Overview of the optomechanical design of the LUVOIR instruments

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Overview

- LUVOIR is one of four concepts being submitted for the 2020 Decadal Survey in Astronomy and Astrophysics
- Two architectures studied by NASA GSFC
  - LUVOIR-A
  - LUVOIR-B
- Three Instruments
  - ECLIPS
  - LUMOS
  - HDI

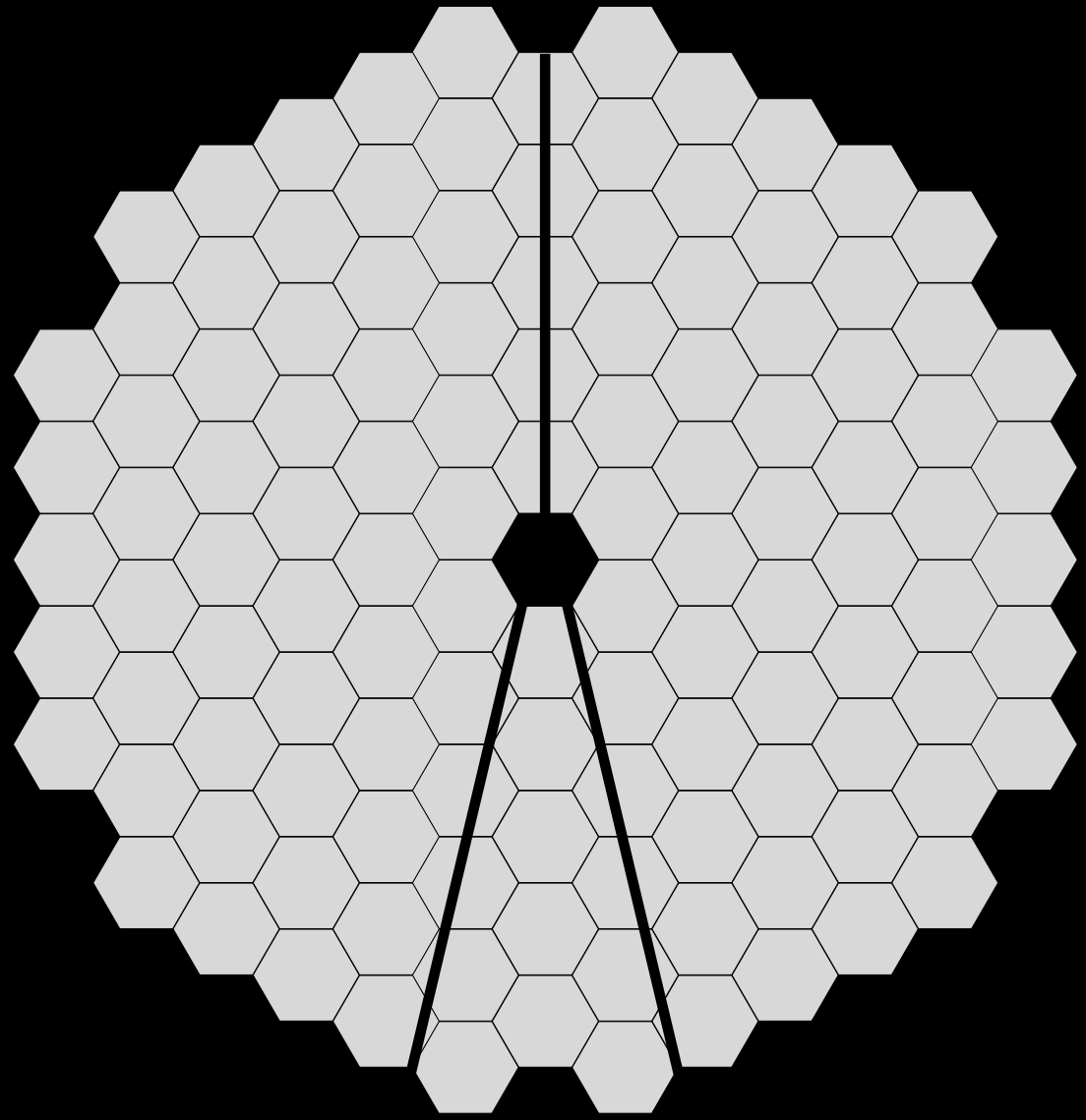
LUVOIR-A

15-m, on-axis telescope

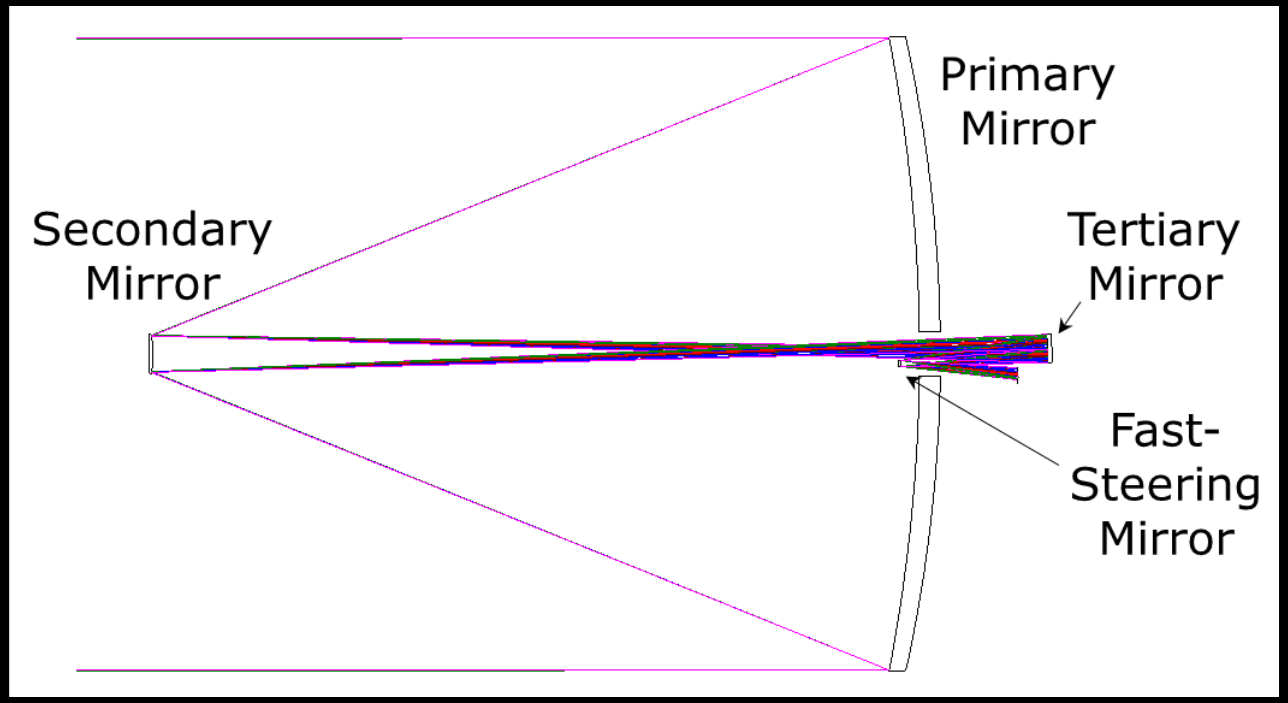
- 120 segments, 1.223-m flat-to-flat
- 155 m^2 collecting area

Four instruments

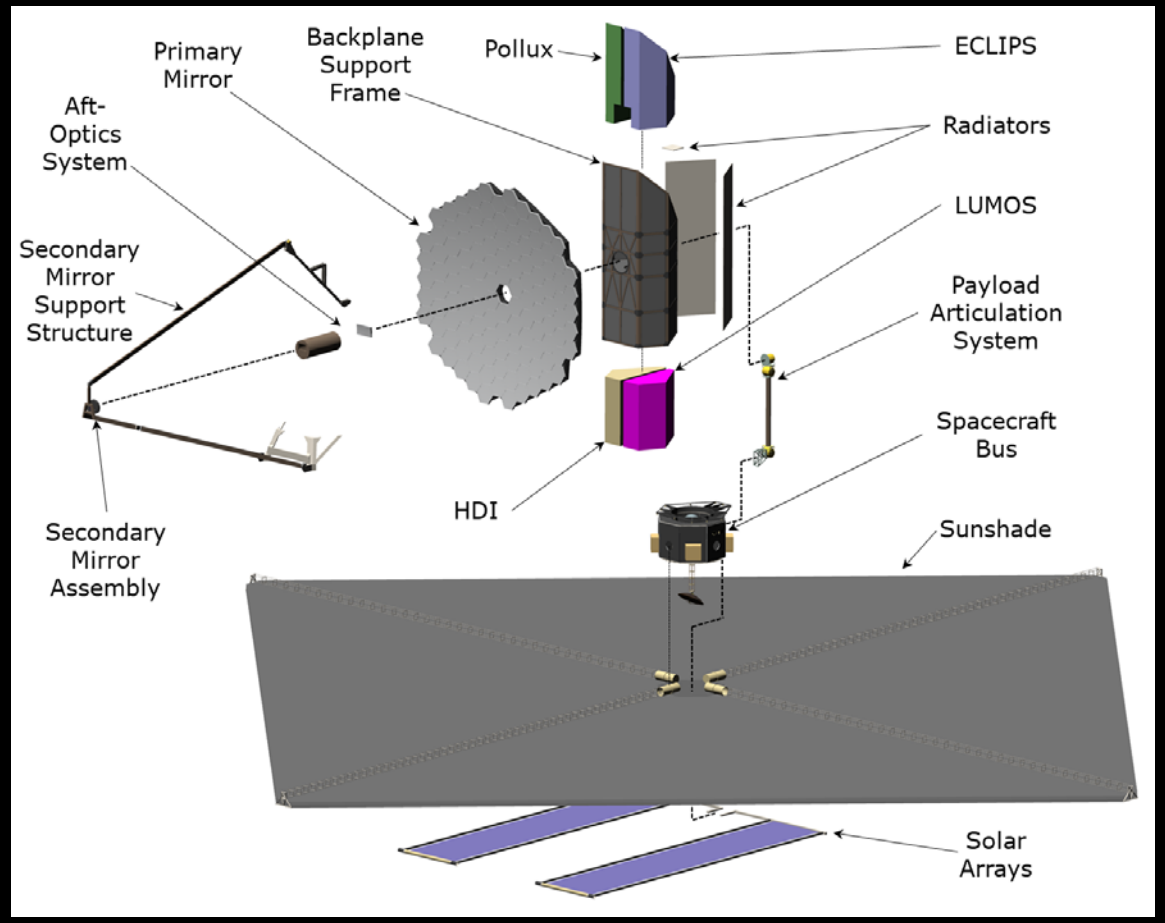
- Extreme Coronagraph for Living Planetary Systems (*ECLIPS*)
- LUVOIR UV Multi-object Spectrograph (*LUMOS*)
- High Definition Imager (*HDI*)
- *Pollux* (CNES-contributed instrument design)



LUVOIR-A



15-m diameter primary mirror
On-axis telescope
Three-mirror anastigmat (TMA)



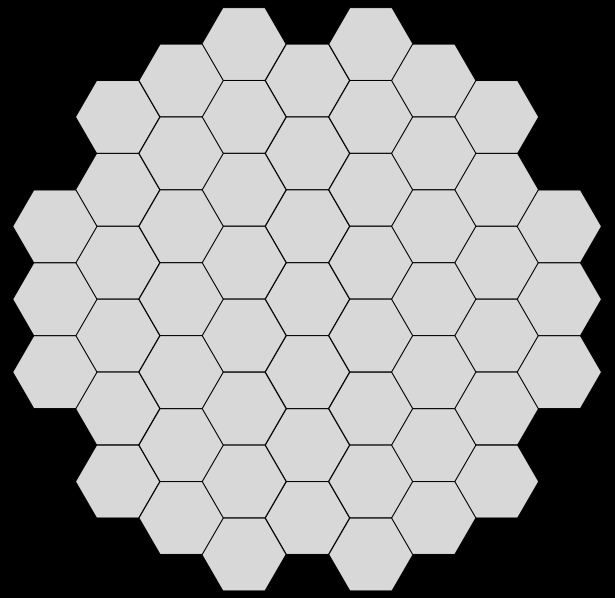
LUVOIR-B

8-m, off-axis telescope

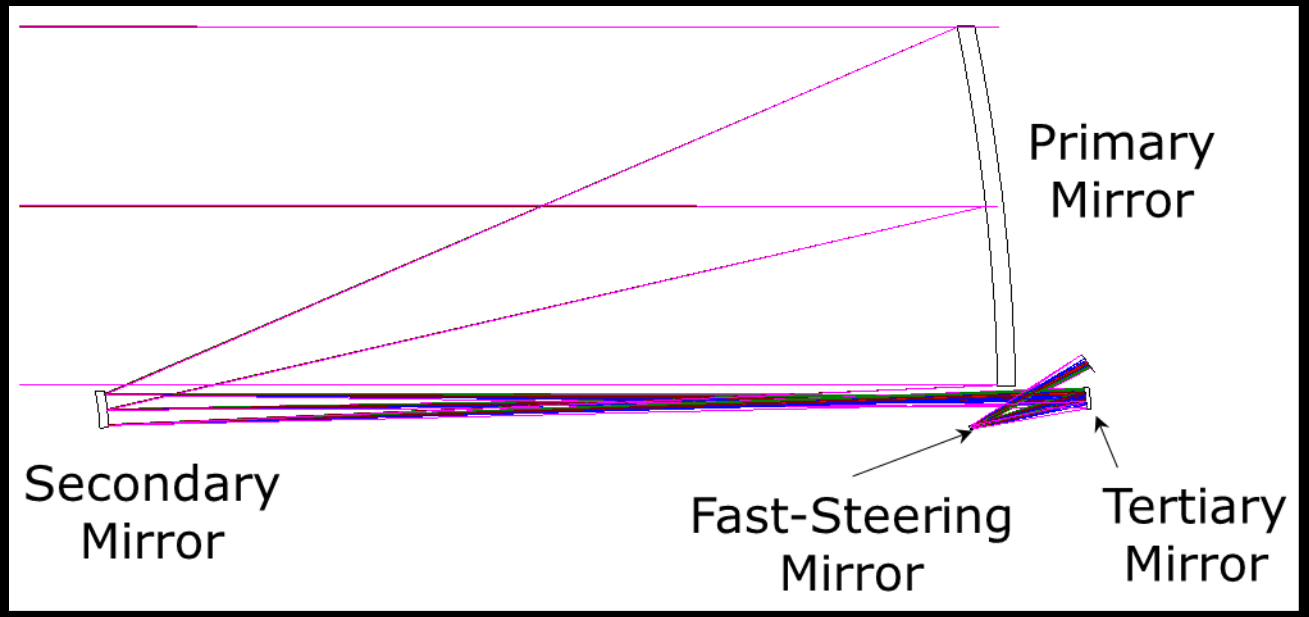
- 55 segments, 0.955-m flat-to-flat
- 43.4 m^2 collecting area

