Warm Zone
(250-300K)
SC Power
CPI/Power board
A digital and analog board for array control
A board for peripheral control for Detectors
Single Board Computer (SBC)
Boards for cryogenic TTMs
Command and Telemetry
Drive Electronics for 1K ADR
CPI/Power board
A digital and analog board for array control
A board for peripheral control for Detectors
Single Board Computer (SBC)
Boards for cryogenicTTMs
Command and Telemetry
Drive Electronics for 1K ADR
to Cryocooler
SC Commands
Inst.Science Data/HK to SC
SC Bus
Instrument Electronics A
Instrument Electronics B

(2-1) MISC Transit Spectrometer

- Densified Pupil Spectrometer

Taro Matsuo (Osaka University); Studies of densified pupil spectrometer for MISC Concept 2
Tomoyasu Yamamuro (Photocoding); Optical designing of MISC Transit Spectrometer
Itsuki Sakon (U Tokyo), Tom Roellig (NASA Ames), Kimberly Ennico (NASA Ames)
MISC Transit Spectrometer Team

How we design the optical system for Concept 2 ?

- Because the requirements on the transit spectrograph are same as those of the Concept 1, we fix the parameters of the densified pupil spectrograph and change only the pupil relay system.

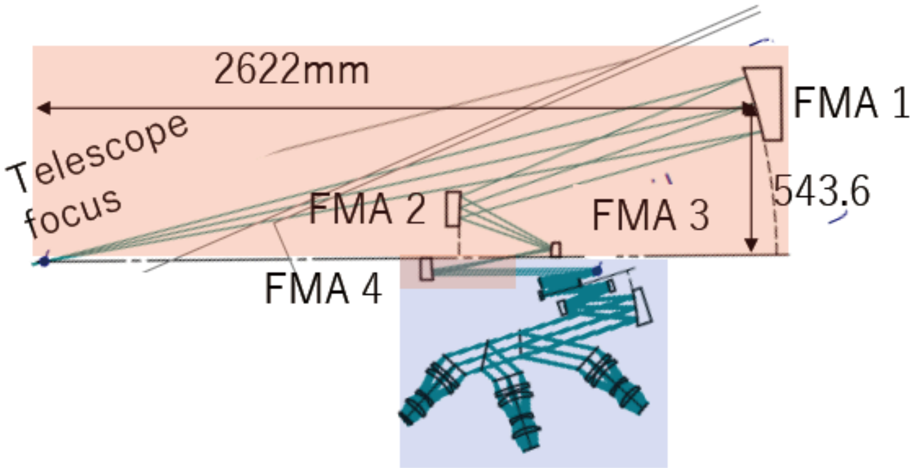
- Two options for optimization of the pupil relay system:

  - 1. To optimize only the parameters of the four mirror assembly to reduce the size of the relay system (option 1)

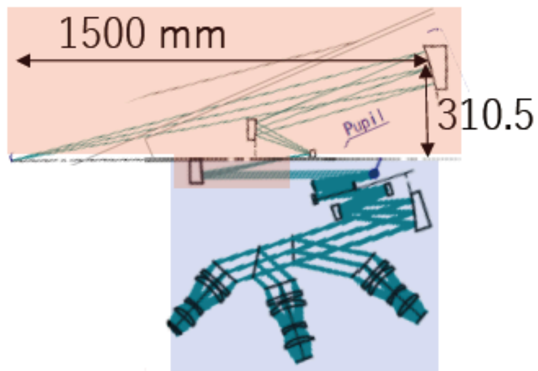
  - 2. To apply only one collimator instead of the four mirror assembly and simplify the pupil relay system (option 2)

Option 1

- We optimize only the parameters of FMA, keeping the parameters of the optics after the pupil slicer.



