Hyper Suprime-Cam

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HSC Collaboration

National Astronomical Observatory of Japan

University of Tokyo (J)

KEK (J)

ASIAA (Taiwan)

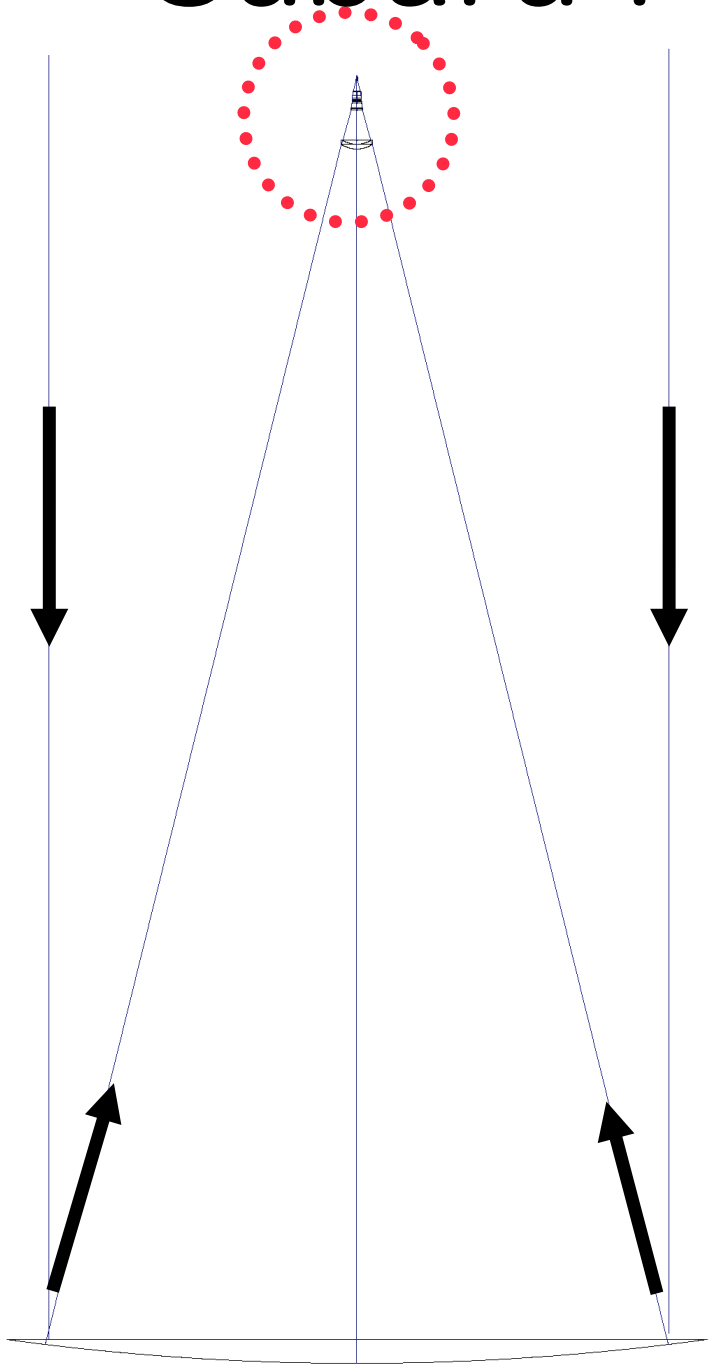
Princeton University (US)

Mitsubishi Electric

Canon

Hamamatsu Photonics

Subaru Prime Focus

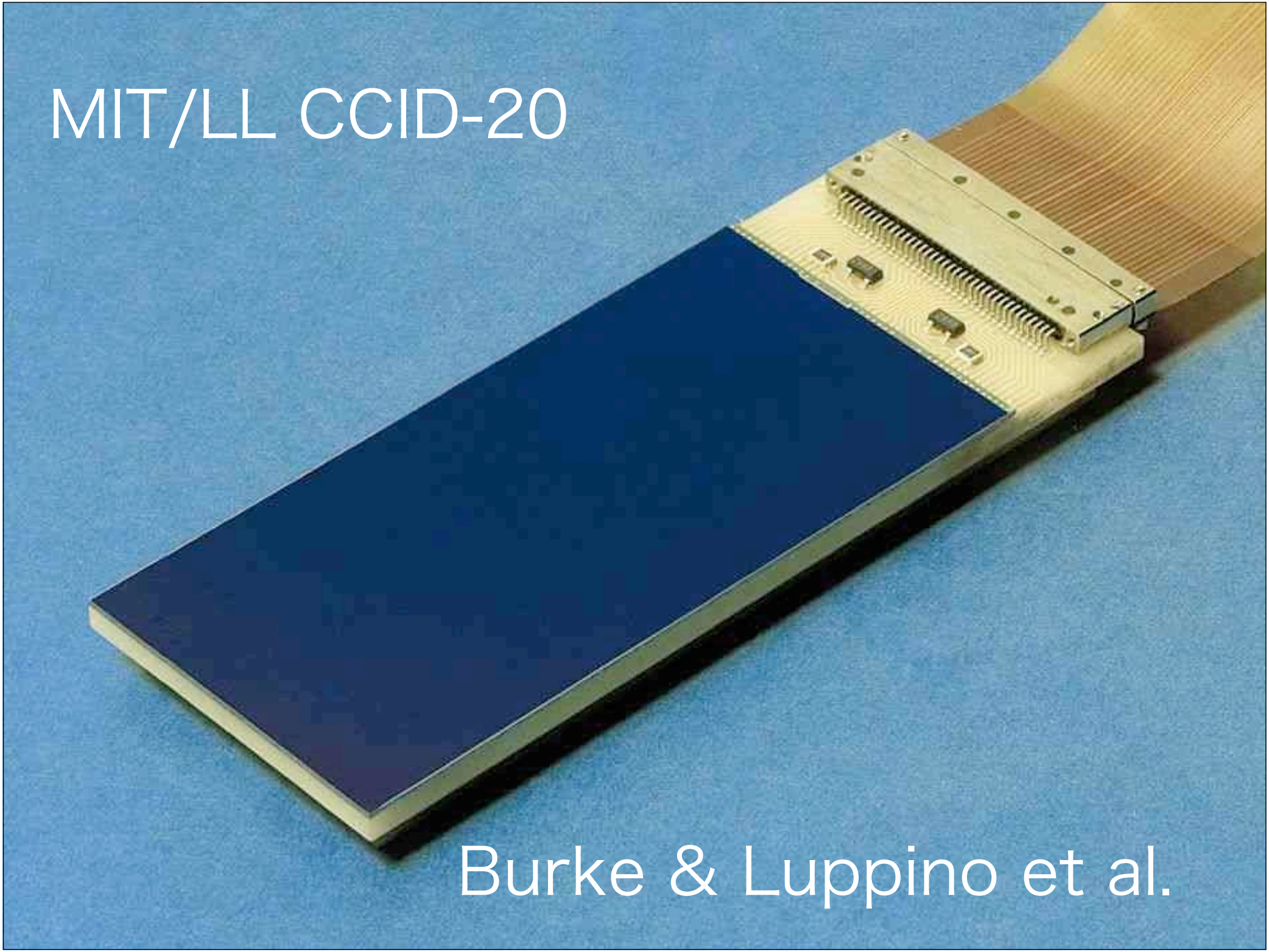


F/2.0

f = 16400 mm

FOV 30 arcmin

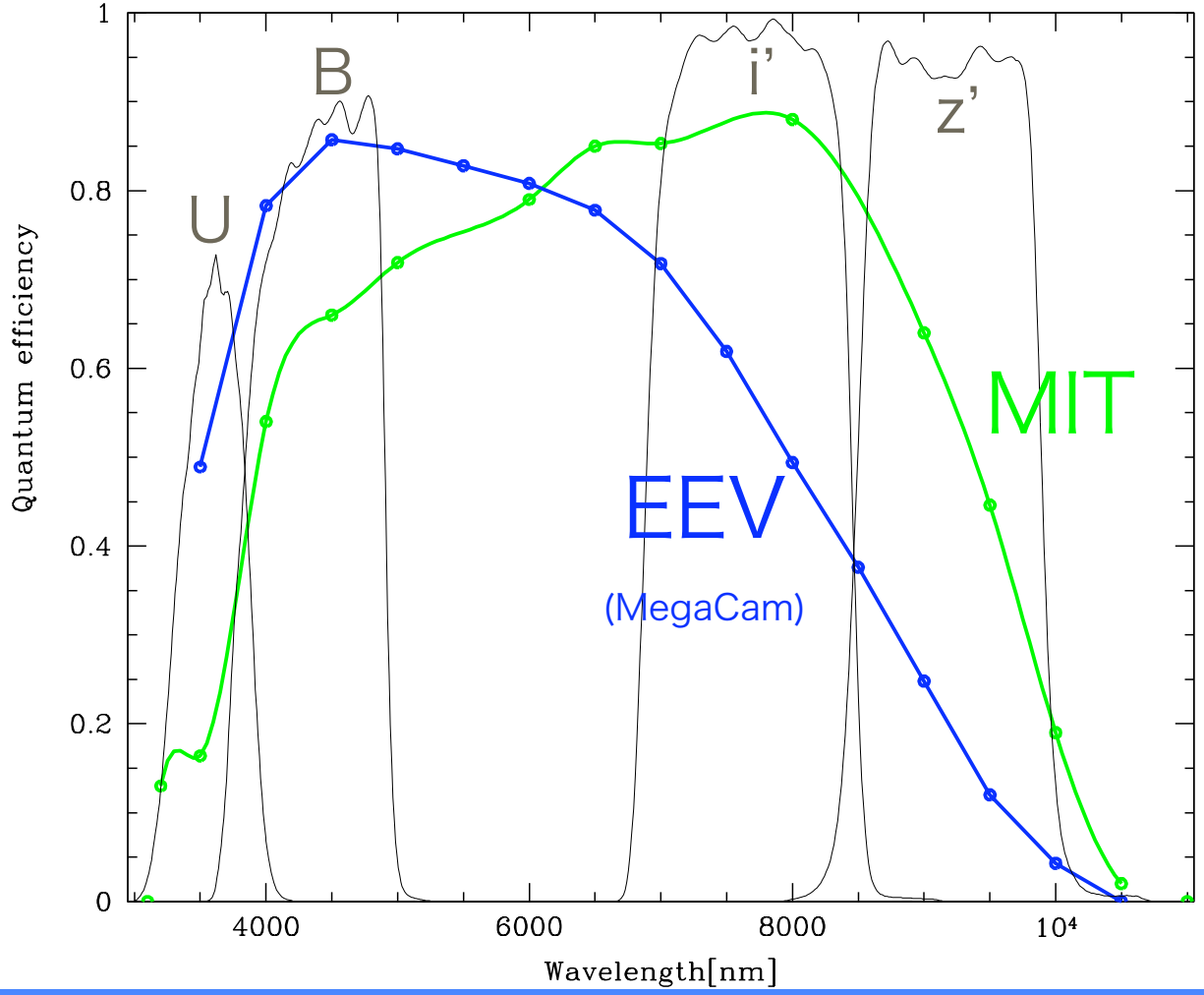
M1 **8.2 m**


MIT/LL CCID-20
Burke & Luppino et al.

MIT/LL CCID-20

Deep depletion $\sim 40\ \mu m$

High Responsivity amp. $\sim 15\ \mu \mathrm{V/e}$



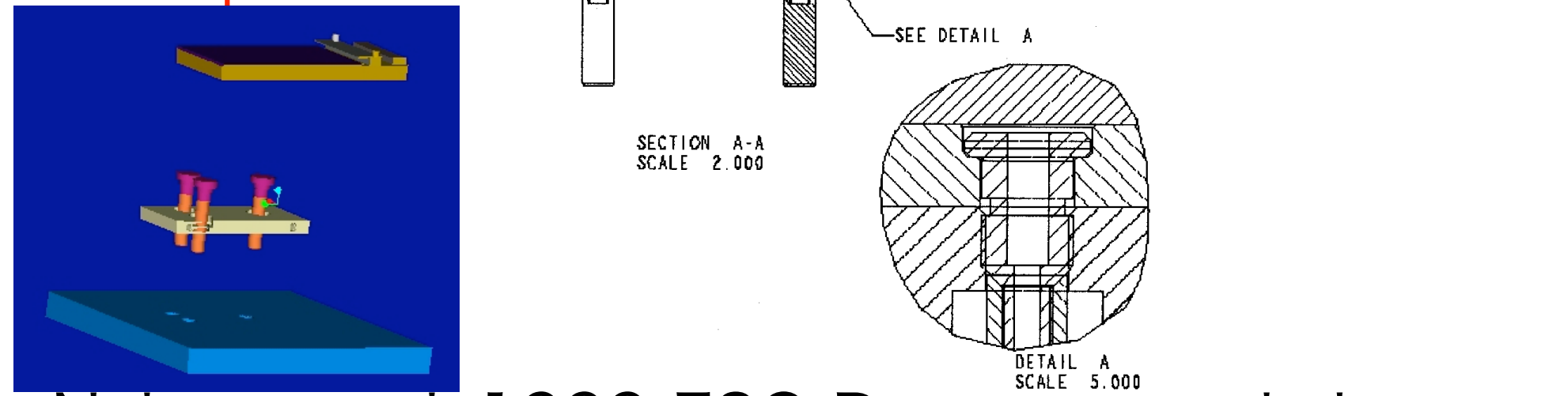
$\sim 2\mathrm{e}$ rms noise

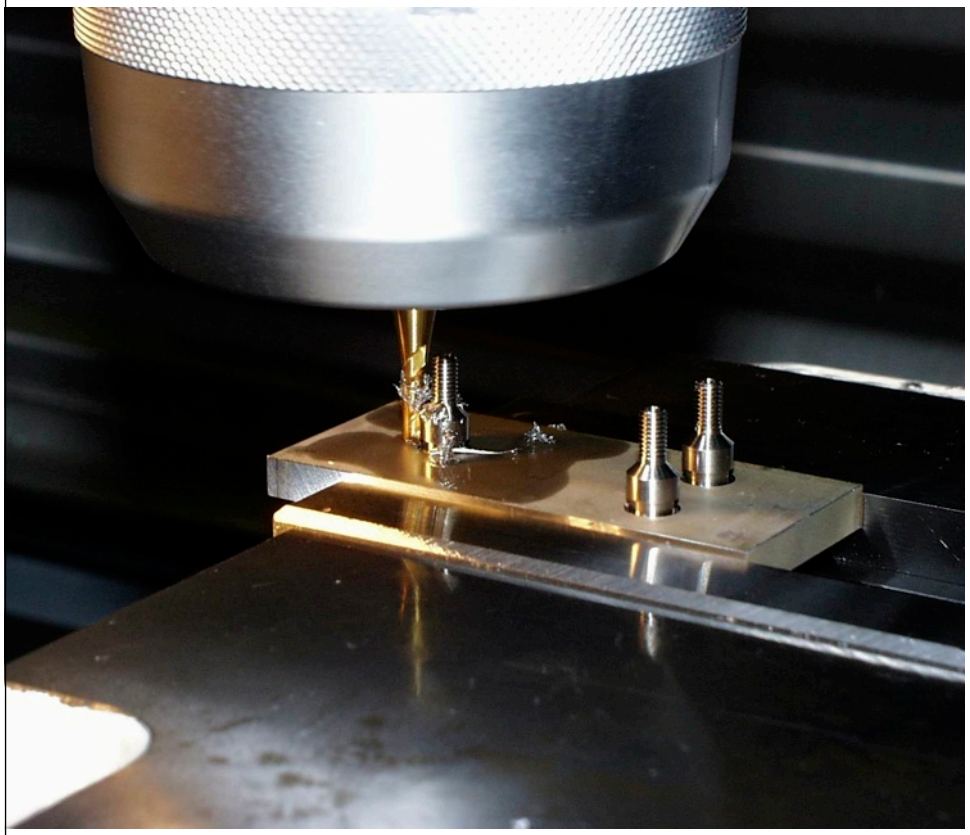
(50 kHz readout)

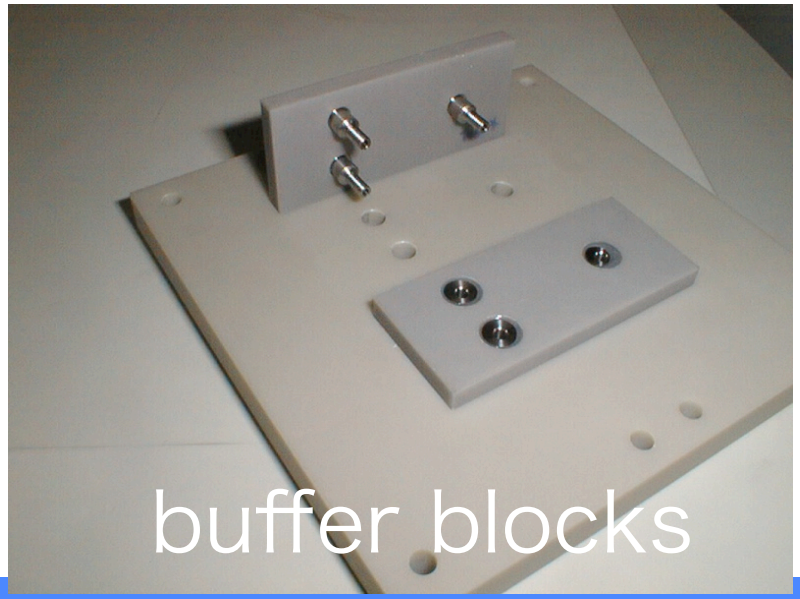
Co-planarity

The correction procedure

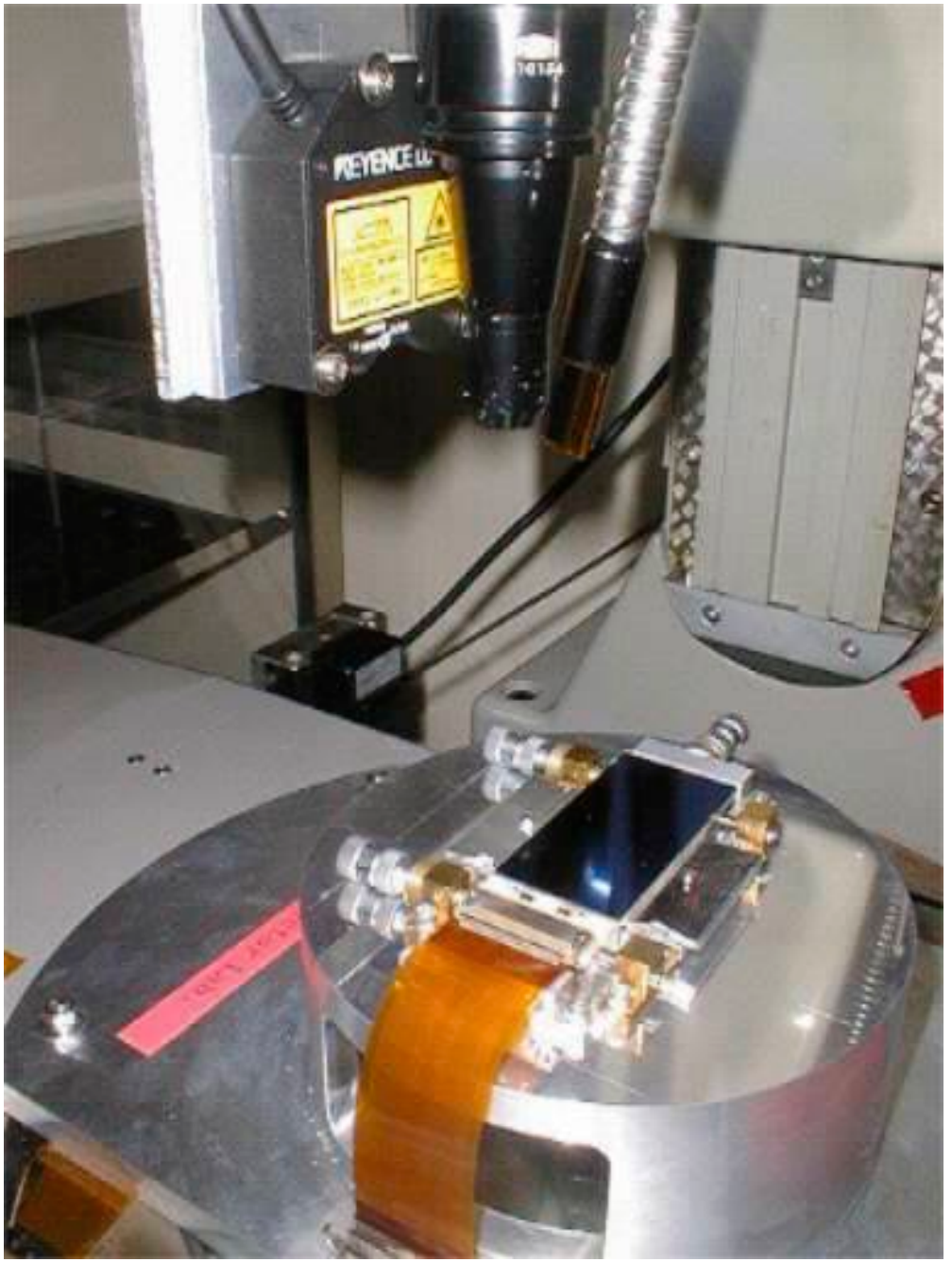
- Employ a buffer block between CCD and cold plate
- Height measurement using laser displacement meter
- Insert thin metal foils with appropriate thickness
- Infusion of epoxy adhesive