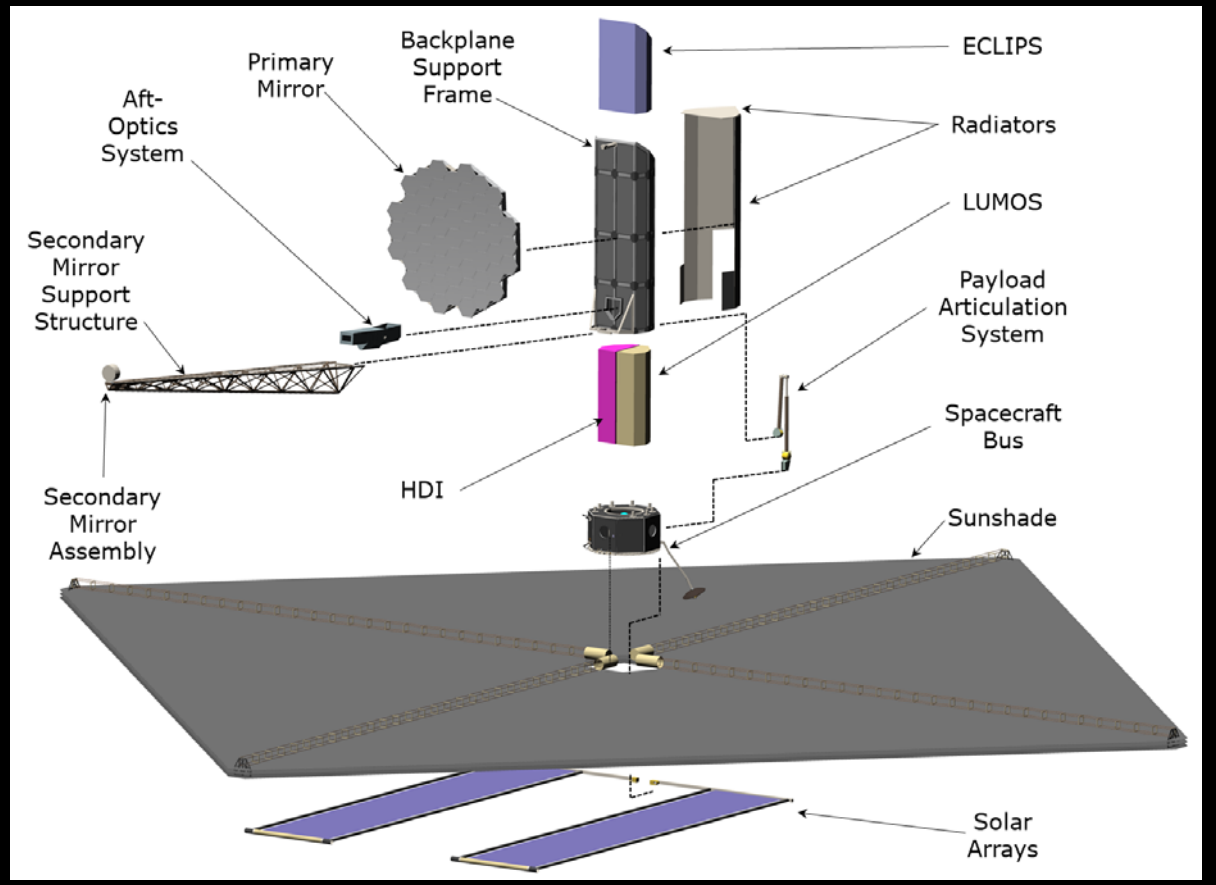
Three instruments

- Extreme Coronagraph for Living Planetary Systems (*ECLIPS*)
- LUVOIR UV Multi-object Spectrograph (*LUMOS*)
- High Definition Imager (*HDI*)



LUVOIR-B

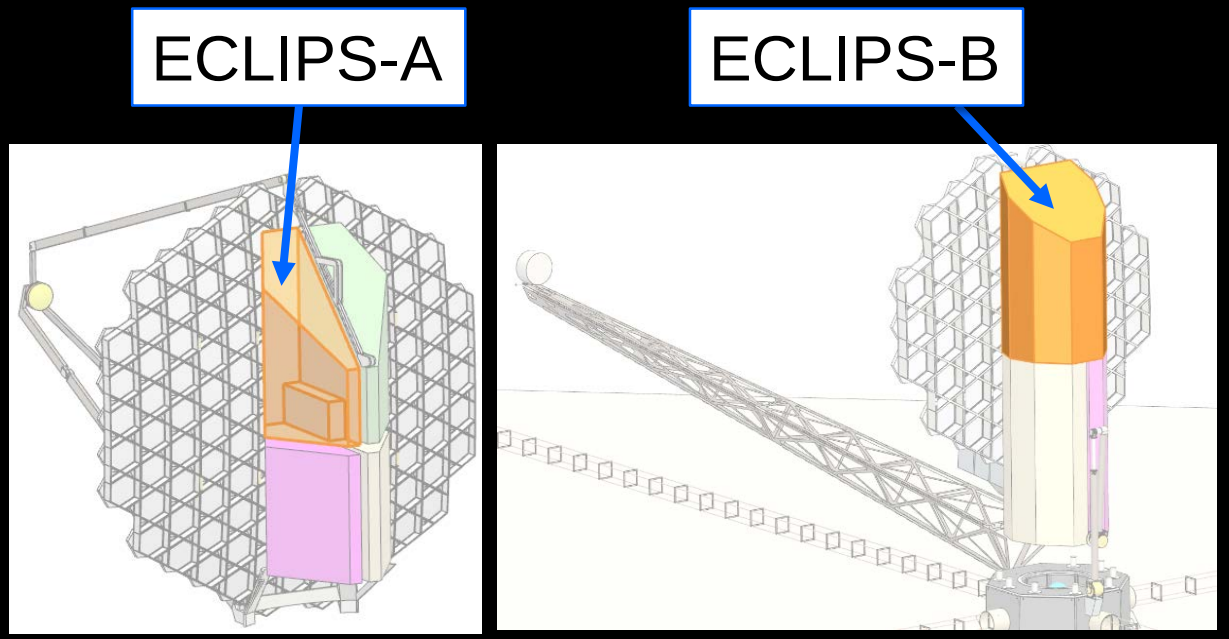




8-m diameter primary mirror
Off-axis telescope
Three-mirror anastigmat (TMA)

Extreme Coronagraph for Living Planetary Systems (ECLIPS)

- High-contrast (10^{-10}) coronagraph
- Inner working angle (IWA): 3.5λ/D
- Outer working angle (OWA): 64λ/D
- Three channels w/ modules
  1. UV (200 – 525nm)
     a. Camera w/ filter wheel
  2. VIS (515 – 1030nm)
     a. Camera
     b. Integral Field Spectrograph (IFS)
  3. NIR (1000 – 2000nm)
     a. IFS
     b. Single point-source spectrometer (SPSS)

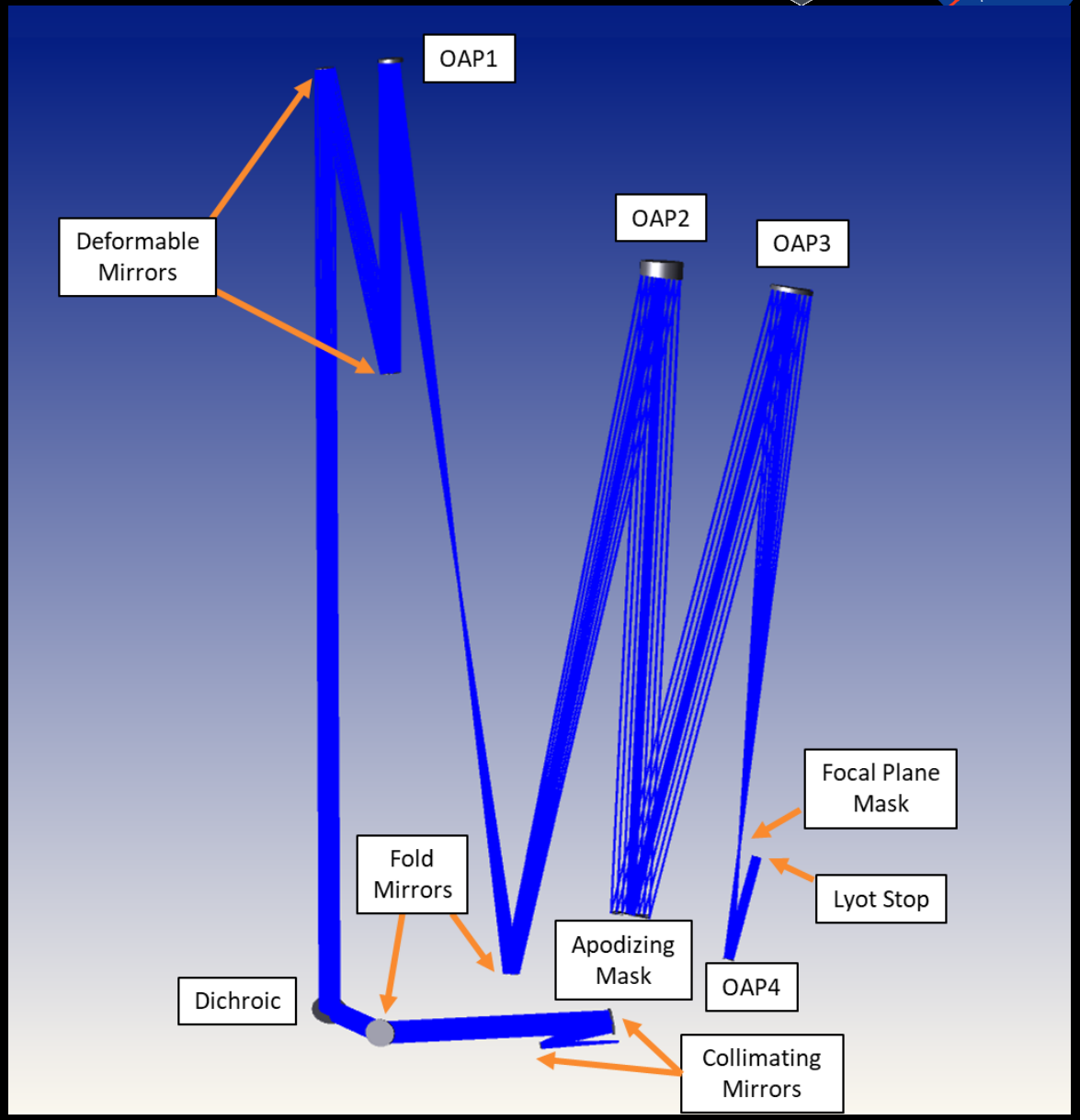


ECLIPS, optical design

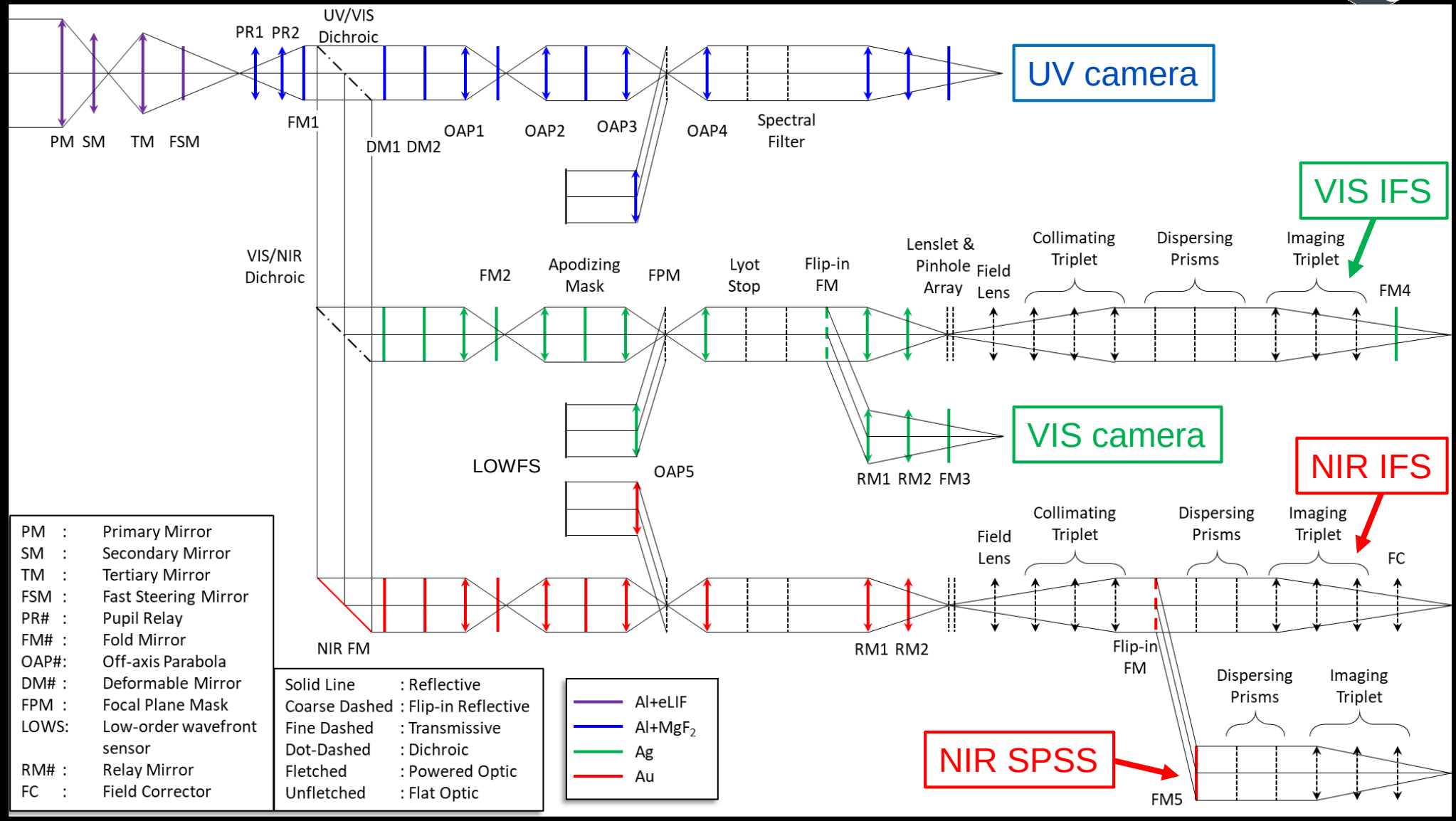
Coronagraph design provides both pupil image planes and intermediate image planes for various masks:

