B03
Development for high speed CMOS to probe the nature of dark matter
FY2024 Report on CMOS

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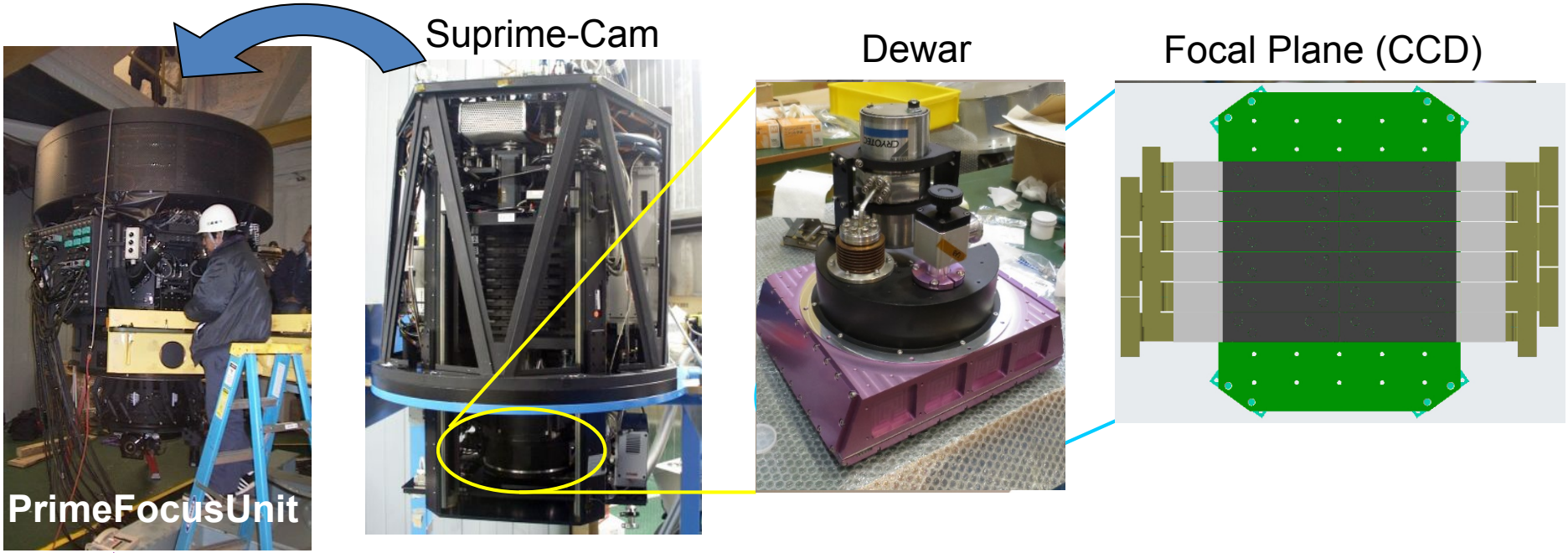
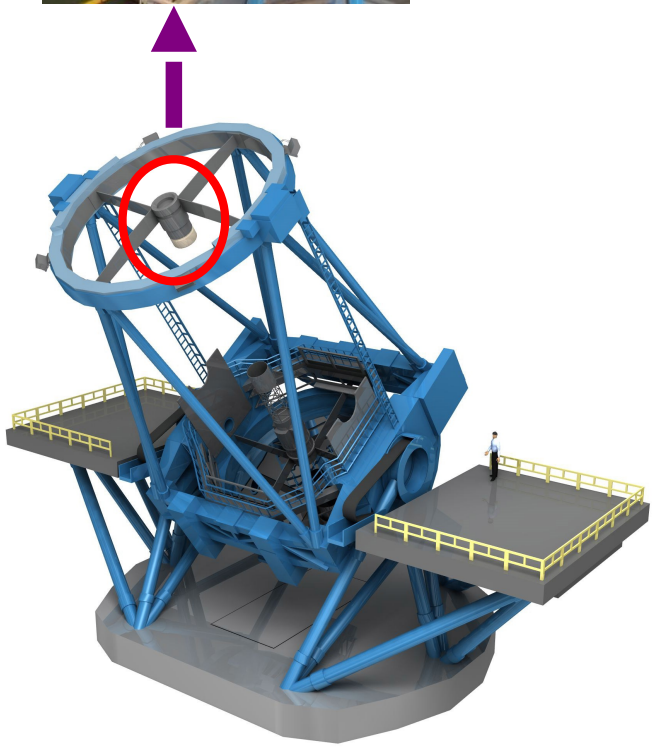
We extended the research term by the end of FY2025 because of the delay of camera delivery. This extension was approved by PI Murayama-san.

CMOS Camera：1-Page Summary

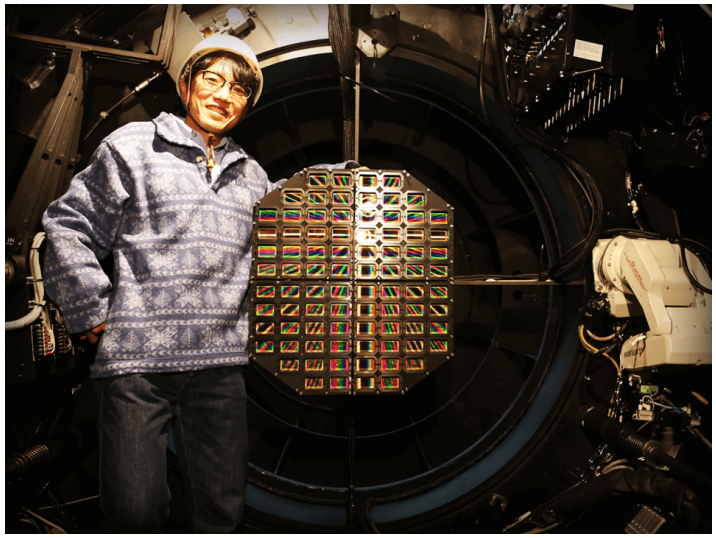




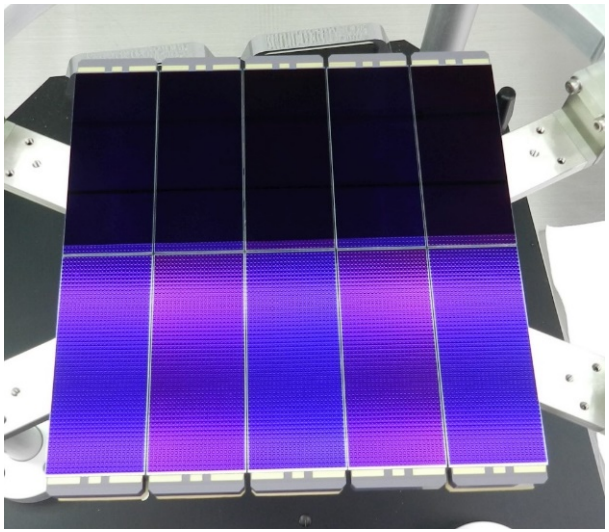
1. Recycle the original Suprime-Cam's Prime Focus Unit by replacing the dewar with a new dewar that has high speed CMOS
2. Realizing 30 arcmin field of view by paving 12 CMOS on the focal plane
3. Unprecedented parameter spaces can be probed when combined with Subaru telescope that has a large aperture and superb image quality; eg detection of faint time variable objects would be feasible.

