Aug. 30th 2018

OST MISC/TRA estimated performance v3

Taro Matsuo

Optical design

- The OST MISC transit spectrograph was successfully updated as follows;

✓ The observing wavelength ranges from 2.8 to 20μm

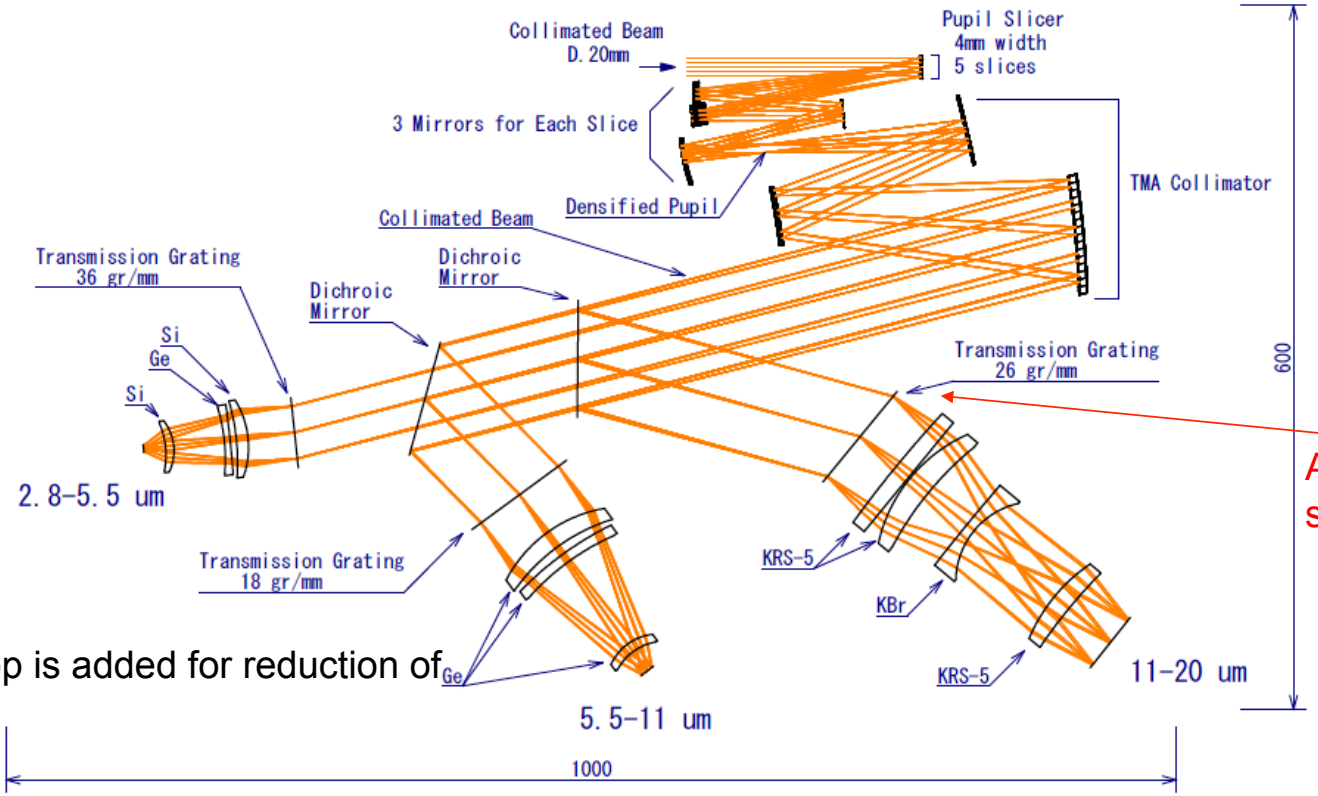
✓ The number of the detector samplings are optimized because of the higher dark current of MCT detector and smaller diameter:

- The number of samplings for each spectral element is 135 pixels for short, 270 pixels for middle and 340 pixels for long band.

✓ The higher throughput over the entire wavelength range is provided.

Updated optical design

Generated by Yamamuro-san

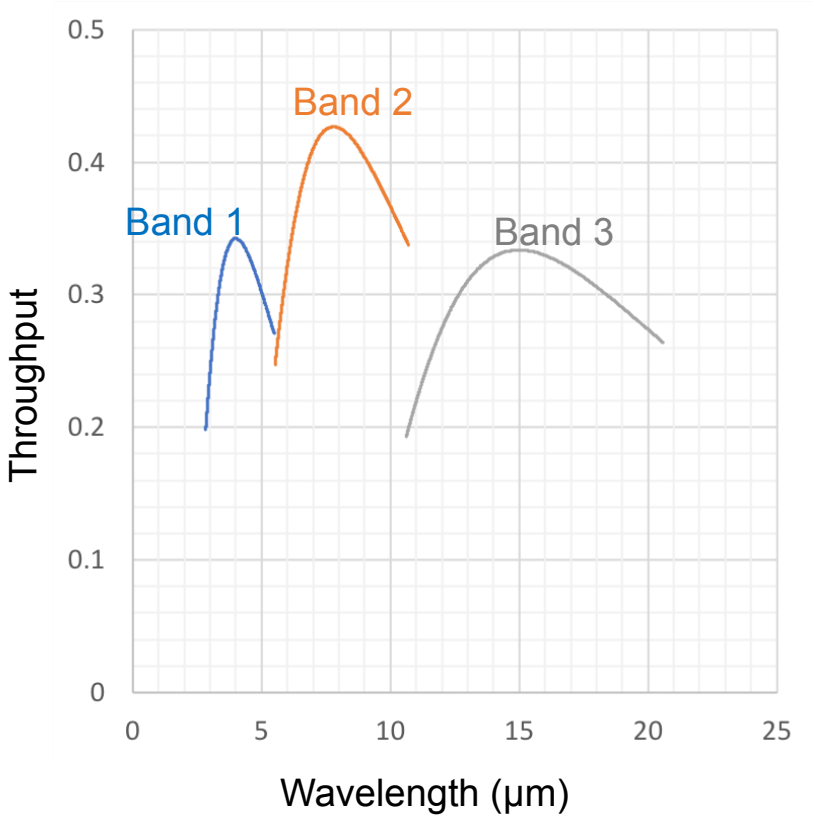


Additional field stop is added.

Additional field stop is added for reduction of

Throughput

	Band 1	Band 2	Band 3
wavelength [μm]	2.8-5.5	5.5-10.5	11-20
Telescope (x4)	0.97	0.98	0.98
Relay mirror (x6)	0.96	0.96	0.96
Densified pupil spectrograph (x 7)	0.96	0.96	0.96
Dichroich mirror 1	0.8	0.8	0.9
Dichroich mirror 2	0.8	0.9	1
Grating at peak	1	1	1
AR coat lens	0.94	0.94	0.66
detector quantum efficiency	0.88	0.78	0.7
Contamination/slit loss	0.9	0.9	0.9



For more information, please refer to Appendix.