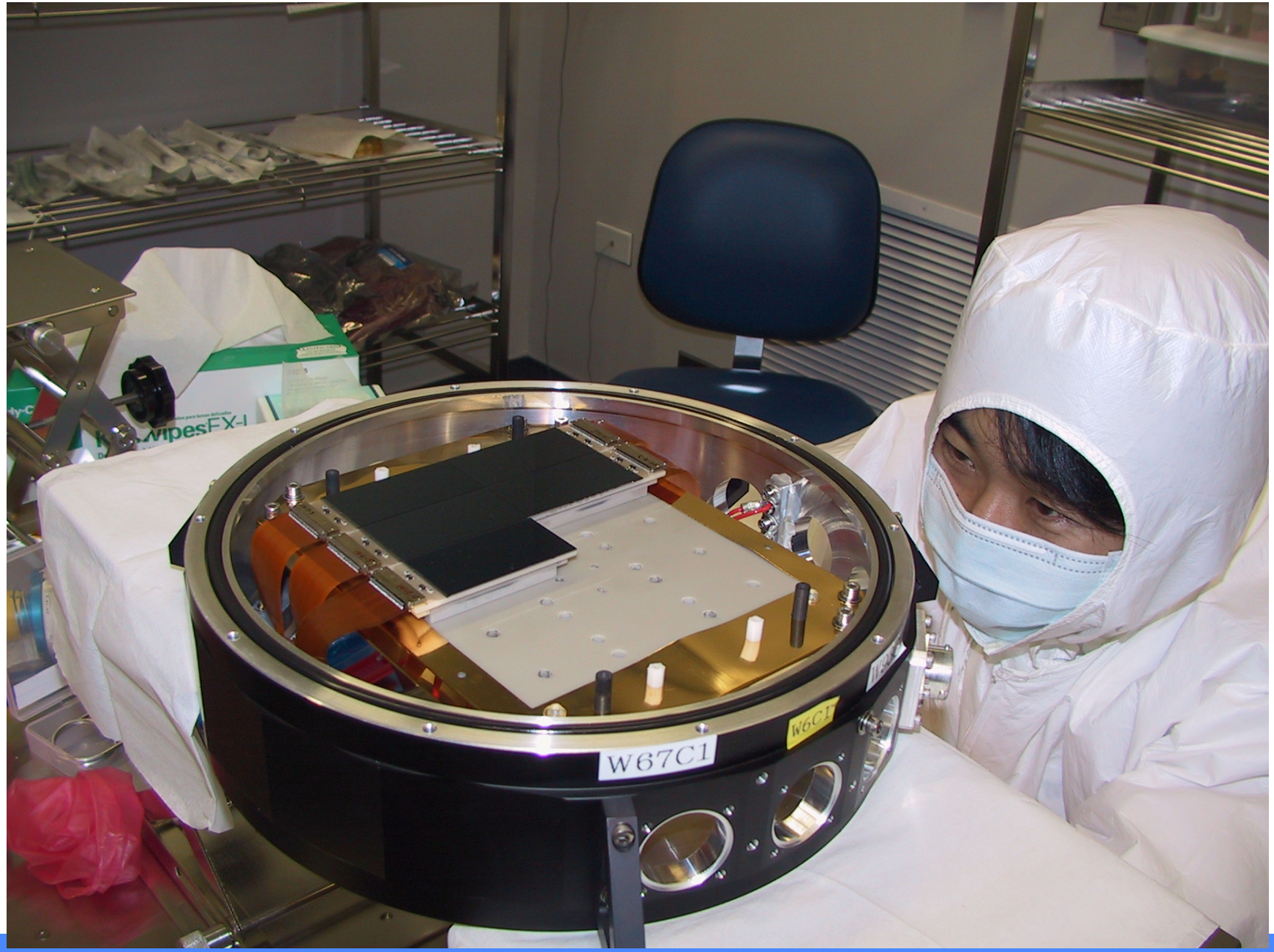


buffer blocks

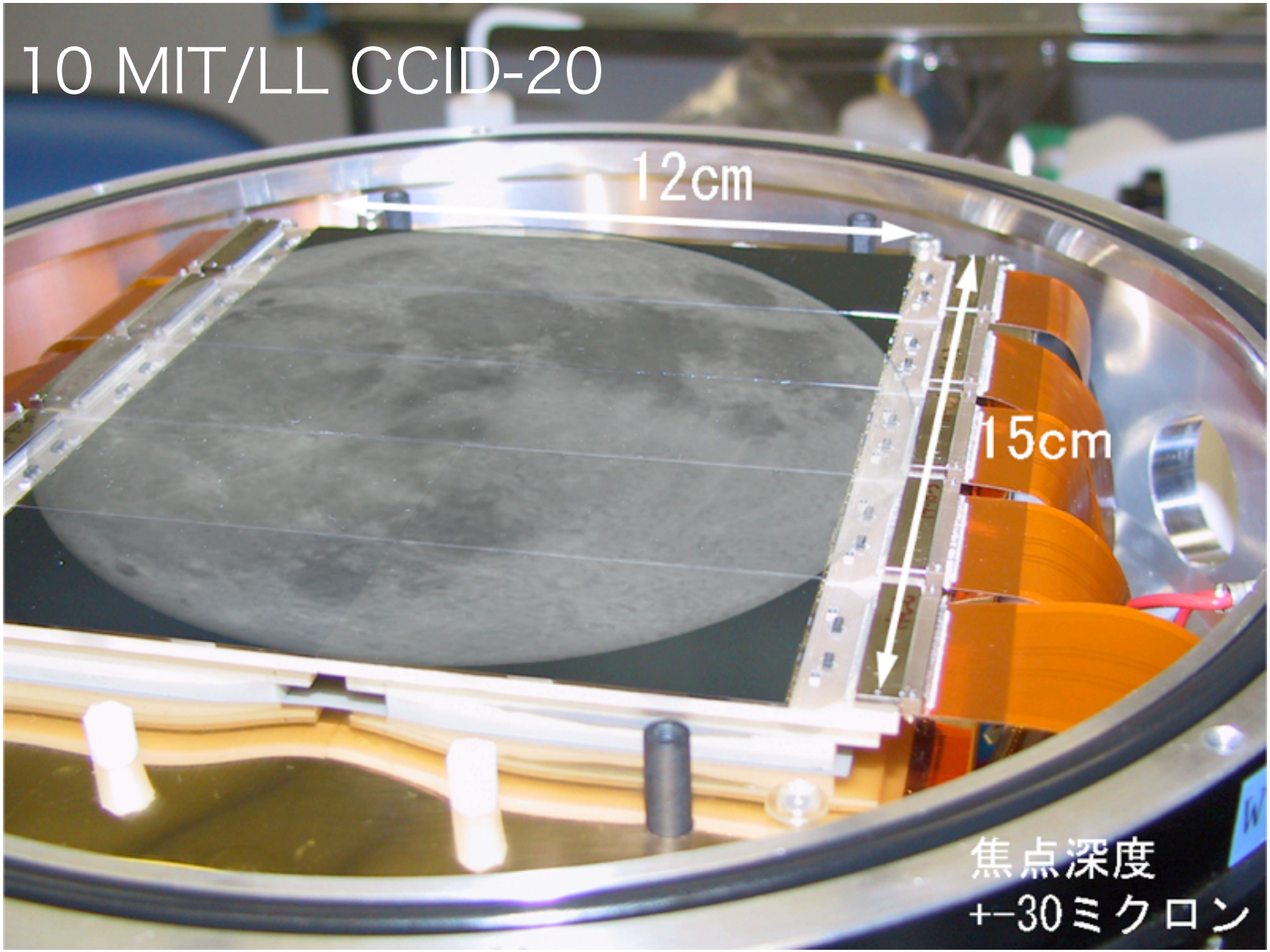


Jig to align CCD and block

Mosaicing



Suprime-Cam



Growth of CCD mosaics

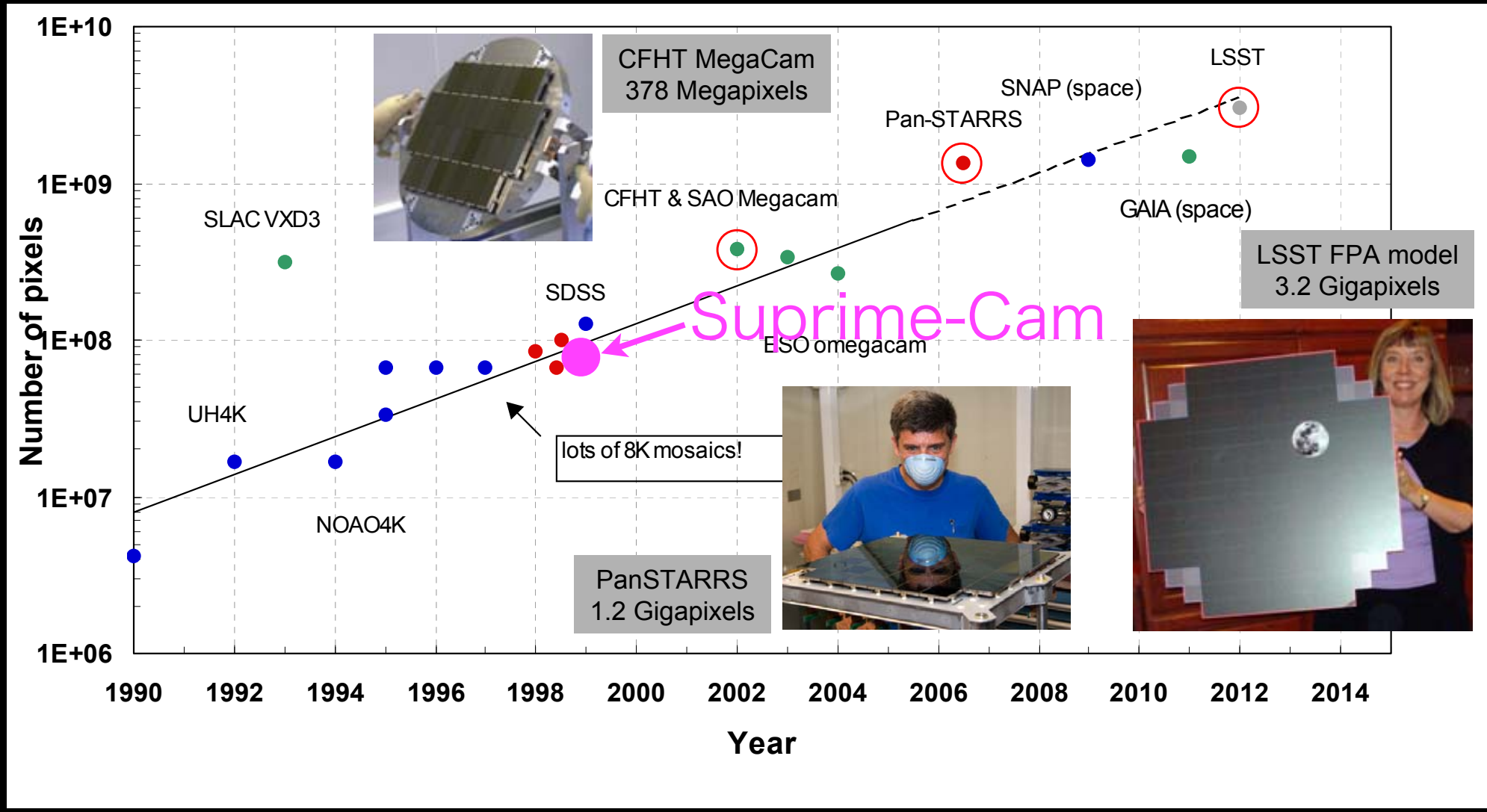


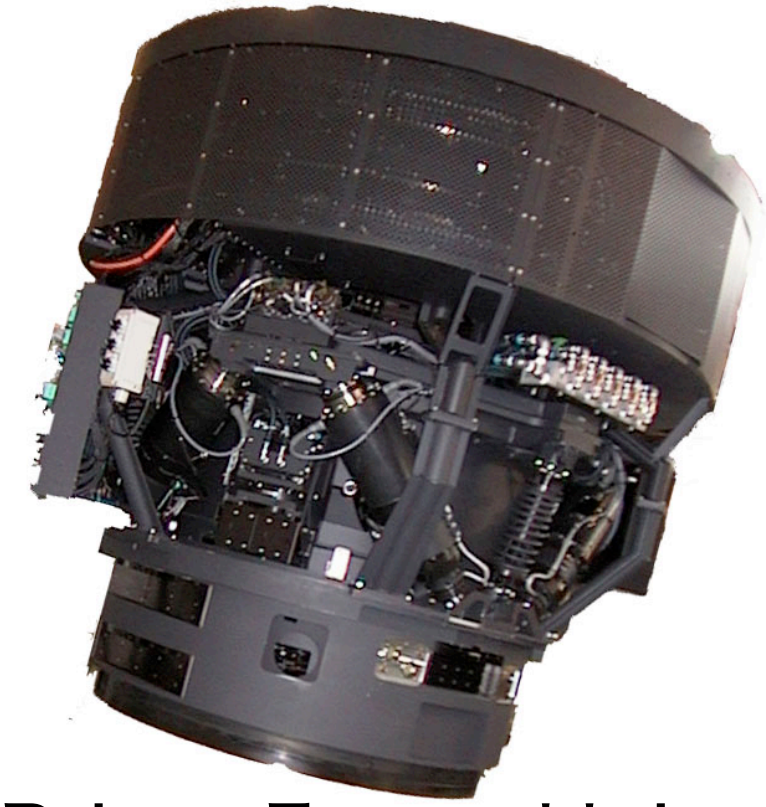
Illustration of large focal plane sizes, from Luppino 'Moore's' law

Focal plane size doubles every 2.5 years

Strength of Suprime-Cam

Wide Field Corrector

Canon

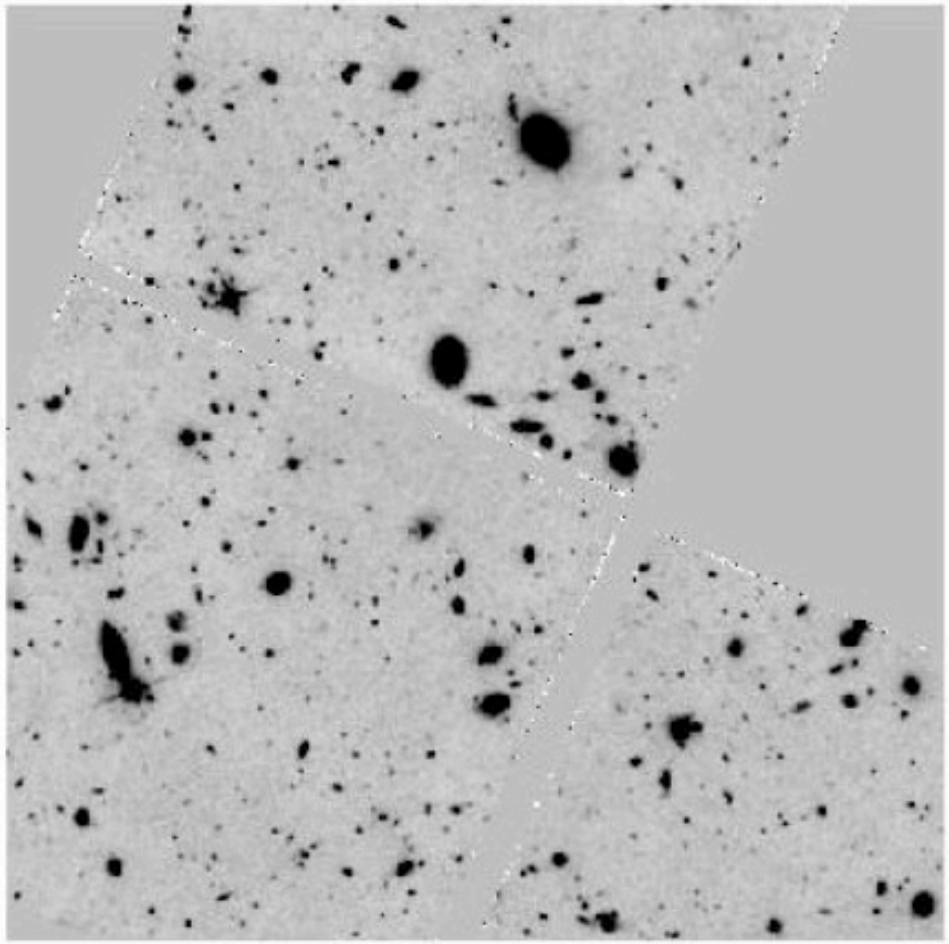


Prime Focus Unit

MITSUBISHI

Opt-mechanics were built by experienced Japanese firms → Superb Image Quality

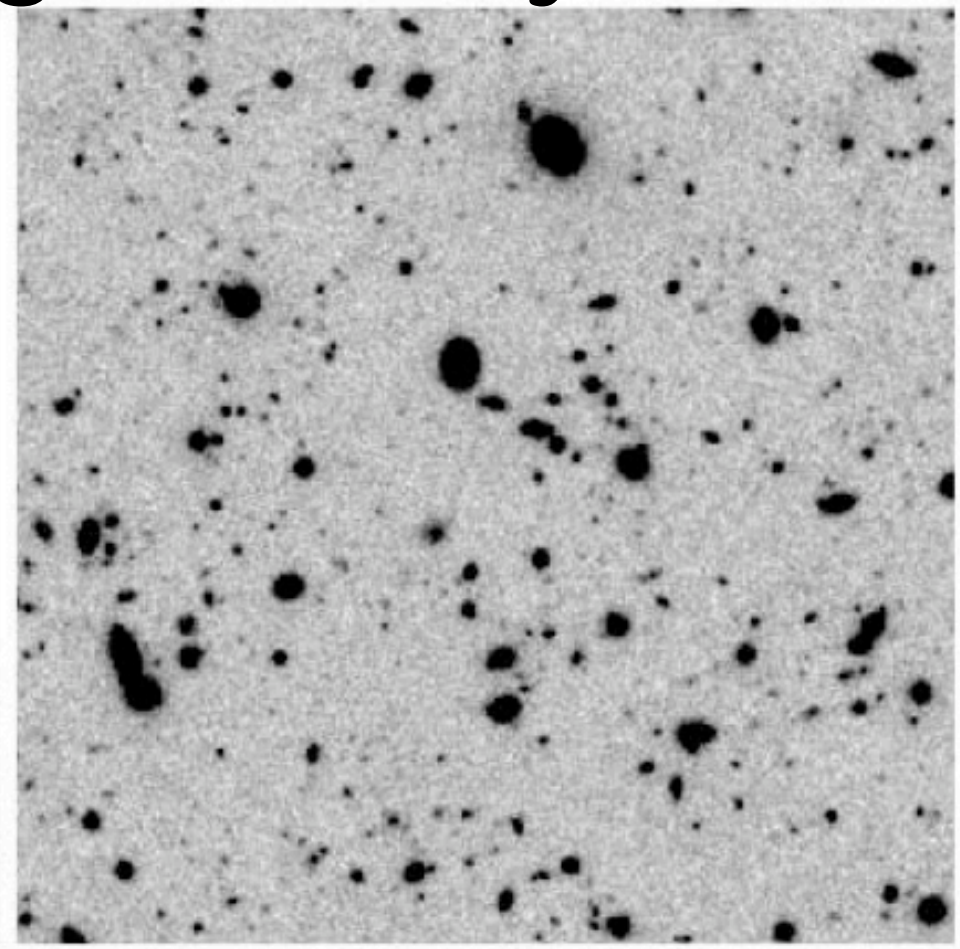
Good Image Quality



HST 'wide-I' continuum

HST WFPC2

(All FOV)



NB816 narrowband

Suprime-Cam

(FOV/100)

High Redshift Galaxies Hunt

Table 1: The most distant galaxies with measured redshift (as of Sep.14, 2006).

Rank	Identification	Coordinates	Redshift	Distance#	Paper	Publishing date
1	IOK-1	J132359.8+272456	6.964	12.8826	Iye et al.	Sep. 14, 2006
2	SDF ID1004	J132522.3+273520	6.597	12.8250	Taniguchi et al.	Feb, 25, 2005
3	SDF ID1018	J132520.4+273459	6.596	12.8248	Kashikawa et al.	Apr. 25, 2006
4	SDF ID1030	J132357.1+272448	6.589	12.8238	Kashikawa et al.	Apr. 25, 2006
5	SDF ID1007	J132432.5+271647	6.580	12.8222	Taniguchi et al.	Feb. 25, 2005
6	SDF ID1008	J132518.8+273043	6.578	12.8219	Taniguchi et al.	Feb. 25, 2005
6	SDF ID1001	J132418.3+271455	6.578	12.8219	Kodaira et al.	Apr. 25, 2003
8*	HCM-6A	J023954.7-013332	6.560	12.8189	Hu et al.	Apr. 1, 2002
9	SDF ID1059	J132432.9+273124	6.557	12.8184	Kashikawa et al.	Apr. 25, 2006
10	SDF ID1003	J132408.3+271543	6.554	12.8178	Taniguchi et al.	Feb.25, 2005

Distance in billion light years calculated for a model of the Universe that has an age 13.66 billion years.
* This object was discovered by Keck telescope. All the rest were discovered by Subaru Telescope in the Subaru Deep Field.