CMOS Camera: Comparison

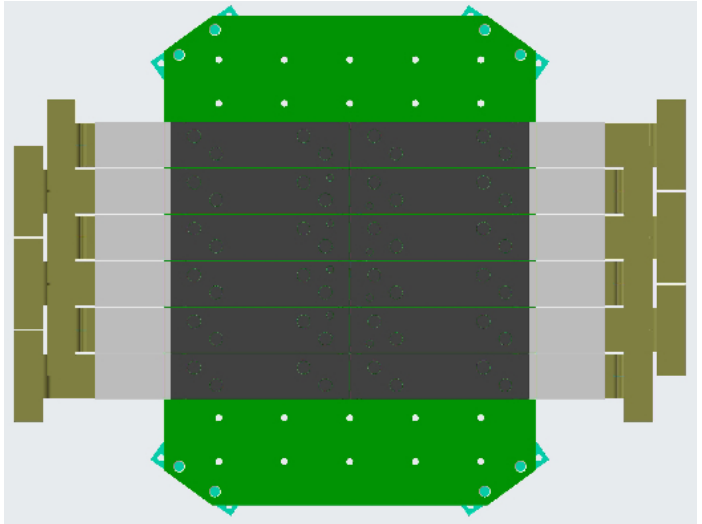
	Tomo-e Gozen	TAOS II	Subaru CMOS
Tel. Aperture	1.05 m	1.3 m	**8.2 m**
Field of View	20 deg^2	2.3 deg^2	0.25 deg^2
Frame Rate	2 sec^{-1} (20 for part)	20 sec^{-1}	**10 sec^{-1}**
Limiting Mag.	~17 mag	~18 mag	~21 mag
Sensor Format	2000x1128 (19um/pix)	1920x4608 (16um/ pix)	2560x10000 (7.5um/pix)
# of Sensors	84	10	12
Vendor	Canon	e2v	Hamamatsu
Site	Kiso	Mexico	**Maunakea**



Tomo-e Gozen



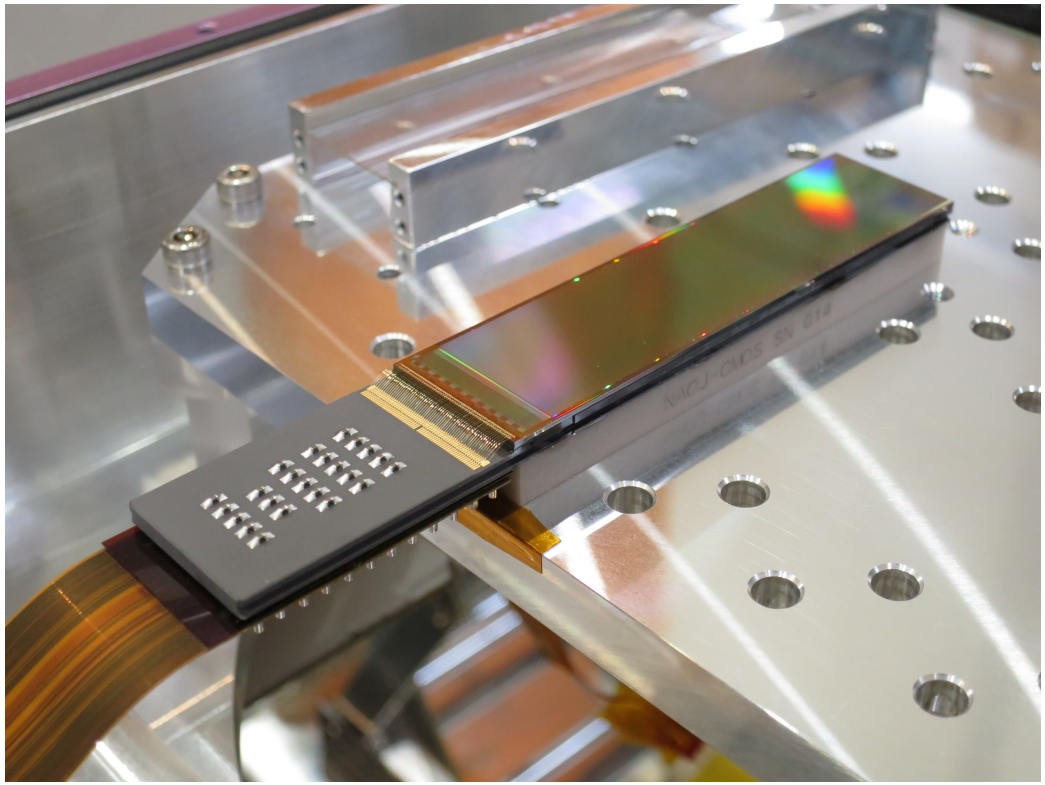
TAOSII Focal Plane



Subaru CMOS Camera

CMOS Specifications:

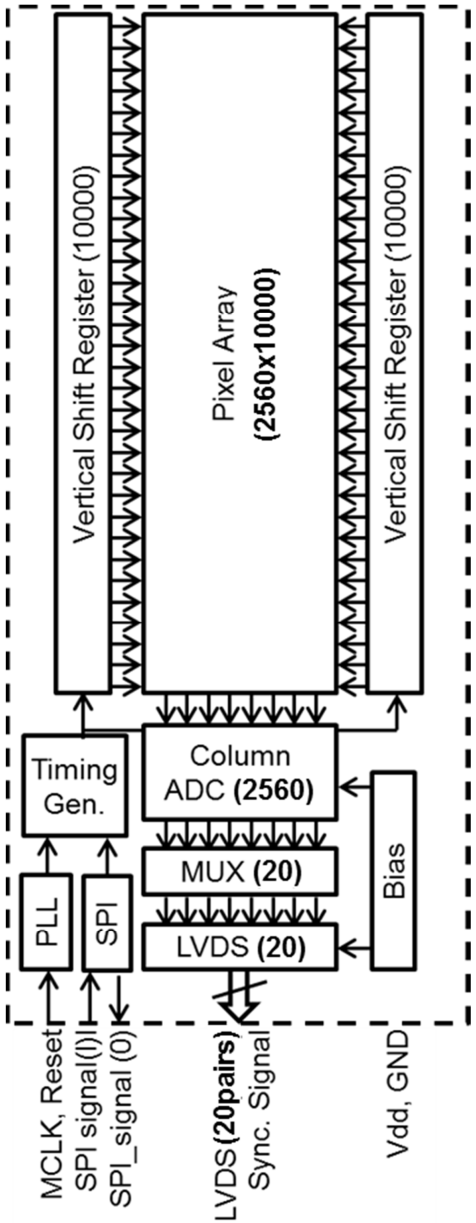
- 2,560 x 10,000 pixels
- 7.5 μm square pixel
- Full well ~ 30,000 e
- R.N. ~ 2 e
- Dark: 90 e/s/pix @ 300 K
- 10 Frame/sec



Structure

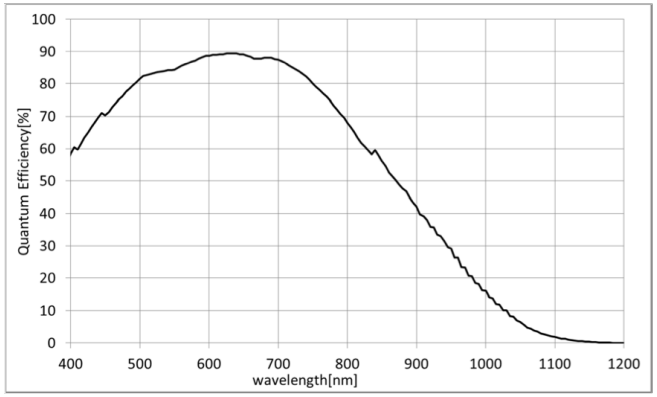
2560 Column ADC that realizes 10 Hz readout LVDS digital output from a device

■ ブロック図



Item	Unit	Back Illuminated	Front Illuminated
Image Size	mm	19.20 x 75.00	
Pixel Size	μm	7.5	
Format	pixel	2560 x 10000	
Fastest Frame Rate	fps	6	10
Quantum Efficiency	%	>= 48 (400 nm) >= 60 (800 nm)	>= 5 (400 nm) >= 11 (800 nm)
Ratio of defect pixels	%	<= 5	
Resolution (*1)	μm	<= 5	<= 5
Dark Current	e / pixel / sec	<= 1000 (Room Temperature)	<= 200 (Room Temperature)
Read Noise (High Gain) (Low Gain)	e rms	<= 5 <= 30	<= 3 <= 25
Full Well (High Gain) (Low Gain)	e	>= 2000 >= 20000	>= 2000 >= 30000
Responsivity (High Gain) (Low Gain)	μV/e	640 40	
ADC Resolution	bit	10 (*2)	