Element	Element Size	Resolution	Mode
Deformable Mirror	50 x 50 mm	128 x 128 elements	Reflective (MEMS)
Apodization masks	100 mm diameter	10 µm pitch	Reflective
Focal plane masks	Depends on λ	*f*/15 beam at mask	Transmissive
Lyot Stop mask	~20 mm diameter	N. A.	Transmissive

After Lyot stop, light enters individual channel modules

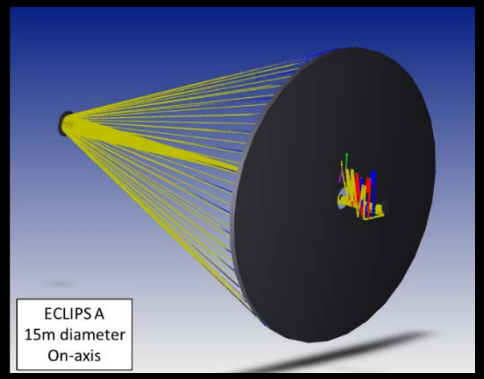


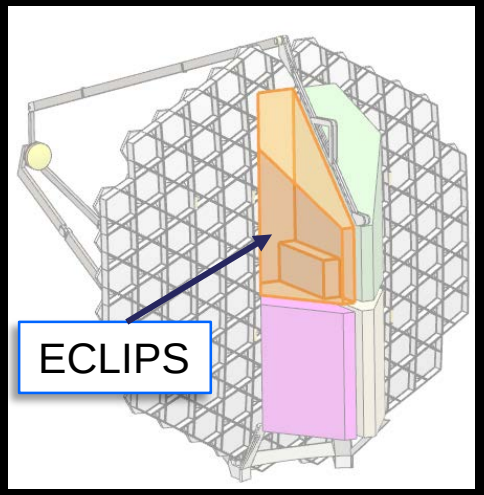
ECLIPS, block diagram

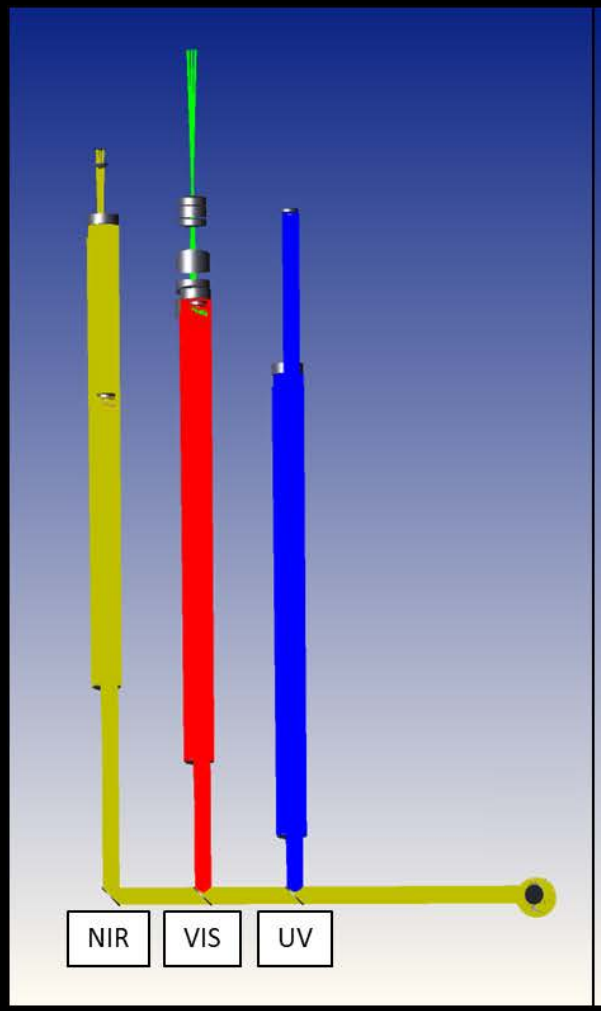


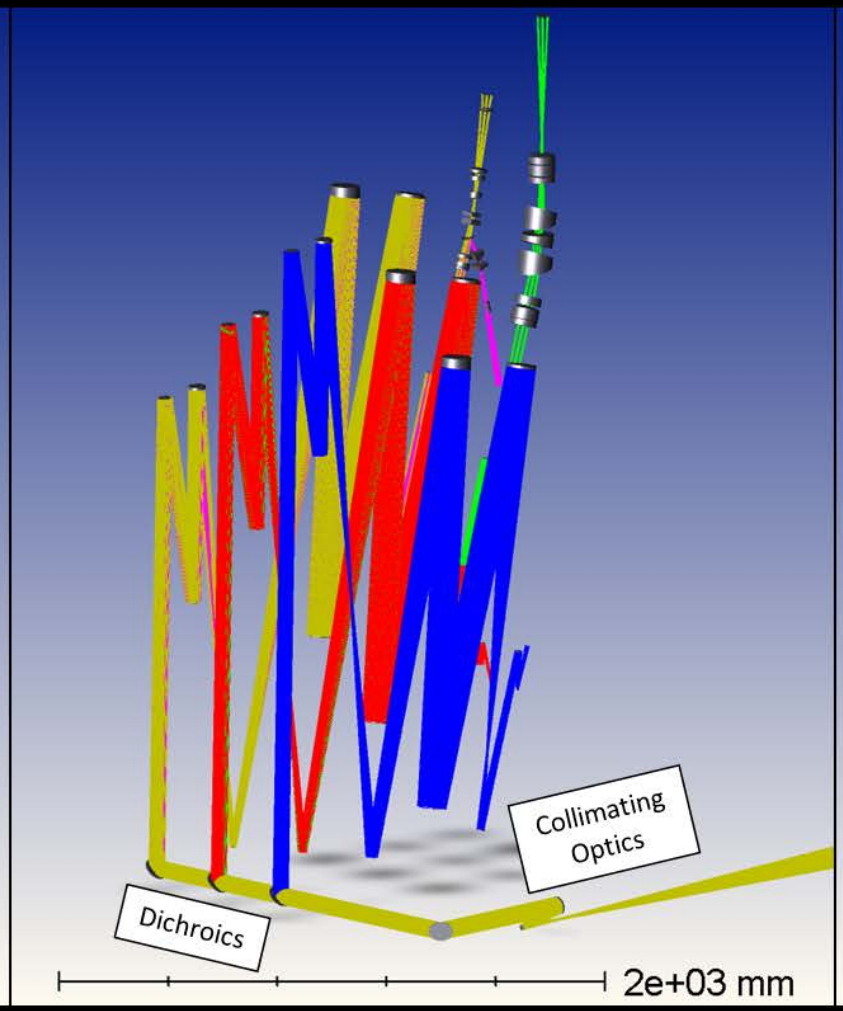
ECLIPS-A block diagram above, HDI-B's identical save folding scheme pre-DMs