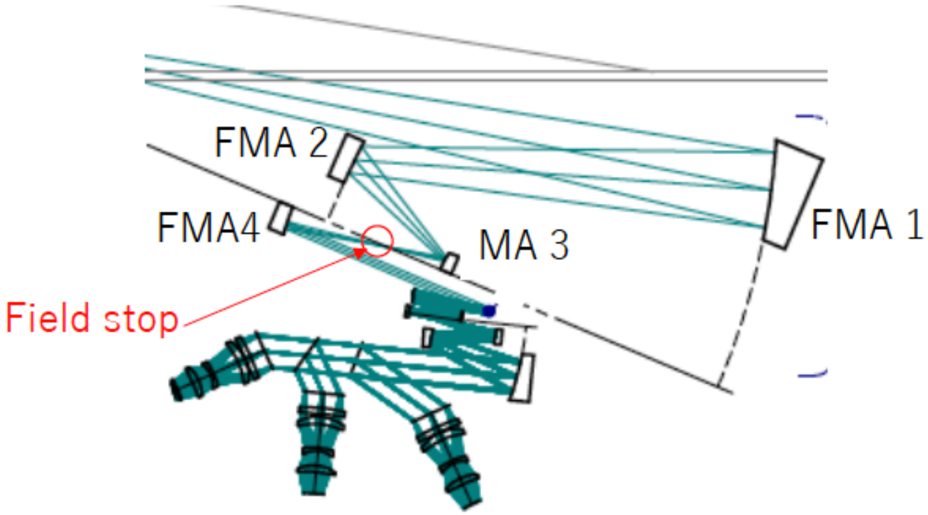
Original FMA (Concept 1)



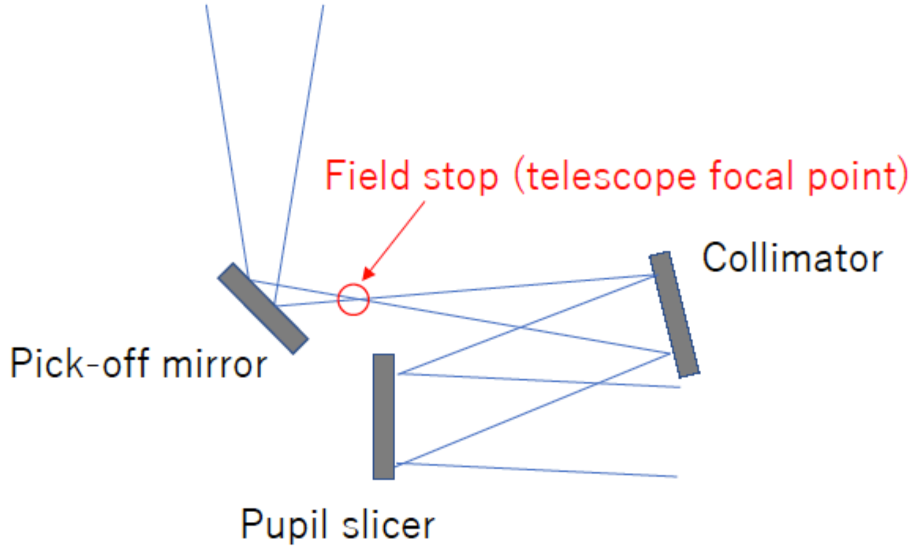
Optimized FMA for Concept 2

Option 2

- If a field stop can put on the telescope focal plane, a collimator system composed of one or two mirrors is potentially applied instead of FMA.