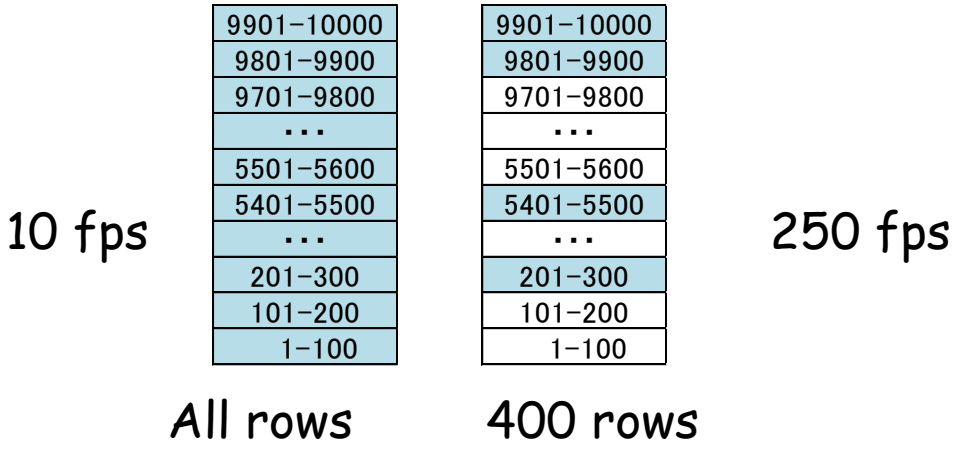
■ 分光感度特性（代表例）



Partial Readout

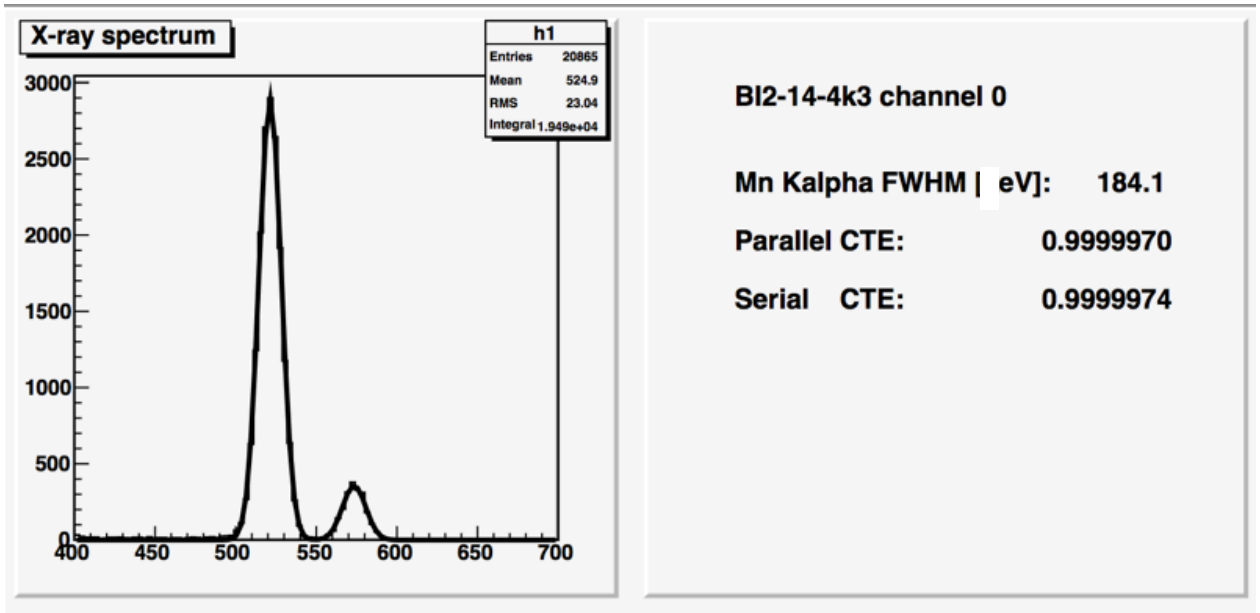
Higher speed (up to 1 k fps) realized by partial readout

100 continuous rows forms a group.
Any group can be selected for readout.

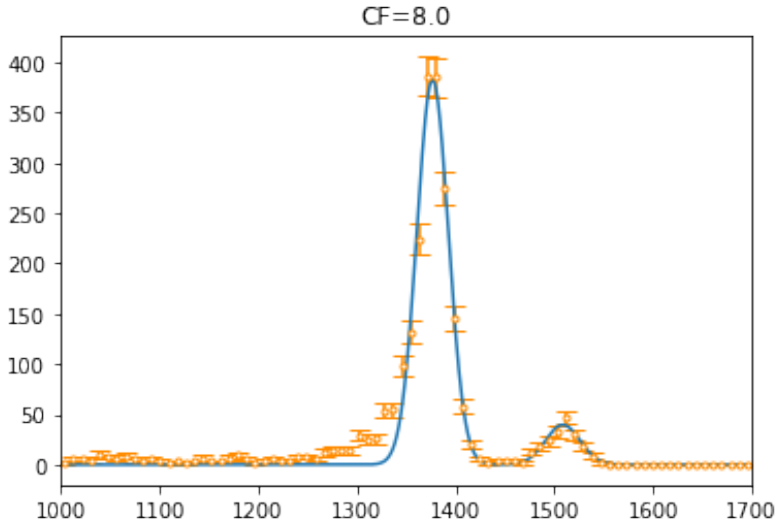


X-ray test result:

HPK CCD



HPK CMOS

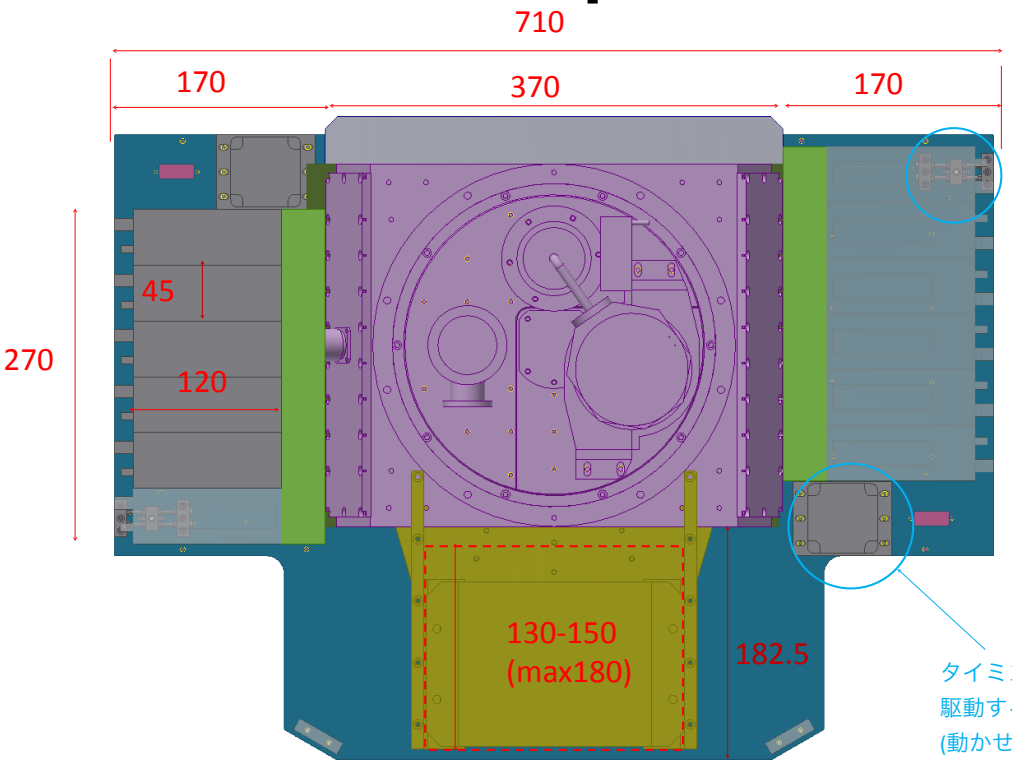


Mn Kalpha FWHM: 160 eV

Readout noise: 2.5 e

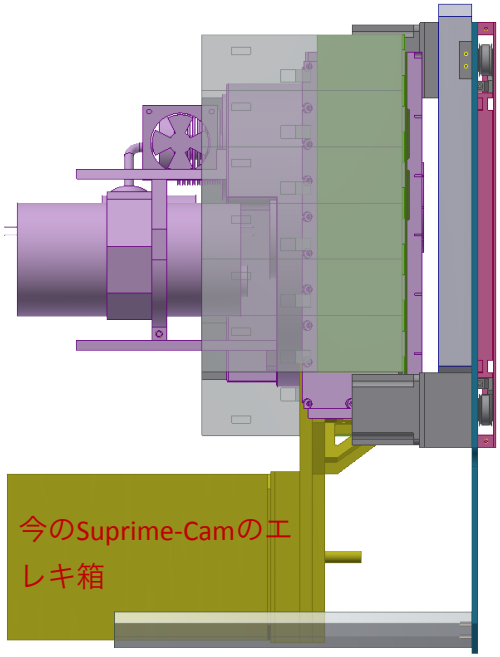
Demonstration of low noise and sufficiently low dark current as designed.