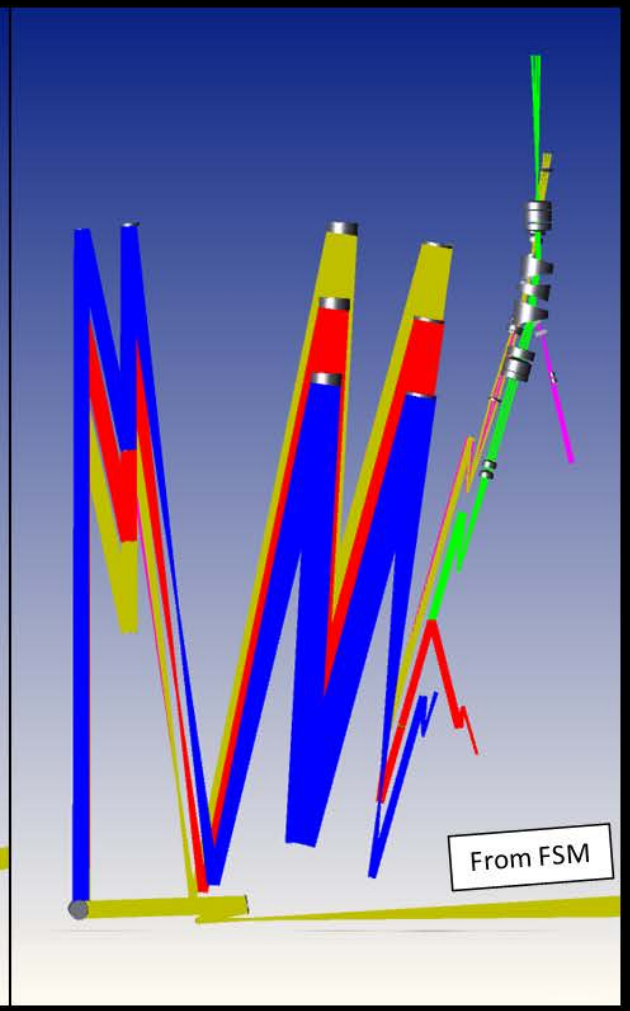
ECLIPS-A, optical design



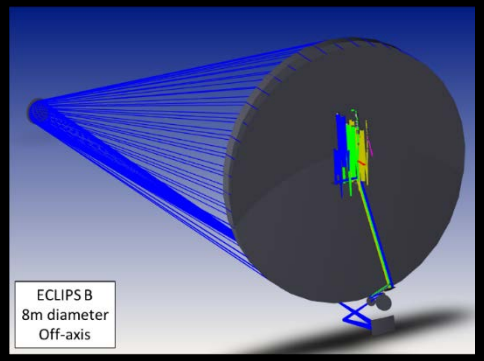


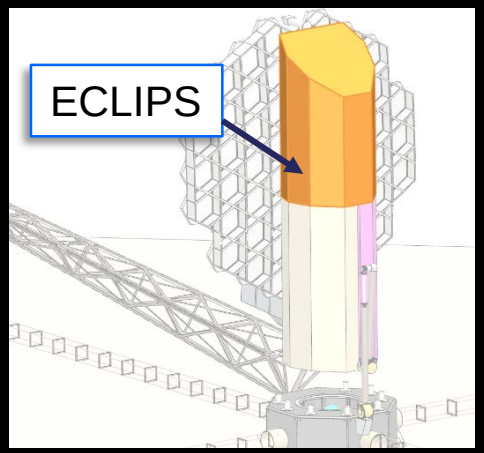


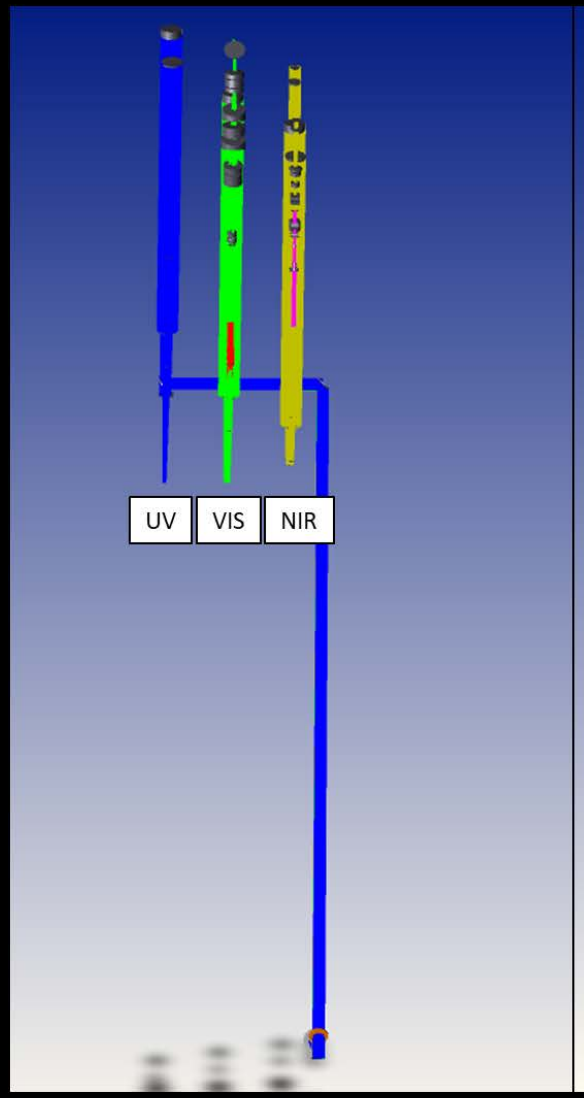


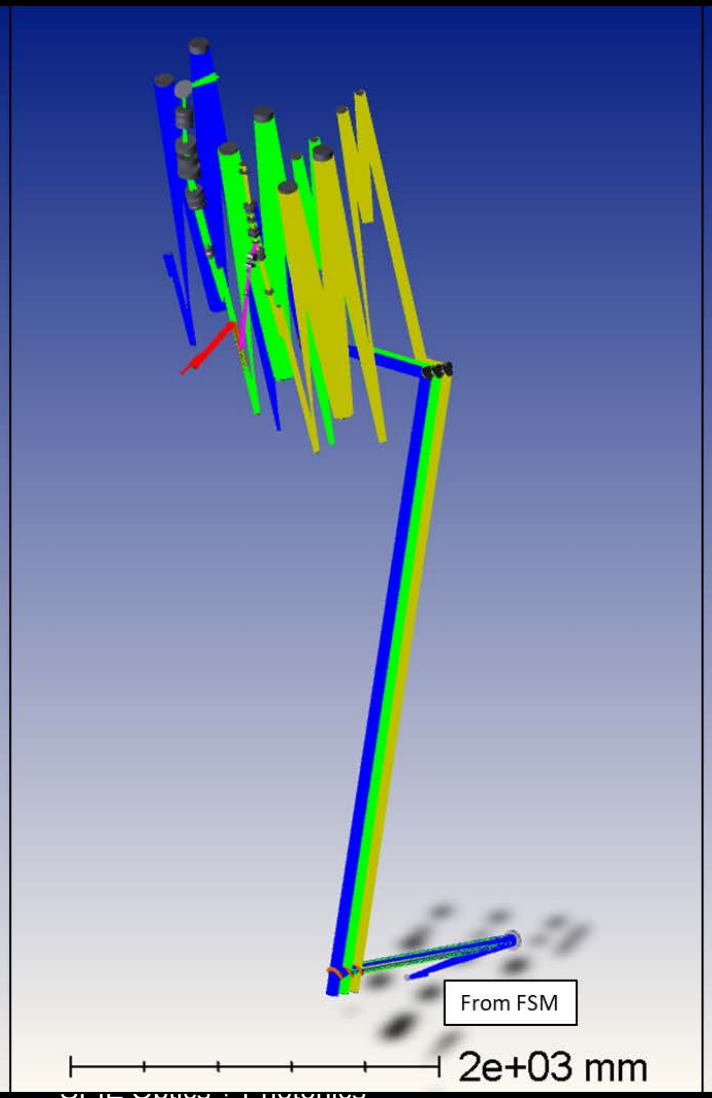


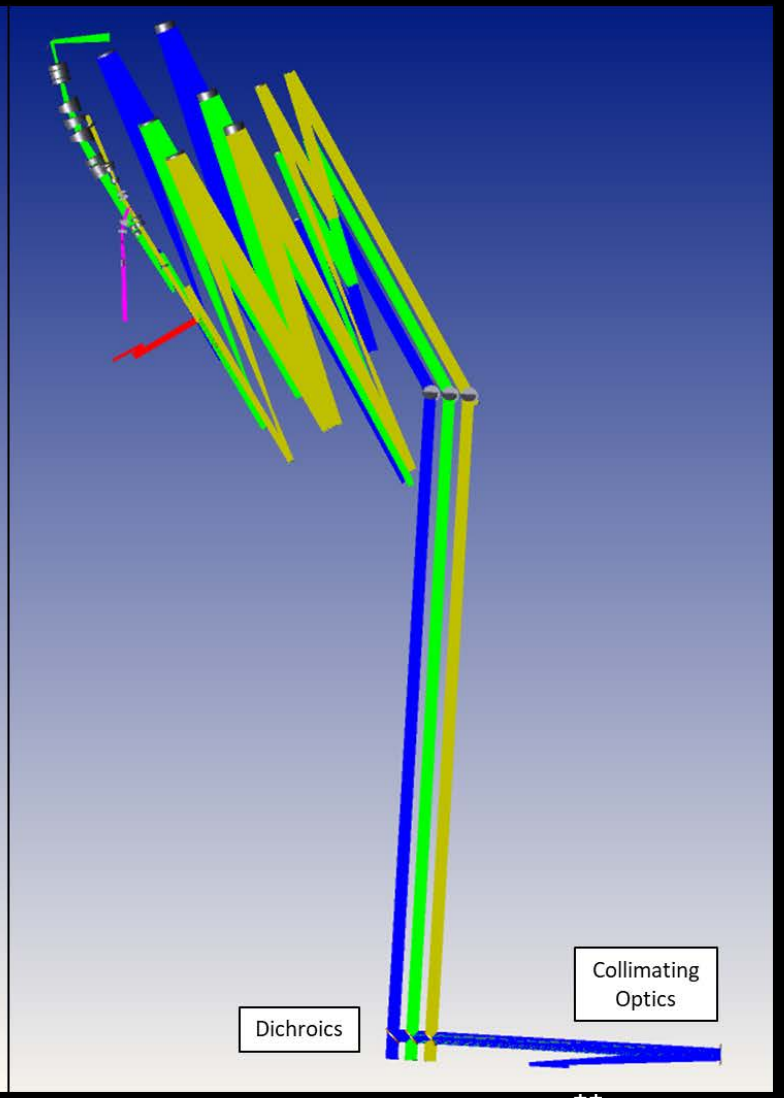
ECLIPS-B, optical design









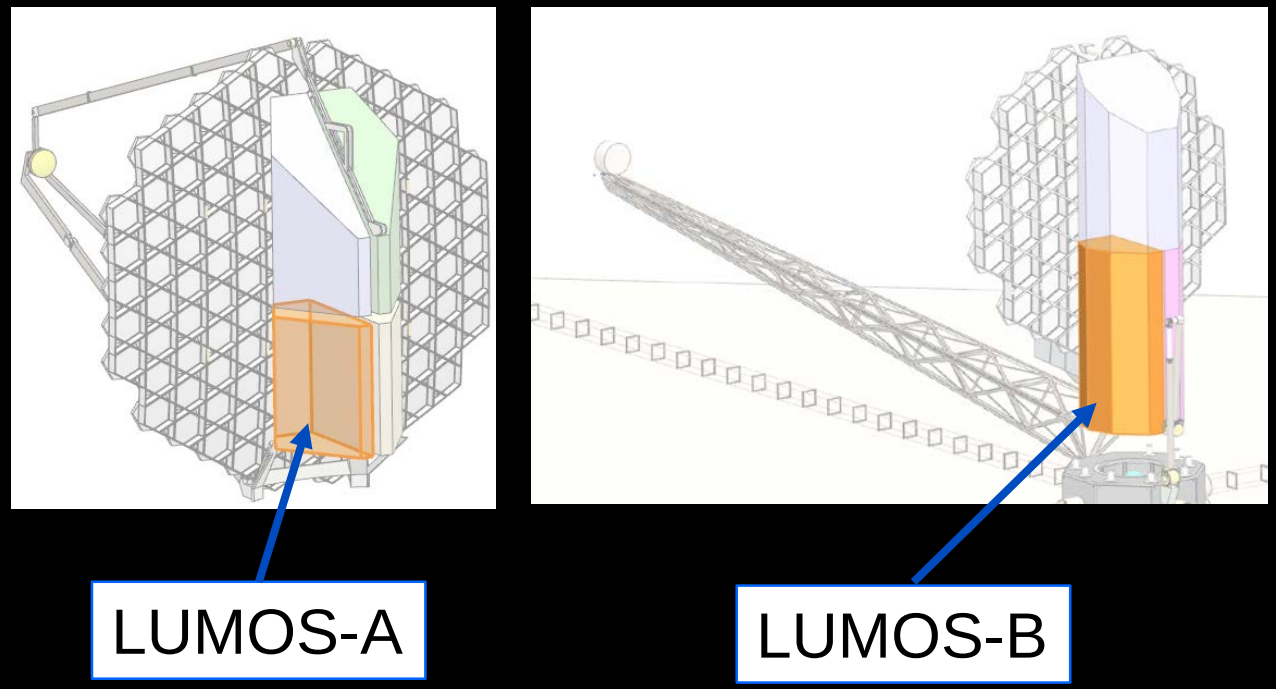


LUVOIR Ultraviolet Multi-Object Spectrograph (LUMOS)

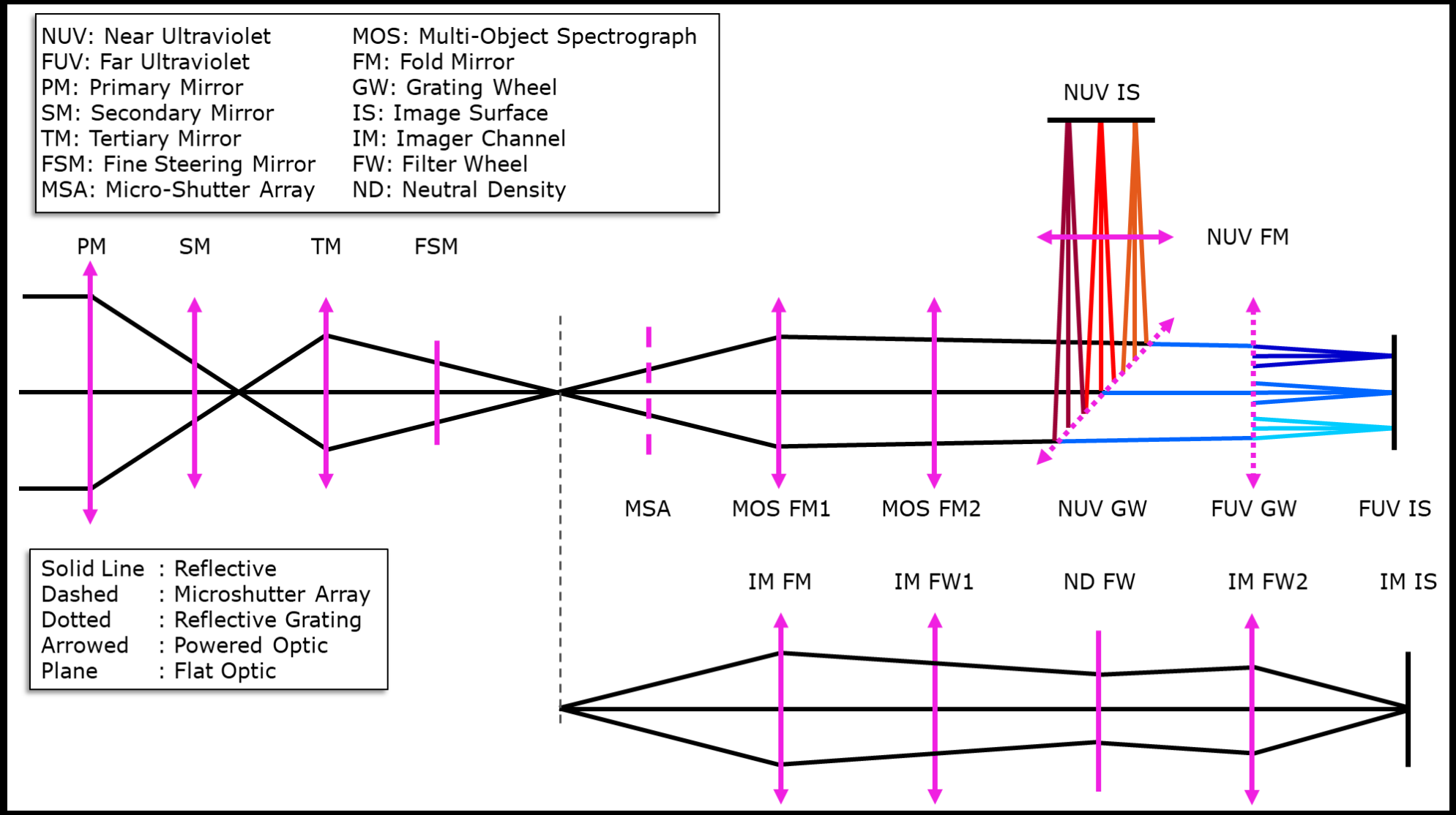
Three channels/capabilities

1) Multi-object Spectroscopy (MOS)
2) Imaging

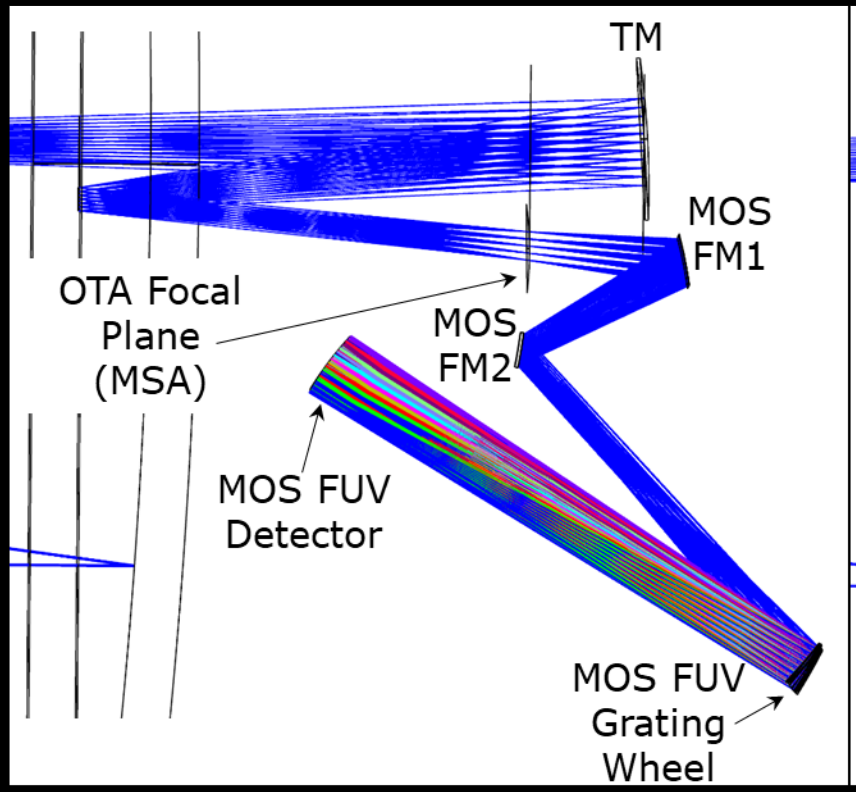
- 2 x 2 arcmin full FOV
- 100 – 1000nm waveband
- R between 500 and 55,000
- Only instrument w/ significant architectural differences between A and B versions