1. Large Aperture
2. Wide Field of View
3. Superb image quality
4. High QE in red

WL Dark Matter Halo Search

Ask Google

Miyazaki dark matter

Gavazzi & Soucail (2007)

Upgrade of Suprime-Cam

Upgrade path

1. Large Aperture
2. Wide Field of View
3. Superb image quality
4. High QE in red

Wider

keep it

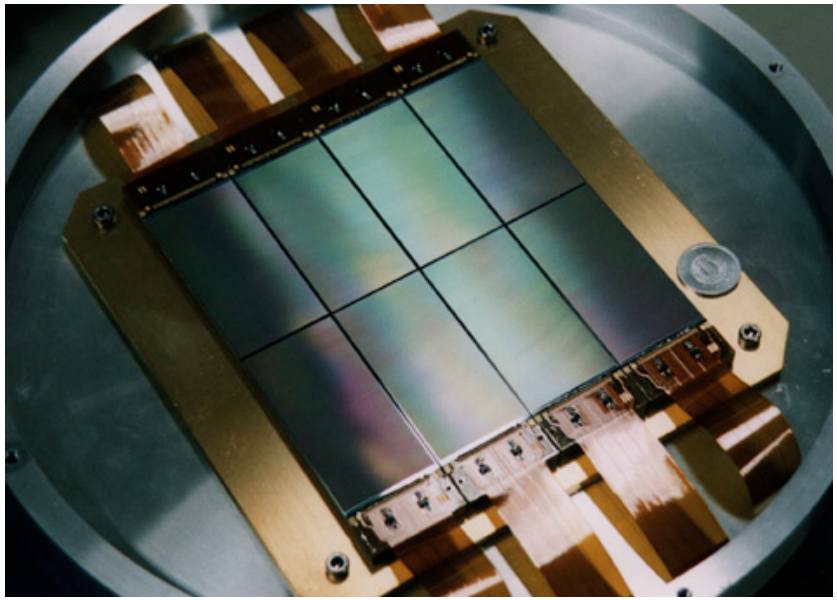
Higher

NAOJ-Hamamatsu Collaboration

1994 - 1996 Back Illuminated small CCD

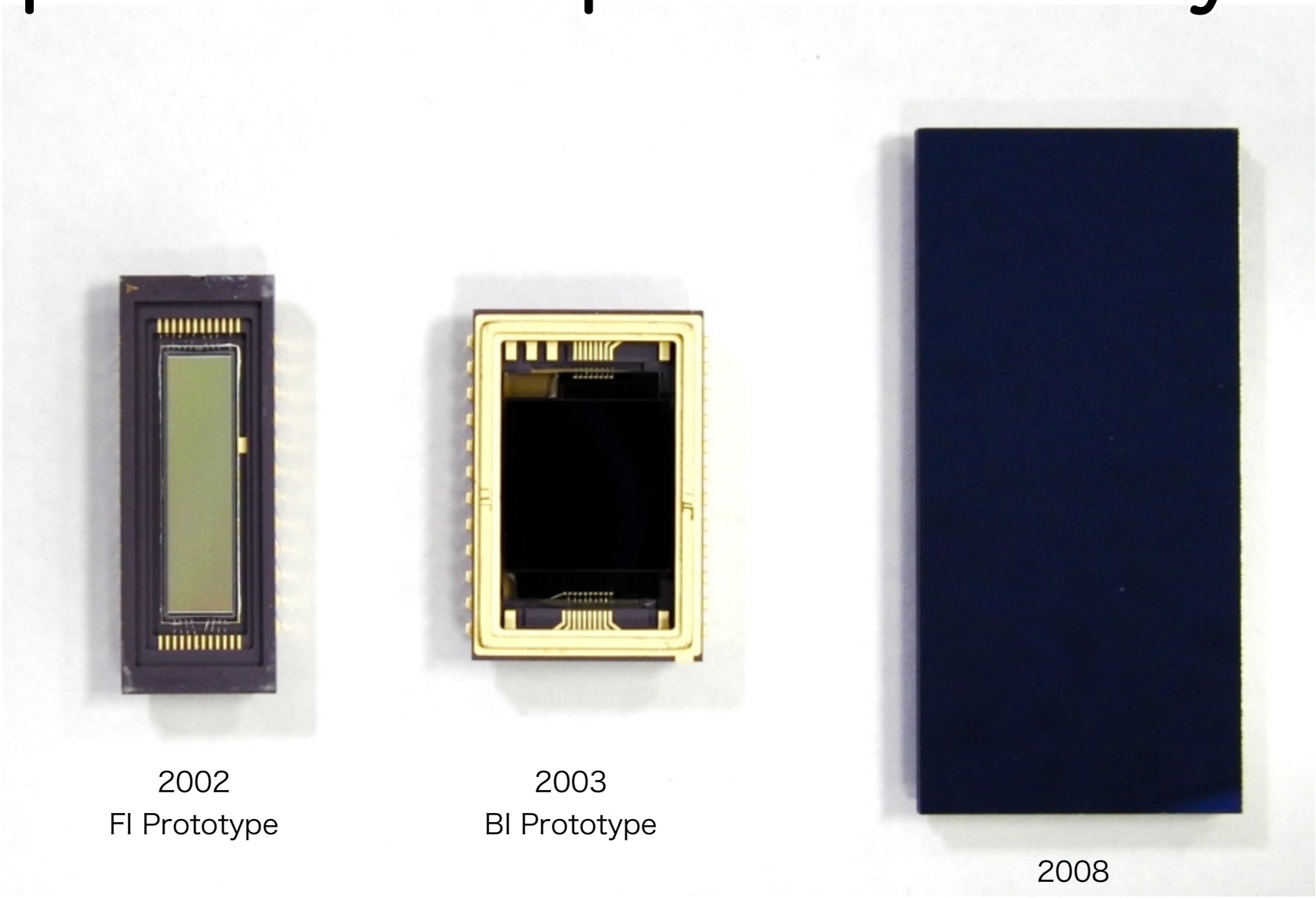
1996 - 1998 2k4k Front illuminated CCD

1999 - 2008 BI 2k4k pch CCD



1998

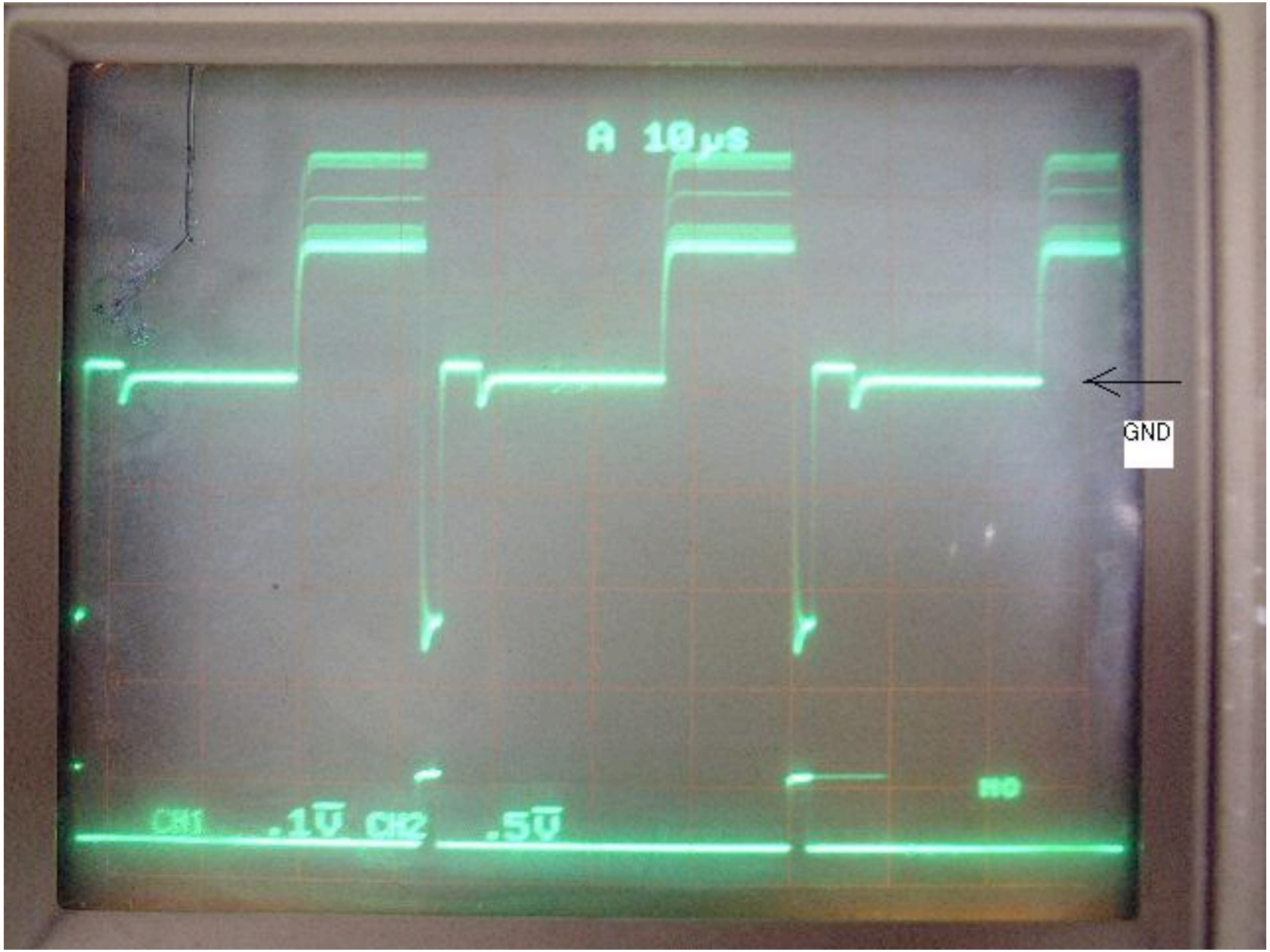
p-ch Development History



2002
FI Prototype

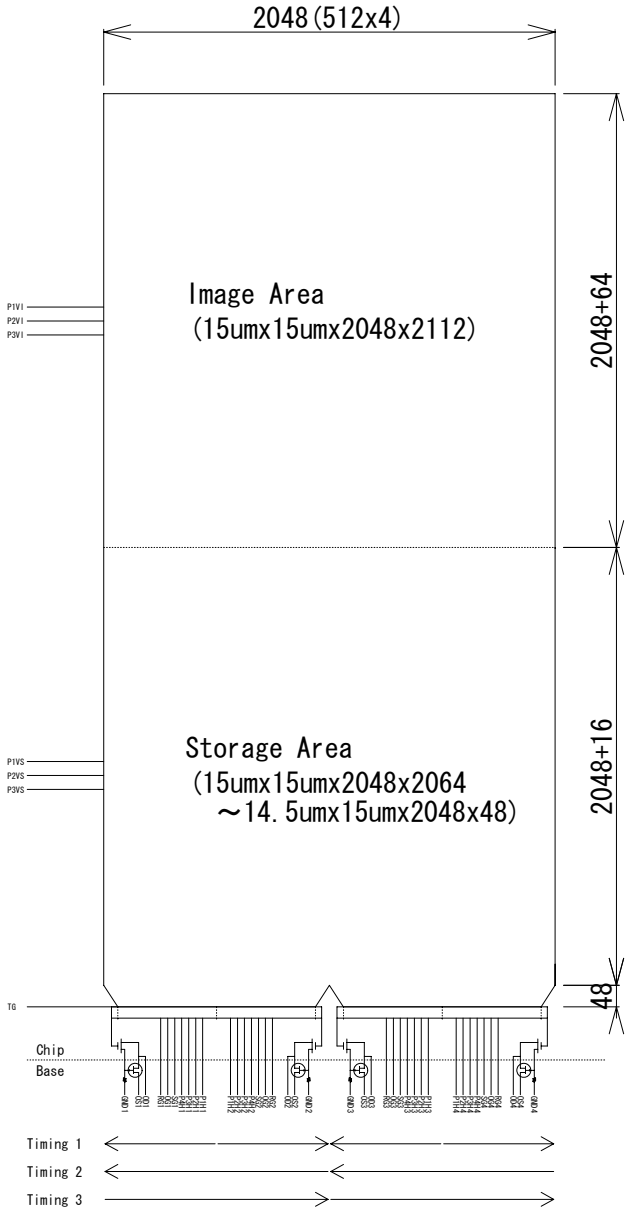
2003
BI Prototype

2008
2k4k BI

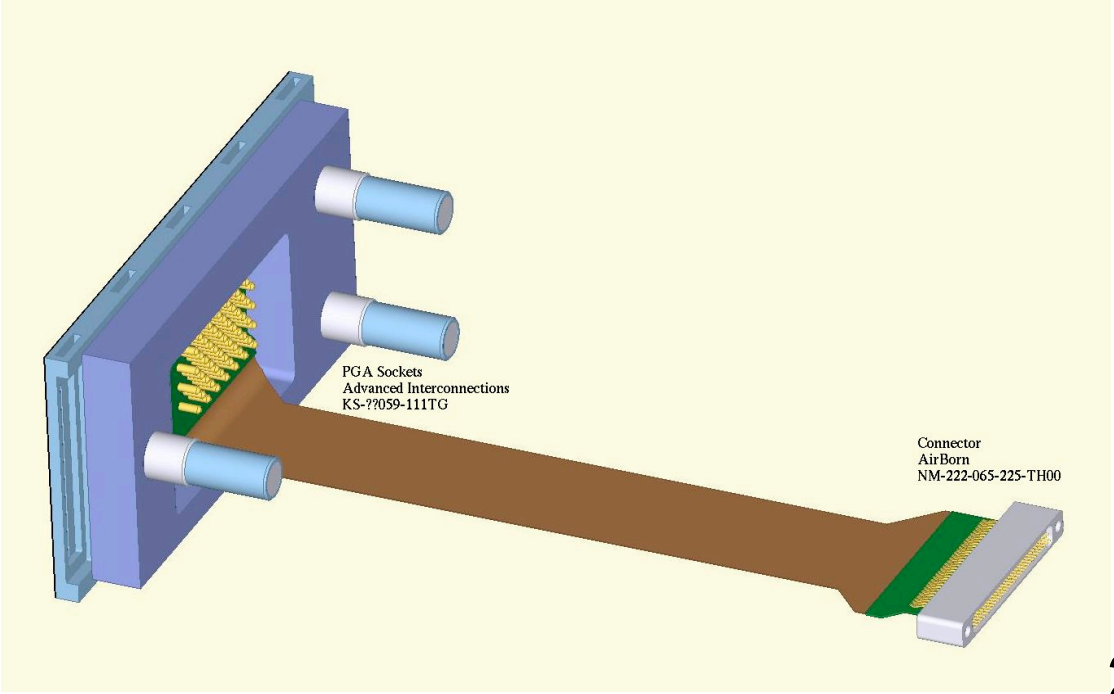


Signal is carried by hole.

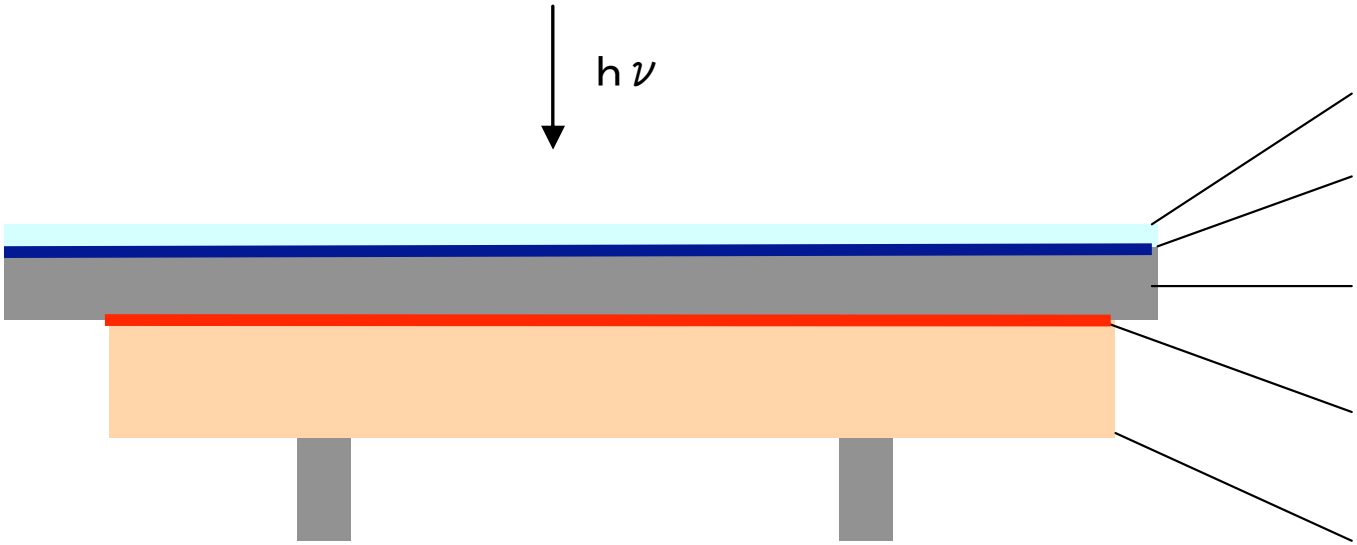
HPK p-ch CCD



CCD Structure	Full Frame Transfer
Si Thickness	200 μm (Can be 100 $\sim$ 300 μm)
Vertical clock phase	3 phases
Horizontal clock phase	2 phases or 4 phases
Output Amprilfiers	4 one stage MOSFET on chip and one J-FET on the package
Package Material	Aluminum Nitride