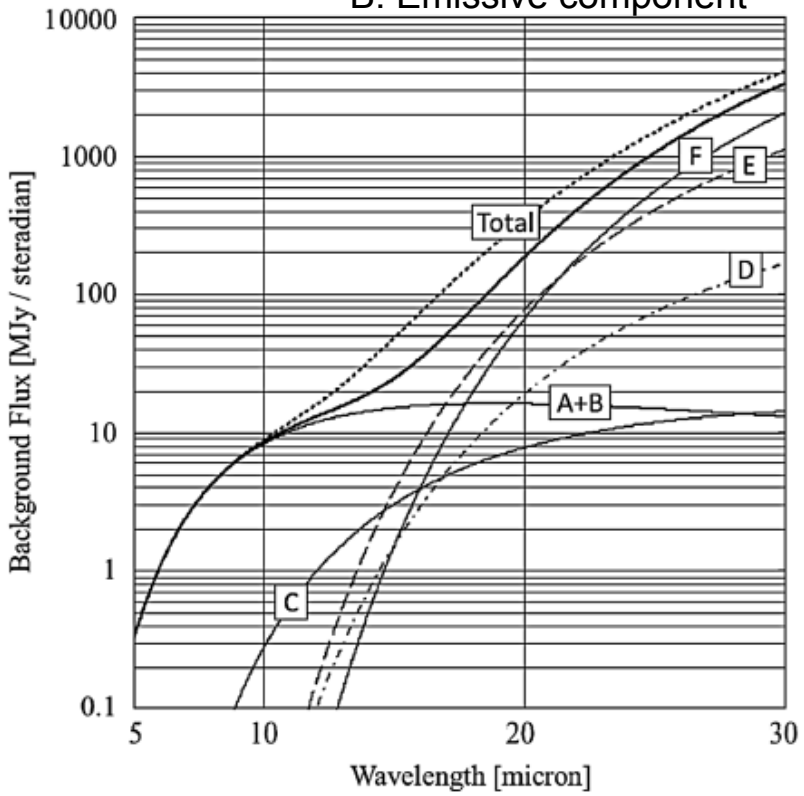
Zodiacal light

- A+B model was applied for calculation.
- The field of view was tentatively set to 2.5” and additional field stop with radius of 1.5”is added to the long channel.

Wavelength (μm)	Background (MJy/steradian)
3	0.1
5	0.35
6	1
8	3
10	8.5
11	11
14	14
20	17

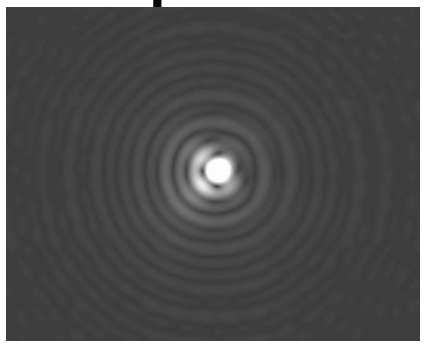
* The background at 3μm was derived from extrapolation.

A: Scattered component
B: Emissive component



Glasse et al. PASP 2015

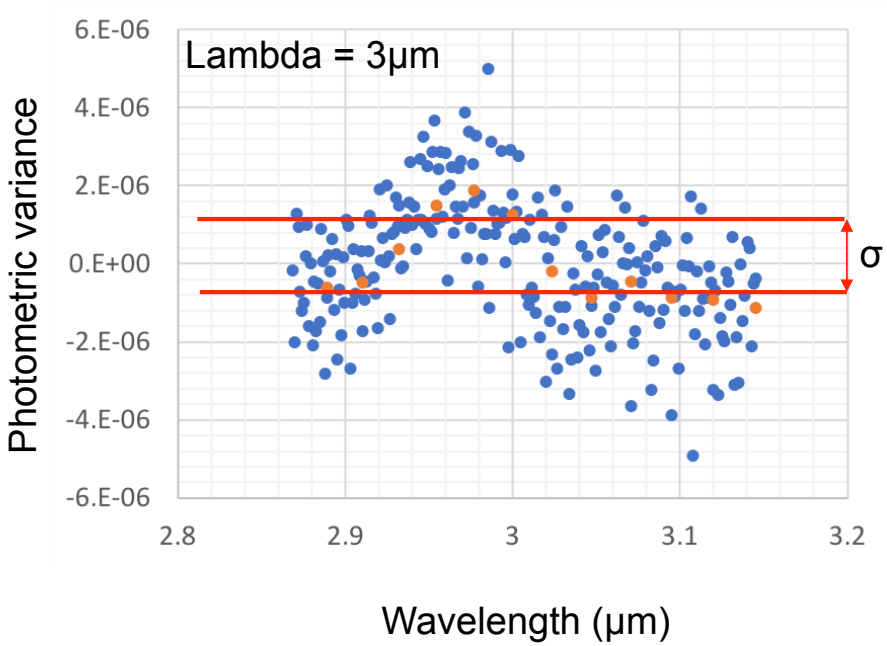
Spectrophotometric accuracy



3μm simulation image (from James Corsetti)
+ 9 mas jitter

1. Calculating photometric variance as monochromatic light
2. Imitating chromatic light and evaluating its photometric variation
3. Deriving spectrophotometric accuracy of chromatic light from standard deviation, σ.

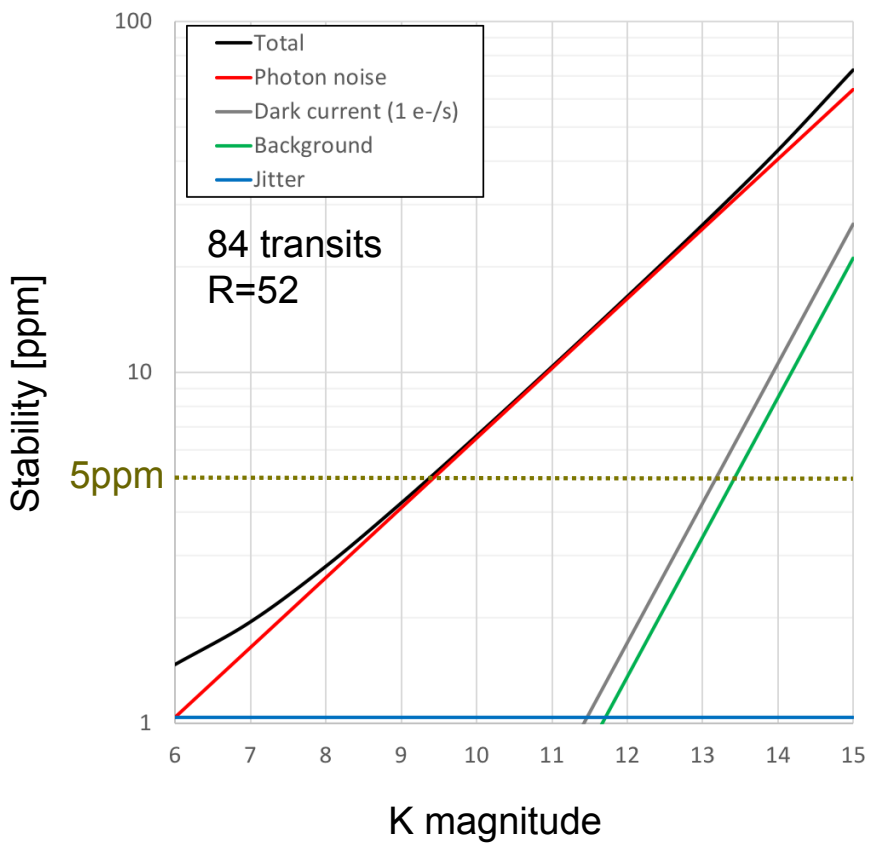
Blue dot: light of 0.0015μm (monochromatic light)
Orange dot: light of bandwidth of R~100 (chromatic light)



Parameters

Wavelength	# of transits	Spectral resolution	Dark current	Field stop radius
3μm	84	50	1.0 e-/s	2.5”
5μm	84	50	1.0 e-/s	2.5”
8μm	84	50	1.0 e-/s	2.5”
10μm	84	50	1.0 e-/s	2.5”
14μm	84	206 (stellar activity mode) 20 (SED measurement)	0.2 e-/s	1.5”
20μm	84	295 (stellar activity) 20 (SED measurement)	0.2 e-/s	1.5”