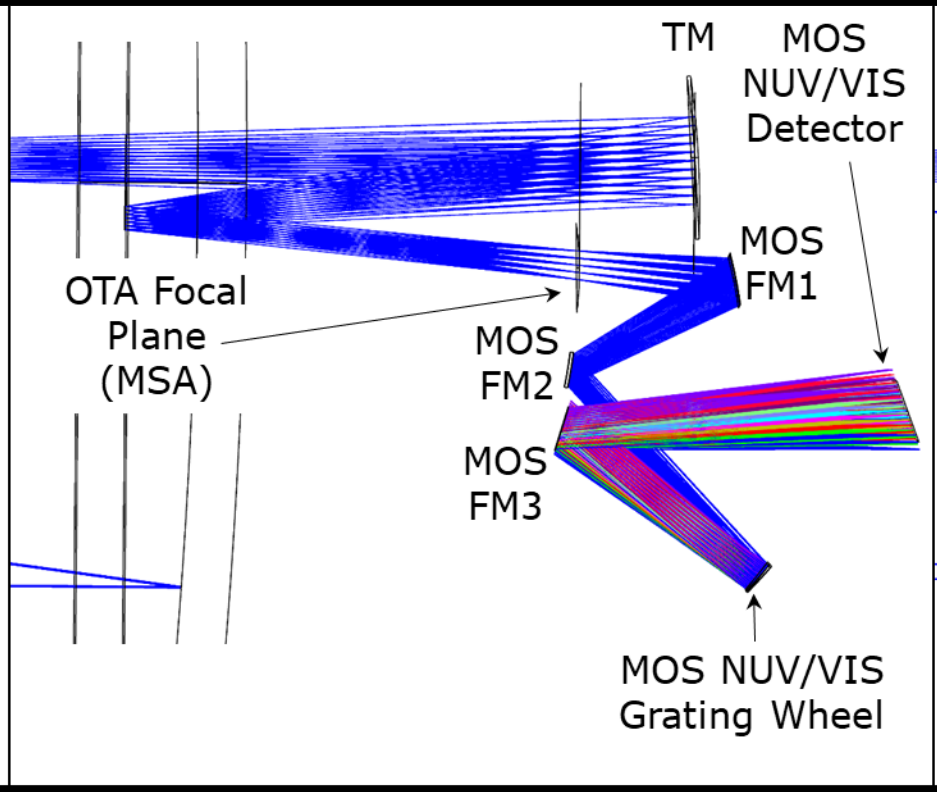
LUMOS-A, block diagram



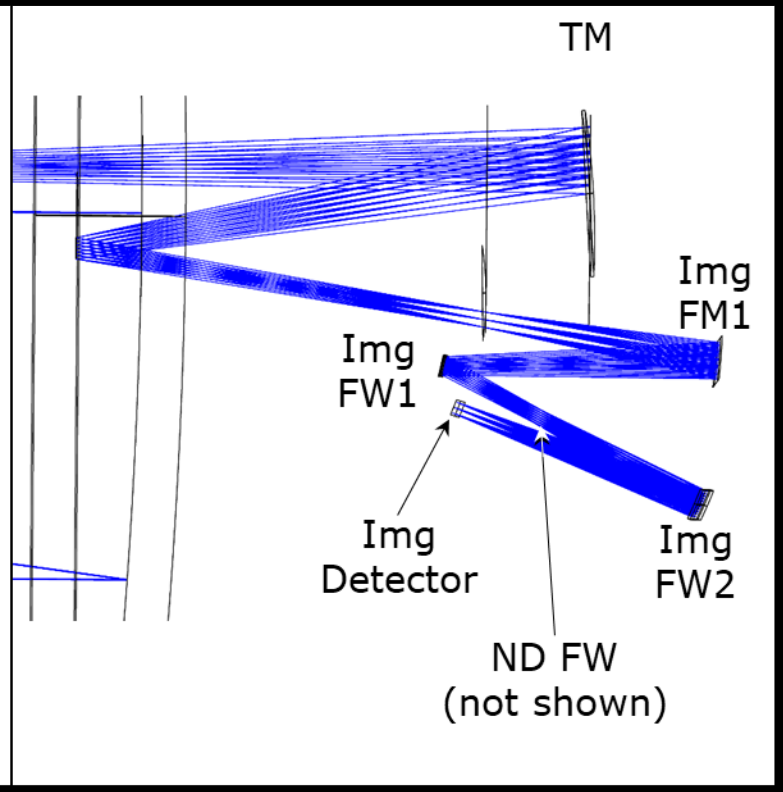
LUMOS-A, optical design



1. FUV multi-object spectrograph



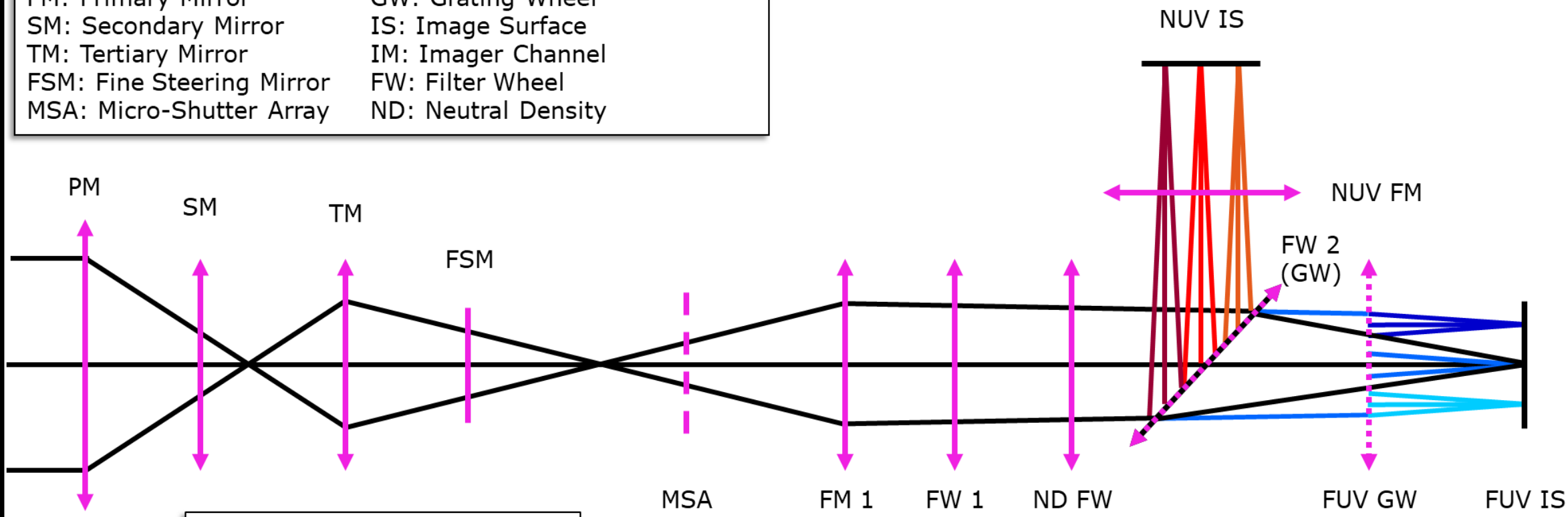
2. NUV/VIS multi-object spectrograph



3. FUV imager

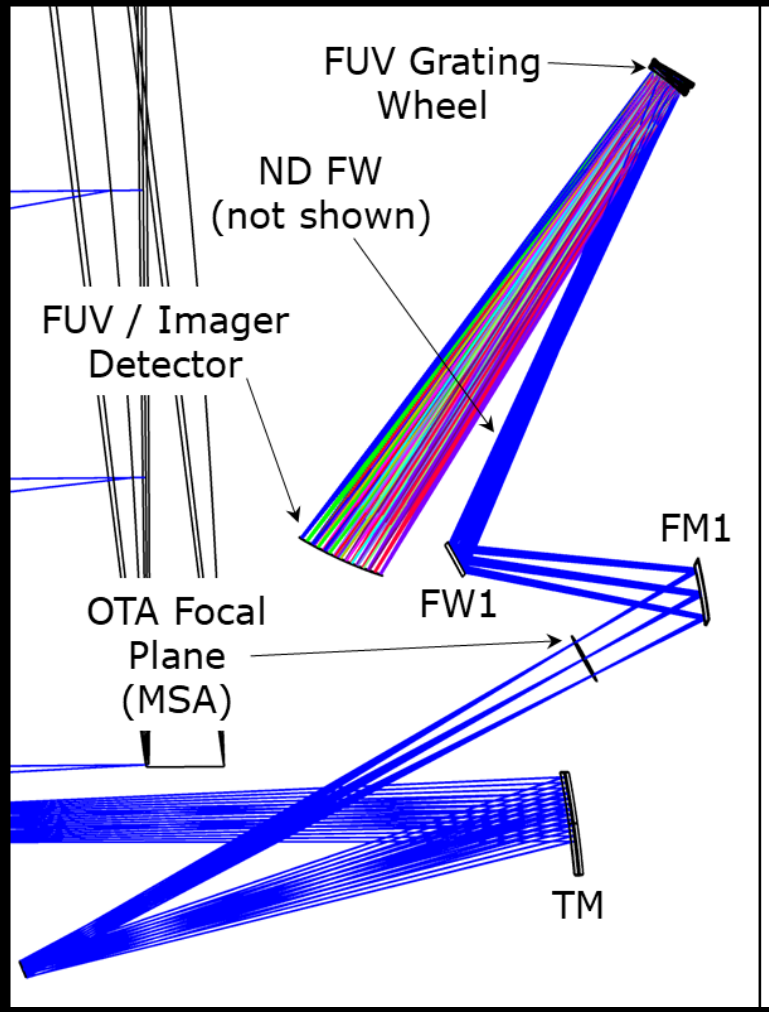
LUMOS-B, block diagram

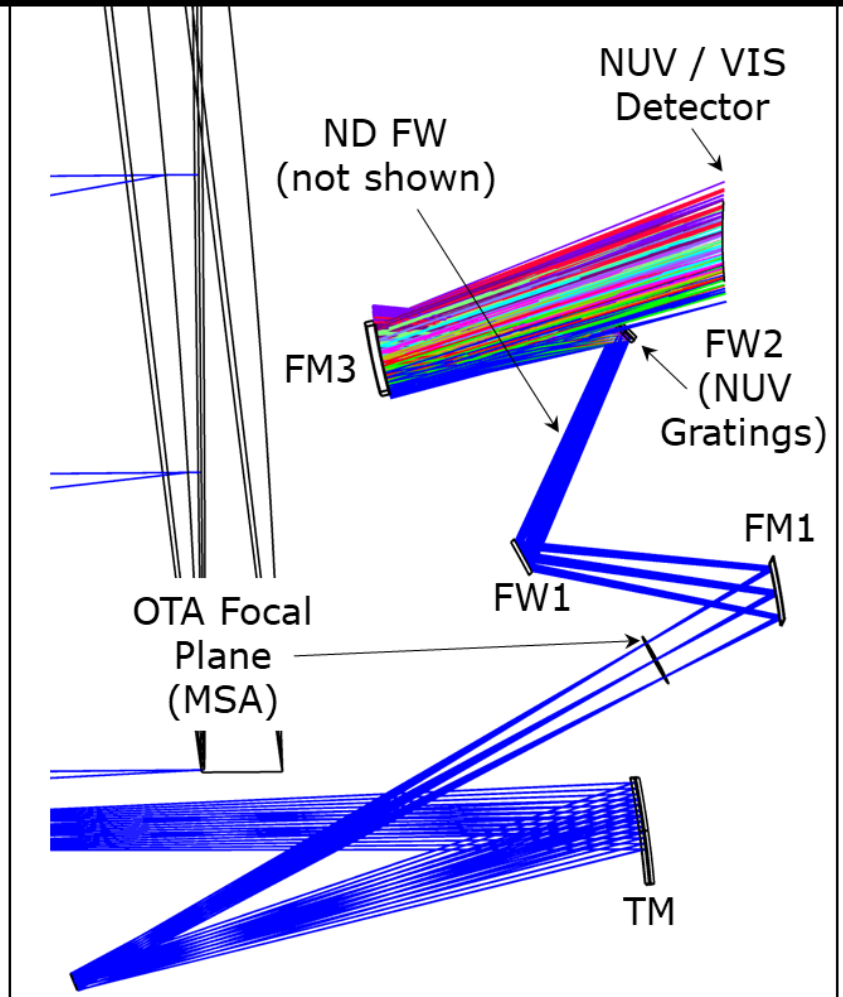
NUV: Near Ultraviolet	MOS: Multi-Object Spectrograph
FUV: Far Ultraviolet	FM: Fold Mirror
PM: Primary Mirror	GW: Grating Wheel
SM: Secondary Mirror	IS: Image Surface
TM: Tertiary Mirror	IM: Imager Channel
FSM: Fine Steering Mirror	FW: Filter Wheel
MSA: Micro-Shutter Array	ND: Neutral Density

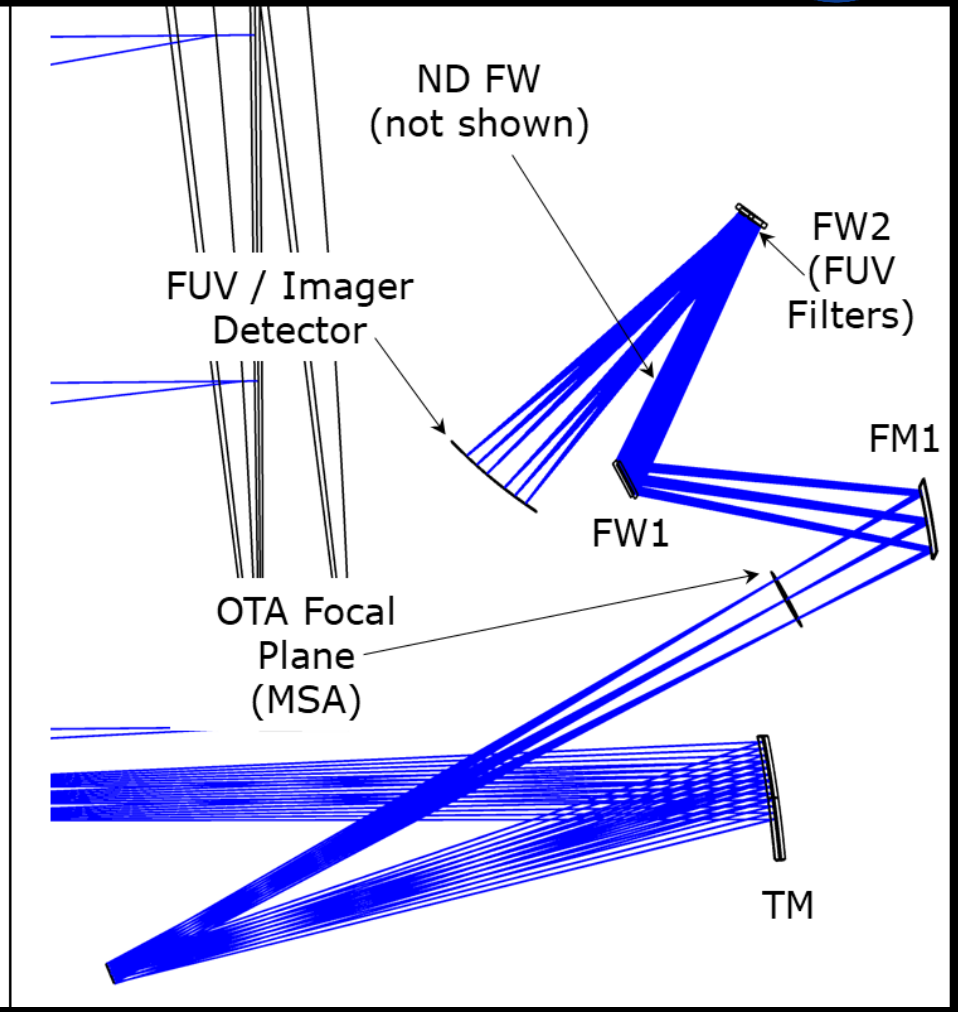


Solid Line	: Reflective
Dashed	: Microshutter Array
Dotted	: Reflective Grating
Arrowed	: Powered Optic
Plane	: Flat Optic