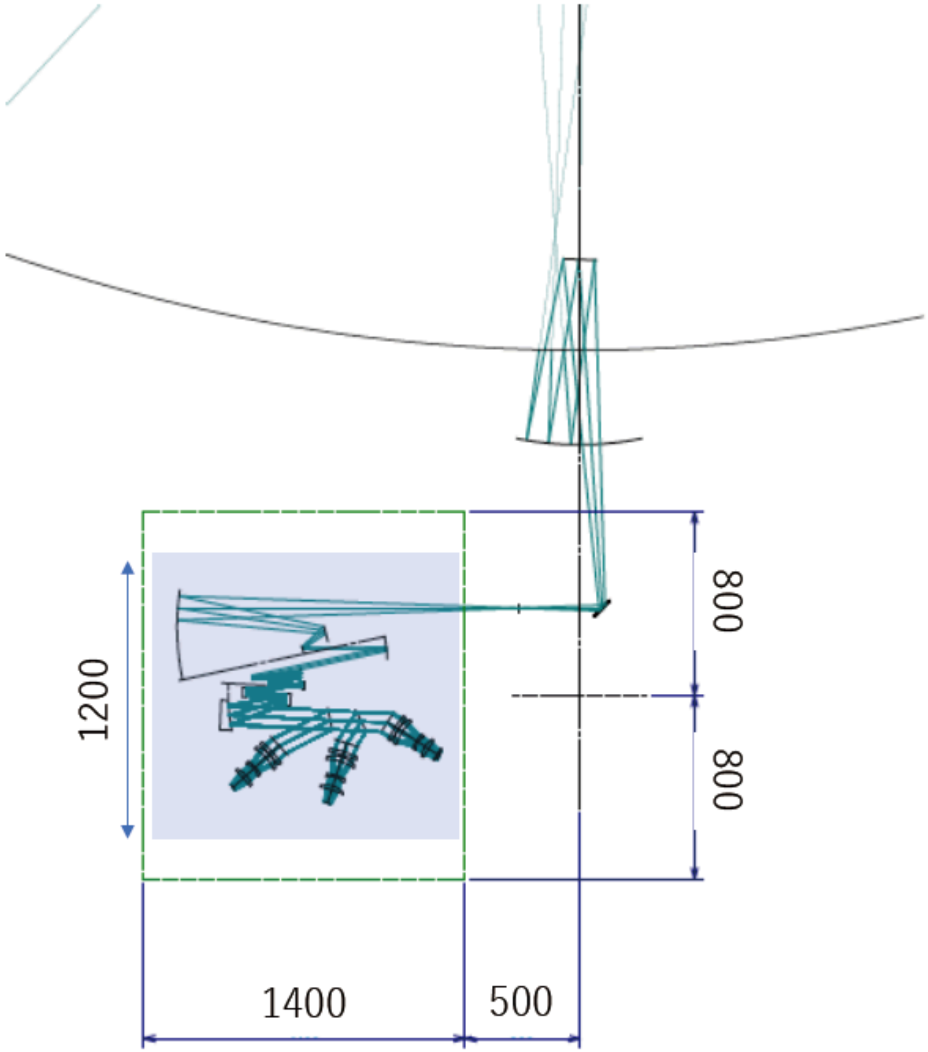
Field stop of option 1



Field stop of option 2

Configuration

- The optimized optical design for the Concept 2 fully meets the requirements on the transit spectrograph with the wavelength range of 6-25µm.
- The size of the transit spectrograph for the option 1 is 1400 x 1200 x 300 mm.
- The size can be reduced if the design of the option 2 is applied.



Cold Mass Estimate for Concept 2 MISC Transit Spectrometer (TRA)

Part No.	Part Name	Material	Quantity	Total mass (kg) Material; Al (Concept 1)	Total mass (kg) Material; Al (Concept 2)	Total mass (kg) Material; Be (Concept 2)	Total mass (kg) Material; CO720 (Concept 2)
1	Body	A6061-T6/Be/CO720	1	56.00	52.00	13.00	21.67
2	Plane Mirror 1	A6061-T6/Be/CO720	1	4.70	2.00	0.40	0.67
3	Plane Mirror 2	A6061-T6/Be/CO720	1	4.70	2.00	0.40	0.67
4	Collimator 1	A6061-T6/Be/CO720	1	13.80	6.00	1.20	2.00
5	Collimator 2	A6061-T6/Be/CO720	1	1.70	1.00	0.20	0.33
6	Collimator 3	A6061-T6/Be/CO720	1	0.60	0.50	0.10	0.16
7	Collimator 4	A6061-T6/Be/CO720	1	0.60	0.50	0.10	0.16
8	Pupil Slicer	A6061-T6/Be/CO720	1	2.00	2.00	0.40	2.00
9	TMA 1	A6061-T6/Be/CO720	1	0.60	0.60	0.12	0.20
10	TMA 2	A6061-T6/Be/CO720	1	0.60	0.60	0.12	0.20
11	TMA 3	A6061-T6/Be/CO720	1	1.90	1.90	0.38	0.63
12	Dichloic Beam Splitter 1	CdTe	1	1.00	1.00	1.00	1.00
13	Dichroic Beam Splitter 2	CdTe/Si	1	1.00	1.00	1.00	1.00
14	Grisms	Other	3	3.00	3.00	3.00	3.00
15	Camera Lens (Short)	KRS-5	1	6.00	6.00	6.00	6.00
16	Camera Lens (Middle)	ZnSe	1	7.20	7.20	7.20	7.20
17	Camera Lens (Long)	ZnSe	1	7.20	7.20	7.20	7.20
18	Detector	A6061-T6	3	4.50	4.50	4.50	4.50
19	Light Shield	CFRP	1	3.10	3.10	3.10	3.10
			Total	120.20	102.10	49.42	61.69