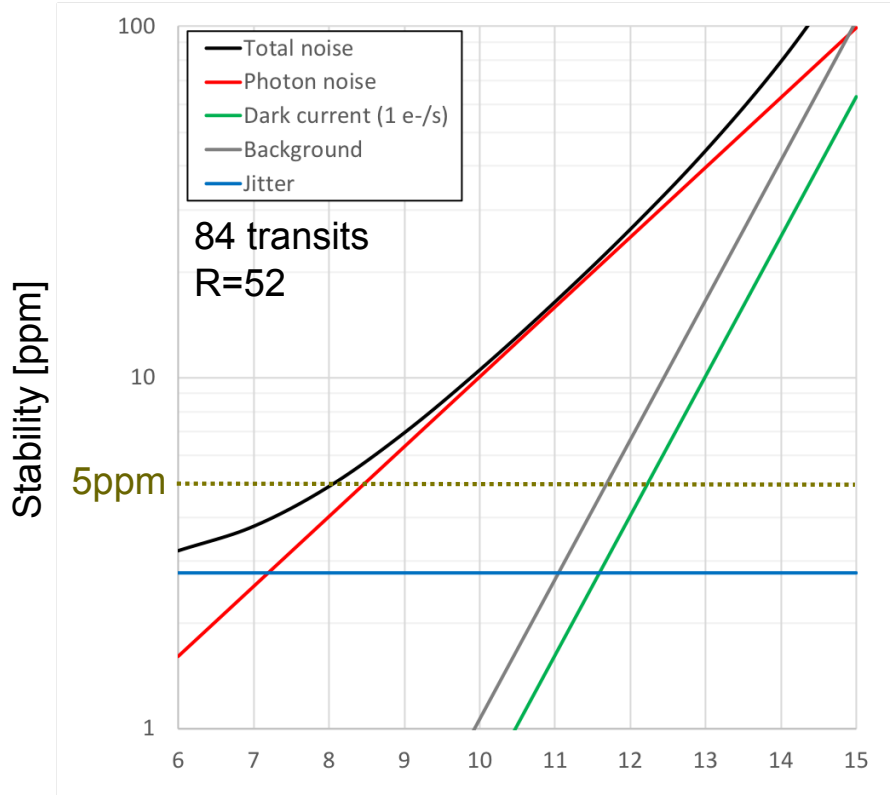
OST MISC/TRA noise performance at 3μm



K (mag)	M8 (pc)	M5 (pc)	M1 (pc)
6	1.3	2.7	7.8
7	2.1	4.2	12.4
8	3.3	6.7	19.6
9	5.2	10.6	30.9
10	8.2	16.8	48.9
11	13.0	26.5	77.3
12	20.5	41.9	122.2
13	32.4	66.2	193.2
14	51.3	104.7	305.5
15	81.0	165.5	483

* The results do not strongly depend on the spectral type of a host star.

OST MISC/TRA noise performance at 5μm



K (mag)	M8 (pc)	M5 (pc)	M1 (pc)
6	1.3	2.7	7.8
7	2.1	4.2	12.4
8	3.3	6.7	19.6
9	5.2	10.6	30.9
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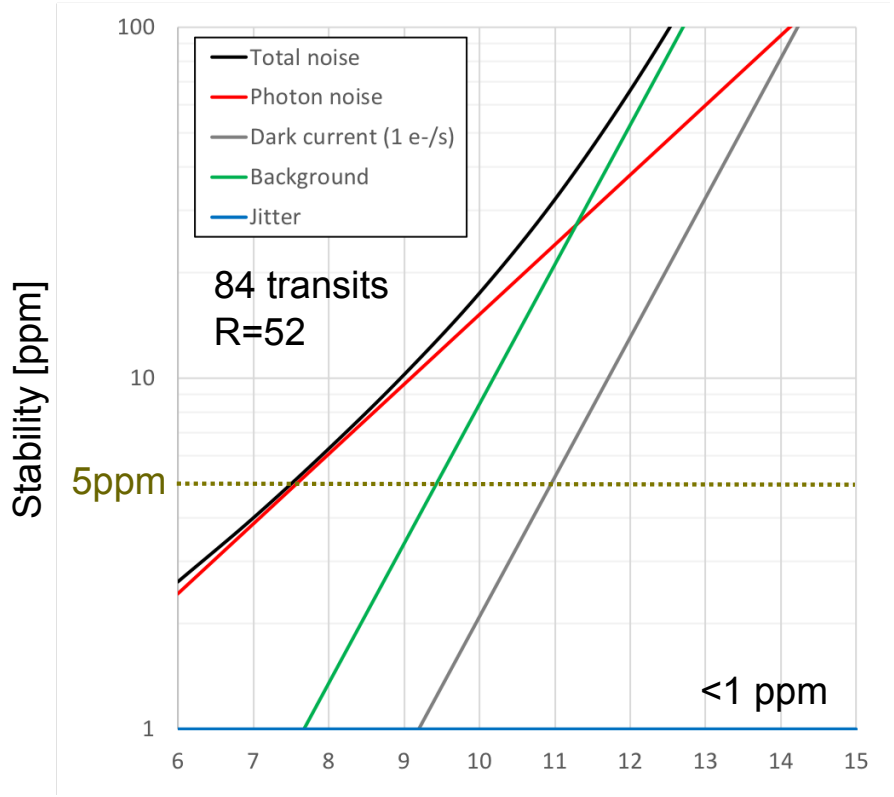
14	51.3	104.7	305.5
15	81.0	165.5	483

* The results do not strongly depend on the spectral type of a host star.

OST MISC/TRA noise performance at 8μm



K (mag)	M8 (pc)	M5 (pc)	M1 (pc)
6	1.3	2.7	7.8
7	2.1	4.2	12.4
8	3.3	6.7	19.6
9	5.2	10.6	30.9
10	8.2	16.8	48.9
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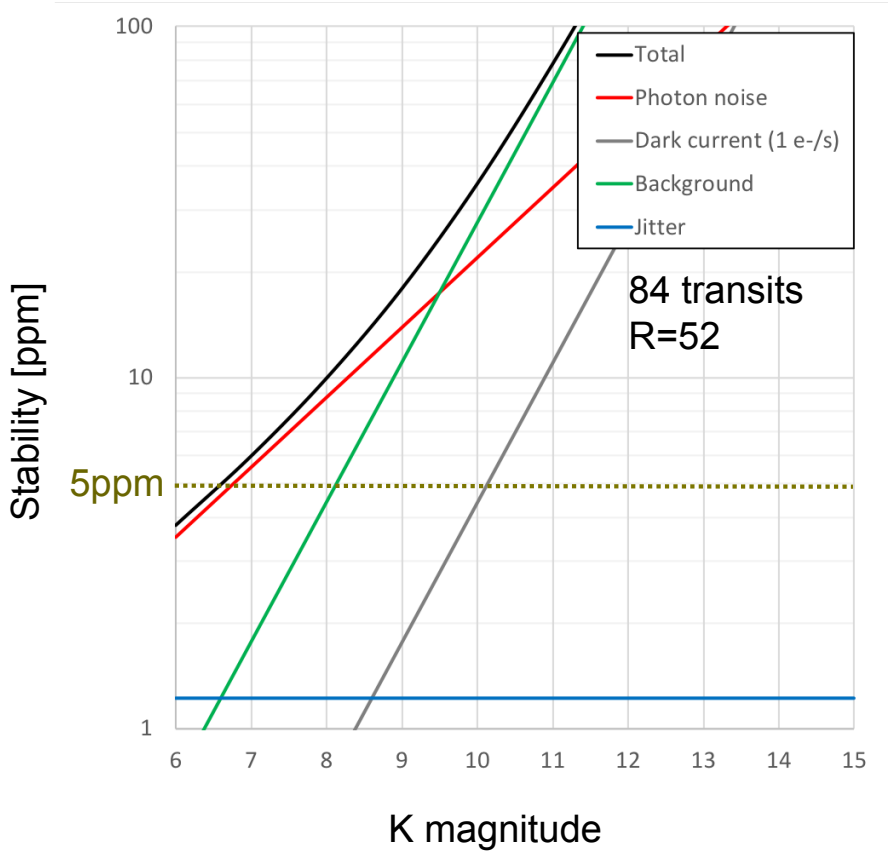
13	32.4	66.2	193.2
14	51.3	104.7	305.5
15	81.0	165.5	483

* The results do not strongly depend on the spectral type of a host star.