LUMOS-B, optical design

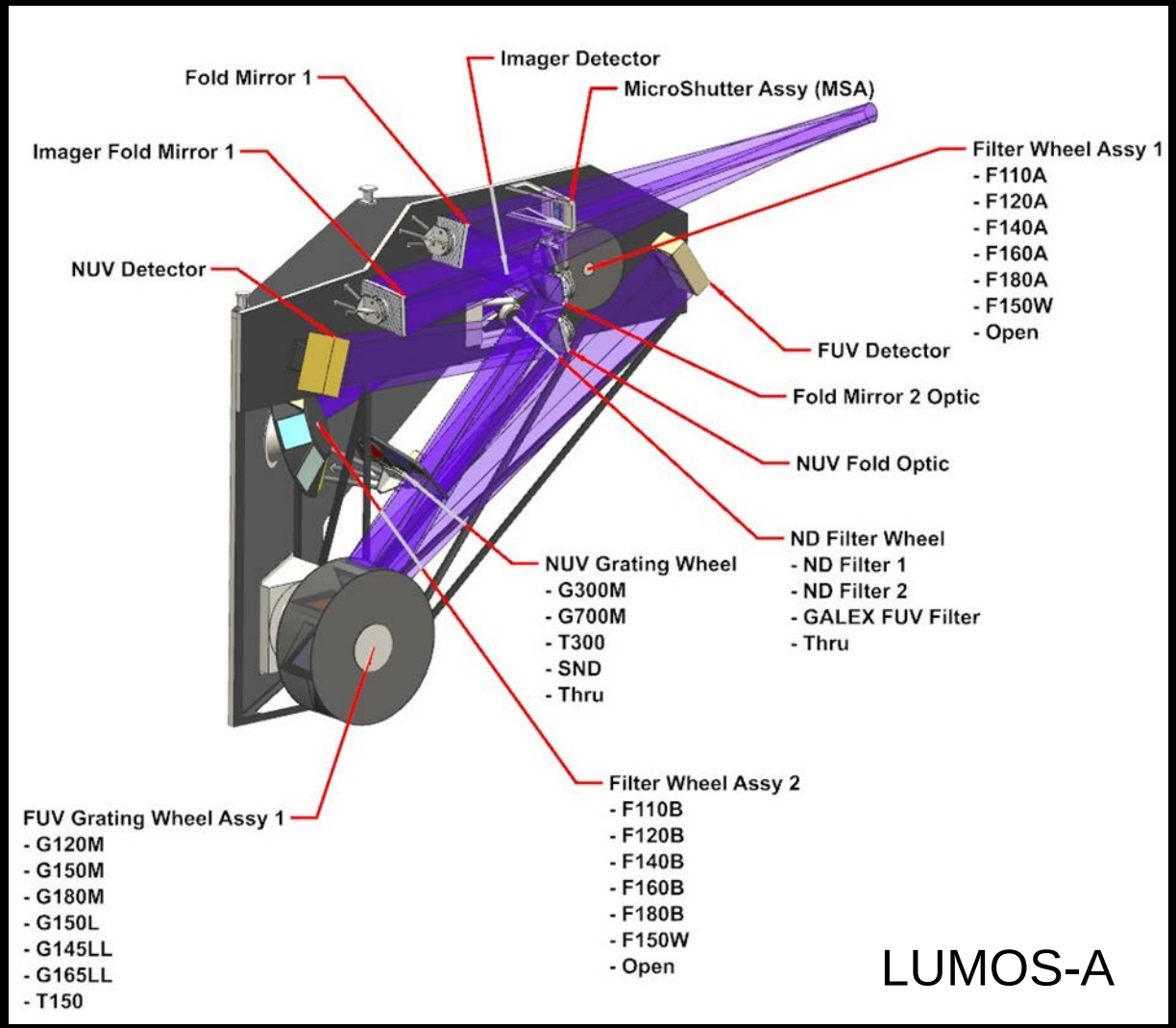


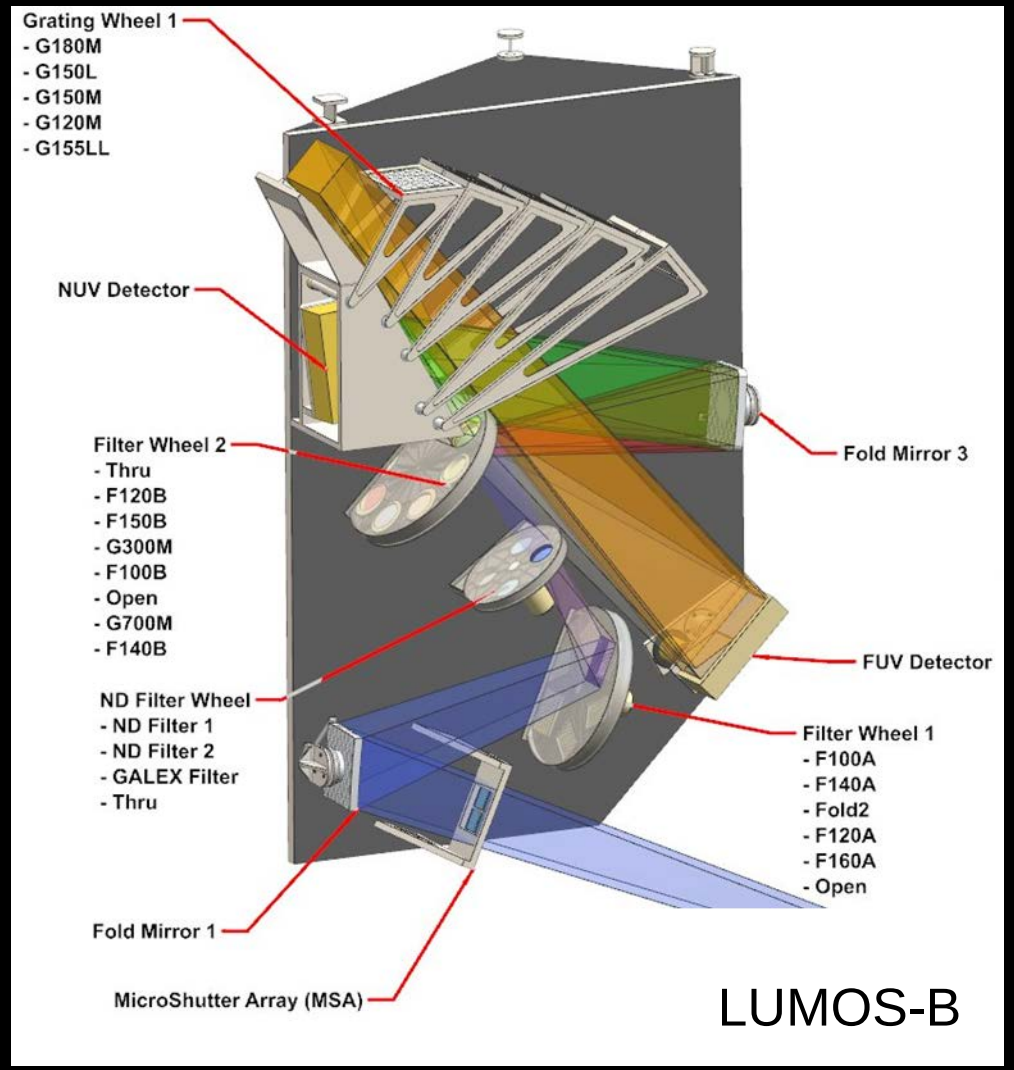




1. FUV multi-object spectrograph 2. NUV/VIS multi-object spectrograph 3. FUV imager

LUMOS


Fold Mirror 1
Imager Detector
MicroShutter Assy (MSA)
Imager Fold Mirror 1
Filter Wheel Assy 1
- F110A
- F120A
- F140A
- F160A
- F180A
- F150W
- Open
NUV Detector
FUV Detector
Fold Mirror 2 Optic
NUV Fold Optic
ND Filter Wheel
- ND Filter 1
- ND Filter 2
- GALEX FUV Filter
- Thru
NUV Grating Wheel
- G300M
- G700M
- T300
- SND
- Thru
Filter Wheel Assy 2
- F110B
- F120B
- F140B
- F160B
- F180B
- F150W
- Open
FUV Grating Wheel Assy 1
- G120M
- G150M
- G180M
- G150L
- G145LL
- G165LL
- T150
LUMOS-A


Grating Wheel 1
- G180M
- G150L
- G150M
- G120M
- G155LL
NUV Detector
Filter Wheel 2
- Thru
- F120B
- F150B
- G300M
- F100B
- Open
- G700M
- F140B
Fold Mirror 3
FUV Detector
ND Filter Wheel
- ND Filter 1
- ND Filter 2
- GALEX Filter
- Thru
Filter Wheel 1
- F100A
- F140A
- Fold2
- F120A
- F160A
- Open
Fold Mirror 1
MicroShutter Array (MSA)
LUMOS-B

High Definition Imager (HDI)

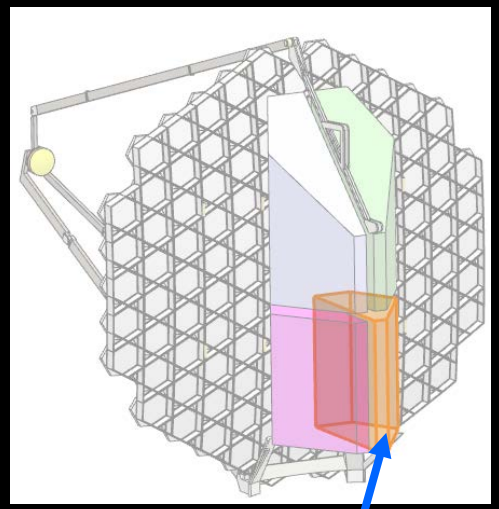
Observatory's primary instrument for imaging over wide FOV

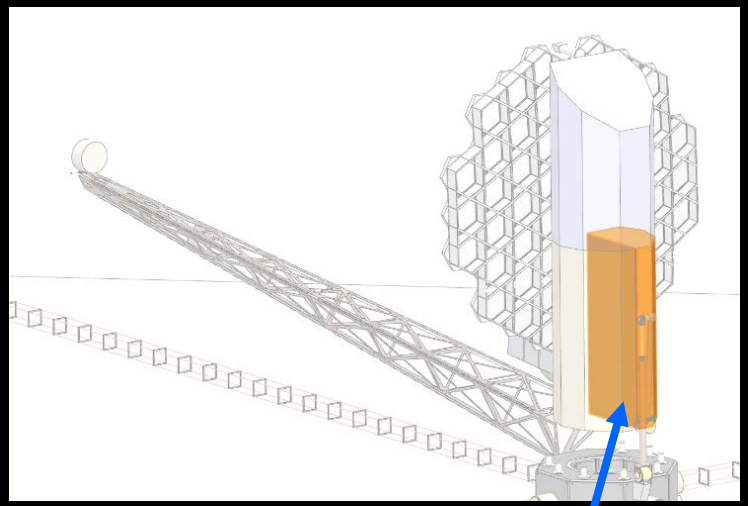
Two waveband channels

- UV-visible (UVIS) 200 – 1000 nm
- Near-infrared (NIR) 800 – 2500 nm

Five operational modes

- NIR transmissive
- UVIS reflective
- 50/50 beamsplitter (full bandpass)
- Dichroic beamsplitter (400 – 800 and 800 – 1600 nm)
- Optimized UV reflective (maximum reflectance, 200 – 400 nm)