Space Envelope of the Camera

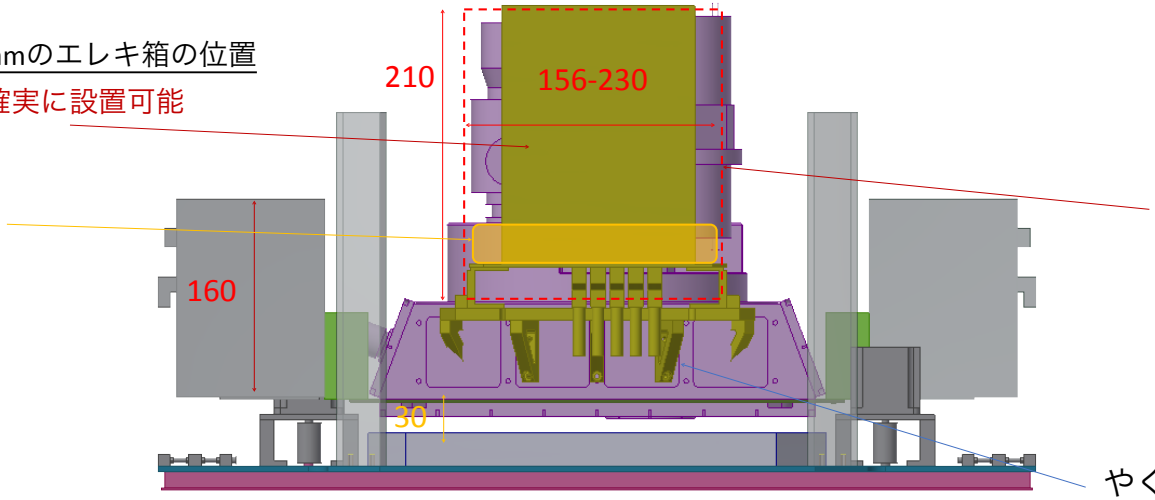


シャッターのモーター
SPMU002の上なのでぶつからない

タイミングベルトを駆動するモーター
(動かせない)