OST MISC/TRA noise performance at 10μm



K (mag)	M8 (pc)	M5 (pc)	M1 (pc)
6	1.3	2.7	7.8
7	2.1	4.2	12.4
8	3.3	6.7	19.6
9	5.2	10.6	30.9
10	8.2	16.8	48.9
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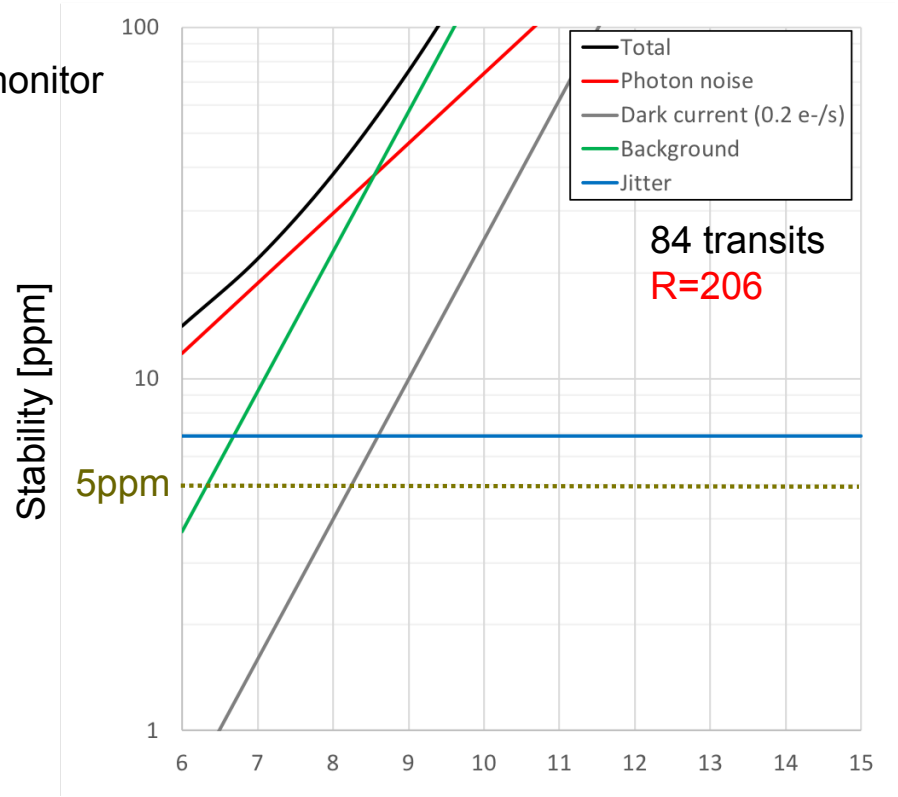
13	32.4	66.2	193.2
14	51.3	104.7	305.5
15	81.0	165.5	483

* The results do not strongly depend on the spectral type of a host star.

OST MISC/TRA noise performance at 14μm

Stellar activity monitor



K (mag)	M8 (pc)	M5 (pc)	M1 (pc)
6	1.3	2.7	7.8
7	2.1	4.2	12.4
8	3.3	6.7	19.6
9	5.2	10.6	30.9
10	8.2	16.8	48.9
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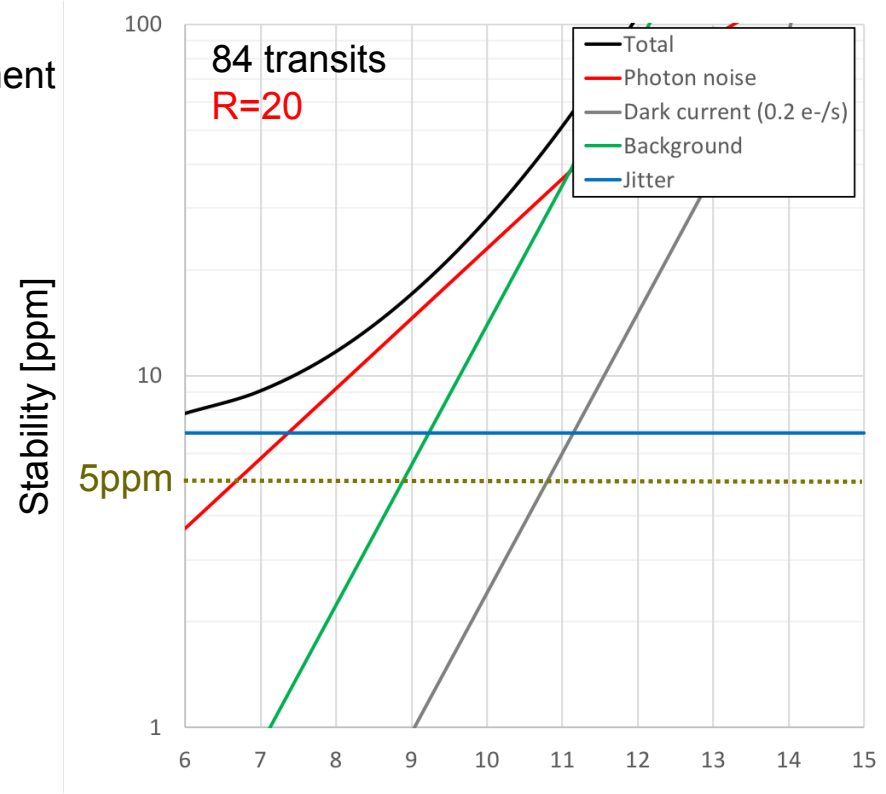
15	81.0	165.5	483

* The results do not strongly depend on the spectral type of a host star.

OST MISC/TRA noise performance at 14μm

SED measurement



K (mag)	M8 (pc)	M5 (pc)	M1 (pc)
6	1.3	2.7	7.8
7	2.1	4.2	12.4
8	3.3	6.7	19.6
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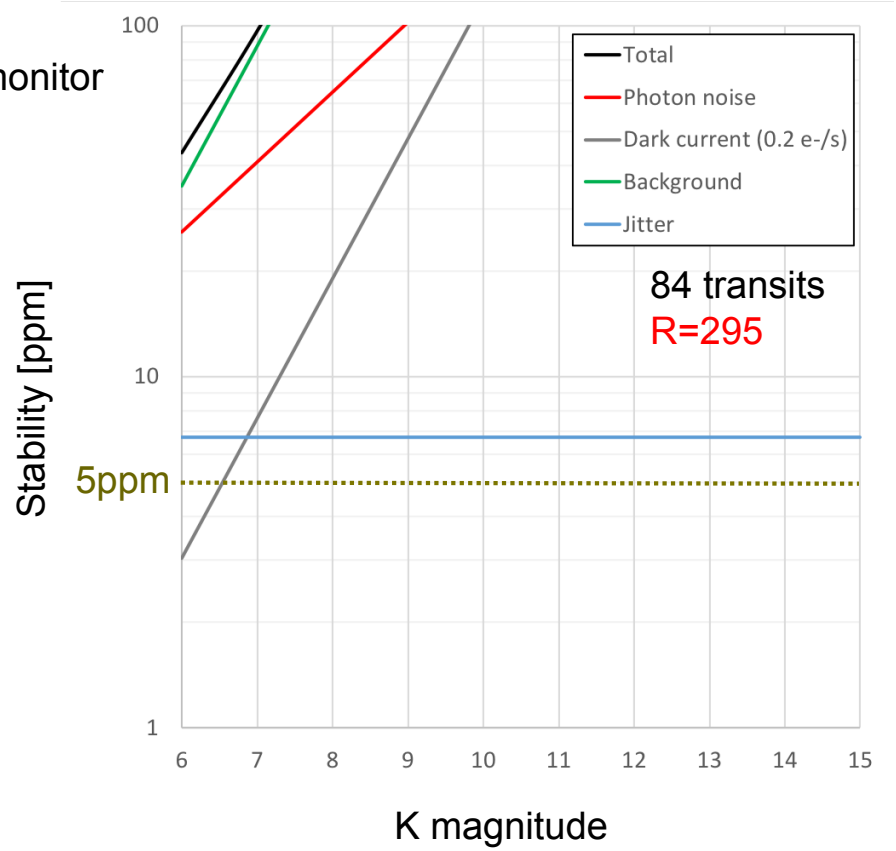
13	32.4	66.2	193.2
14	51.3	104.7	305.5
15	81.0	165.5	483

* The results do not strongly depend on the spectral type of a host star.