Fact Sheet of MISC for Concept 2 OST

Parameter	MISC Camera		MISC Transit Spectrometer
	Wide-Filed Imager	Coronagraph	
Operating modes	MIR Imaging MIR Low-Resolution Spectroscopy (slit) MIR Low-Resolution spectroscopy (slitless) MIR Scan	MIR Coronagraph Imaging MIR Coronagraph Spectroscopy	MIR Ultra Stable Spectrpscopy
Sensitivity (5σ, 1 hr)	1h5σ continuum sensitivity for a point source MIR Imaging (R=5): 0.06 μJy @5.0 μm 0.25 μJy @9.0 μm 0.64 μJy @16.0 μm 0.96 μJy @23.0 μm 1.93 μJy @27.6 μm 1h5σ line sensitivity for a point source MIR Low-resolution Spectroscopy (Slit, R=300) 5.0E-21 W/m2 @6μm 4.5E-21 W/m2 @8μm 5.3E-21 W/m2 @10μm 4.3E-21 W/m2 @12μm 5.2E-21 W/m2 @18μm 5.4E-21 W/m2 @24μm 1.1E-20 W/m2 @26μm 5.4E-19 W/m2 @28μm	1h5σ continuum sensitivity for a point source MIR Imaging (R=5): 1 μJy in 5-25 μm	Sensitivity is not as important as a few ppm stability

Fact Sheet of MISC for Concept 2 OST

<table>
<tr><th rowspan="2">Parameter</th><th colspan="2">MISC Camera</th><th rowspan="2">MISC Transit Spectrometer</th></tr>
<tr><th>Wide-Filed Imager</th><th>Coronagraph</th></tr>
<tr><td>Resolving power</td><td>R=5-10 for MIR Imaging
R=300 For MIR Low-Resolution Spectroscopy</td><td>R=5-10 for MIR Imaging
R=300 For MIR Low-Resolution Spectroscopy</td><td>R=100 in 6-17 μm
R=300 in 17-25 μm</td></tr>
<tr><td>Angular resolution</td><td>0.21 arcsec @ 5 μm
0.38 arcsec @ 9 μm
0.68 arcsec @16 μm
0.98 arcsec @23 μm
1.18 arcsec @27.6 μm</td><td>0.25 arcsec @6μm</td><td>Angular resolution is not important</td></tr>
<tr><td>Spectral range</td><td>5 - 28 μm</td><td>5 - 28 μm</td><td>6 - 25 μm</td></tr>
<tr><td>Field of View (instantaneous)</td><td>3 x 3 arcmin
(20 arcsec x 20 arcsec of the FOV is used for Coronagraph)</td><td>10 arcsec x 10 arcsec</td><td>N/A</td></tr>
<tr><td>Saturation limit</td><td>Saturation limit for a point source
MIR Imaging (R=5):
100 mJy @ 5μm
200 mJy @ 10μm
500 mJy @ 20μm
1Jy @25μm
MIR Low-Resolution Spectroscopy (R=300):
4 Jy @ 5μm
8 Jy @ 10μm
20 Jy @ 20μm
50 Jy @25μm</td><td>N/A</td><td>N/A</td></tr>
</table>

Fact Sheet of MISC for Concept 2 OST

Parameter	MISC Camera		MISC Transit Spectrometer
	Wide-Filed Imager	Coronagraph	
Scanning speed (survey mode)	MIR Scan Maximum 1.5 [arcsec/sec] (AKARI type) Maximum 22.5 [arcsec/sec] (using TTM)	N/A	N/A
Detectors	three 2kx2k Si:As arrays - two for WFI-S - one for WFI-L	one 1kx1k Si:As array	tweleve super-conducting nanowire detector arrays (a single array size; 5pix x 140 pix) - four 5 pix x 140 pix arrays for TRA-S - four 5 pix x 140 pix arrays for TRA-M - four 5 pix x 140 pix arrays for TRA-L
Detector NEP	N/A	N/A	N/A
Detector cold readout	MUX	MUX	MUX (TBD)
Photometric stability	N/A	N/A	5 ppm with a goal of 1 ppm on a timescale of hours to days