今のSuprime-Camのエレキ箱の位置
この範囲なら確実に設置可能



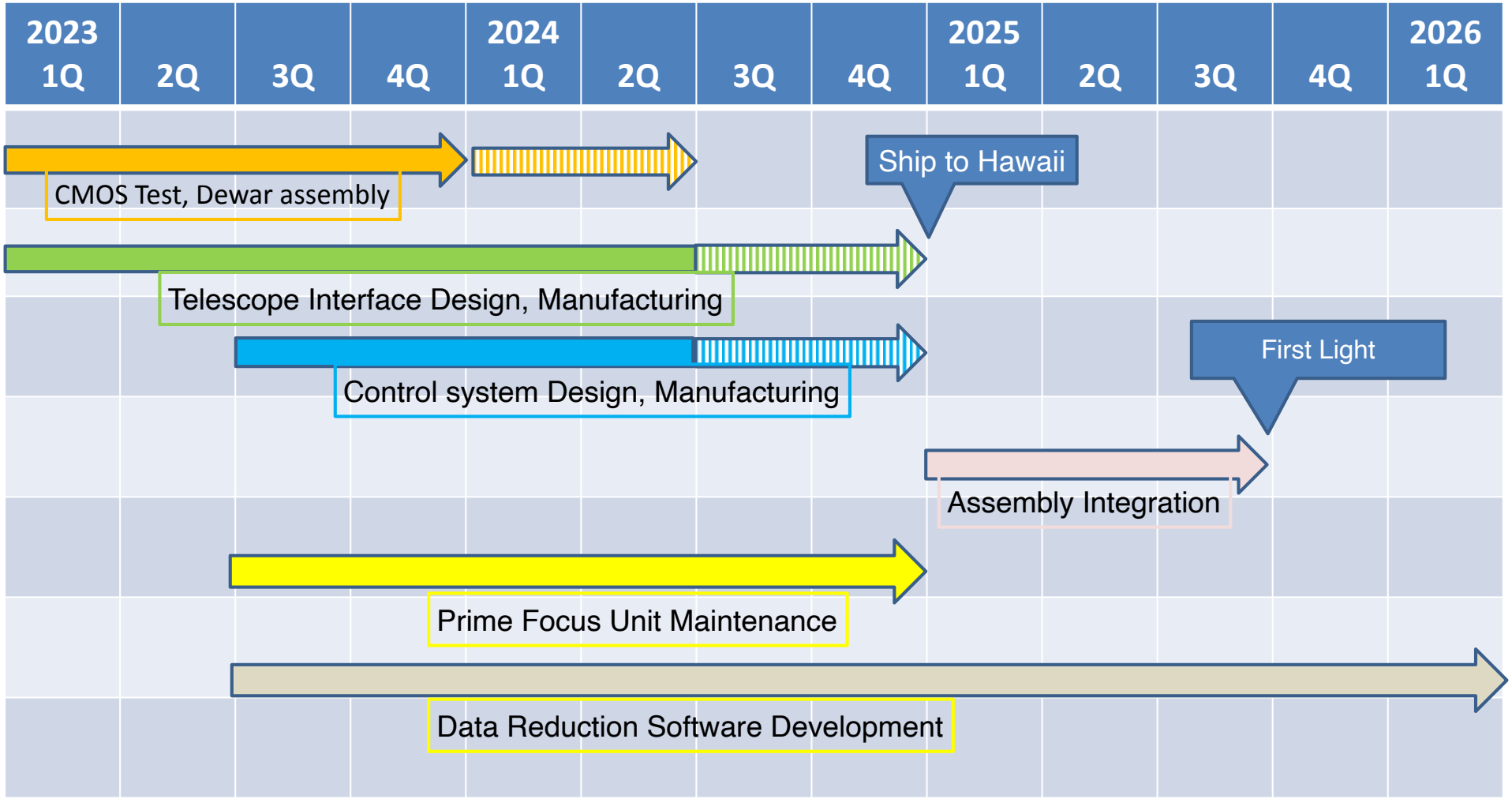
やぐら

(参考)トラスと干渉しない範囲

	元の サイズ	max
横幅	156	230
奥行	132	150(180)
高さ		210

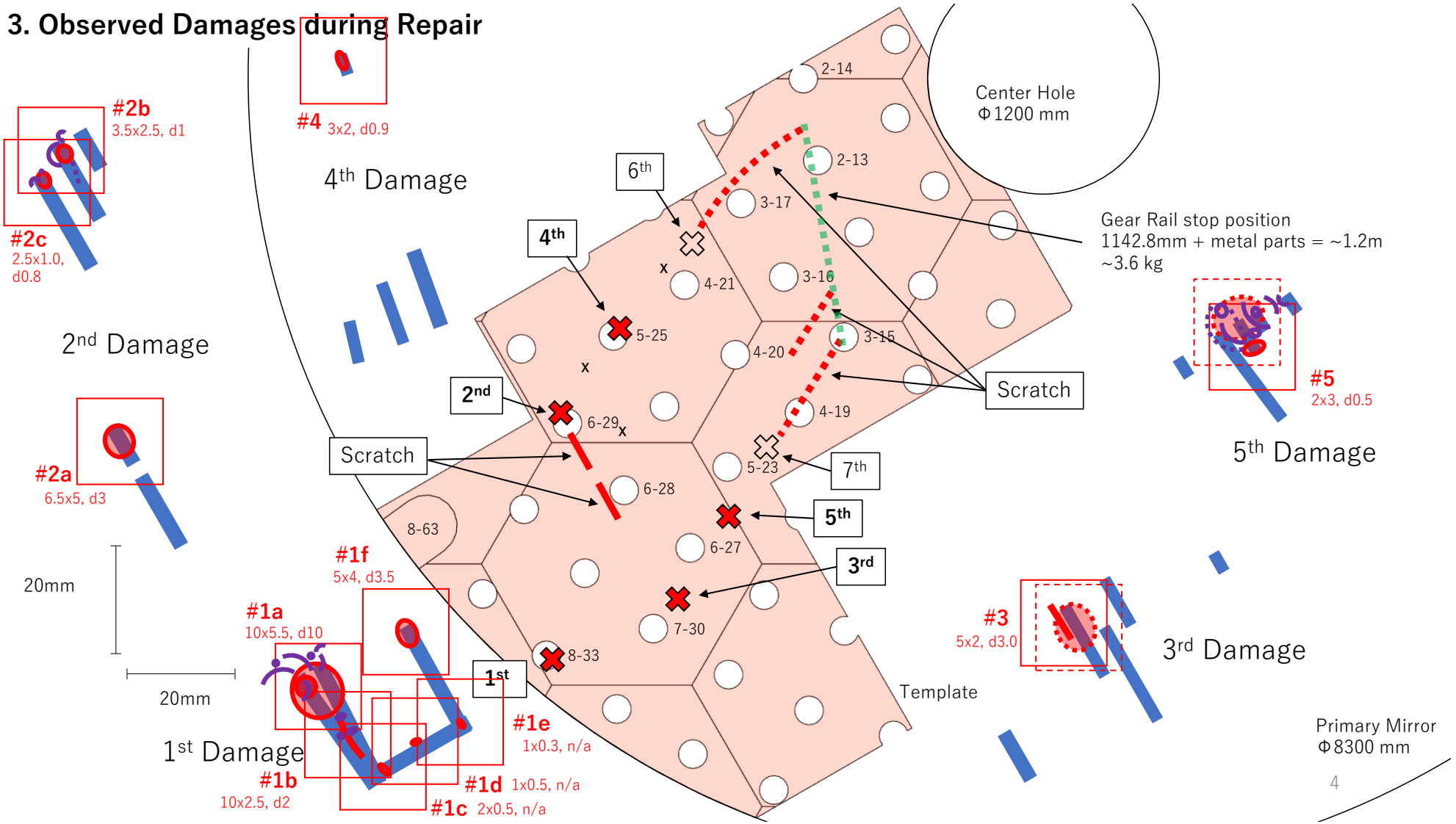
Original

CMOS Camera : Development Schedule



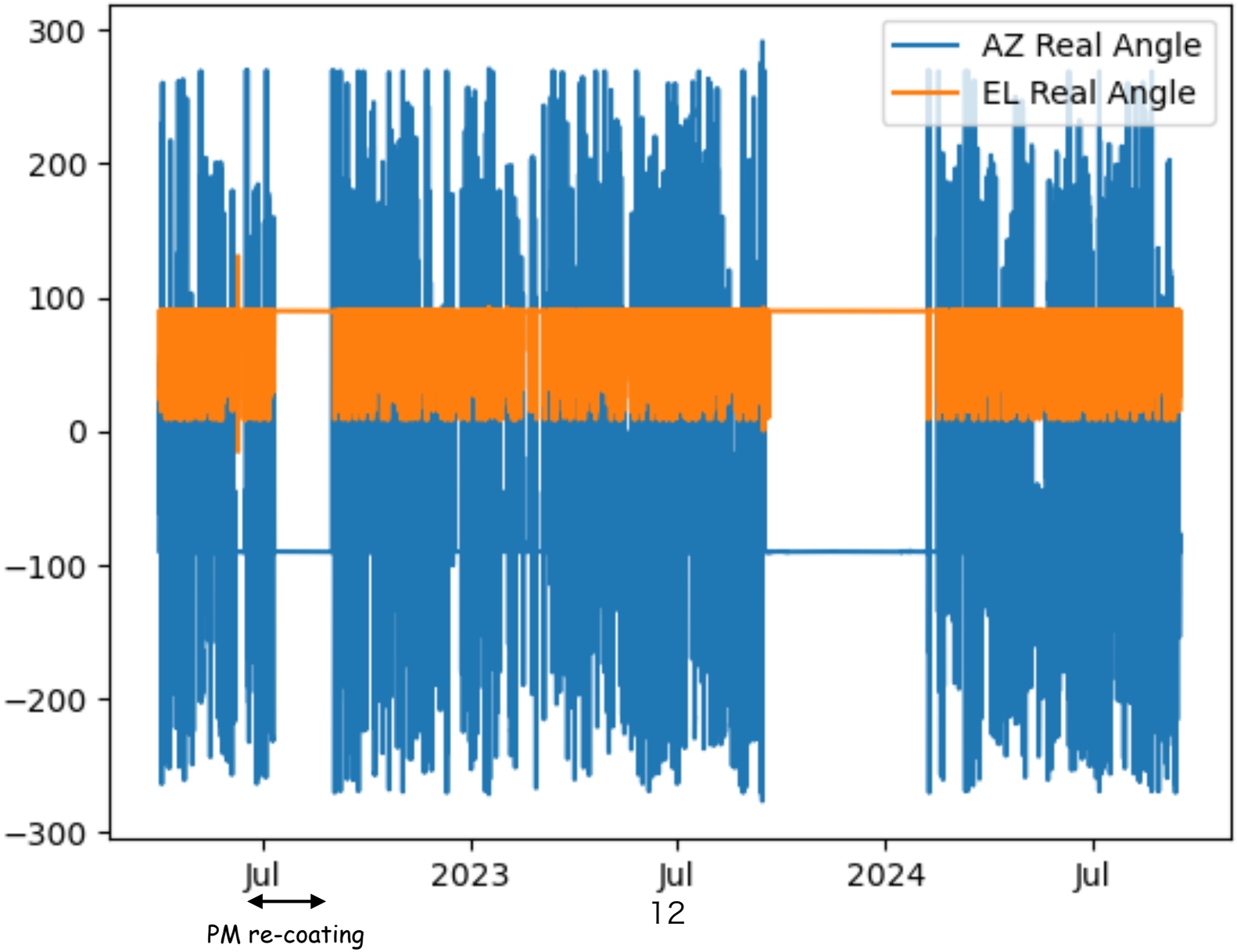
Test Observing at small telescope using the concept proof system

Primary Mirror damaged due to the accident in Sep. 2023



Telescope

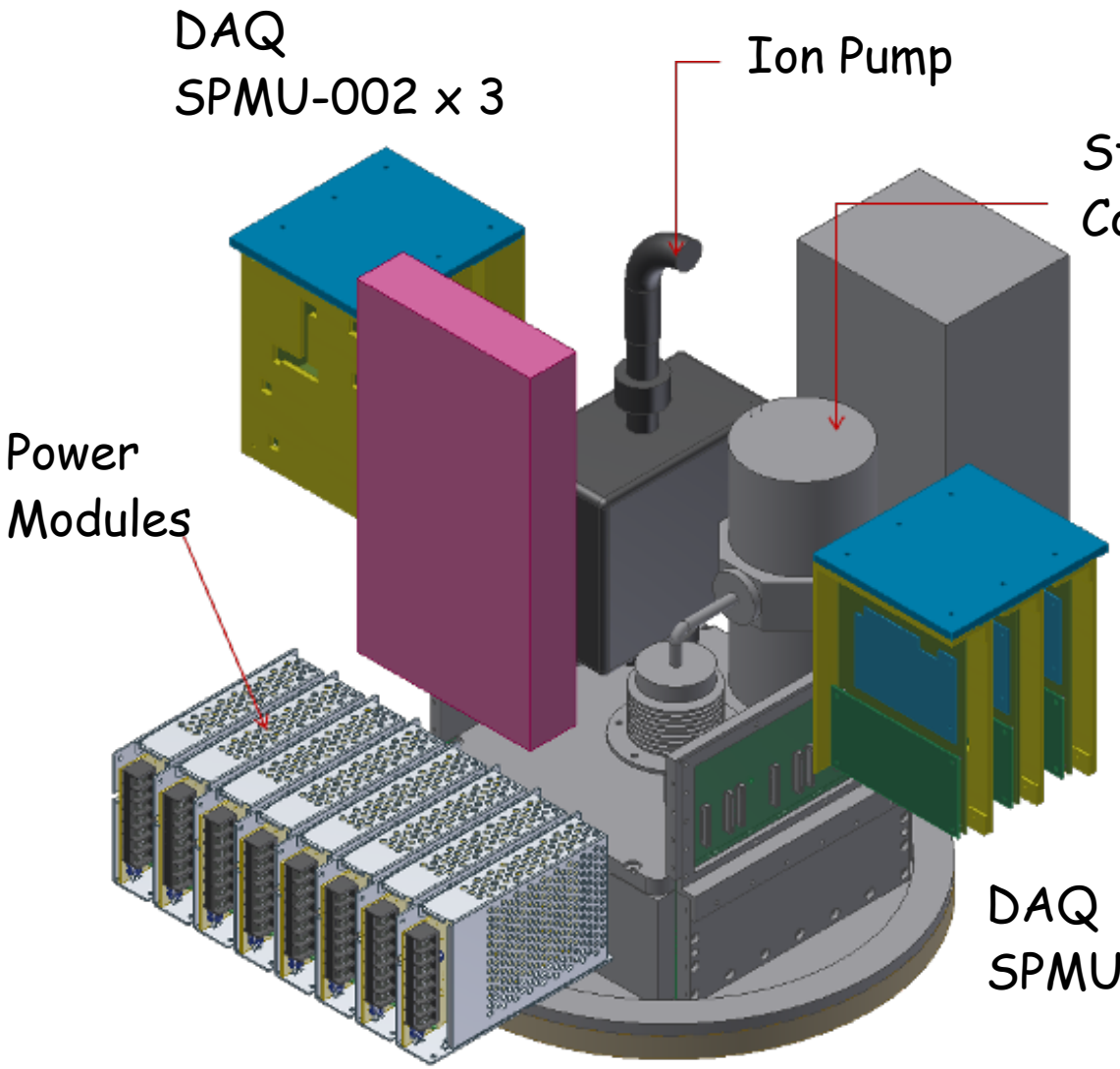
Incidents on the primary mirror results in 6 months shutdown: the longest shutdown in the Subaru operation history ⟷