OST MISC/TRA noise performance at 20μm

Stellar activity monitor

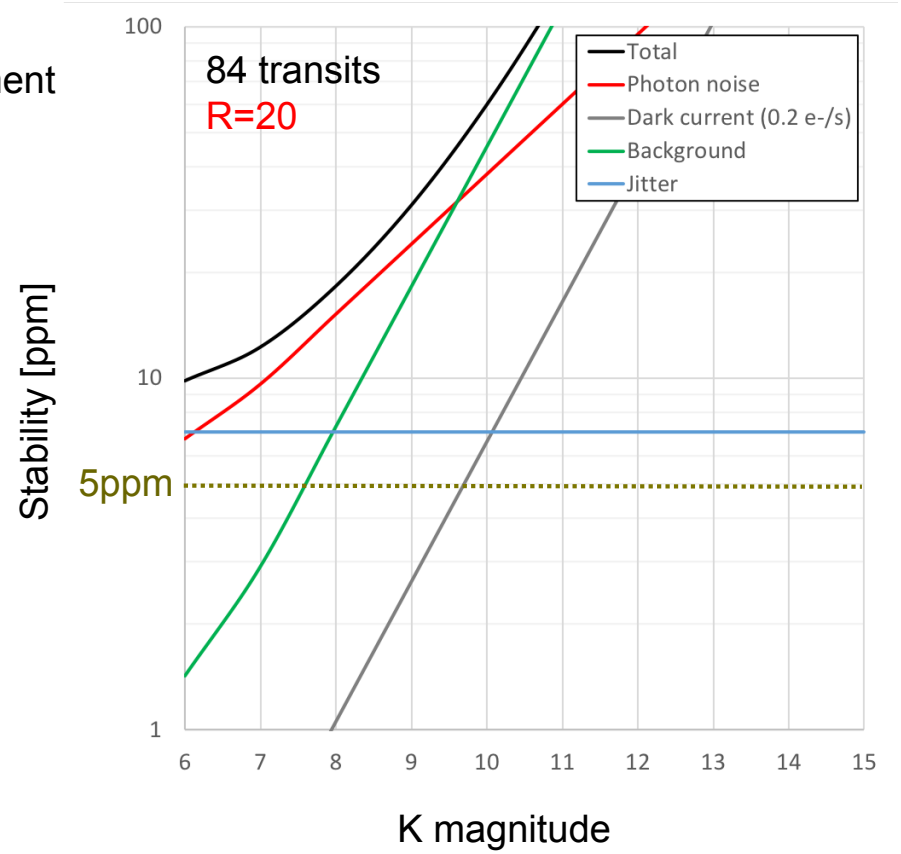


K (mag)	M8 (pc)	M5 (pc)	M1 (pc)
6	1.3	2.7	7.8
7	2.1	4.2	12.4
8	3.3	6.7	19.6
9	5.2	10.6	30.9
10	8.2	16.8	48.9
11	13.0	26.5	77.3
12	20.5	41.9	122.2
13	32.4	66.2	193.2
14	51.3	104.7	305.5
15	81.0	165.5	483

* The results do not strongly depend on the spectral type of a host star.

OST MISC/TRA noise performance at 20μm

SED measurement



K (mag)	M8 (pc)	M5 (pc)	M1 (pc)
6	1.3	2.7	7.8
7	2.1	4.2	12.4
8	3.3	6.7	19.6
9	5.2	10.6	30.9
10	8.2	16.8	48.9
11	13.0	26.5	77.3
12	20.5	41.9	122.2
13	32.4	66.2	193.2
14	51.3	104.7	305.5
15	81.0	165.5	483

* The results do not strongly depend on the spectral type of a host star.