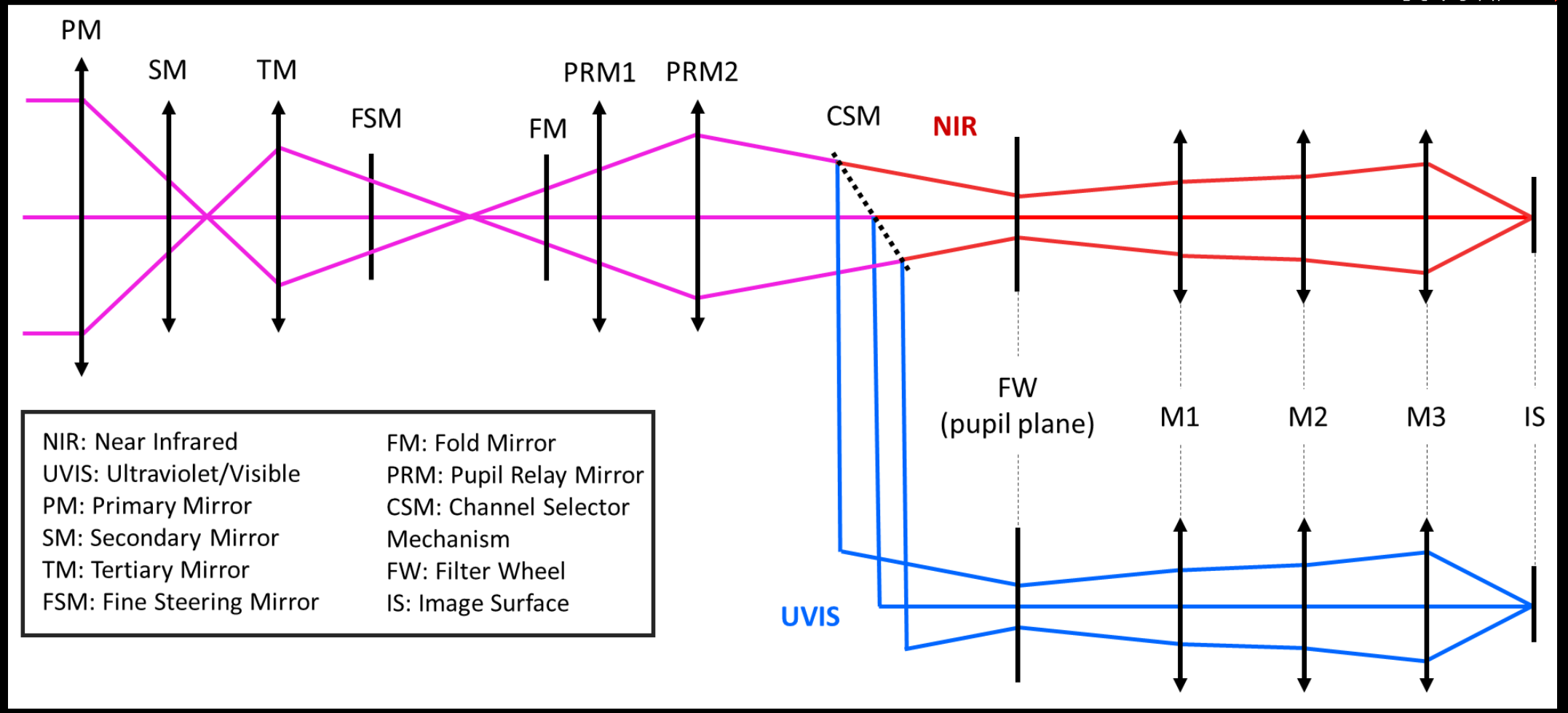




HDI-A

HDI-B

HDI – Block Diagram

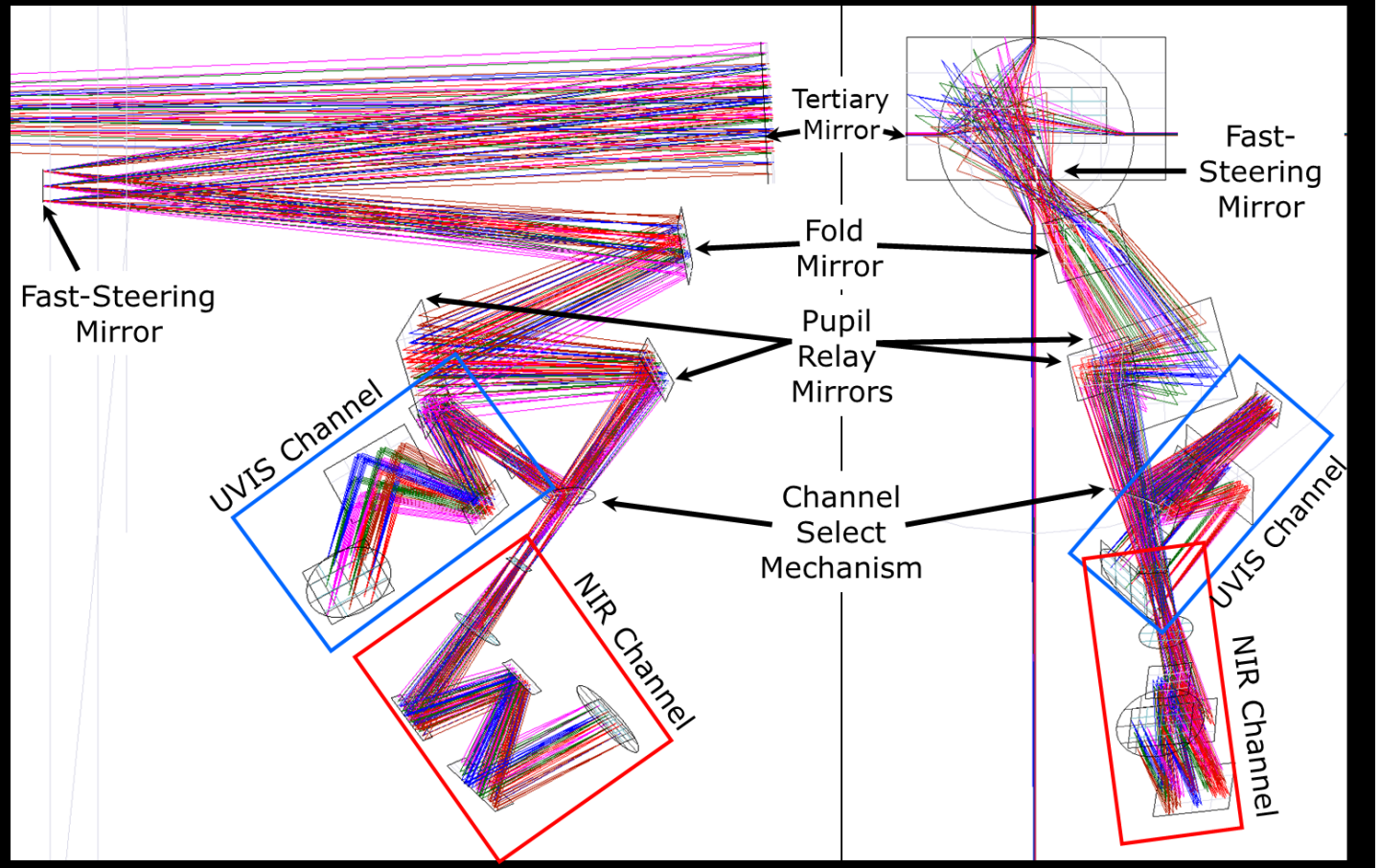


- HDI-A block diagram shown above, HDI-B's identical save fold mirror (FM)
- Pupil relay and channel mirrors are freeform surfaces (xy polynomial)

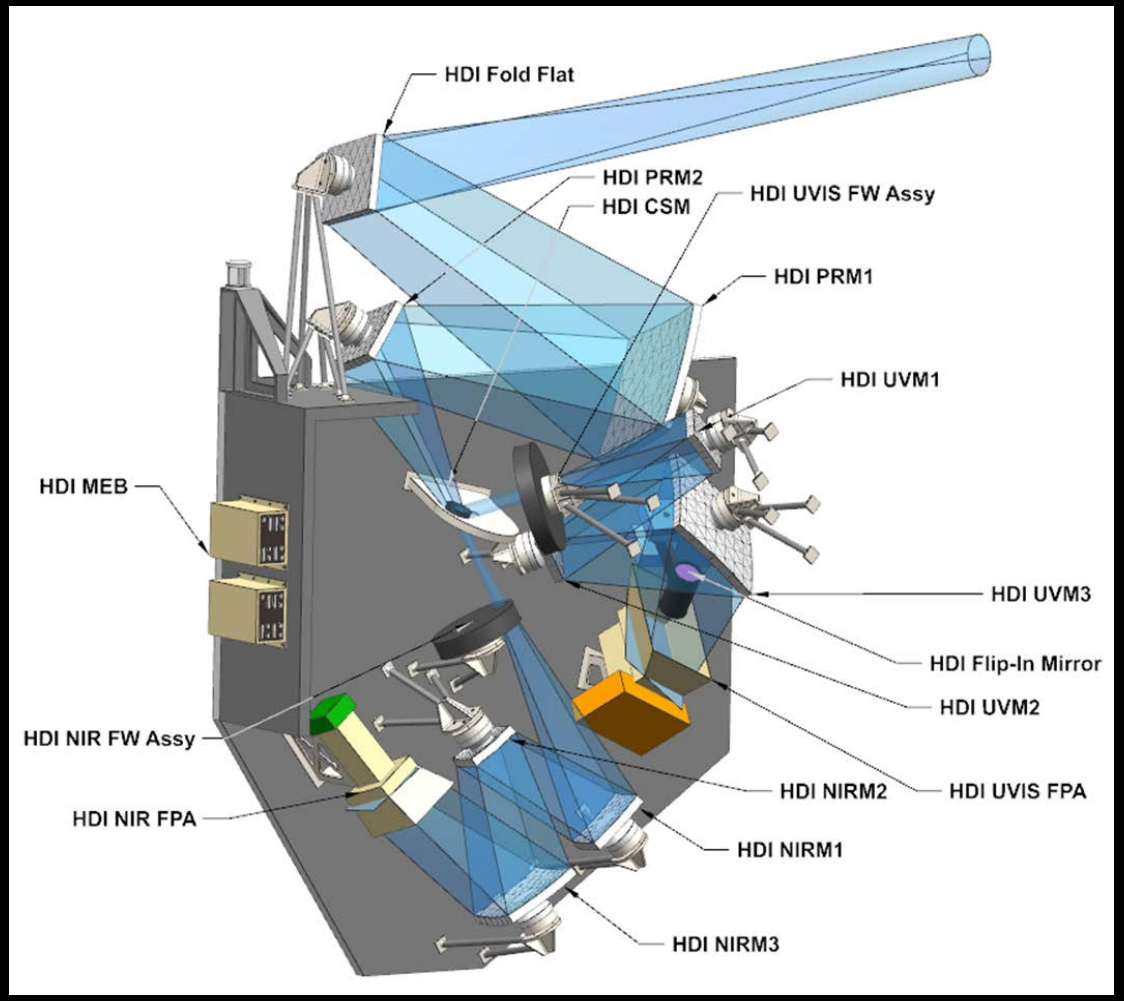
HDI Specifications

Parameter	Units	HDI-A		HDI-B	
		UVIS	NIR	UVIS	NIR
Bandpass	μm	0.2 - 1.0	0.8 - 2.5	0.2 - 1.0	0.8 - 2.5
Aperture Diameter (D)	m	15	15	8	8
f-number	--	26	20	26	20
Focal Length	m	390	300	208	160
Field of View	arcmin	2.93 x 1.94	2.97 x 1.96	2.73 x 1.80	2.75 x 1.81
Platescale	mas / pixel	3.43	6.88	6.45	12.89
DLSS	μm	31.72	48.80	31.72	48.80
RMS Pointing Stability	1-σ mas	0.43	0.86	0.81	1.61
RMS Wavefront Error	nm	< 35	< 71	< 35	< 71
Detector Type	--	CMOS	HgCdTe	CMOS	HgCdTe
Pixel Size	μm	6.5	10.0	6.5	10.0
Detector Format	pixels	8192 x 8192	4096 x 4096	8192 x 8192	4096 x 4096
Array Tiling	--	6 x 4	6 x 4	3 x 2	3 x 2
Total Number of Pixels	Gigapixels	1.611	0.403	0.403	0.101