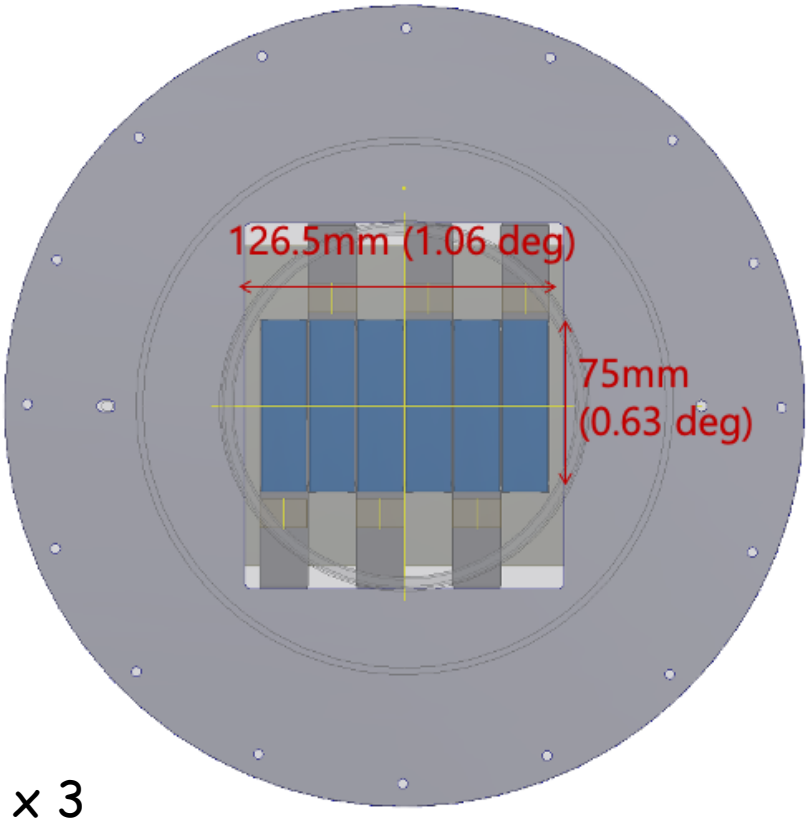


Switched to UA telescope

- University of Arizona, Steward Observatory has access to many telescopes located in Arizona.
- Among them, 2.2 m BOK telescope has "prime focus"
- Completely new cryogenic dewar became necessary.

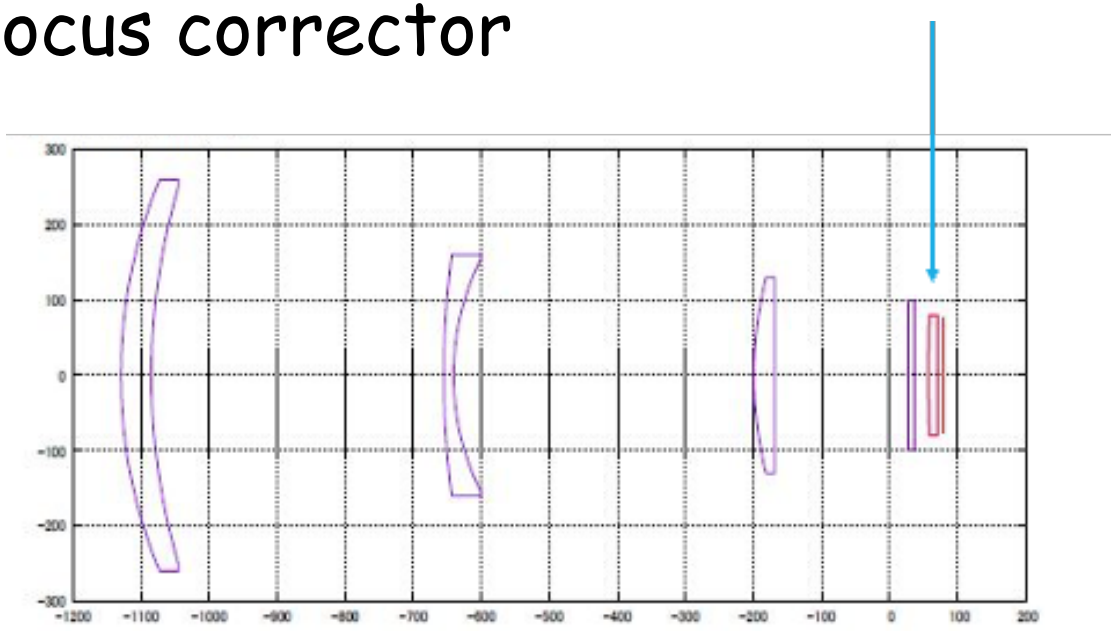
Dewar Configuration for BOK telescope

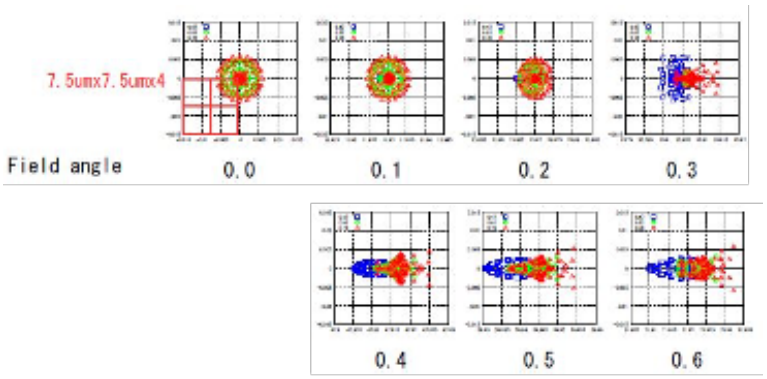




Dewar Window

- Dewar window is supposed to be a part of the prime focus corrector





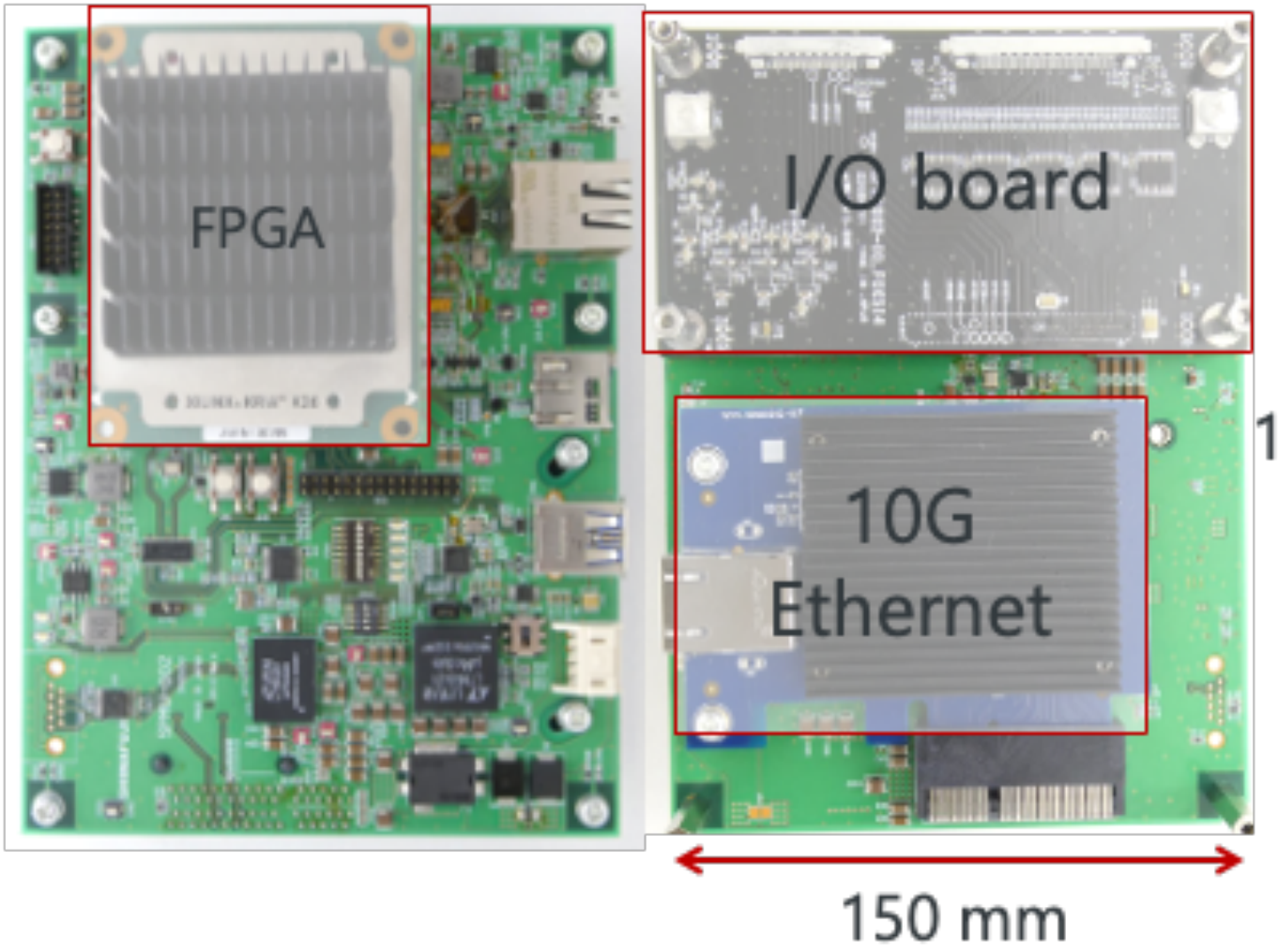
2 x 3 mosaic CMOS:
1.06 degrees x 0.63 degrees
0.23 arcsec / pix