Package Structure



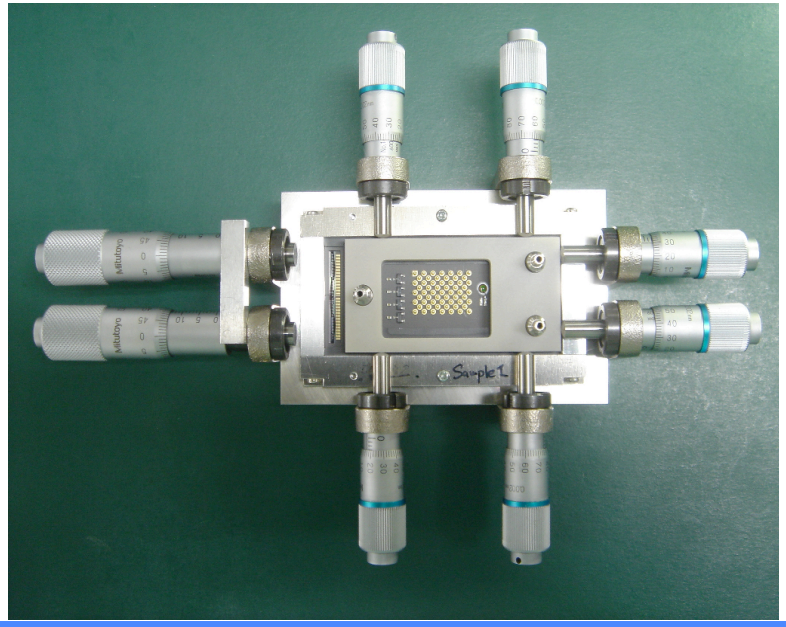
CCD chip

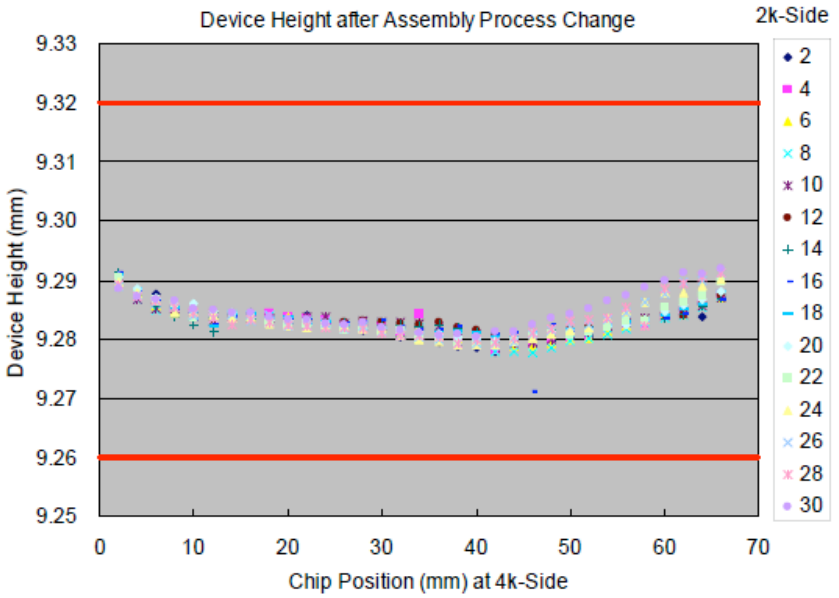
Low viscosity epoxy

CCD base

Printed epoxy resin adhesive

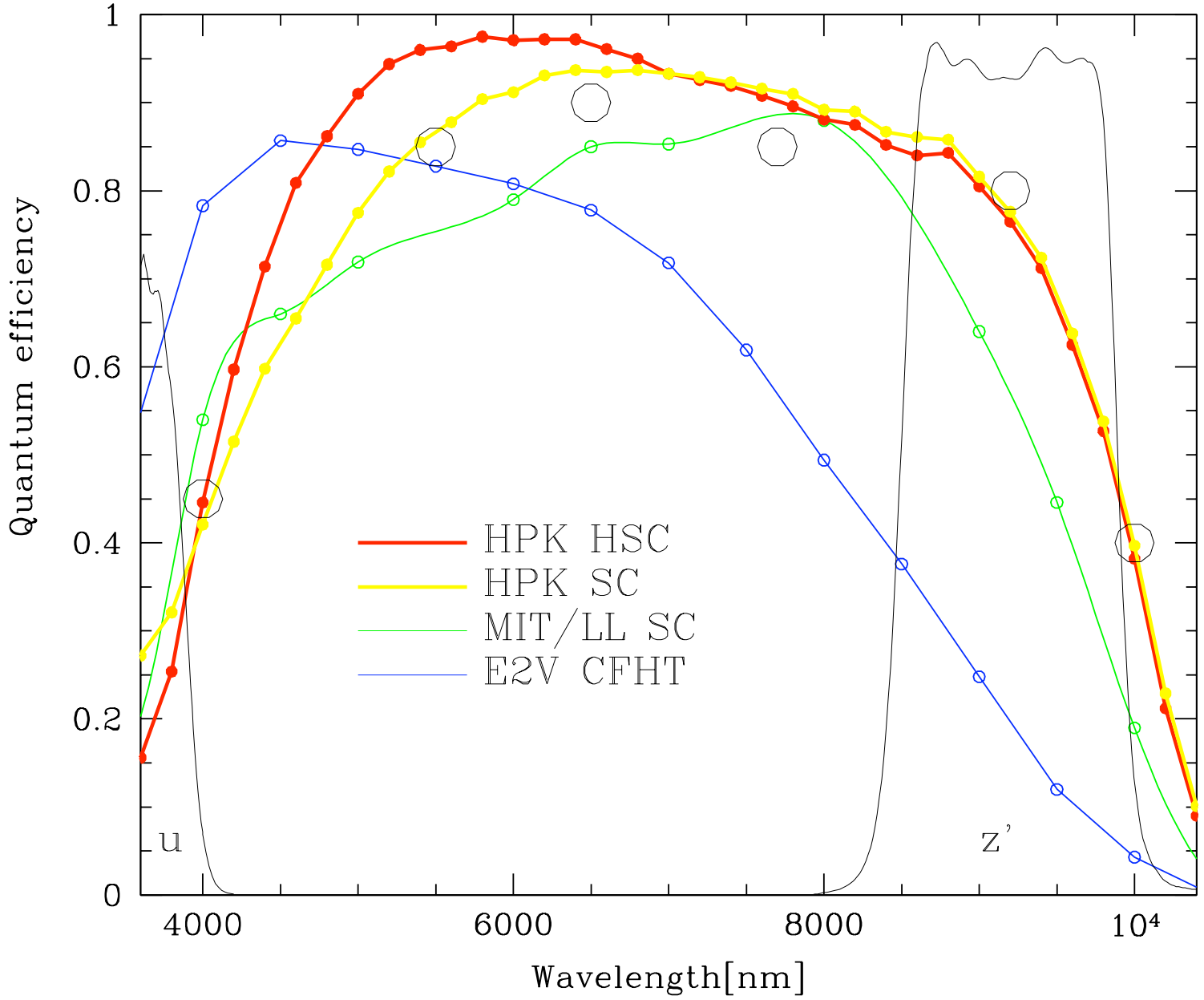
Pin base



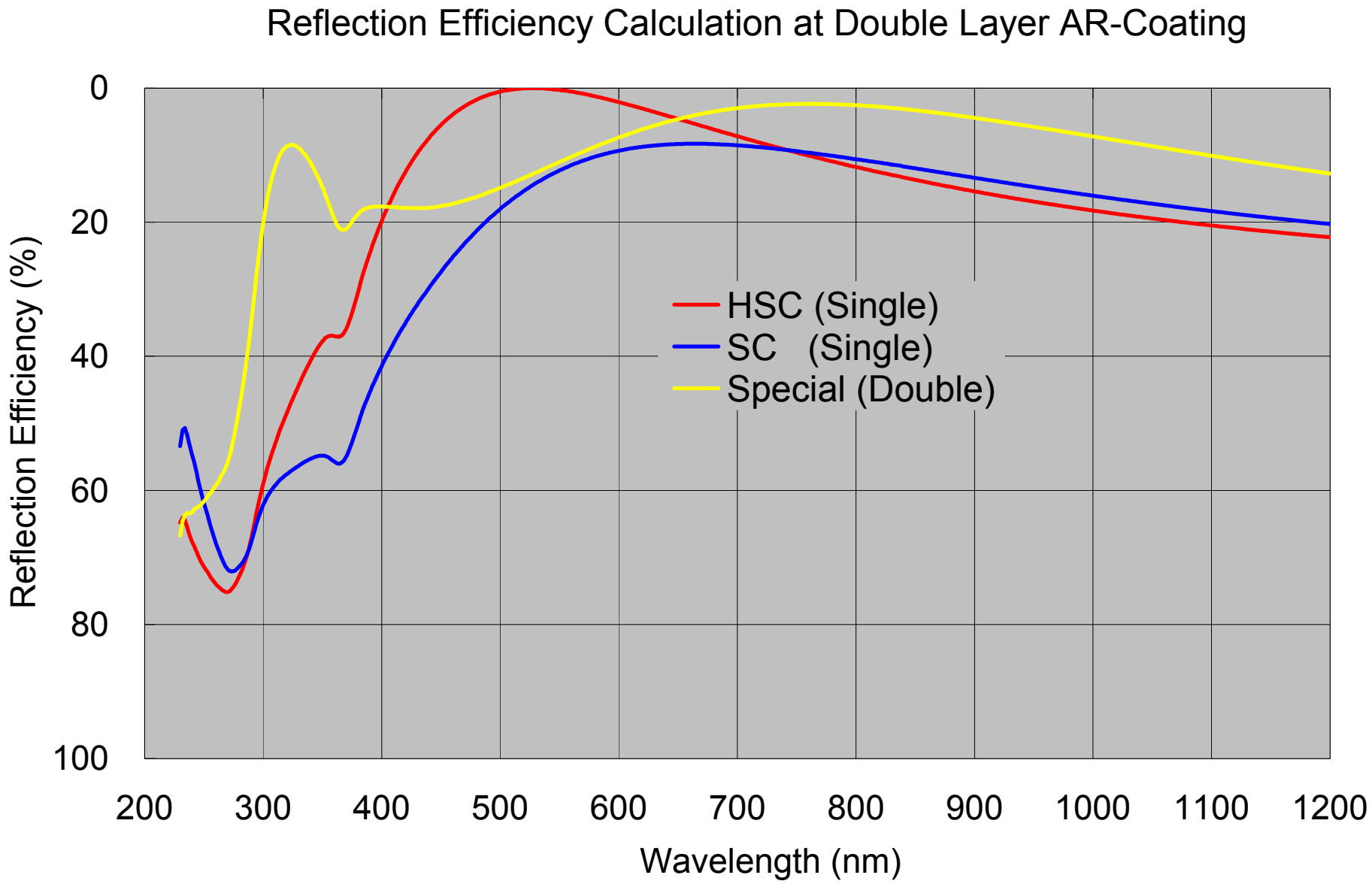


10um flatness achieved

Quantum Efficiency



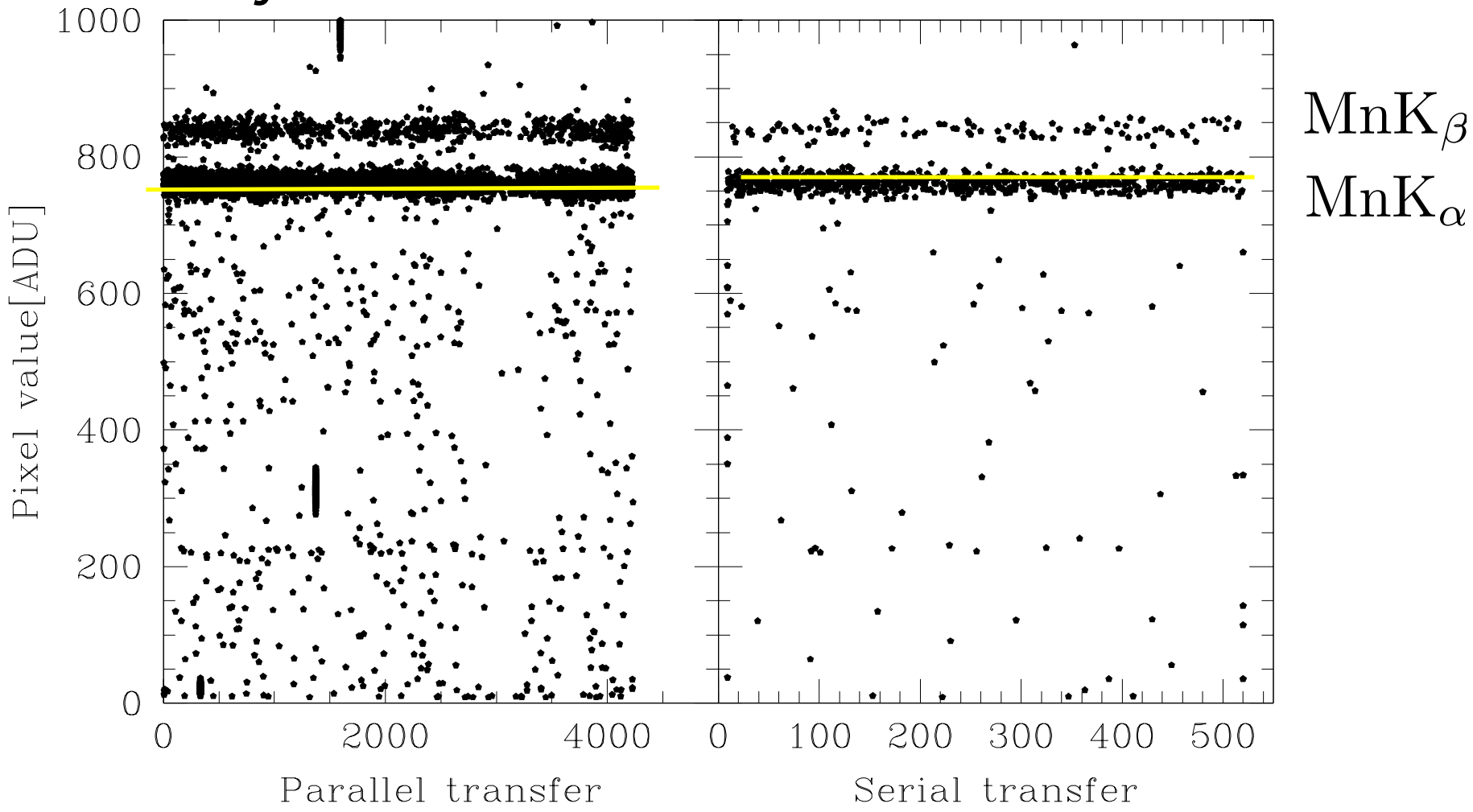
QE Improvement Plan



Merit of Double AR coating

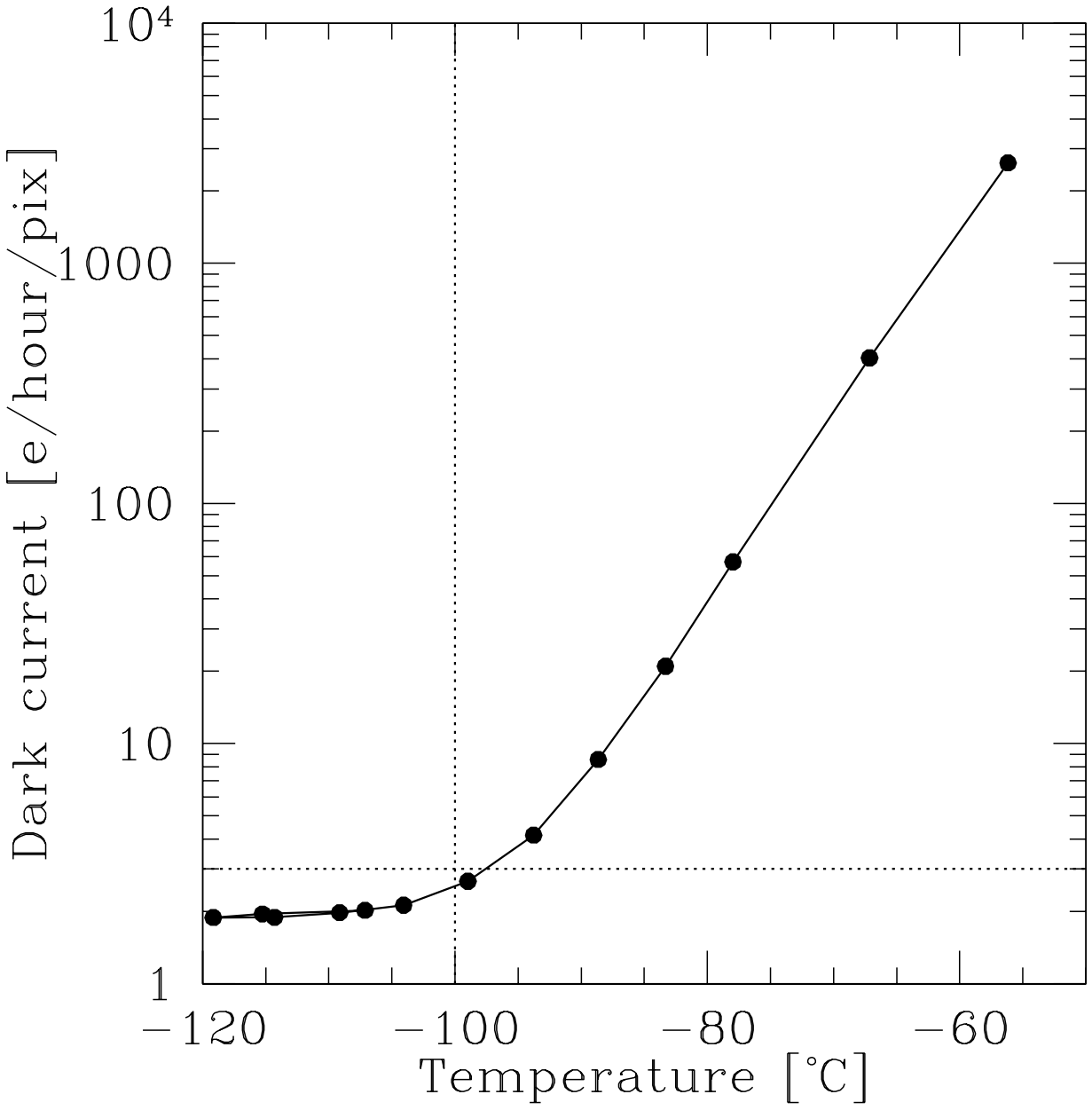
Charge Transfer Efficiency

X-ray test

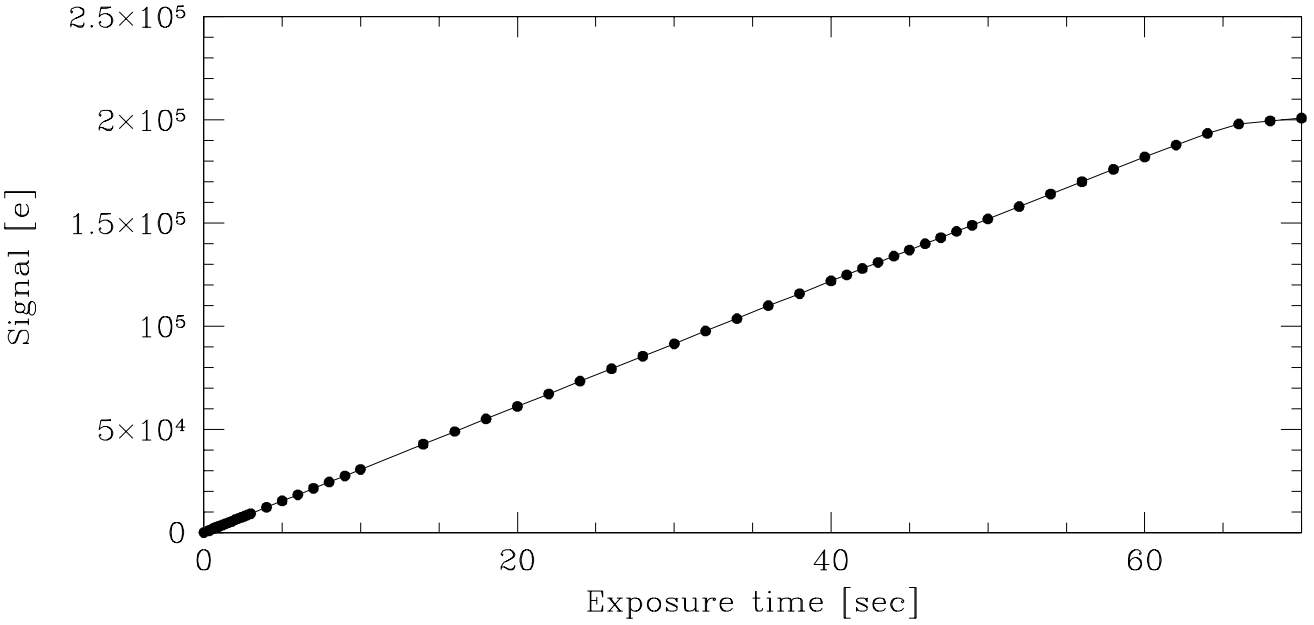


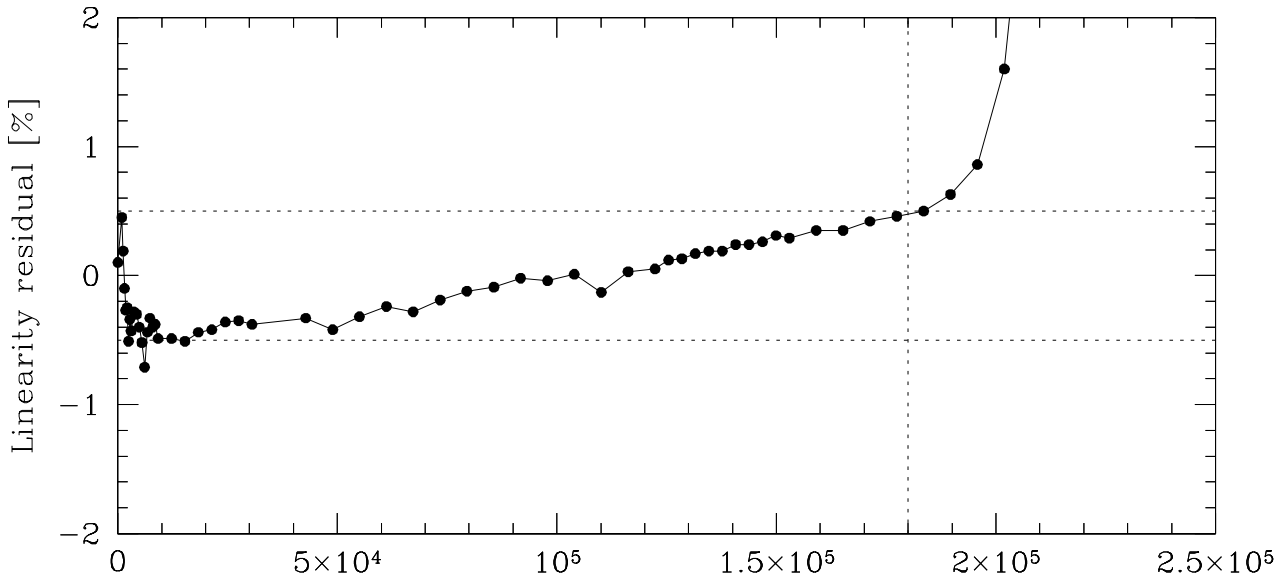
No slope indicates good CTE (>0.999995)

Dark Current

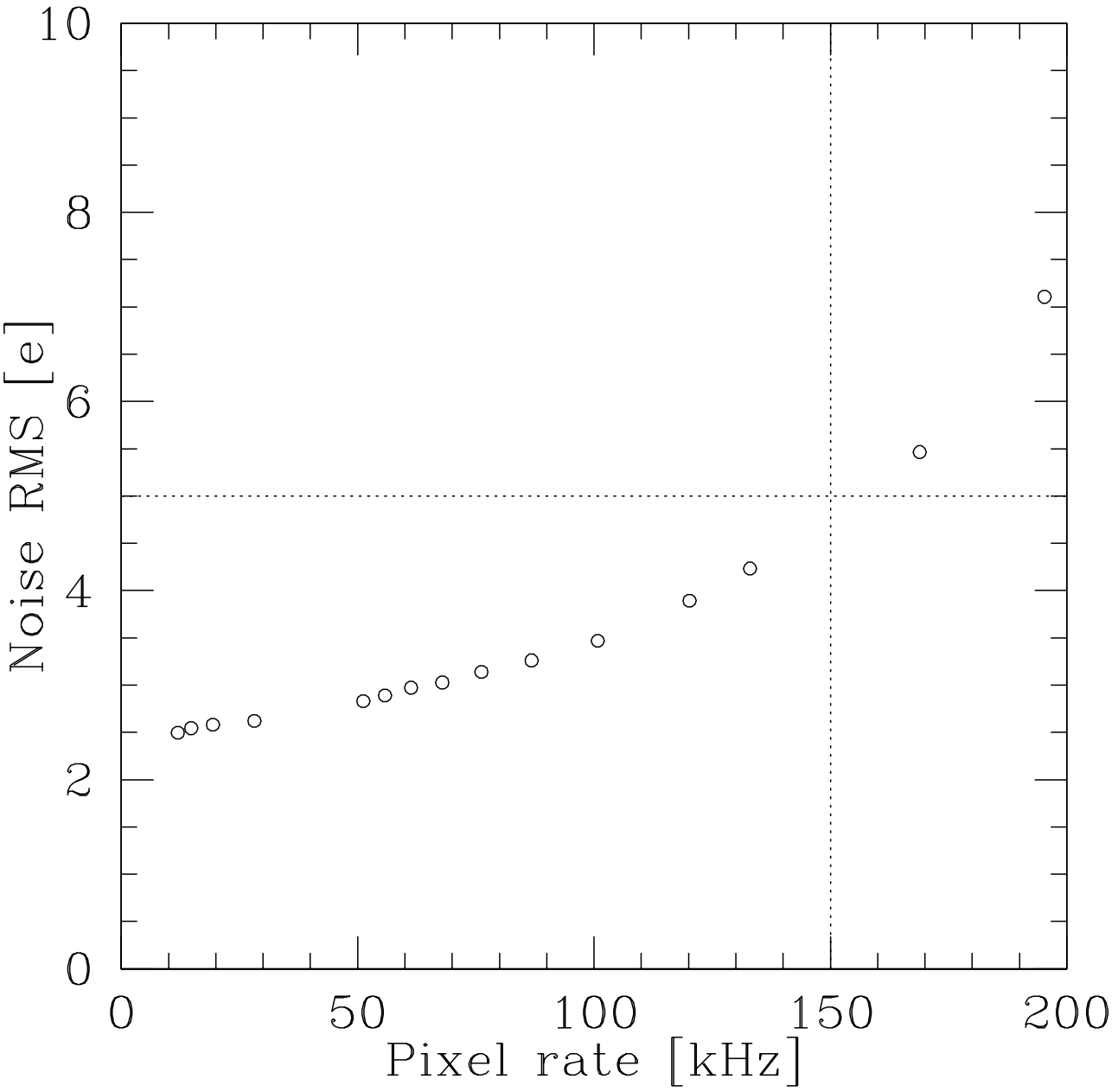


Full well


2.5×10⁵
2×10⁵
1.5×10⁵
10⁵
5×10⁴
0
Signal [e]
0
20
40
60
Exposure time [sec]


2
1
0
−1
−2
Linearity residual [%]
0
5×10⁴
10⁵
1.5×10⁵
2×10⁵
2.5×10⁵

Read noise



4.5 e rms
(150 kHz)
MFront2

Charge Diffusion

Expected Charge diffusion: $\sigma_D = 7\mu\mathrm{m},\ \mathrm{t} = 200\ \mu\mathrm{m}$

Suprime-Cam

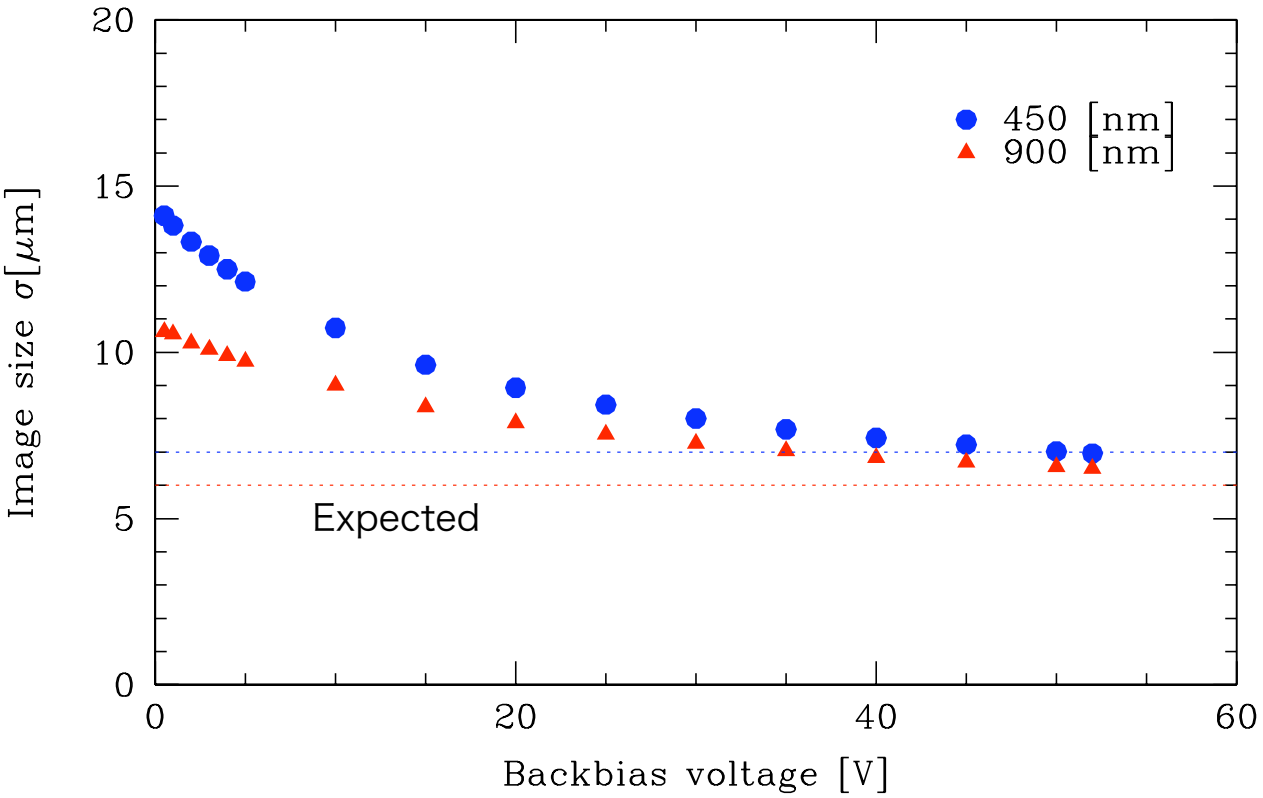
λ [nm]	focus pos. [μm]	σ [μm]	FWHM ["]
700	5.6	6.9	0.21
800	19.2	6.6	0.20
900	43.8	5.8	0.18
1000	84.7	4.5	0.14

lambda of 700 nm results can be adopted for shorter lambda

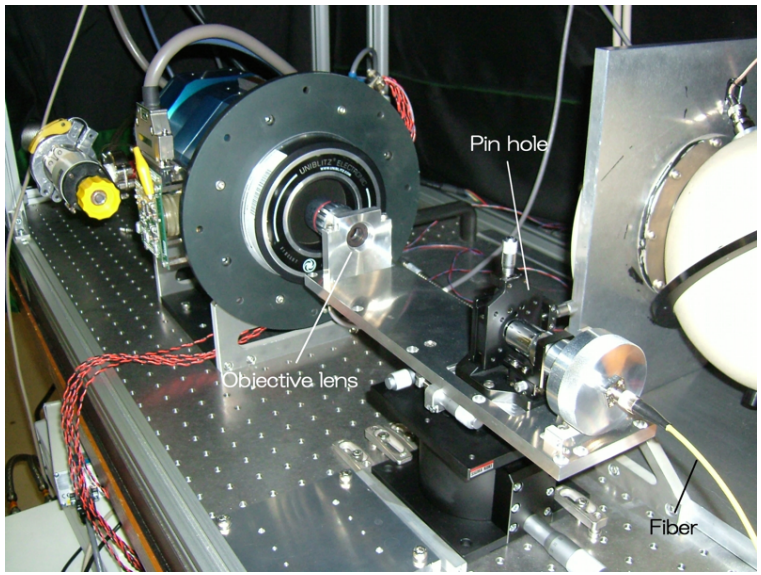
Sufficiently small charge spread

(HSC pixel scale is 15 % smaller)