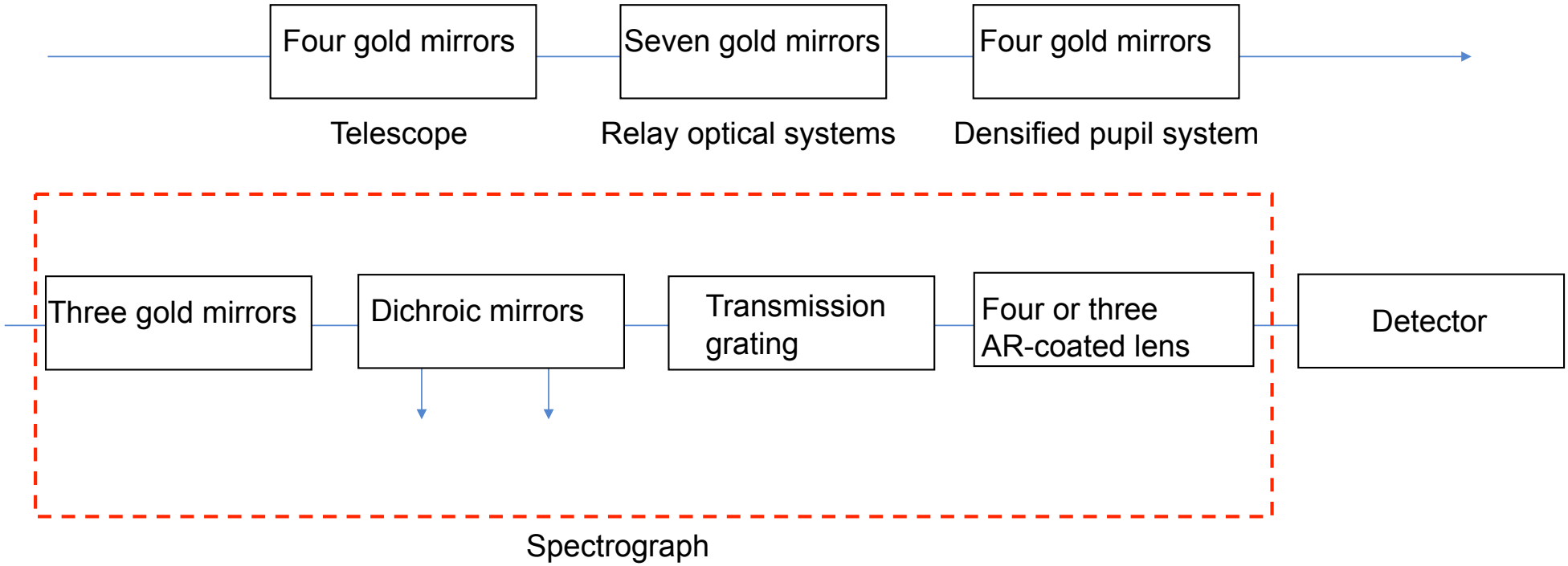
Appendix

July 23, 2018

Calculation of efficiency for OST MISC concept 2 v2

Taro Matsuo

Configuration of OST Concept 2

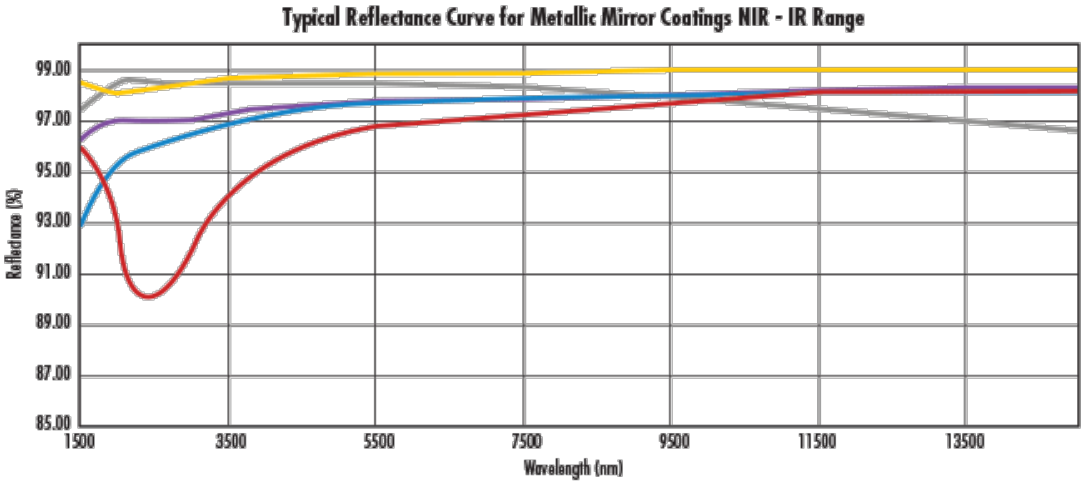


Gold mirror

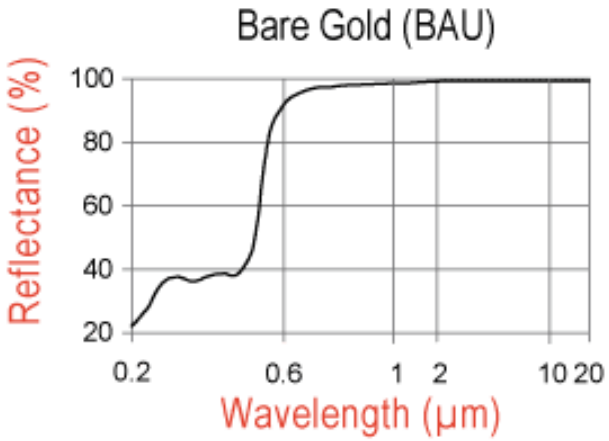
- Two types of gold mirrors are considered.
- The reflectivity was set to:

✓ for protected gold mirror,
0.985 in shortest channel,
0.988 in middle one,
0.990 in longer one.

✓for bare gold mirror,
0.994 in all channels

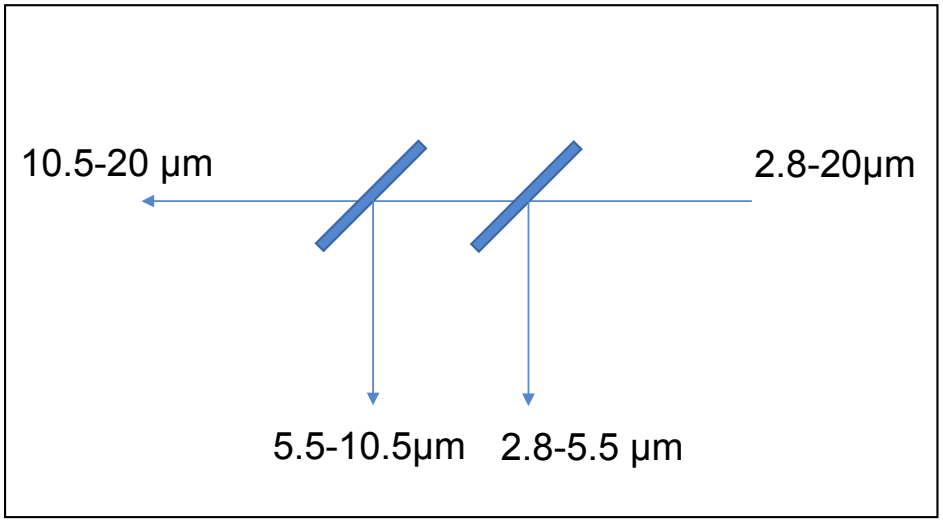


Edmund optics

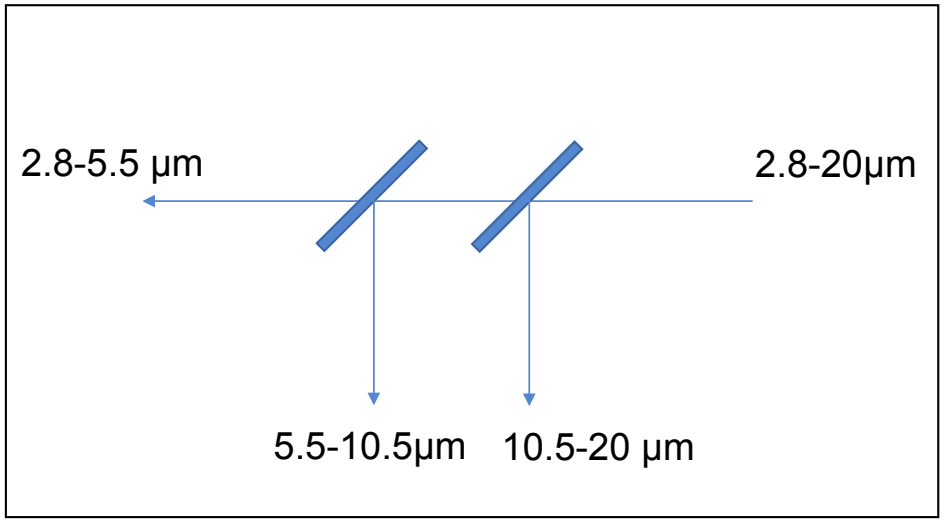


Rocky Mountain Instrument

Two Configurations for dichroic mirror



Configuration 1 (Current)



Configuration 2 (Current)

Dichroic mirror

- I asked about the performances of two dichroic mirrors used for the OST concept 1 (6-25μm) to MATERION;

✓ the material is KRS-5

✓ the following reflectivity and transmissivity are expected and developments are necessary

✓ the reflectivity is probably higher than 90 % over the whole wavelength range.

✓ the transmissivity is probably higher than 80 % for 6- 14μm and 70% for 14-25μm.

- In this calculation, the reflectivity was set to 90% for the three channels and the transmissivity was set to 80% for the shortest and middle channels and 70% for the lonest one.