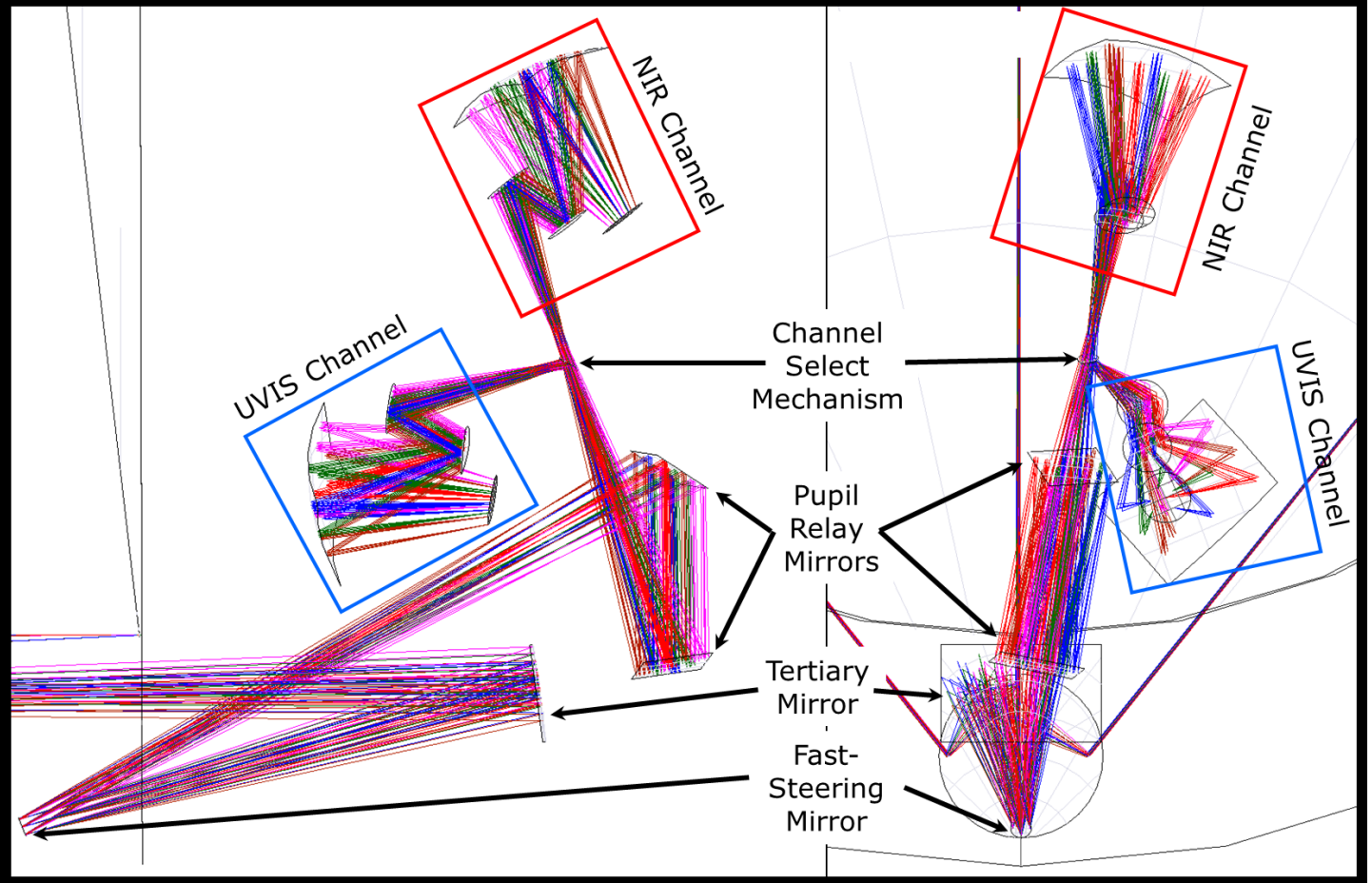
HDI-A, optical design



Side View Back View

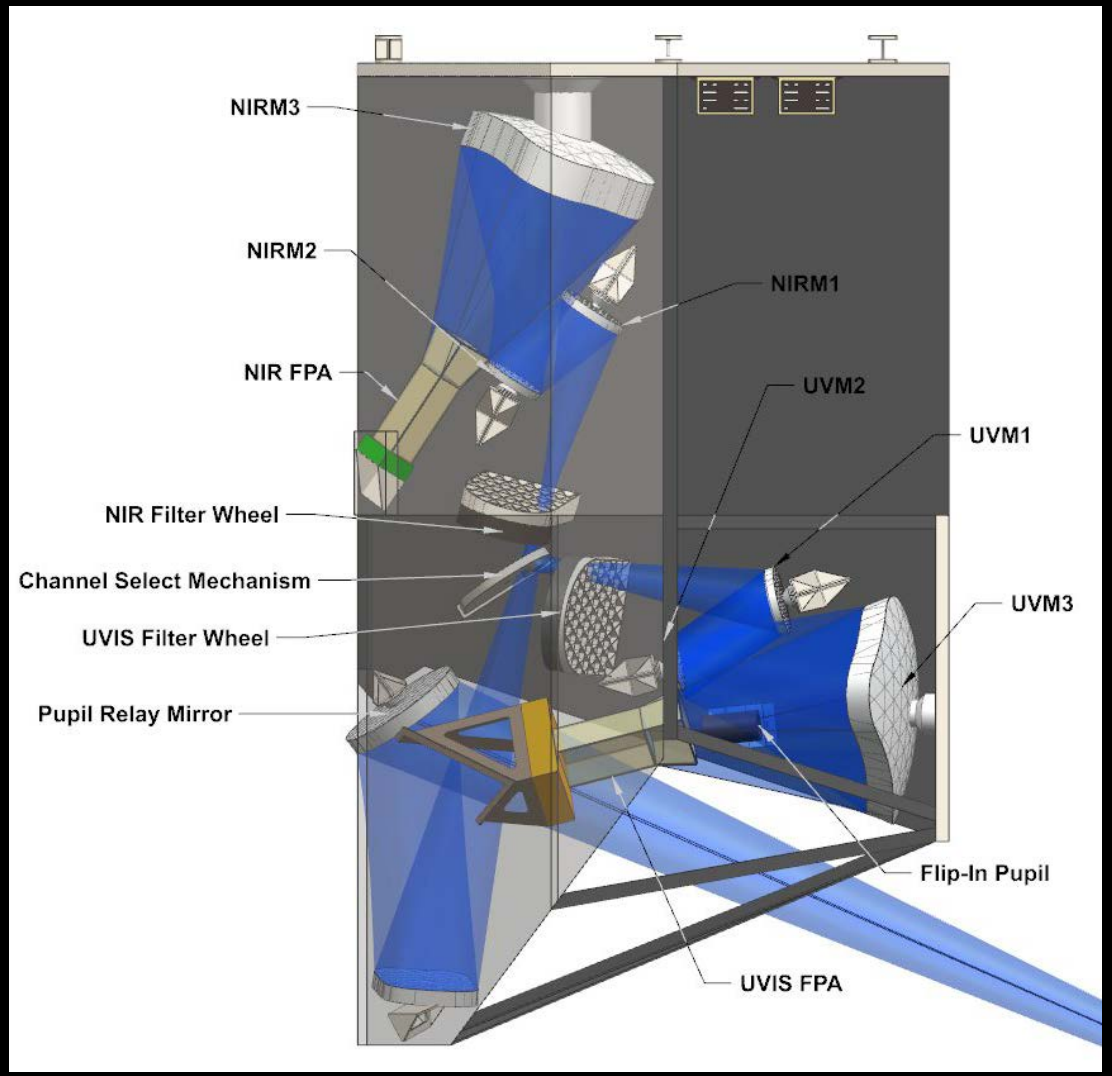


HDI-B, optical design

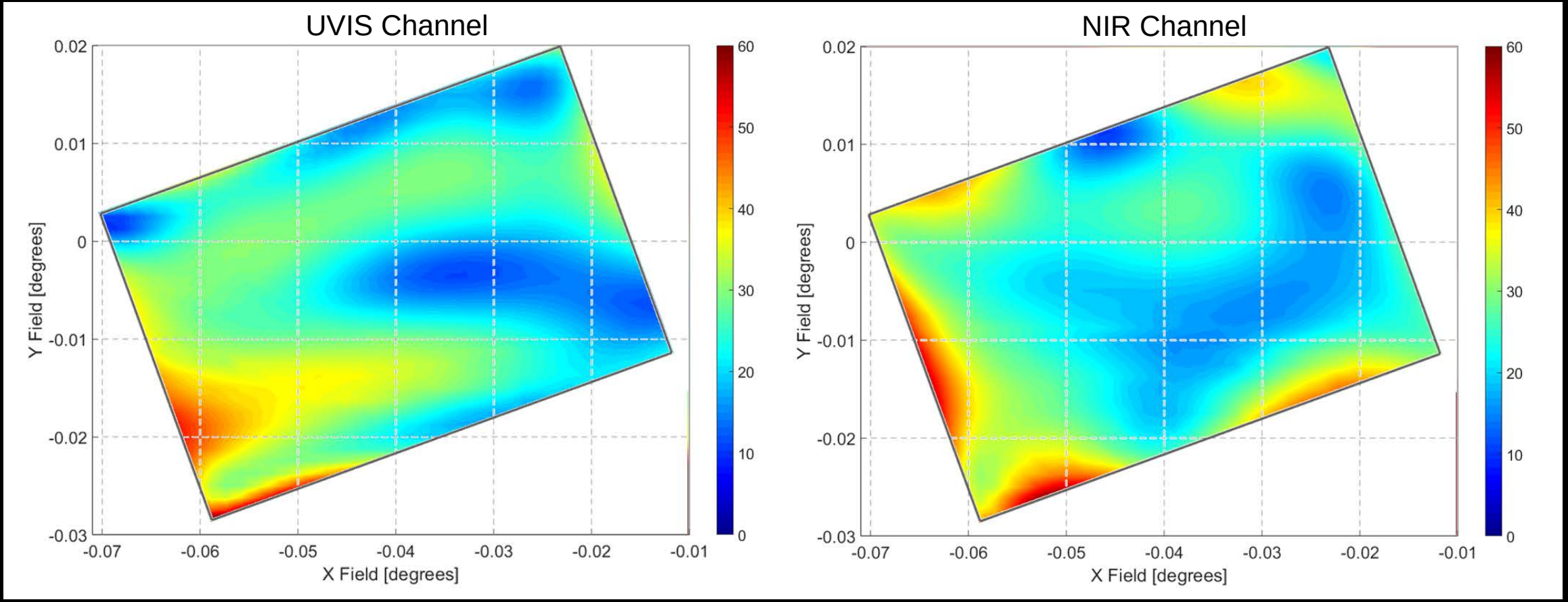


Side View

Back View

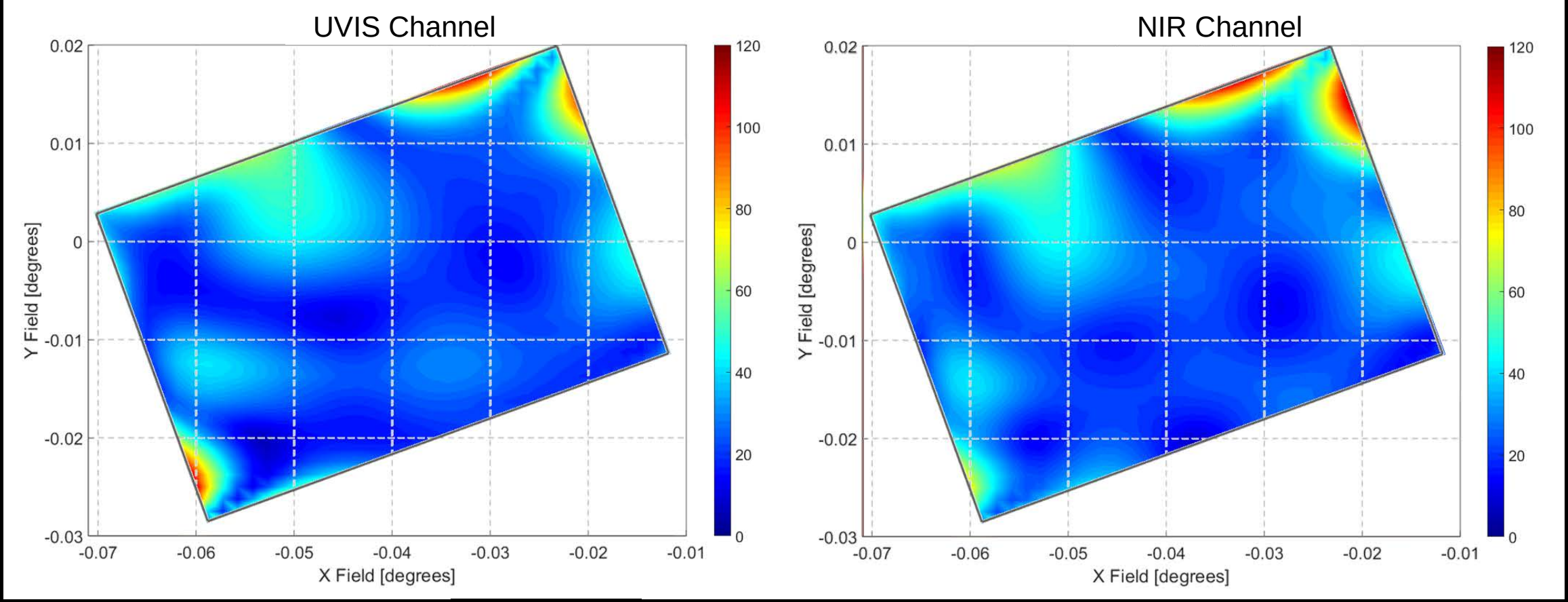


HDI-A, RMS wavefront performance



	HDI-A		HDI-B	
	UVIS	NIR	UVIS	NIR
Requirement	< 35	< 71	< 35	< 71
Average	25.8	25.7	28.3	29.3
Maximum	53.5	59.0	104.6	104.9
Minimum	9.5	9.9	6.6	9.4

HDI-B, RMS wavefront performance



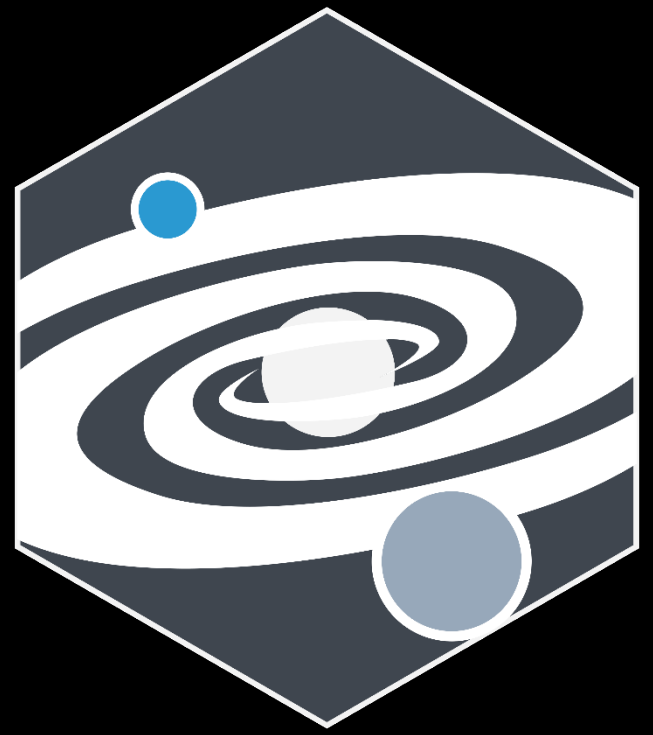
	HDI-A		HDI-B	
	UVIS	NIR	UVIS	NIR
Requirement	< 35	< 71	< 35	< 71
Average	25.8	25.7	28.3	29.3
Maximum	53.5	59.0	104.6	104.9
Minimum	9.5	9.9	6.6	9.4

Thank you for your attention!

For more information:

https://asd.gsfc.nasa.gov/luvoir/

Twitter: @luvoirtelescope



L U V O I R

Backup

LUMOS Specifications

Instrument Parameter	G120M	G150M	G180M	G155L	G145LL	G165LL	G300M	G700L	FUV Imager
Optimized Spectral Bandpass (nm)	100 - 140	130 - 170	160 - 200	100 - 200	100 - 200	110 - 200	200 - 400	400 - 1000	100 - 200
Actual Spectral Bandpass (nm)	93 - 159	111 - 189	141 - 219	93 - 267	93 - 210	110 - 270	193 - 460	340 - 1000	100 - 200
Field of View (FOV)	2' x 2'	2' x 2'	2' x 2'	2' x 2'	2' x 2'	2' x 2'	1.5' x 2' (A) 2' x 2' (B)	1.5' x 2' (A) 2' x 2' (B)	1.2' x 2' (A) 2' x 2' (B)
Spectral Resolving Power (Objective: λ/Δλ)	**30,000**	**30,000**	**30,000**	**8,000**	**500**	**500**	**20,000**	**15,000**	**----**
Imaging Resolution (Objective: mas)	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**
LUMOS A									
Effective Area (Peak, cm^2)	311,540	136,780	160,610	304,300	184,880	311,545	324,950	302,750	~ 100,000
Effective Area (Central Wavelength, cm^2)	293,270	102,750	160,610	91,250	31,460	91,240	247,630	266,690	~ 100,000
Grating Ruling Density (groove/mm)	1,950	2,050	2,020	815	21	43	450	150	----
Average Resolving Power (All Microshutters)	29,875	35,990	40,991	14,063	408	820	20,531	14,466	----
Average Resolving Power (Best 1' x 1')	39,276	47,004	54,812	17,508	583	1,170	28,431	19,950	----
Average Angular Resolution (All Microshutters)	37	43	39	42	38	38	31	33	50
Average Angular Resolution (Best 1' x 1')	28	32	30	34	26	26	19	21	42
LUMOS B									
Effective Area (Peak)	86,140	37,820	44,410	84,140	51,120	----	89,850	83,710	~ 27,500
Effective Area (Central Wavelength)	81,090	28,410	44,410	25,230	8,700	----	68,470	73,740	~ 27,500
Grating Ruling Density (groove/mm)	2,555	2,630	2,610	1,060	50	----	865	349	----
Average Resolving Power (All Microshutters)	29,422	36,863	49,699	13,699	455	----	19,983	17,604	----
Average Resolving Power (Best 1' x 1')	40,264	52,223	59,310	17,414	537	----	32,745	28,223	----
Average Angular Resolution (All Microshutters)	41	42	43	48	28	----	25	48	48
Average Angular Resolution (Best 1' x 1')	31	32	33	39	23	----	23	41	40