Measurement



Measurement setup



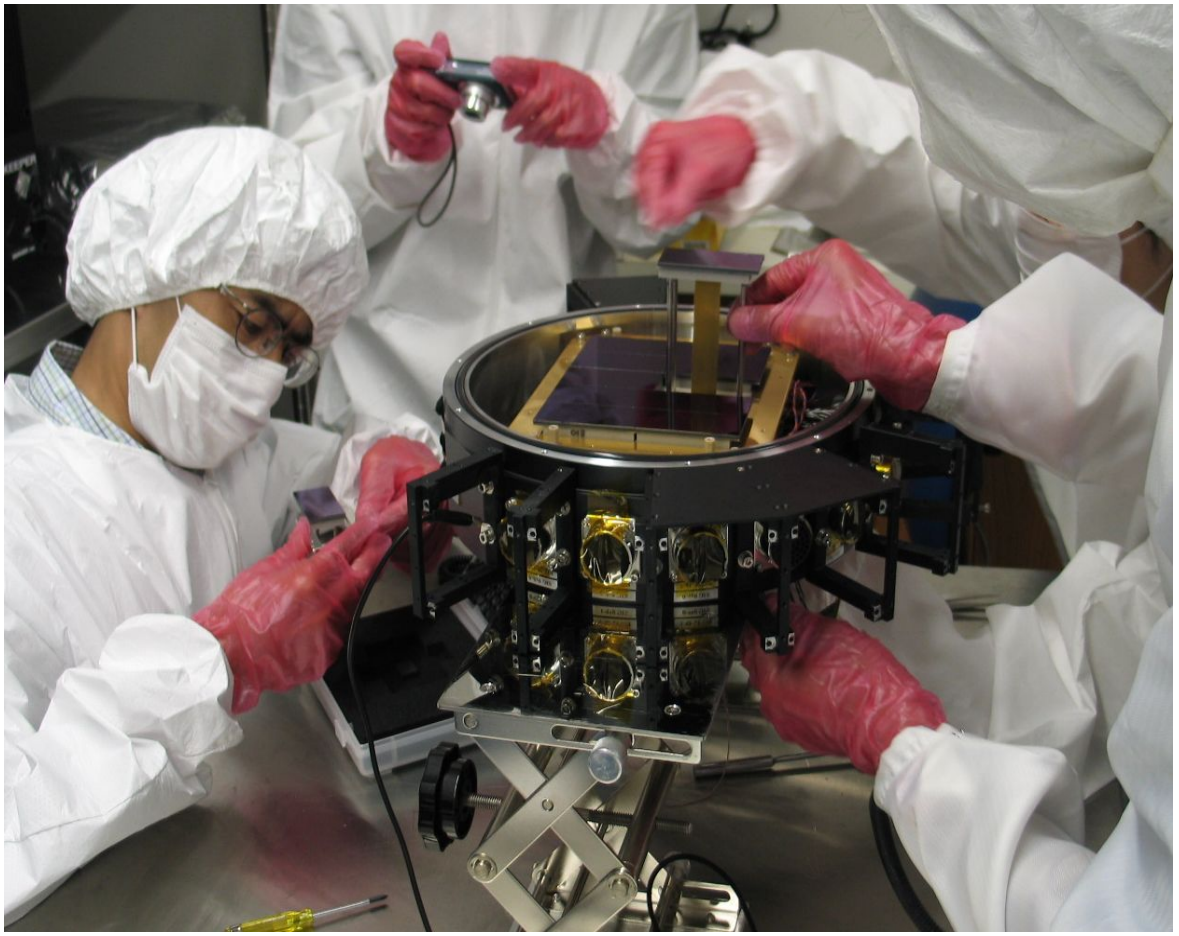
10 micron pin hole is projected with X 1/10 (NA ~ 0.25) optics

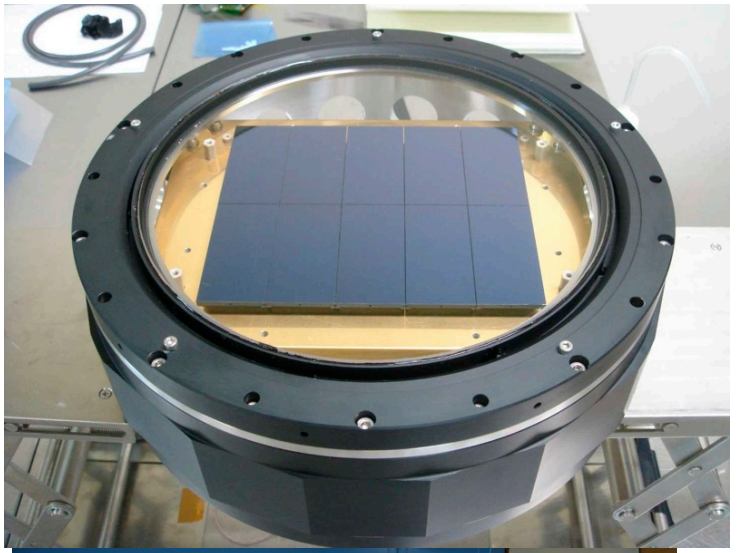
Measurement is consistent with expected value.

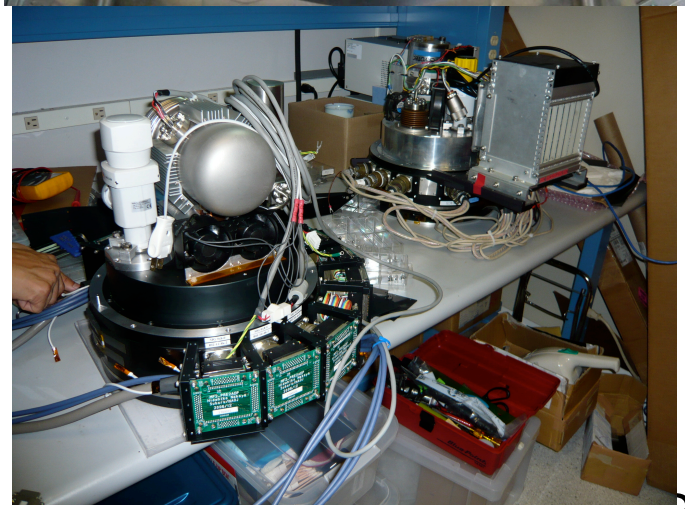
Mounted on Subaru

Replacement of MIT/LL CCID-20

July, 2008







Mounted on Subaru

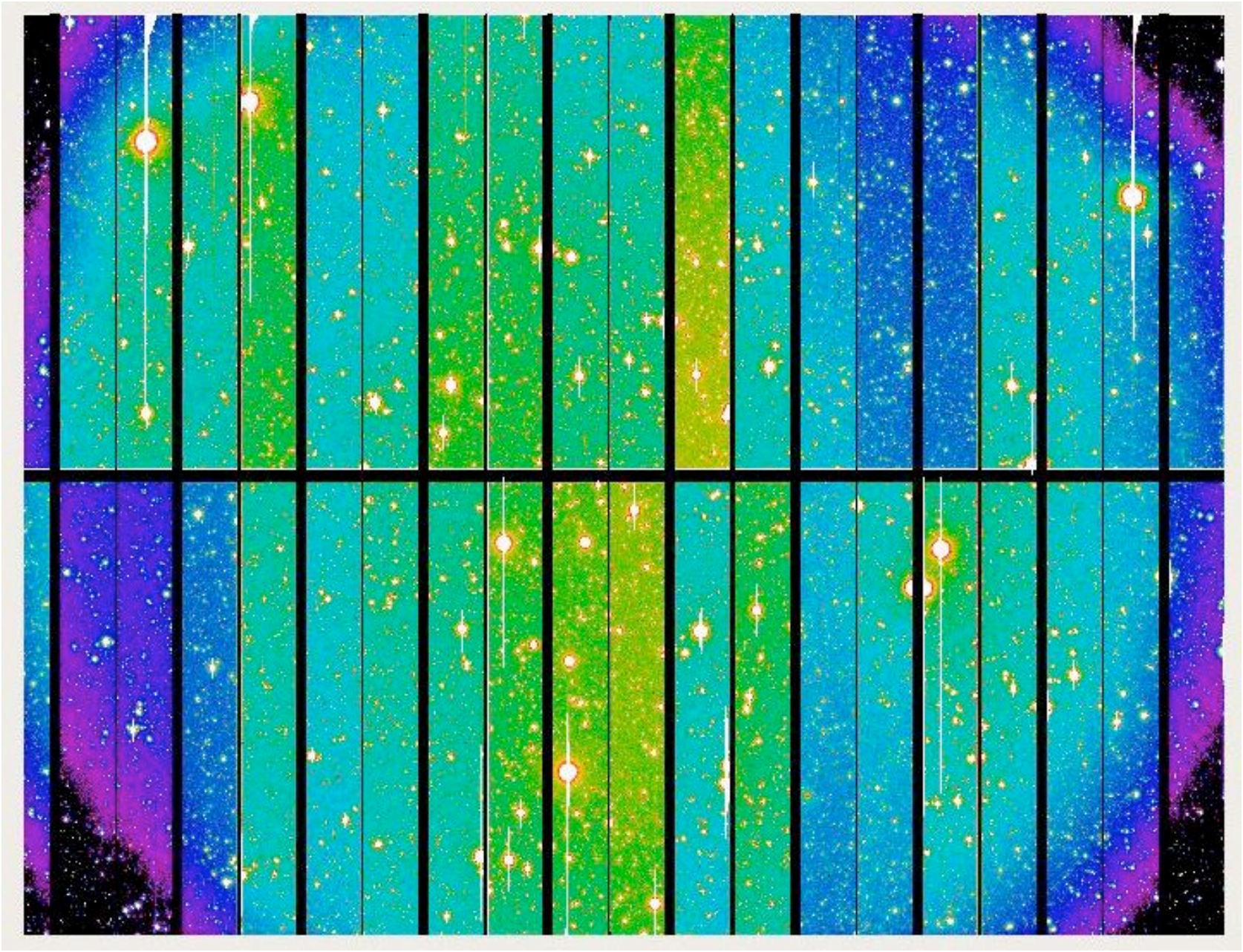
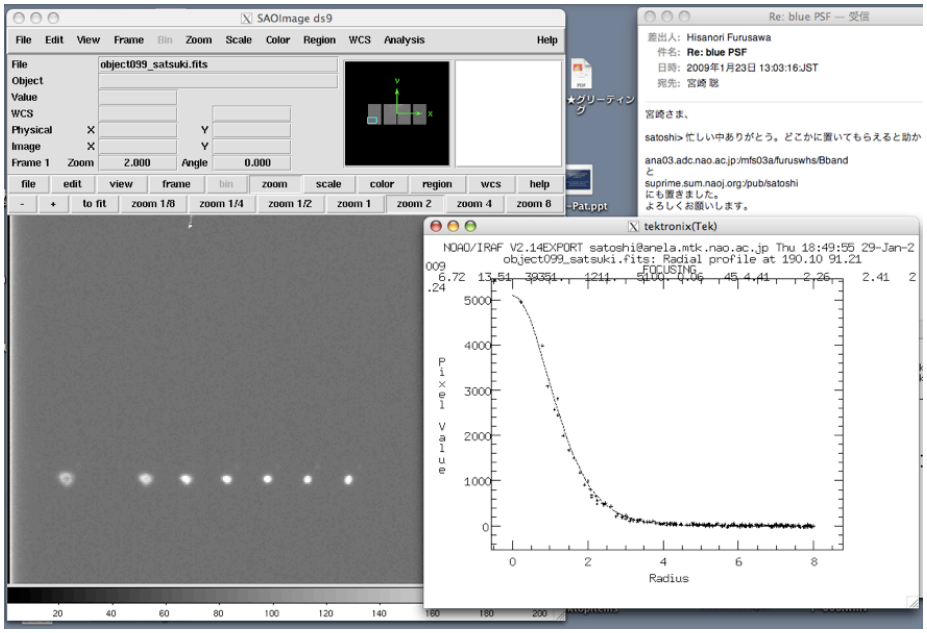
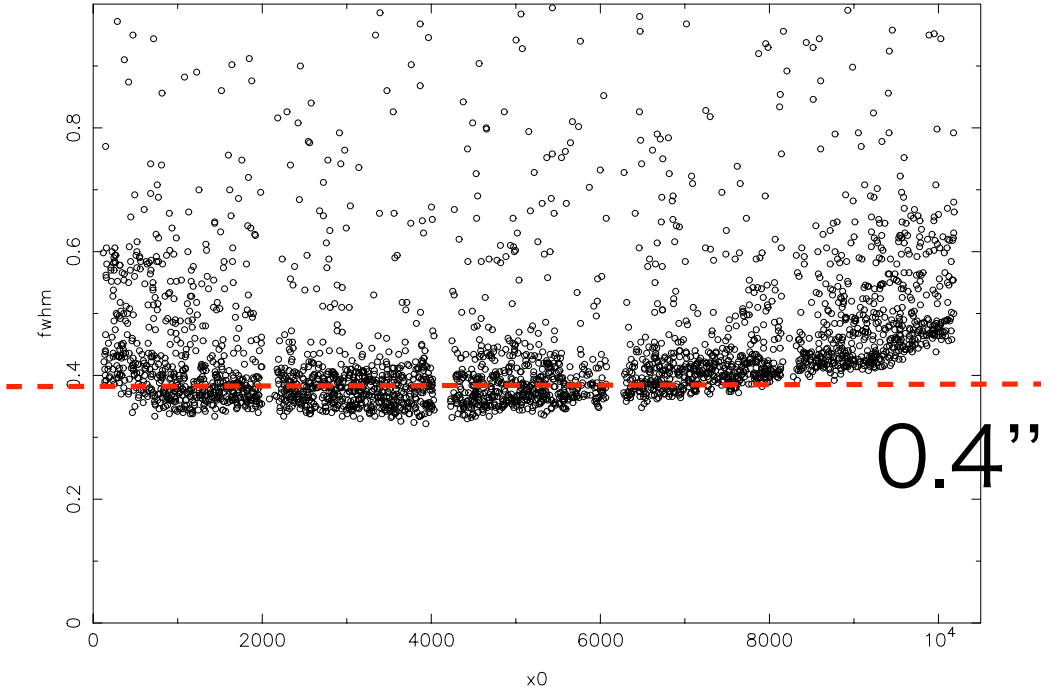


Image size at Subaru

B band

z’ band





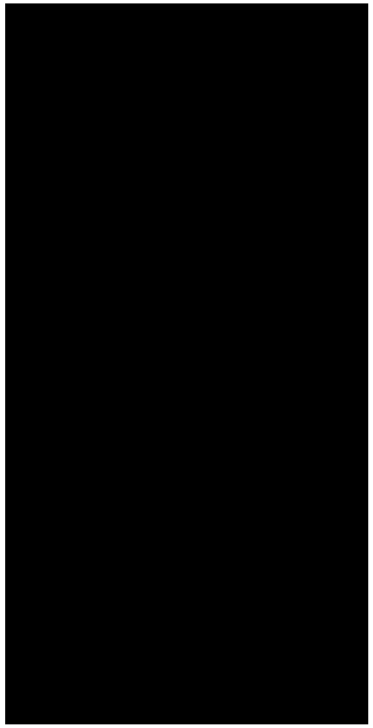
0.48” FWHM

0.38” FWHM

Cosmetic defects

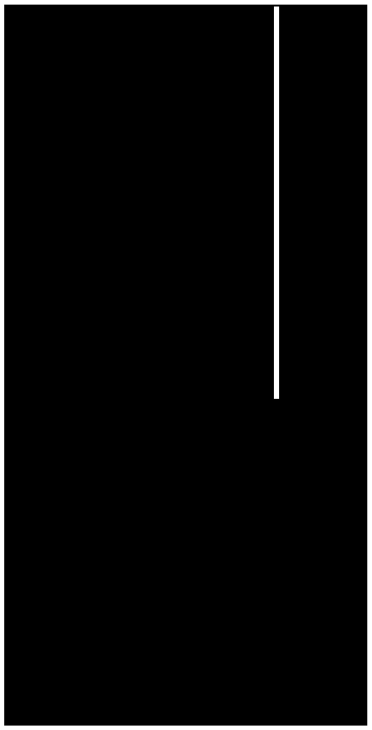
New Suprime-Cam case (10 CCDs):

No defect



3 CCD

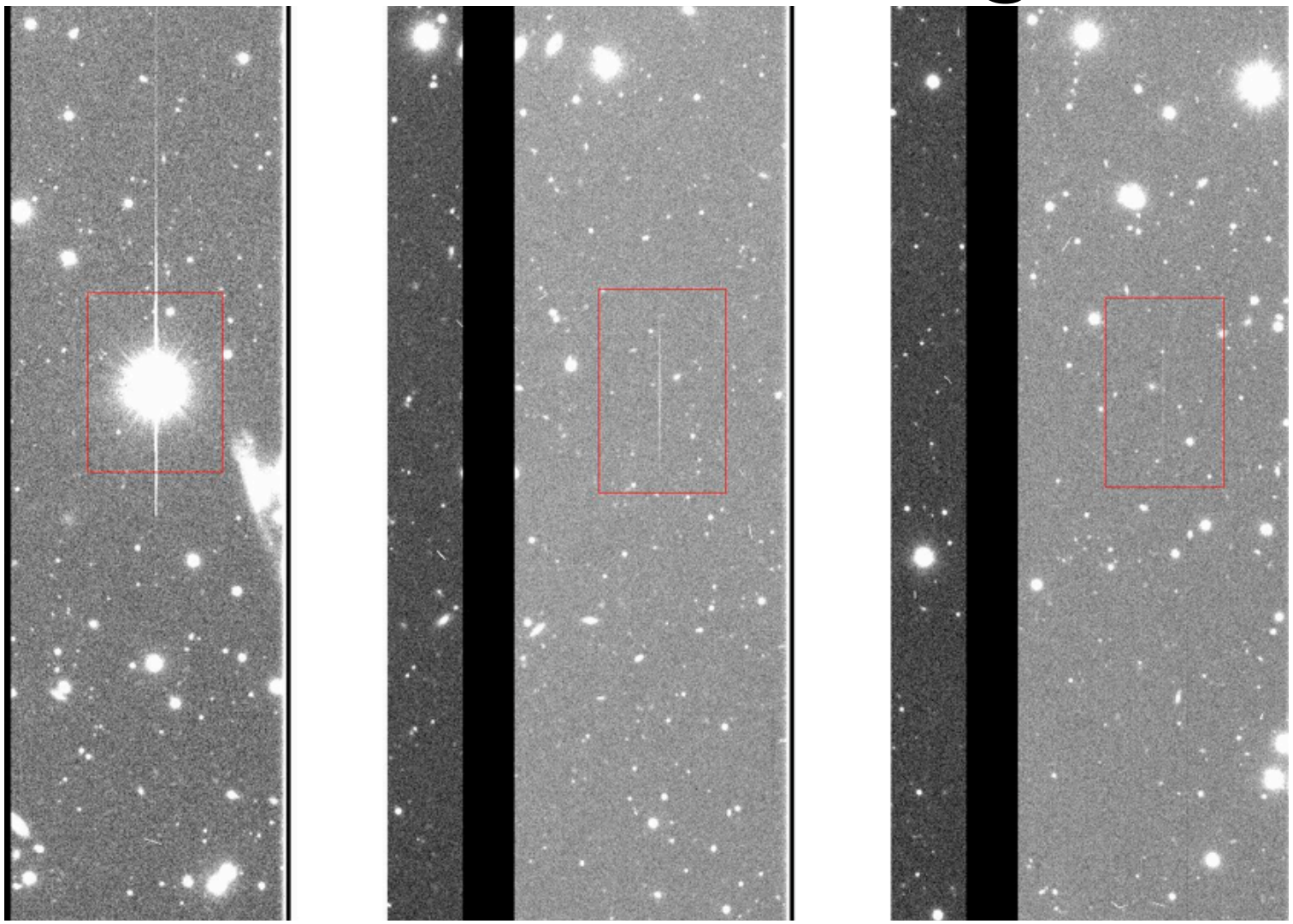
One block of bright columns



7 CCD

Block width:
6 CCD: 2 column
1 CCD: 5 column

Residual Images

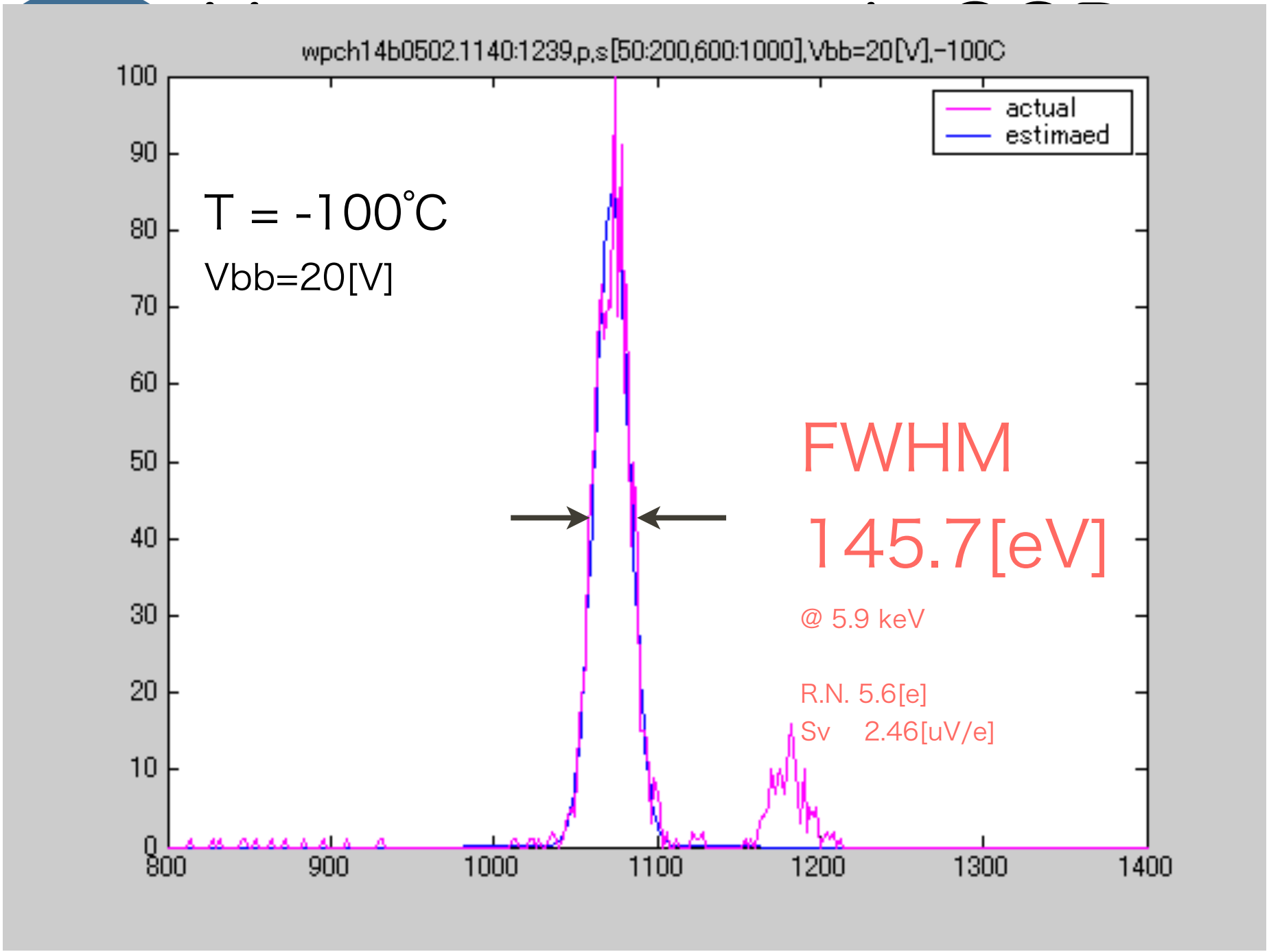


Delayed charge emission from surface traps

Pinning clock sequence between exposures fixes this entirely.