Comparison

	Subaru	BOK	Tomo-e Gozen	TAOS II
F ratio	1.9	3.0	3.1	
M1 Diameter	8.2 m	90inch（2.2m)	1.05 m	1.3 m
pixel scale	0.10 arcsec/pix	0.23 arcsec/pix	1.186 arcsec/pix	
Field of View	0.25 deg^2	1.06 x 0.63 deg^2	20 deg^2	2.3 deg^2
Seeing	0.6 arcsec	1 arcsec		
Limiting Mag.	~21 mag		~17 mag	~18 mag
Frame rate	10 sec-1	10 sec-1	2 sec-1	20 sec-1
Sensor format	2560x10000	2560x10000	2000x1128	1920x4608
Pixel size	7.5 um	7.5 um	19 um	16 um
# of sensors	12	6	84	10
Vendor	HPK	HPK	Canon	E2v
Site	Maunakea	Arizona	Kiso	Mexico

DAQ: SPMU-002

Development led by KIPMU Takahashi-lab in collaboration with SHIMAFUJI



I/O board customary designed and built for each detector

Because 10 G Ethernet driver did not exist, we have developed it.

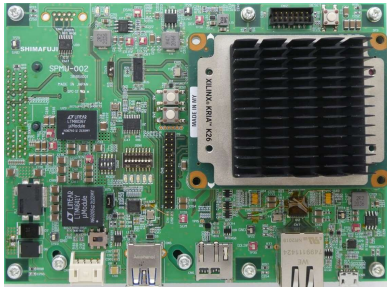
AMD Kria SOM employed (SM-K26-XCL2GI)

SPMU-002

カメラ・センサー制御用SOC搭載ボード
（型番：SPMU-002）

SHIMAFUJI

・SPMU-002は、各種カメラ、センサーを制御するSOC搭載のCPUボードです
・本ボードには、CPU（QuadCore ARM CortexA53）、メモリ（2GB）が搭載され、 PCIe（4レーン）、GigabitEther、マイクロSDカード等のインタフェースがサポートされています
・本ボード上のFPGAには、各種カメラ、センサーに対応する制御用IPが実装可能です

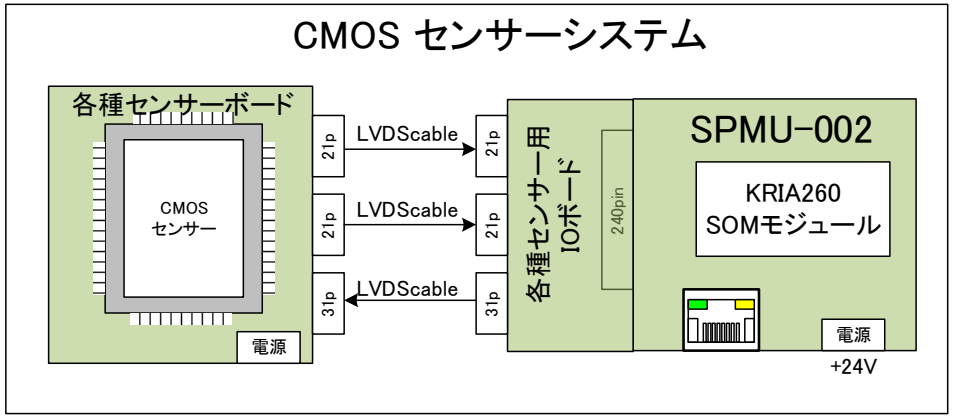


SPMU-002

仕様一覧

項目	機能
FPGA	・ZYNQ-UltraScale+
CPU	・QuadCore ARMCortexA53,1.2GHz
メモリ	・DDR4　2GB
I/O	・PCIe×4レーン1slot、 ・GEther、uSD ・USB2.0 ・SpaceWire（MDM9）option
電源	・+24V/1.0A（SPMU002）
動作温度	・0℃～50℃(FAN空冷要）
サイズ	150mm×110mm