Relative grating efficiency

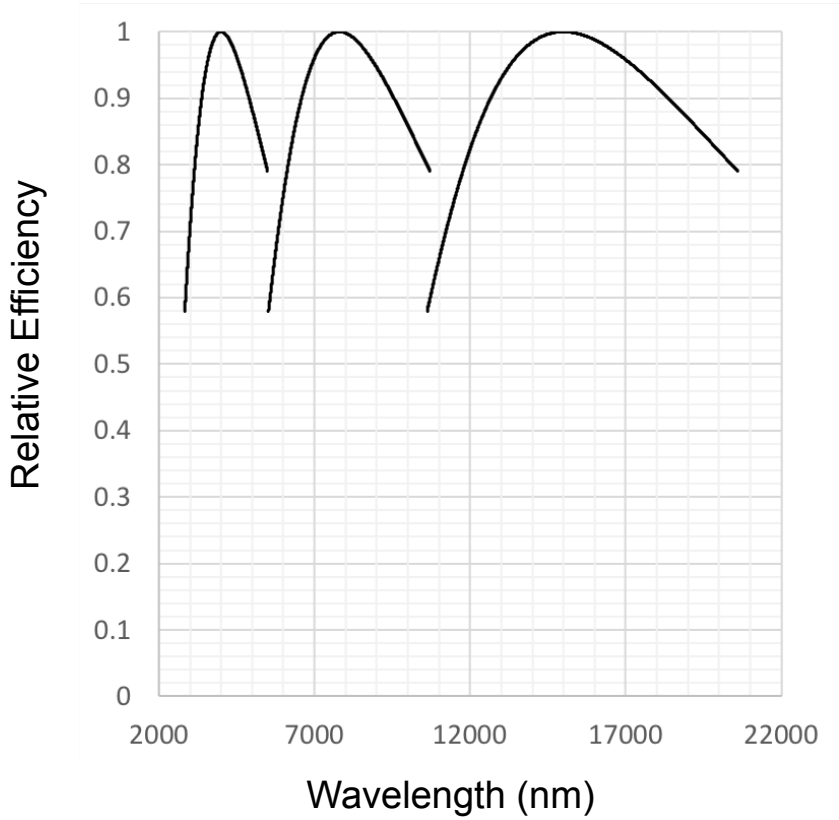
- Blaze wavelength:

✓ 4000nm for channel 1

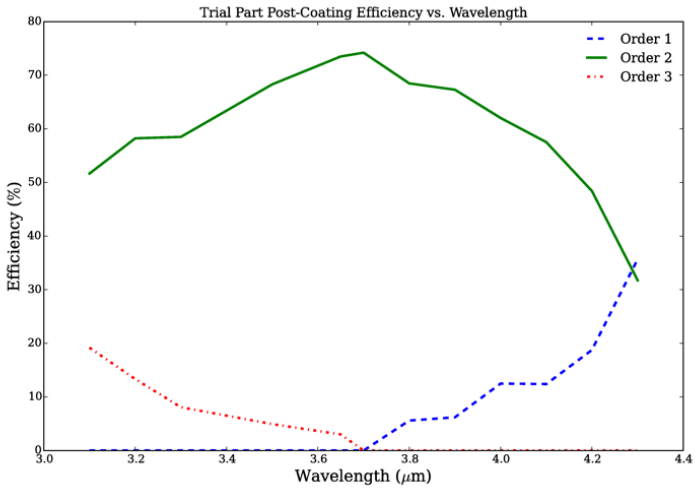
✓ 7800nm for channel 2

✓ 15000nm for channel 3

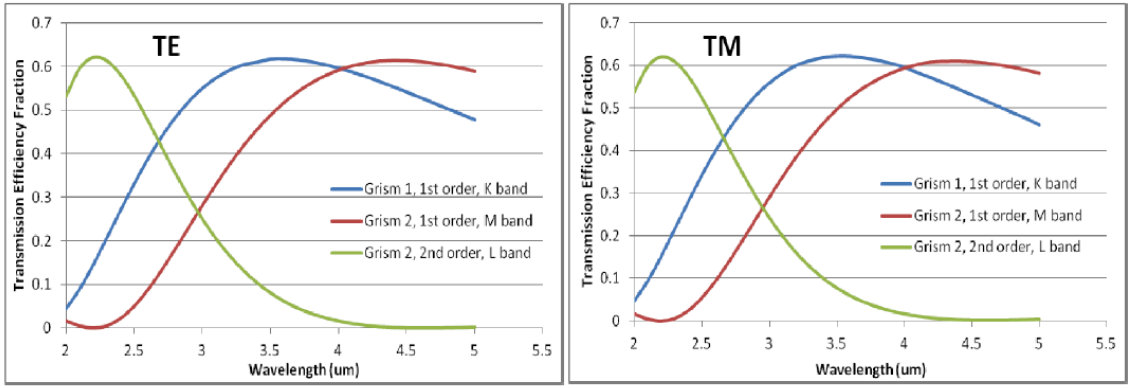
- The peak of the efficiency was set to 0.8 for all channels.



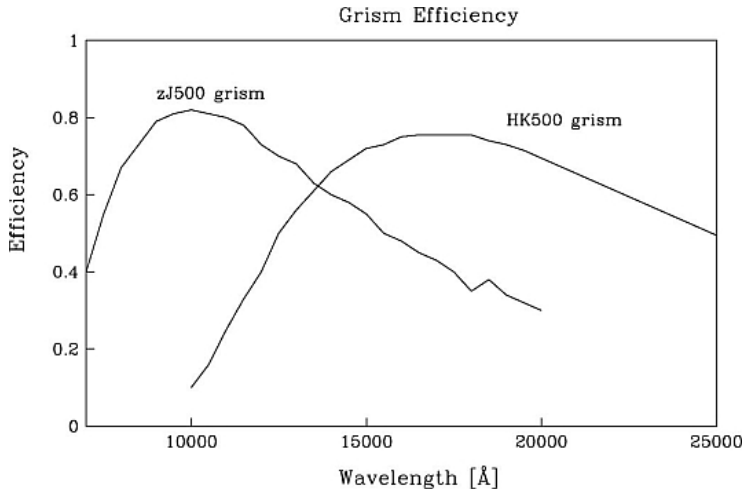
Grism Efficiency



Si Grism for JWST (Deen et al. 2016)



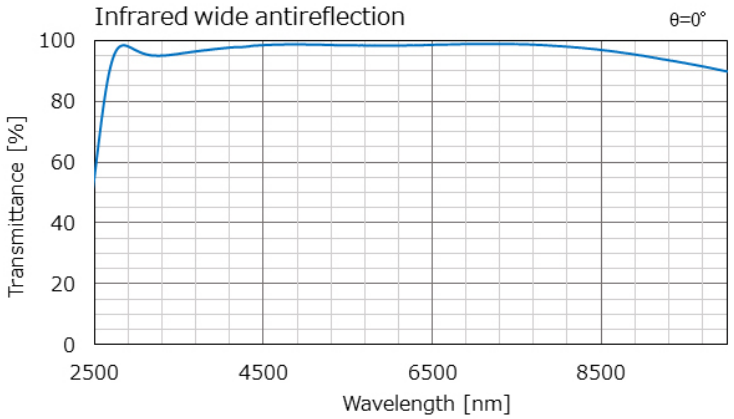
Ge grism for LBT/LMIRCam (Kuzumenko et al. 2012)



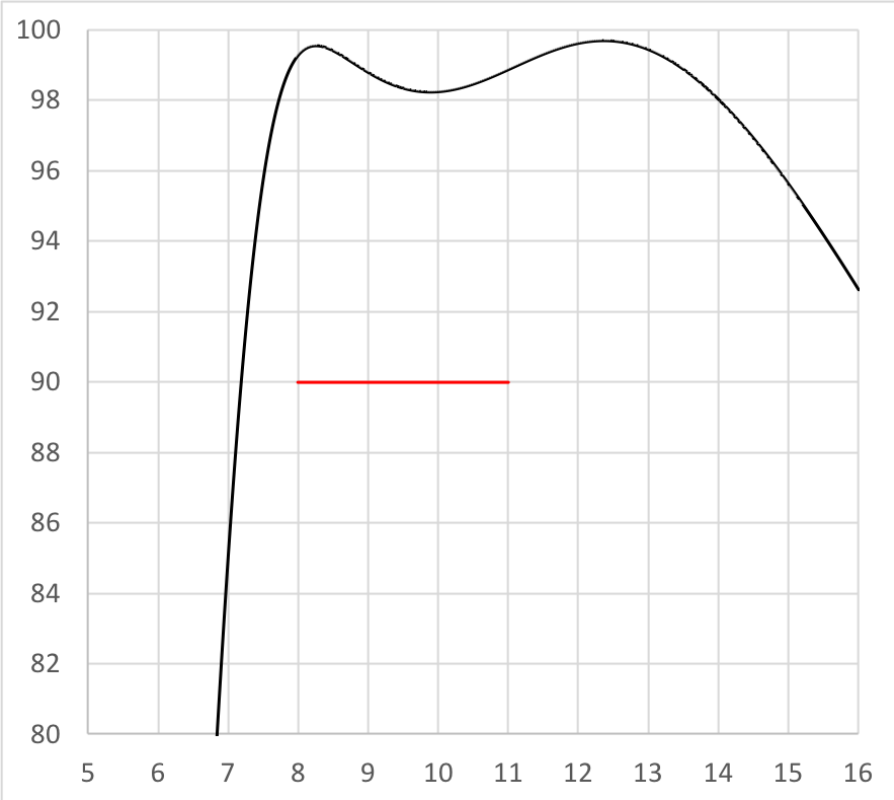
KRS-5 for Subaru/MOIRCS (Tokoku et al. 2007)