CCD Performance

Items		Requirement (-100°C)	Measured
Packaging	Format (pixel size)	2048×4096 (15 μm□)	-
	Pixel to Package edge	$<$ 0.5 mm	0.410±0.025
	(Serial register side)	$<$ 5.0 mm	4.975±0.025
	Global height variation	$<$ 25 μm Peak-to-Valley	
QE	400 nm	$>$ 45	42
	550 nm	$>$ 85	87
	650 nm	$>$ 90	94
	770 nm	$>$ 85	91
	920 nm	$>$ 80	78
	1000 nm	$>$ 40	40
CTE (per pix)	Parallel direction	$>$ 0.999995 (1600 e)	0.999999
	Serial direction	$>$ 0.999995 (1600 e)	0.999998
Dark Current		$<$ a few e/hour/pix	1.4
Charge diffusion		$\sigma_D < 7.5$ μm ($400 < \lambda < 1050$ nm)	7.5
Full well	1 % departure	$>$ 150,000 e	180,000
Amp. Responsivity		$>$ 4 μV/e	4.5
Readout noise	150 kHz readout	$<$ 5 e	4.5


wpch14b0502.1140:1239,p,s[50:200,600:1000],Vbb=20[V],-100C
actual
estimaed
T = -100℃
Vbb=20[V]
FWHM
145.7[eV]
@ 5.9 keV
R.N. 5.6[e]
Sv 2.46[uV/e]
100
90
80
70
60
50
40
30
20
10
0
800
900
1000
1100
1200
1300
1400

Wider Field of View

Hyper Suprime-Cam

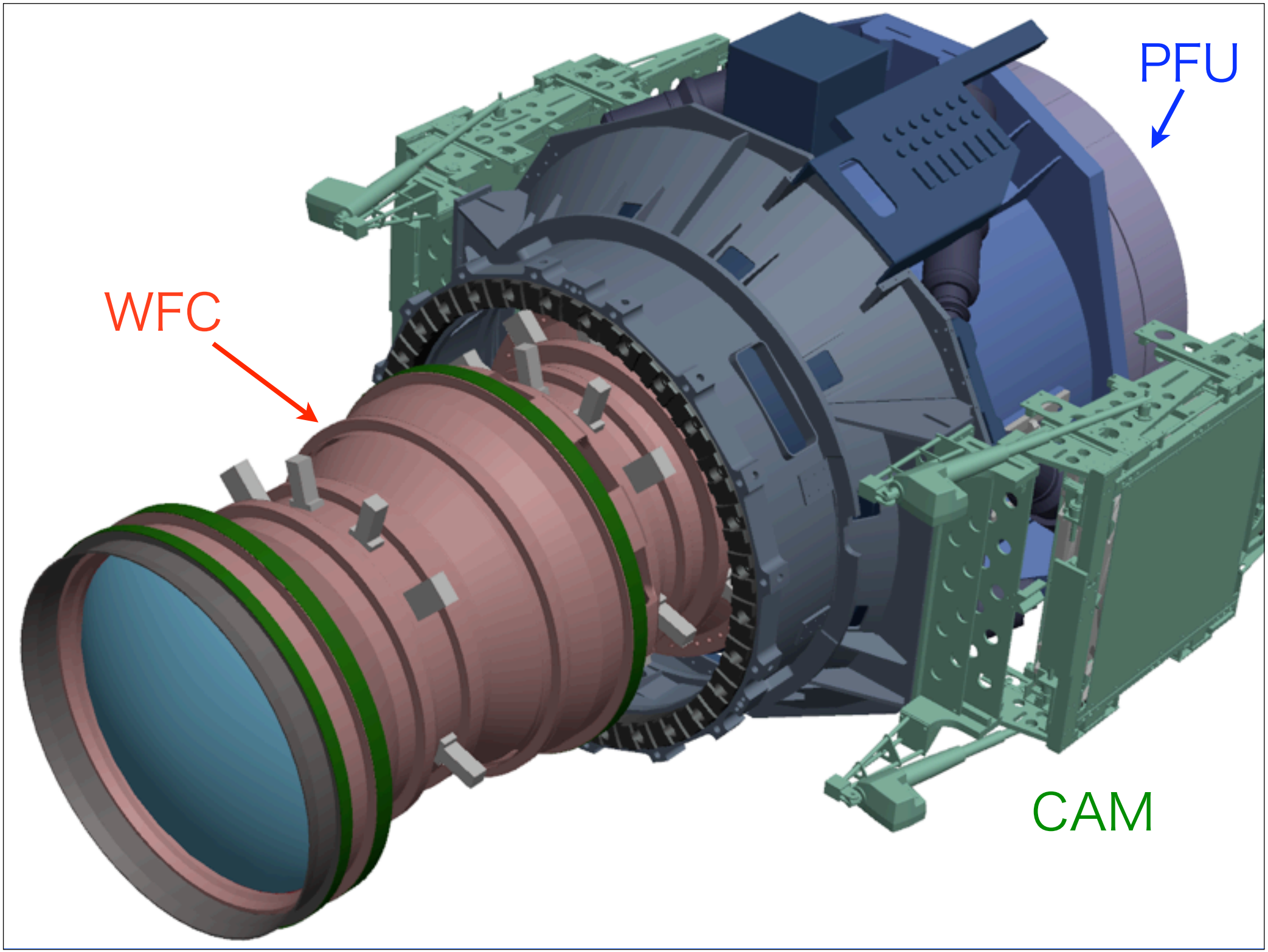
HSC Developments

- Larger Focal Plane　1.5 deg diameter
  - More CCDs
  - Large Filters
- New Wide Field Corrector
- New Prime Focus Unit
  - Optics alignment system
  - mechanical interface to the telescope

HAMAMATSU

Canon

MITSUBISHI


PFU
WFC
CAM

HSC Components

PFU Mechanics

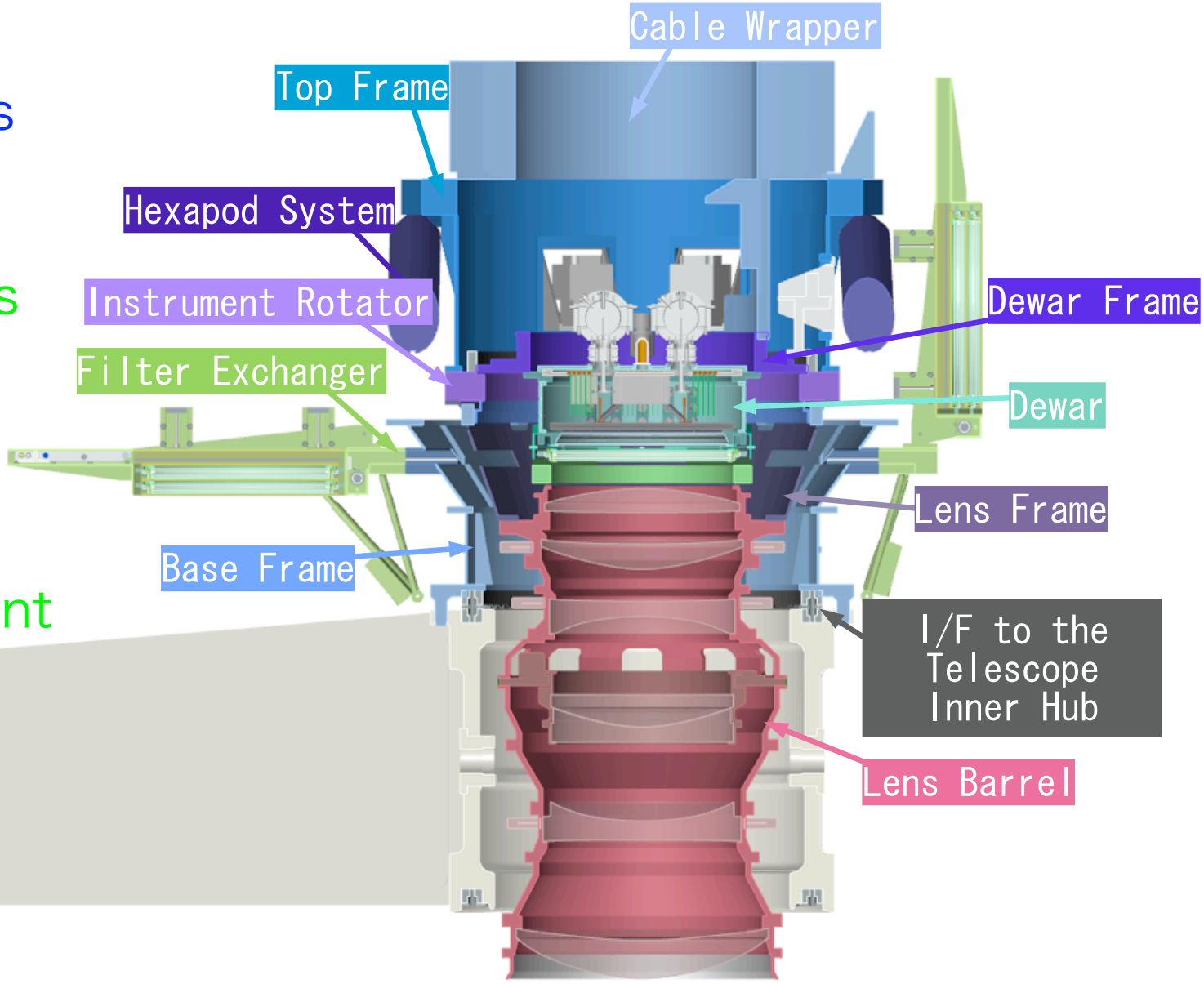
WFC

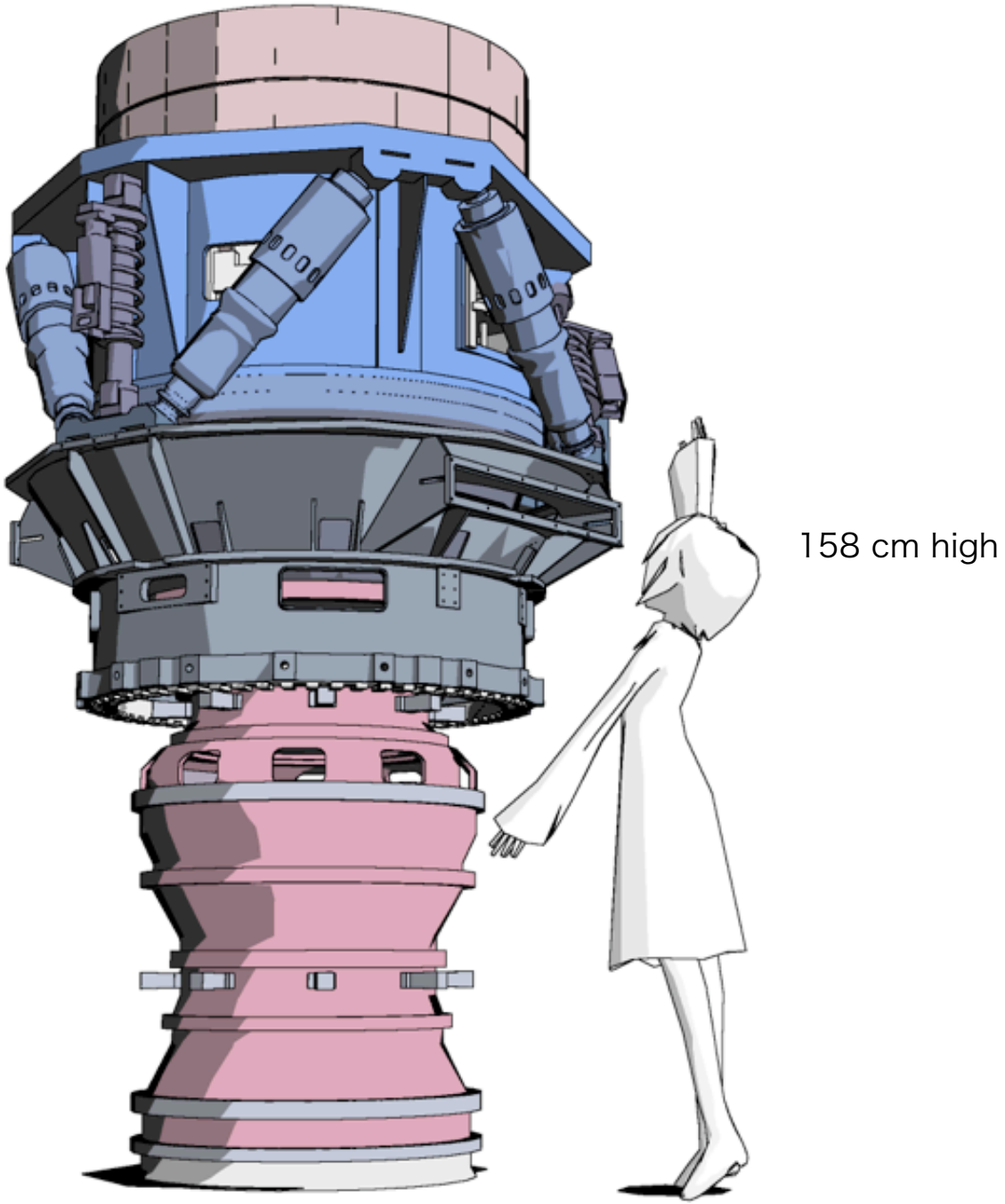
HSC Mechanics

Sensor

Filter

Data Management

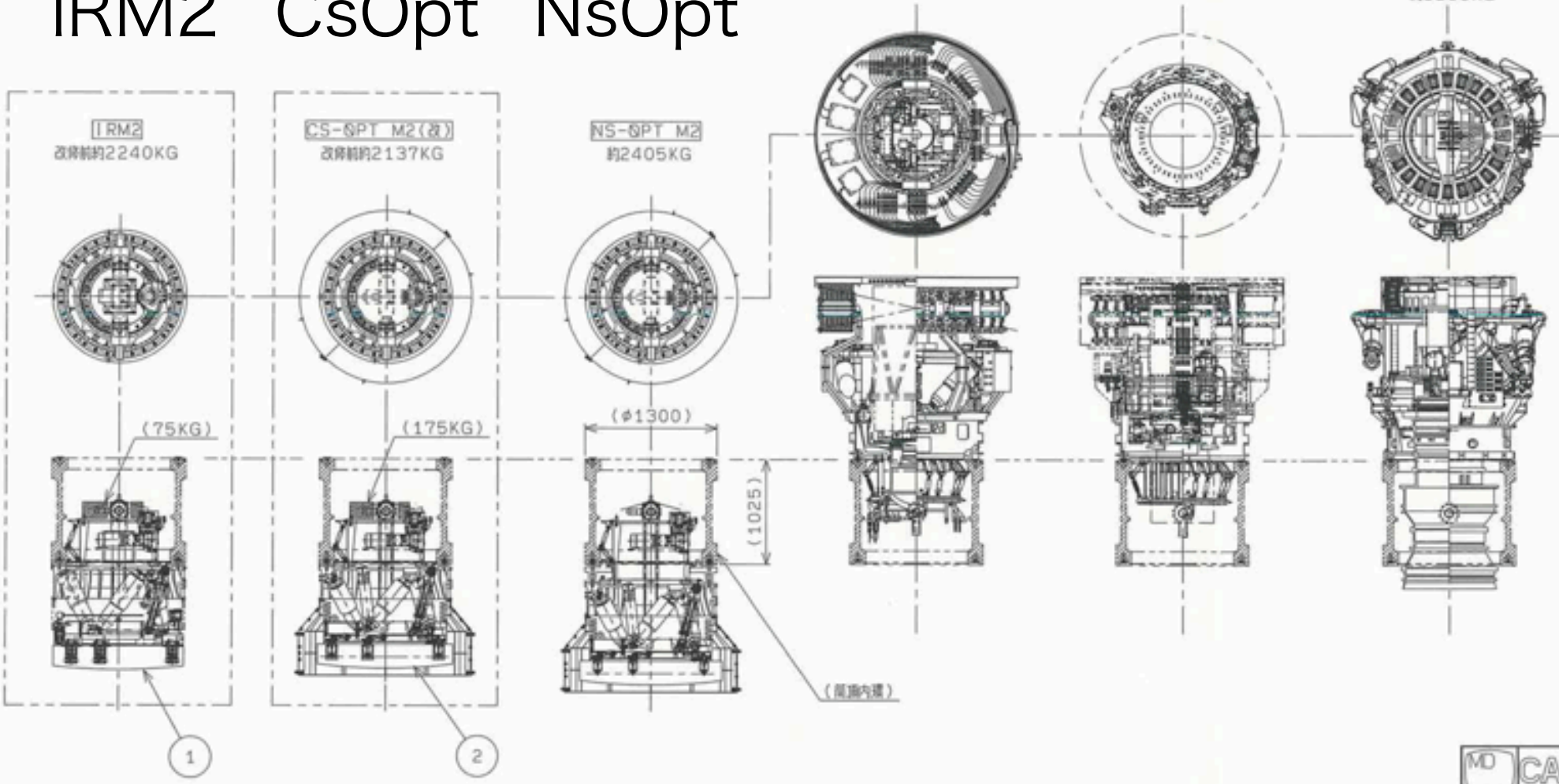



158 cm high
310 cm high

副鏡ユニット一覧

SC FMOS HSC

IRM2 CsOpt NsOpt



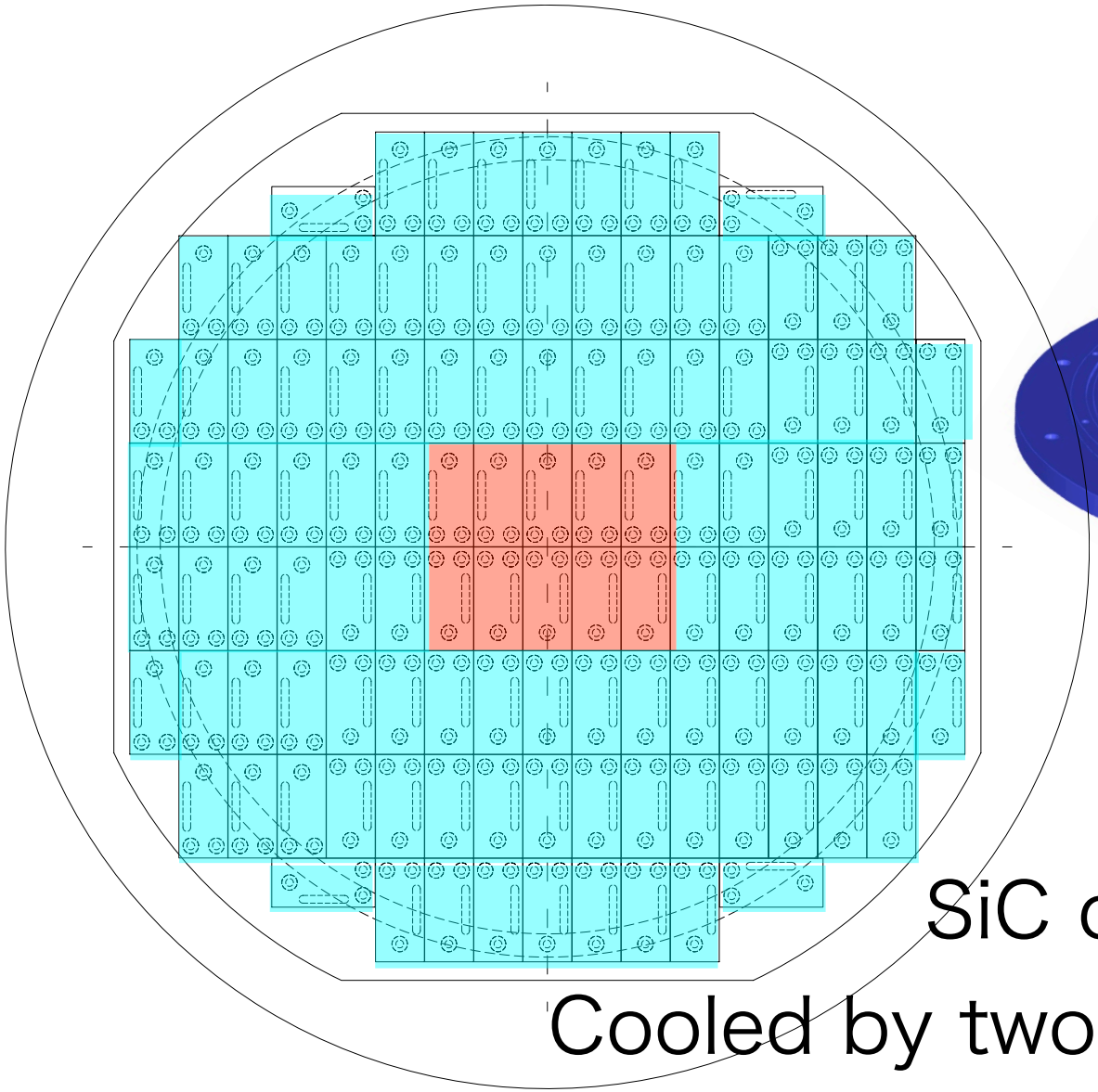
MD CAD

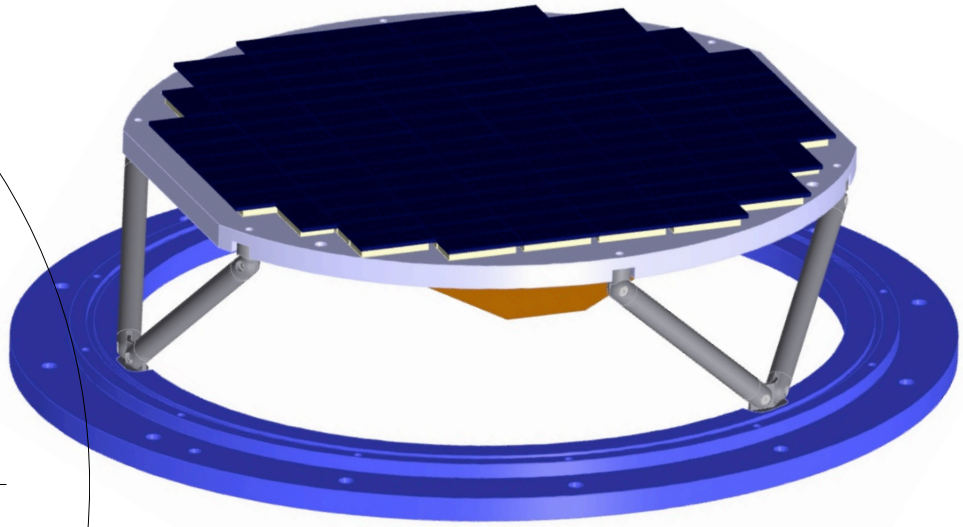
2RC CHANGE	A	部品製図番号 RK49B991-G01	第三角法	DIMENSION IN mm	SCALE 1:50 NTS
			MITSUBISHI ELECTRIC CORPORATION		DATE 2009. 3.17
			APPROVED	DESIGNED 三好	CHECKED 永江
					DRAWN 岡本