システム構成図



SP332B01

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Shimafuji Electric Inc.
〒144-0051 東京都大田区西蒲田6-36-11 NSビル3階
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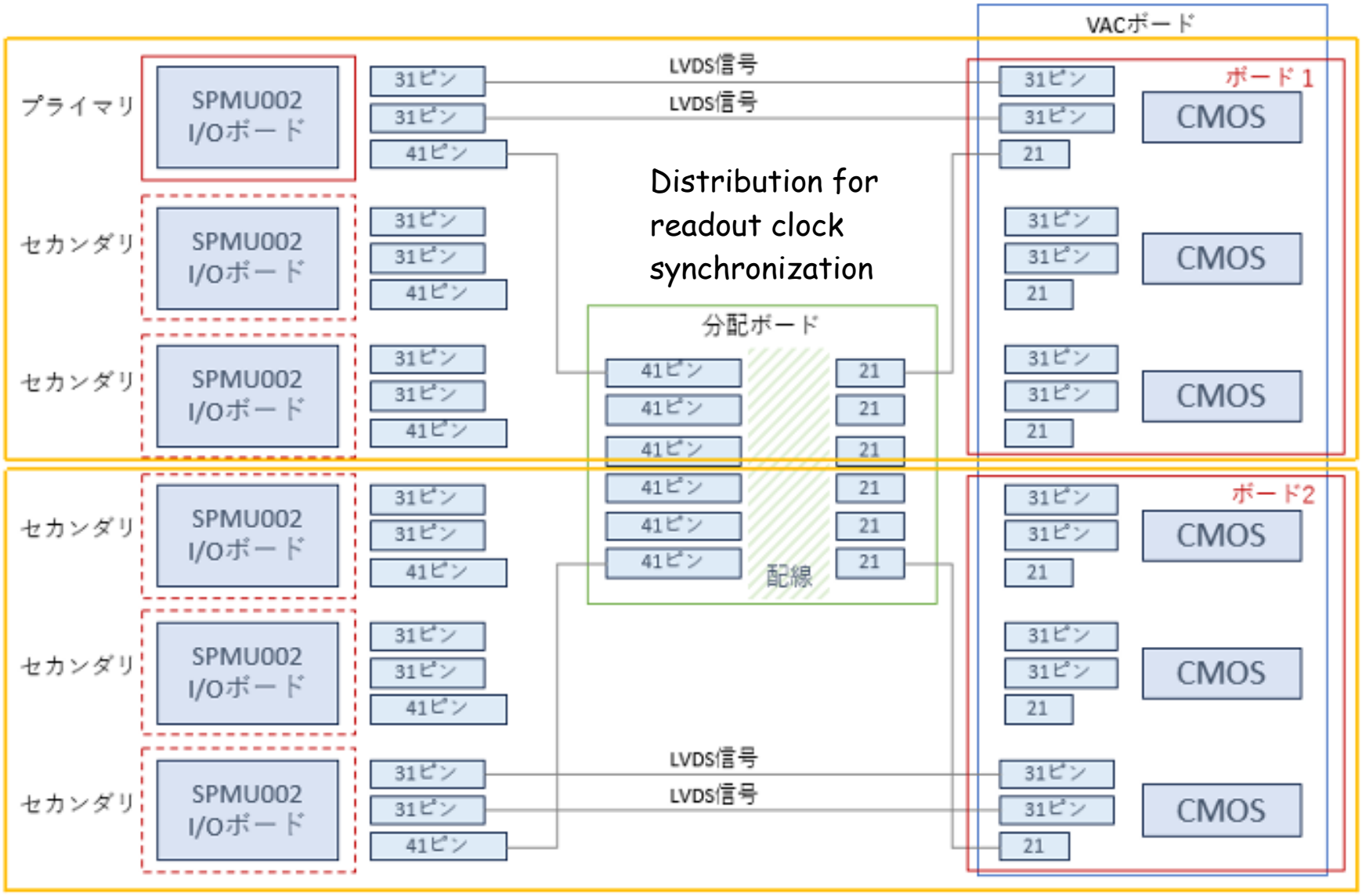
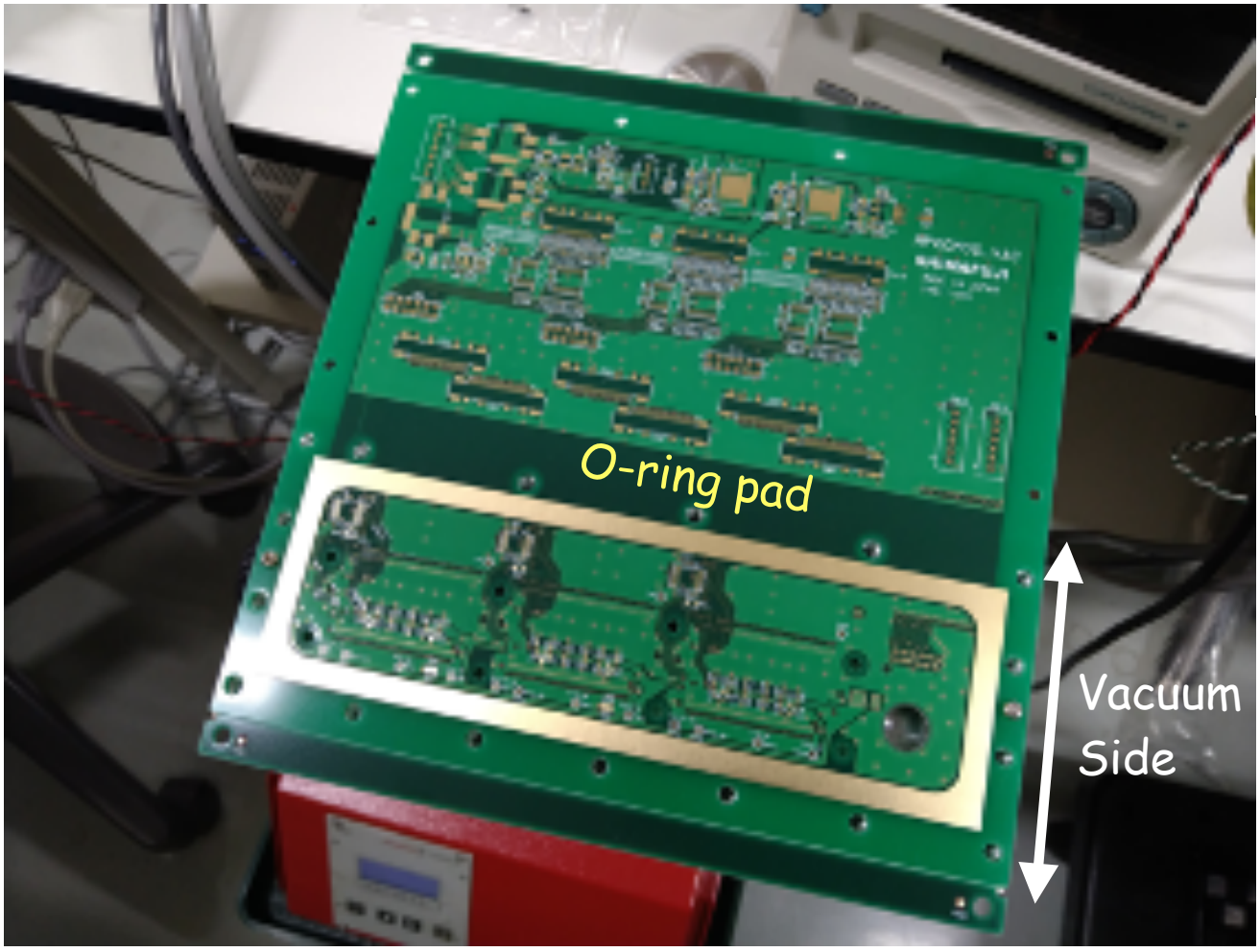
FAX: 03-3733-8318　http://www.shimafuji.co.jp

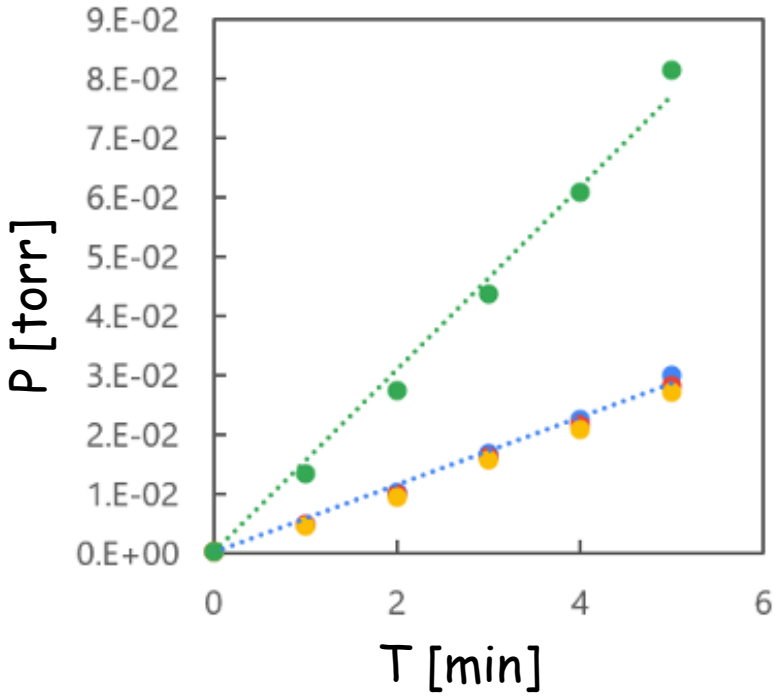
Block Diagram of DAQ



Independent except readout clock synchronization

Vacuum Feed-through



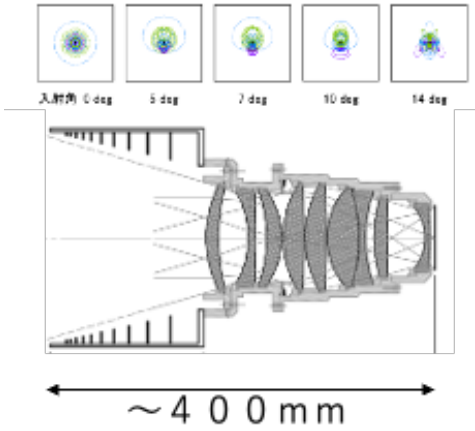


Leak rate becomes three times higher but is acceptable when we employ an ion-pump.

During the monsoon shutdown in August at Kitt Peak, we will install the camera. The first observing run will be made when they restart the operation after shutdown; in early September, 2025.

The target include blind optical pulsar search in star clusters and lucking imaging of quasar pairs candidates.

Other parties that have interests on our CMOS



- Kawahara Group (JAXA): LOTUS
  - Wide field camera (30 deg) on board small satellite
  - Monitor tens of thousands of stars to look for planetary occultations
- Izumiura Group (OAO/NAOJ):
  - Ultra High Resolution (> 3 x 10^5) spectrograph to detect exo-planet
  - FY2025 - 2030 Tokubetu Suishin funded
- Narukage Group (NAOJ)
  - Solar X-ray detection

Thank you very much

Continue to Oguri-san's report on science that favor high speed read-out sensor