AR coat

- AR coat is commonly used for the wavelength shorter than 12μm.
- There are several companies that provide AR coat with 95% transmissivity.
- In this simulation, transmissivity of each lens was set to 98% for the shortest and middle channels and 90% for the longest channel.



Wide anti-reflection coating for optical window



Transmission curve of Ge lens used for testbed

Detector responsivity

Table 1: DCL performance measurements

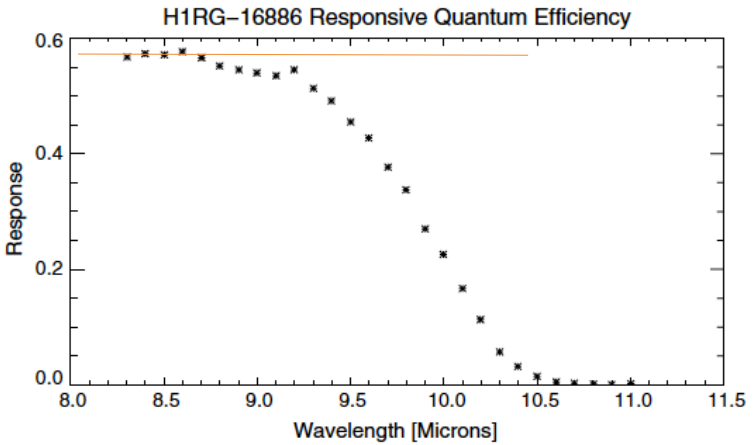
Parameter	Req.	Unit	NIRSpec flight candidate SCA serial number[1] 17163	17280	17167	17169	17378	17168	17166	17195
Flight application:										
NIRSpec flight SCA identifier			**491**	**492**	N/A	N/A	N/A	N/A	N/A	N/A
Flight ranking			**1**	**2**	3	4	5	6	7	8
NIRSpec requirements:										
Mean dark current per pixel	< 0.01	e^-/s/pix	**0.0032**	**0.0041**	0.0051	0.0027	0.0043	0.0032	0.0043	0.0047
Latent or residual images	< 0.1%	%	**0.009**	**0.013**	0.019	0.012	0.014	0.016	0.009	0.063
Total noise per pixel[2]	< 6	e^- rms	**< 4.32**	**< 5.18**	< 4.8	< 5.19	< 5.07	< 5.02	< 4.46	< 5.8
Mean DQE										
$0.6 < \lambda < 1$ µm	≥ 70%	%	**79.5**	**80.4**	78.9	83.9	86.5	75.8	89.4	81.5
$1 \leq \lambda < 5$ µm	≥ 80%	%	**88.0**	**88.3**	87.2	85.9	91.0	80.6	88.7	88.1
Pixel operability for science observations	> 89%	%	**99.02**	**98.25**	98.92	98.06	97.7	98.65	98.91	97.74
Pixel cross talk	< 5%	%	**0.54**	**0.49**	0.52	0.62	0.6	0.61	0.52	0.48
Other information:										
Test start date		MM/YY	**08/13**	**09/13**	08/13	09/13	11/13	10/13	10/13	11/13
Conversion gain		e/DN	**0.873**	**0.978**	0.935	0.94	0.904	0.925	0.882	0.946
Transimpedance gain		$\mu V/e^-$	**4.372**	**3.903**	4.082	4.060	4.222	4.126	4.327	4.035
Read noise per CDS[2]		e^- rms	**< 7.4**	**< 8.9**	< 7.9	< 9.1	< 8.4	< 8.3	< 7.4	< 8.8
Open pixels		# pix	**470**	**63**	7	0	0	863	1292	357
RTN pixels		%	**3.3**	**4.0**	2.3	4.3	3.6	3.2	2.7	3.6
Snowball rate		snowballs/hr	**0.66**	**0.02**	0.17	0.14	0.20	0.07	0.07	0.03
Bad rows		#	**0**	**0**	0	0	0	1	0	0
Void pixels		%	**< 1**	**0**	1	< 1	3	3	10	0
Cutoff wavelength from PEC		µm	**5.45**	**5.37**	5.42	5.44	5.47	5.32	5.41	5.36

[1] The two flight SCAs are displayed in boldface font.

[2] These values are an upper limit and the apparent differences are not necessarily real. The test controller was injecting variable 1/*f* noise during the test. This was fixed by moving a card.

5.5µm cut HgCdTe detector (Rauscher et al. 2018)

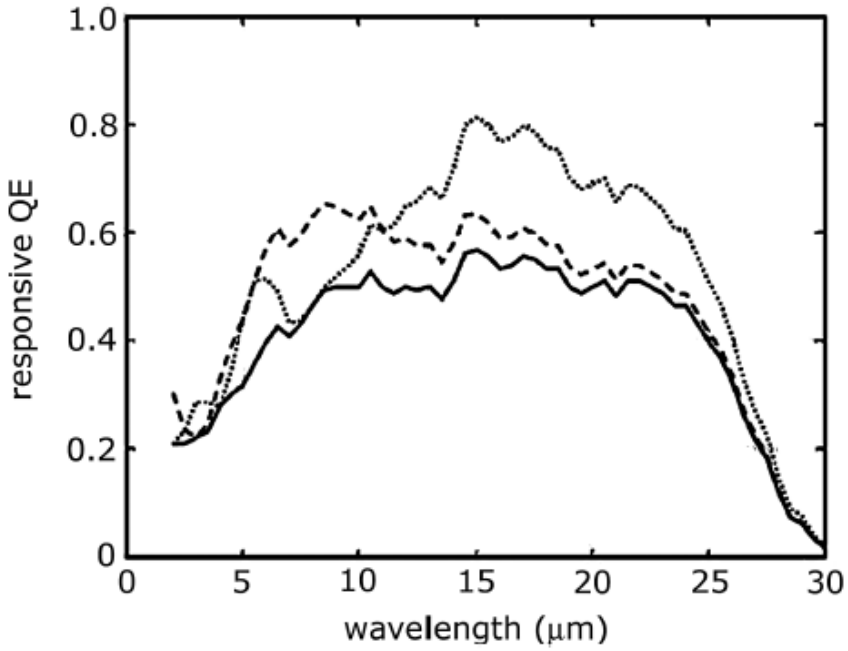
- 5.5µm- and 10.5µm-cut HgCdTe detectors can be used for the shortest and middle channels.
- The detector responsivities were set to 0.88 and 0.78 for the shortest and middle channels.



McMurty et al. 2013

Detector responsivity (longest channel)

- Si:As detector with 16μm AR-coated window was referred as the responsivity.
- The detector responsivity for the longest wavelength was set to 70%.



Rieke et al. 2015