副鏡ユニット改修

RK384204

HSC Focal Plane





112 + 4 Guides

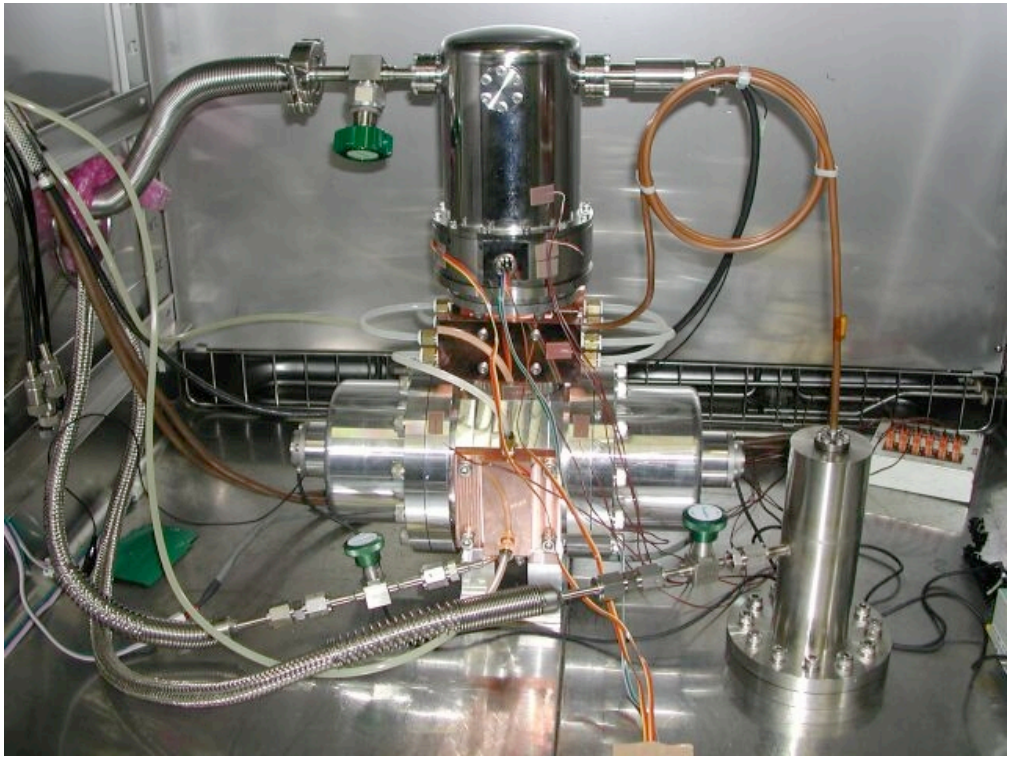
SiC cold plate

Cooled by two pulse tube coolers

45 W@-100 C each

CCD Dewar
Cooler

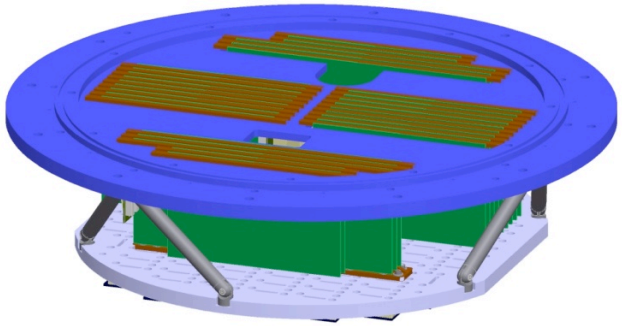
- Development Status
  - Production model prototype is just assembled, now in test
  - Cooling power and vibration : to be measured
  - Delivered to NAOJ by the end of March



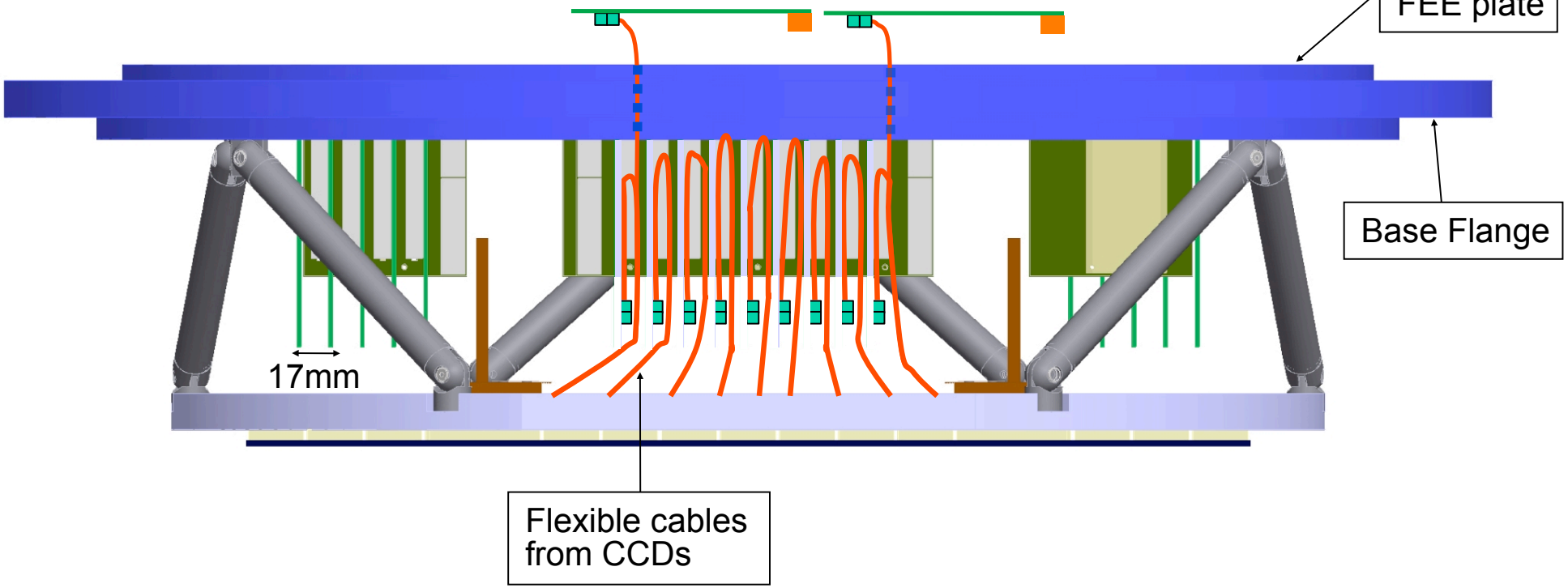
Pulse tube cooler just assembled in Fuji Electric

CCD Dewar
Front End Electronics

- FEE Assembly
  - Interval of FEE boards: 17mm
  - FPC cables from CCDs are folded and placed between FEE boards



Back side view



HSC Cryostat

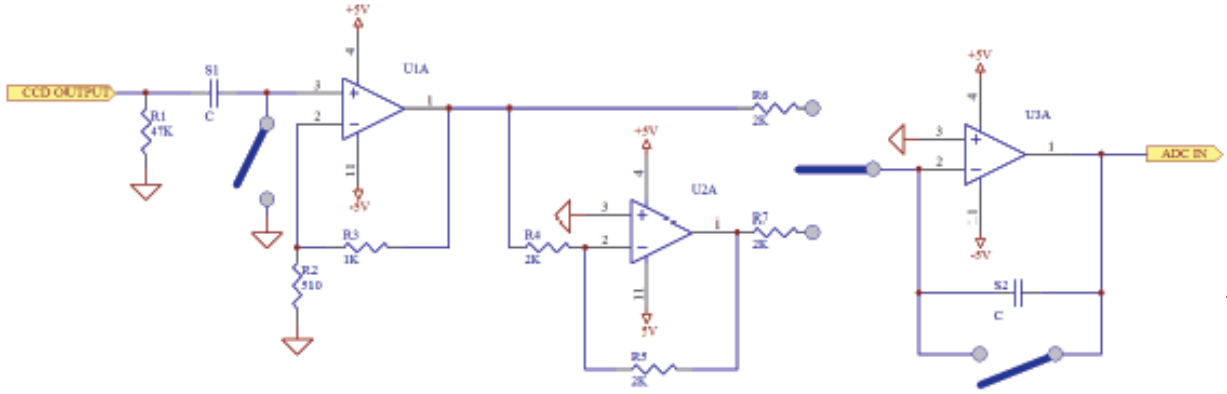
Dewar Vacuum test

FEE: Signal processing circuit

- Double-slope type CDS circuit based on SDSS photometric camera
- 3 op-amps signal processor to achieve low power consumption
  - Pre-amp
  - Inverting amp
  - Integration amp
- AC coupling with DC level restoration
- Low power and fast op-amps with quick overload recovery (No need of clamp diode)
- 0.05% linearity error over the full signal range
- -150ppm/C of the gain temperature dependency

pixel rate: 250 kpix/s

CCD



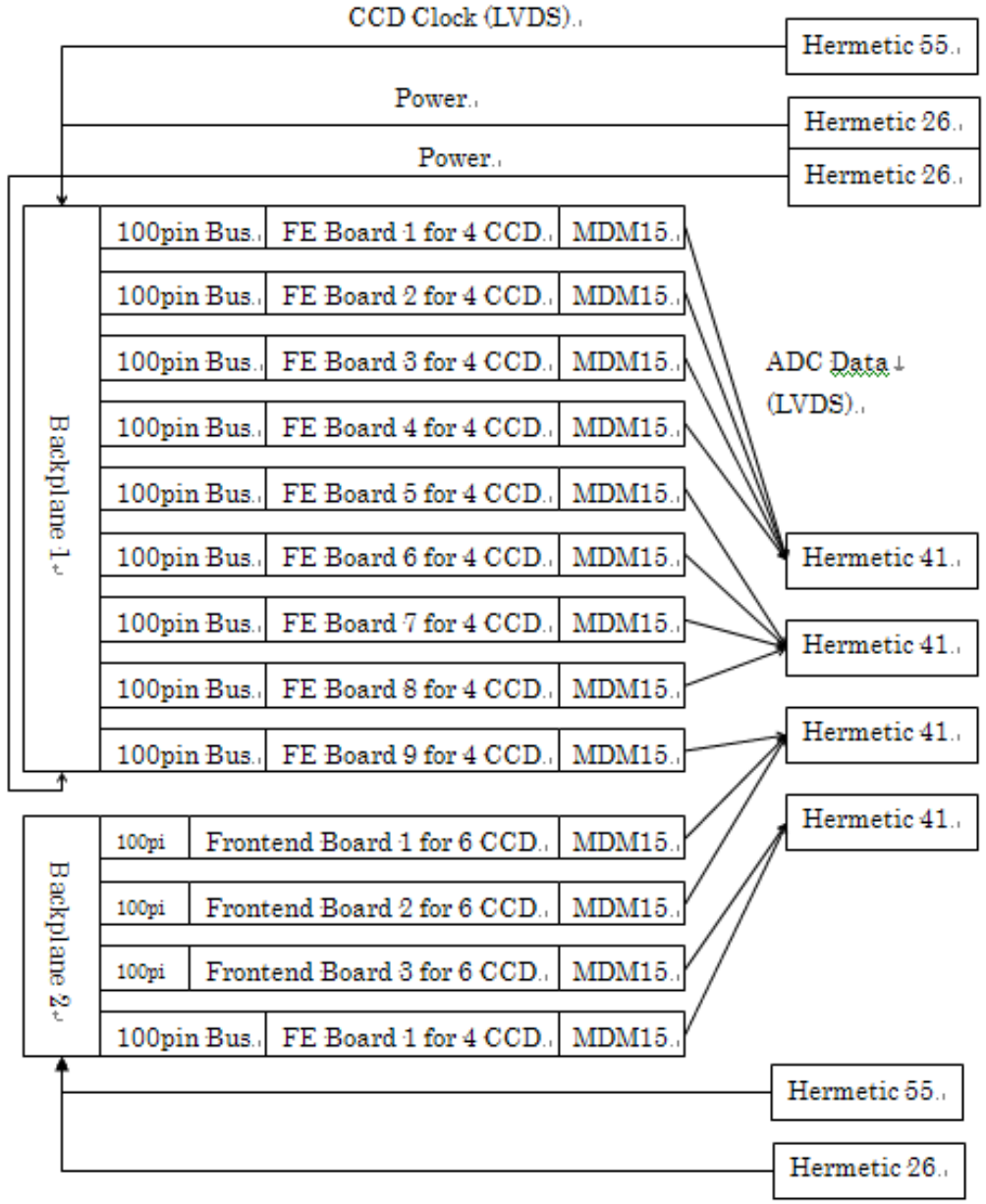
ADC

AD7686

Figure 1.4: Pre-amplifire and CDS circuit

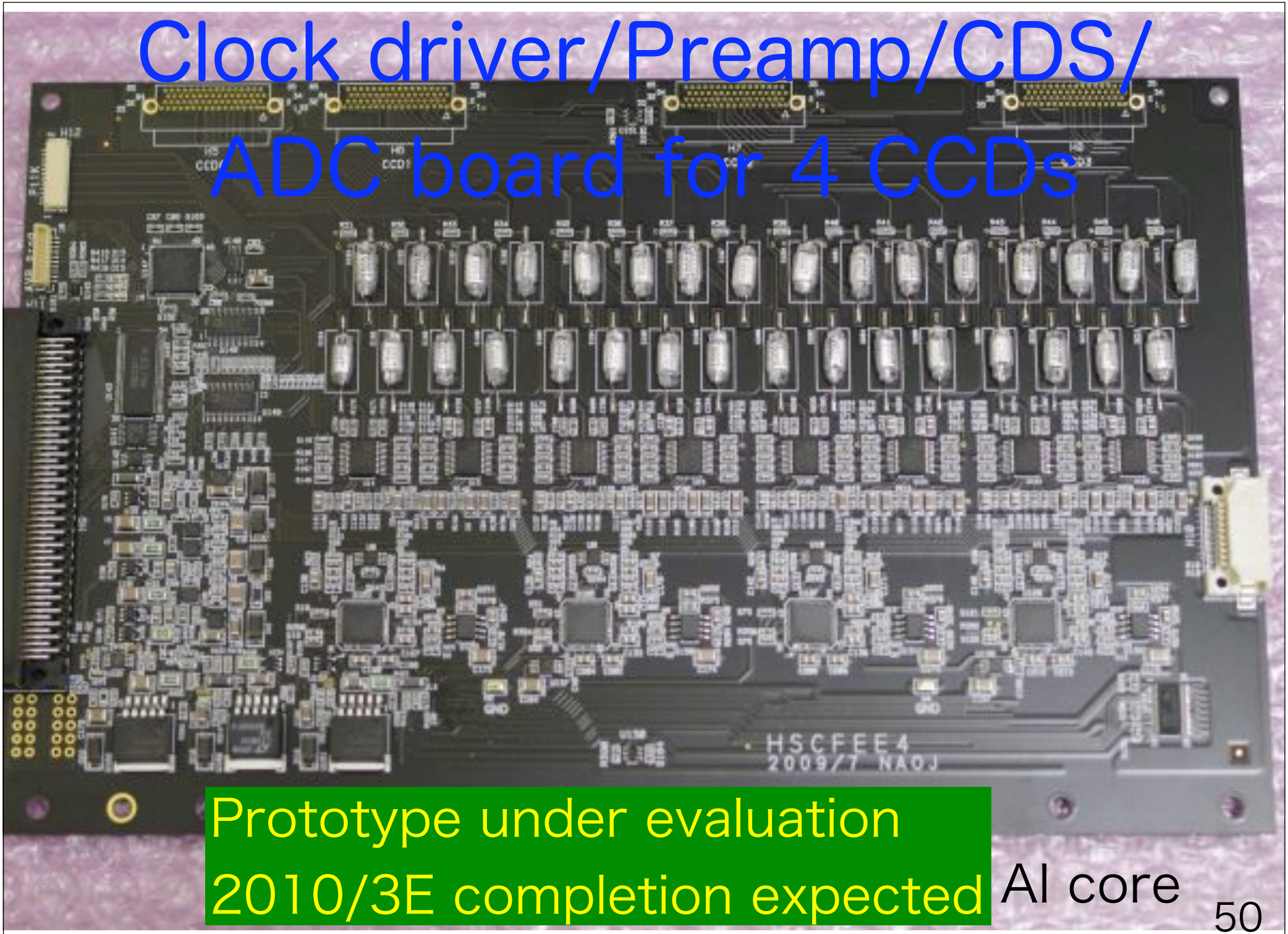
OPA 627

FEE: Connection diagram



- Frontend for a Half of Science CCD (56 CCD)
  - 4CCD FE board x9
  - 6CCD FE board x3
  - 4CCD FE board x1 (Used only 2CCD)
- Hermetic Connector (MIL circular type)
  - 55 pins x2 for CCD Clock
  - 41 pins x4 for ADC Data
  - 26 pins x3 for Power
  - Total 9 hermetic connectors

Clock driver/Preamp/CDS/ ADC board for 4 CCDs



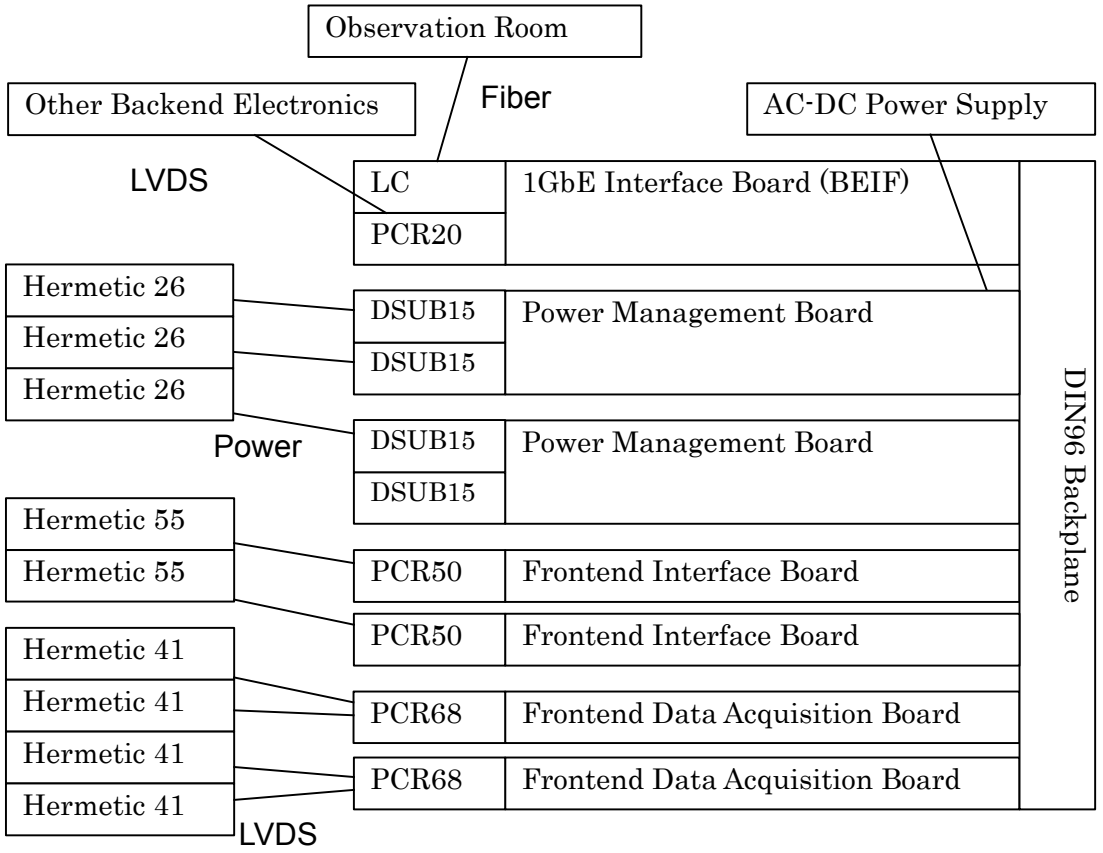
Prototype under evaluation

2010/3E completion expected

AI core

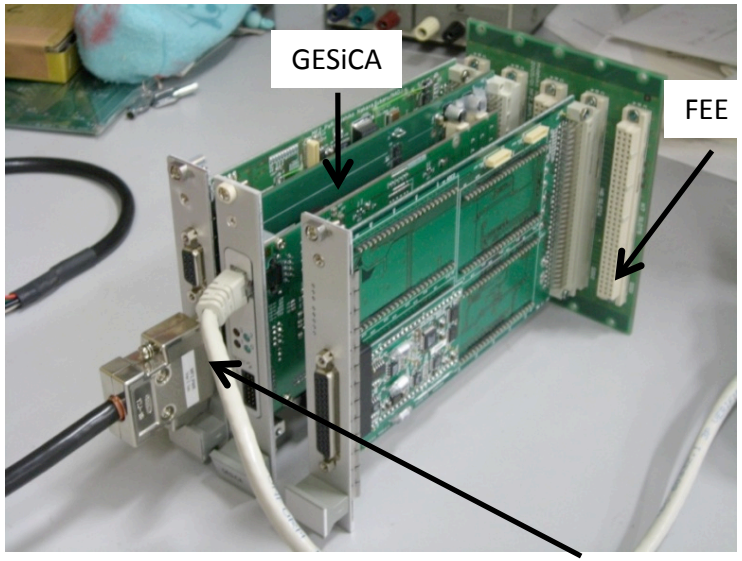
BEE: Connection diagram

- Frontend for a Half of Science CCD (56 CCD)
  - 1GbE Interface Board x1
  - Power Management x2
  - FE Interface x2
  - FE DAQ x2
  - Total 7 boards
- One pair of Optical Fiber going out from the Prime Focus
- Two sets of BEE for the science CCD is connected to synchronize the CCD clock.



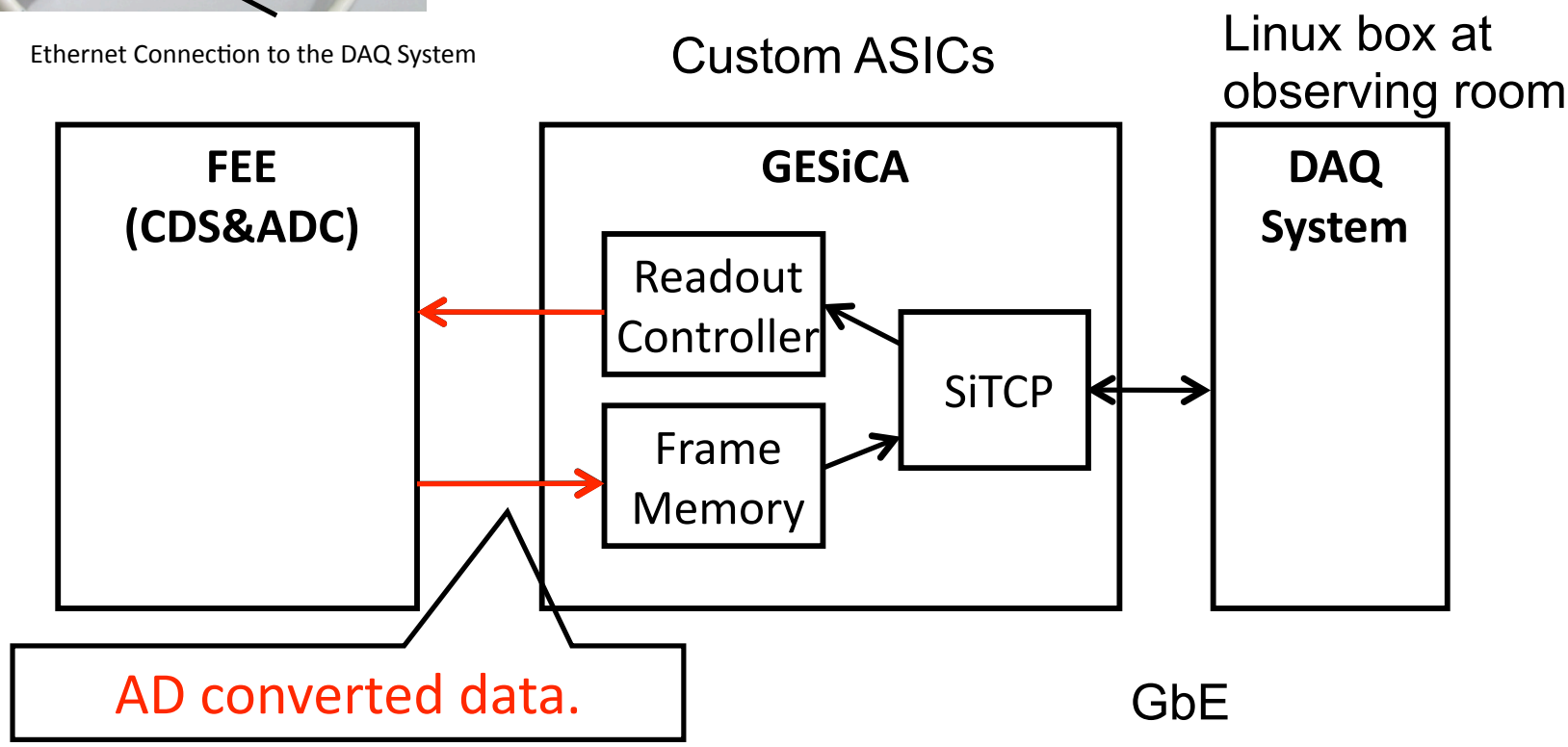
Connections of Backend Electronics

BEE: Prototyping

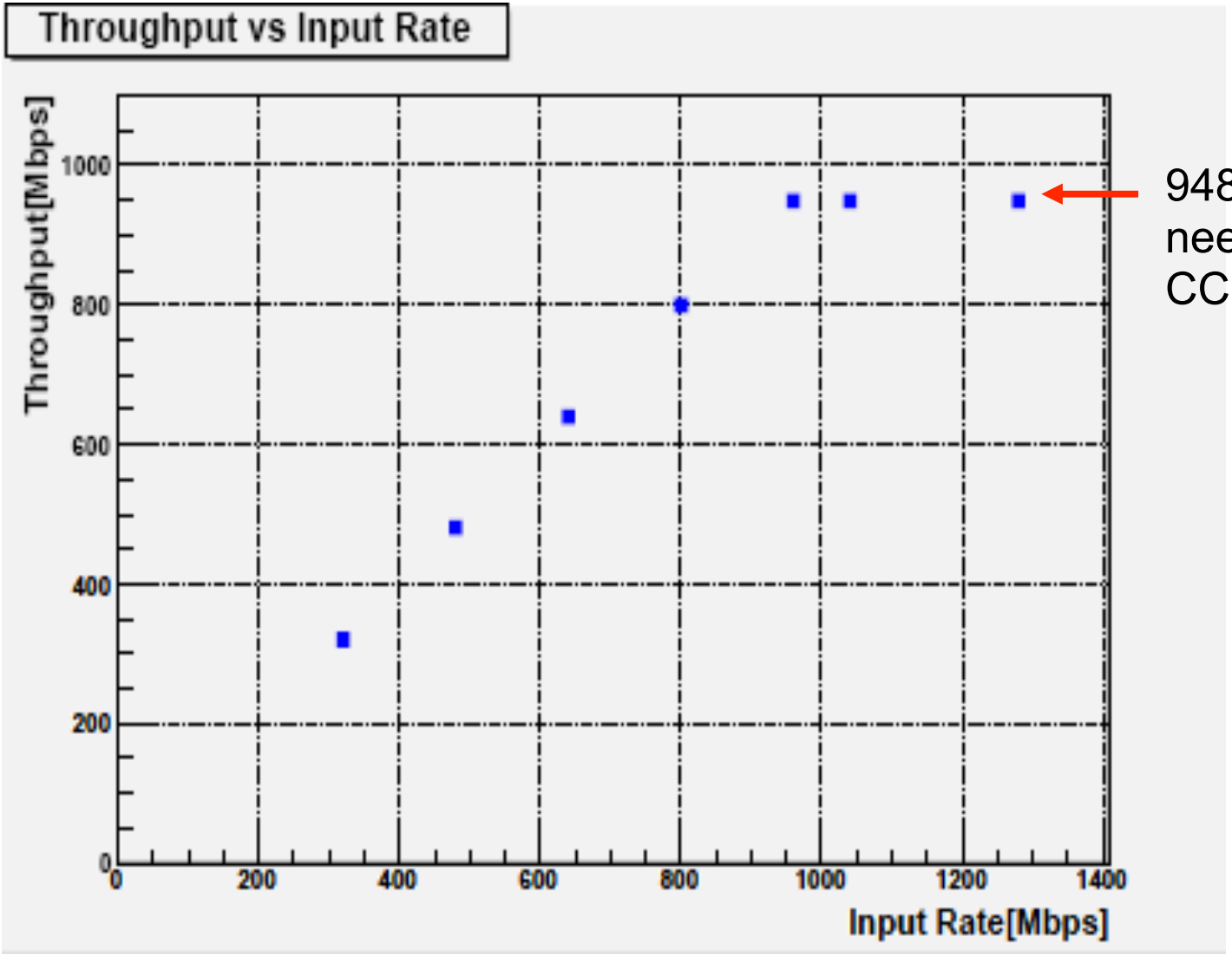


Ethernet Connection to the DAQ System

Designed by U-tokyo and KEK
Uchida et al. 2008 SPIE



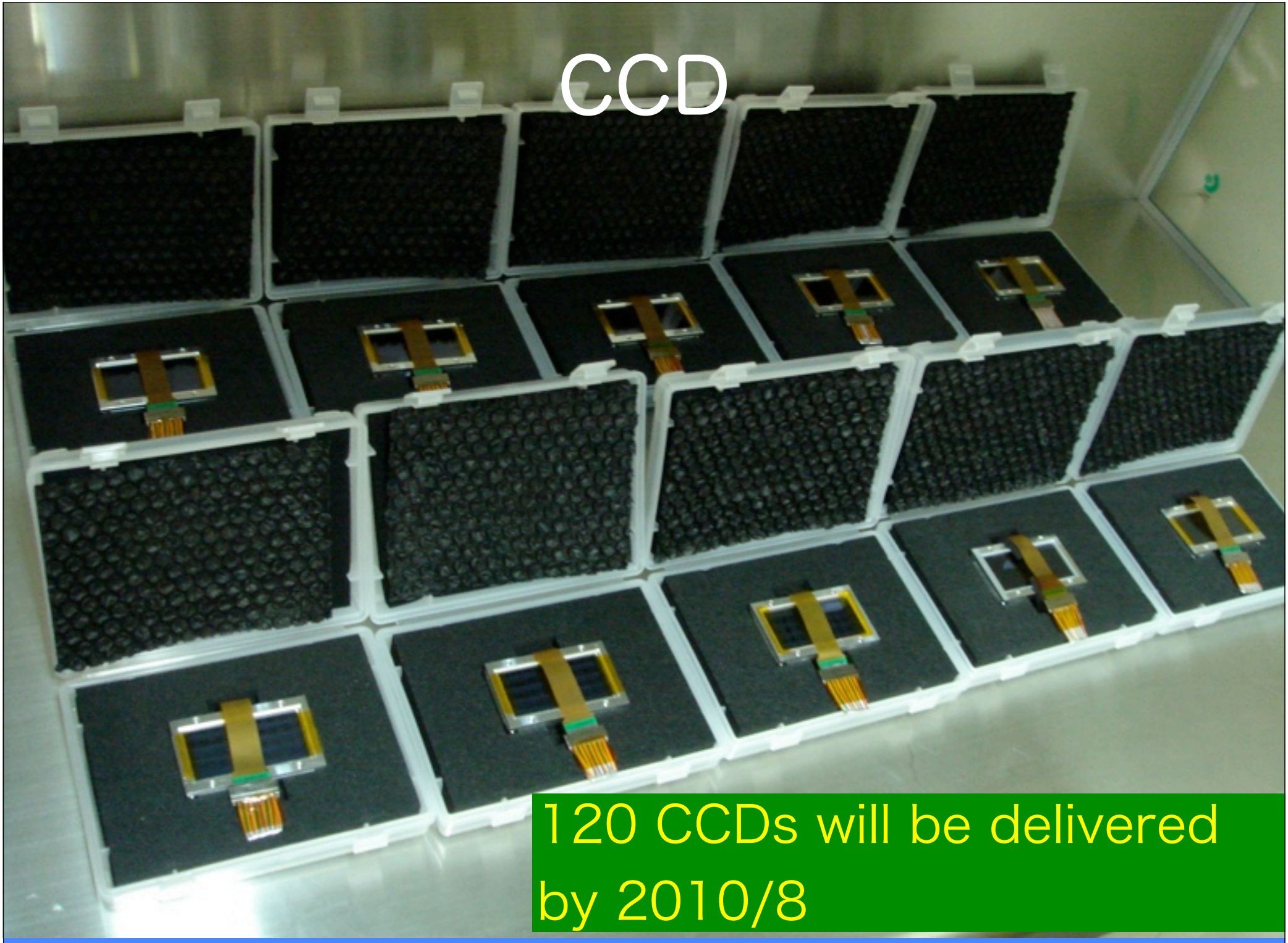
BEE: Data transfer speed to a remote host



948 Mbps just need for 64 CCDs readout

Stable Transfer to the limit of Gigabit Ethernet

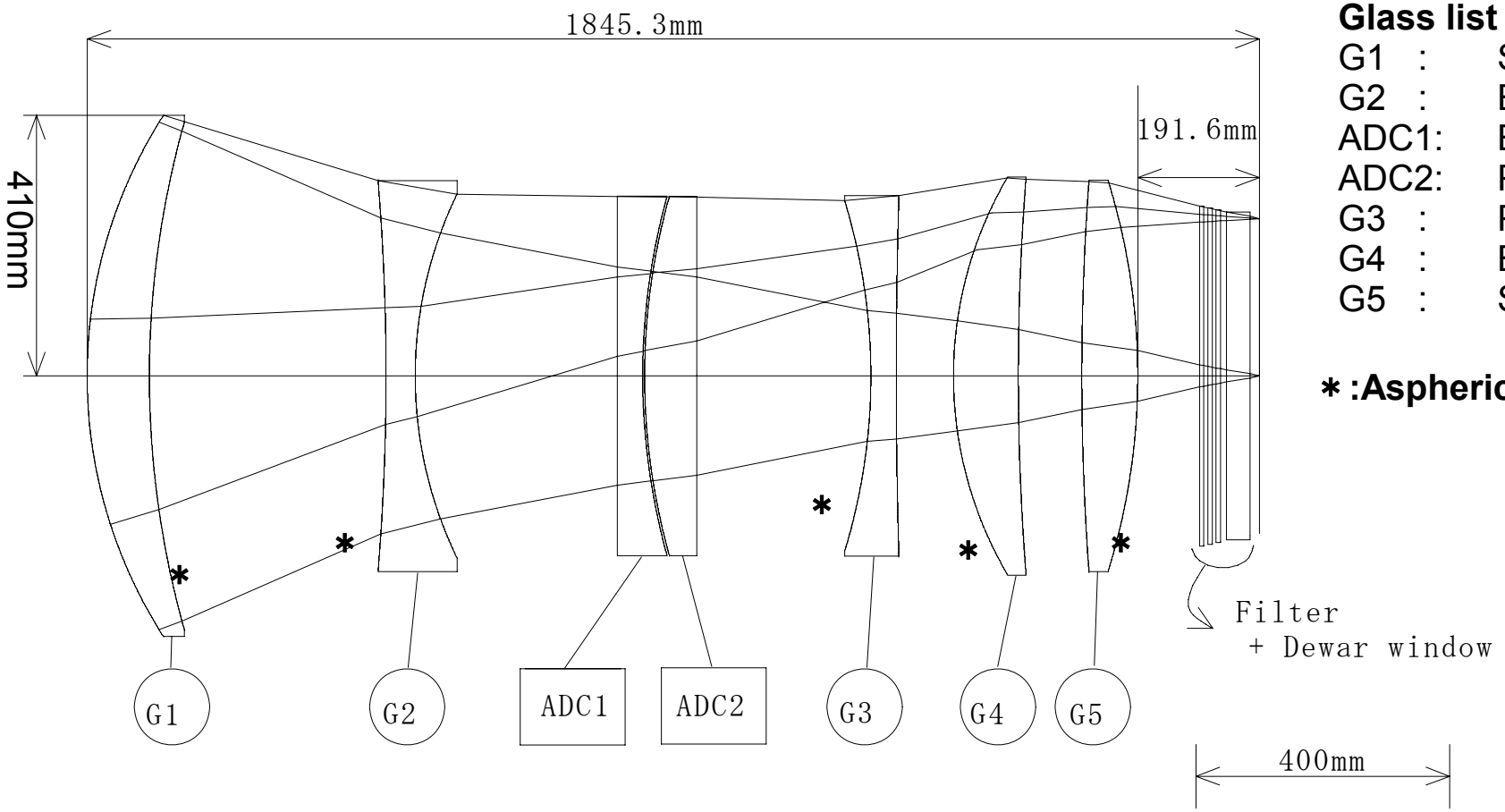
CCD



120 CCDs will be delivered by 2010/8

Wide Field Corrector

Details of Design



Glass list

G1	:	SILICA
G2	:	BSL7Y
ADC1:		BSL7Y
ADC2:		PBL1Y
G3	:	PBL1Y
G4	:	BSL7Y
G5	:	SILICA

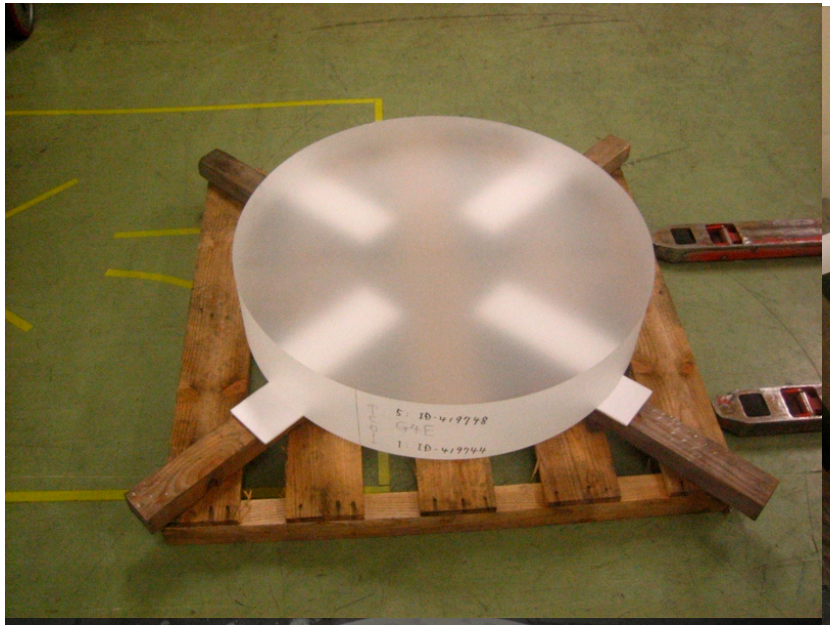
＊:Aspherical Surface

General Optical Datas

focal length	18320mm
image scale	0.0888[mm/arcsec]
image size(1.5deg	Φ495mm

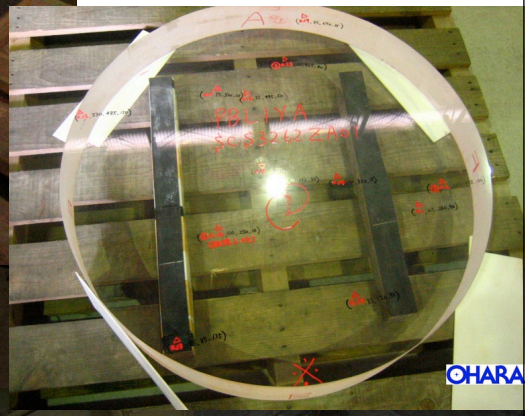
designed by Canon

WFC



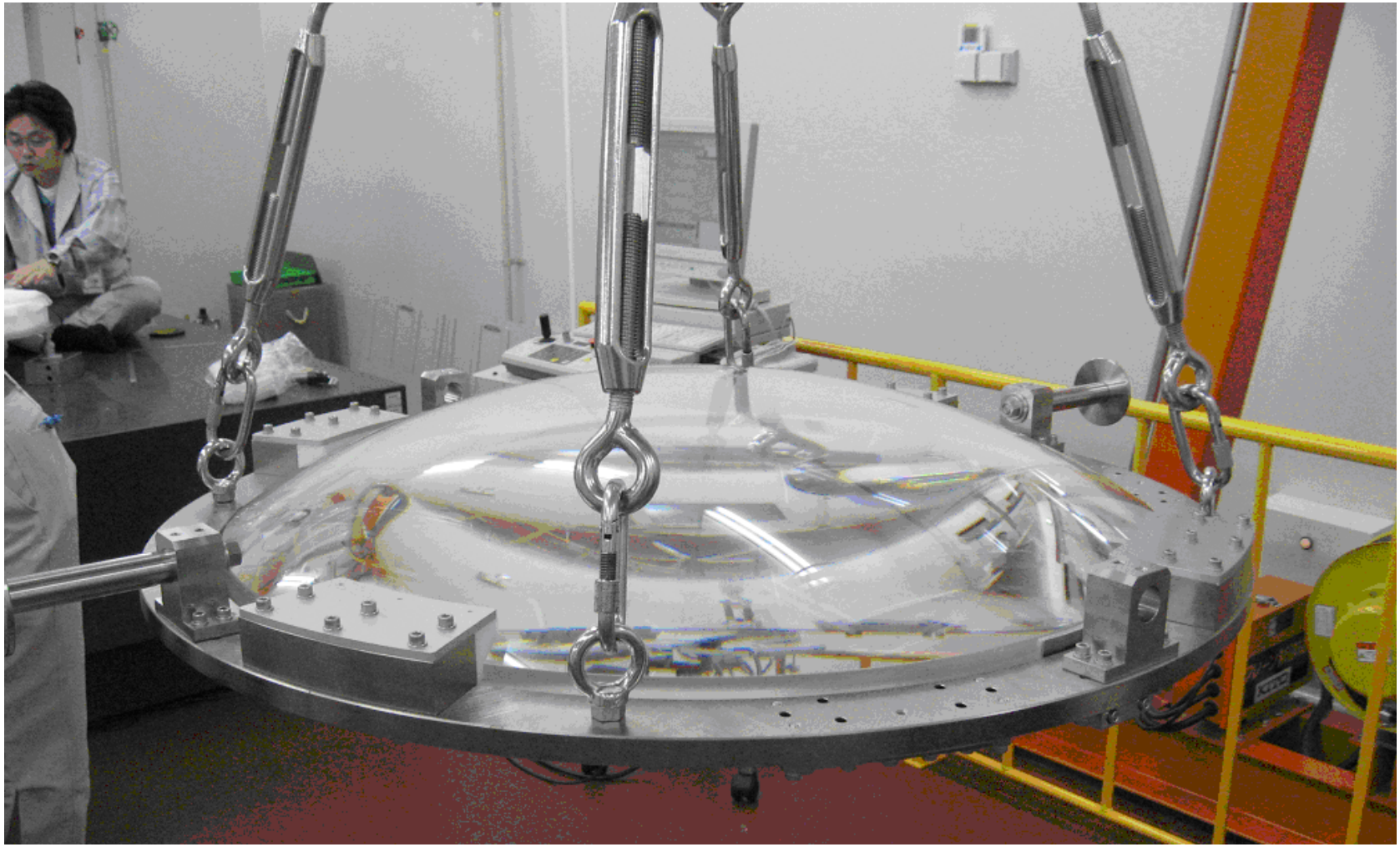
Silica: Corning

i-lines: OHARA



Procurement completed

Polishing at Canon

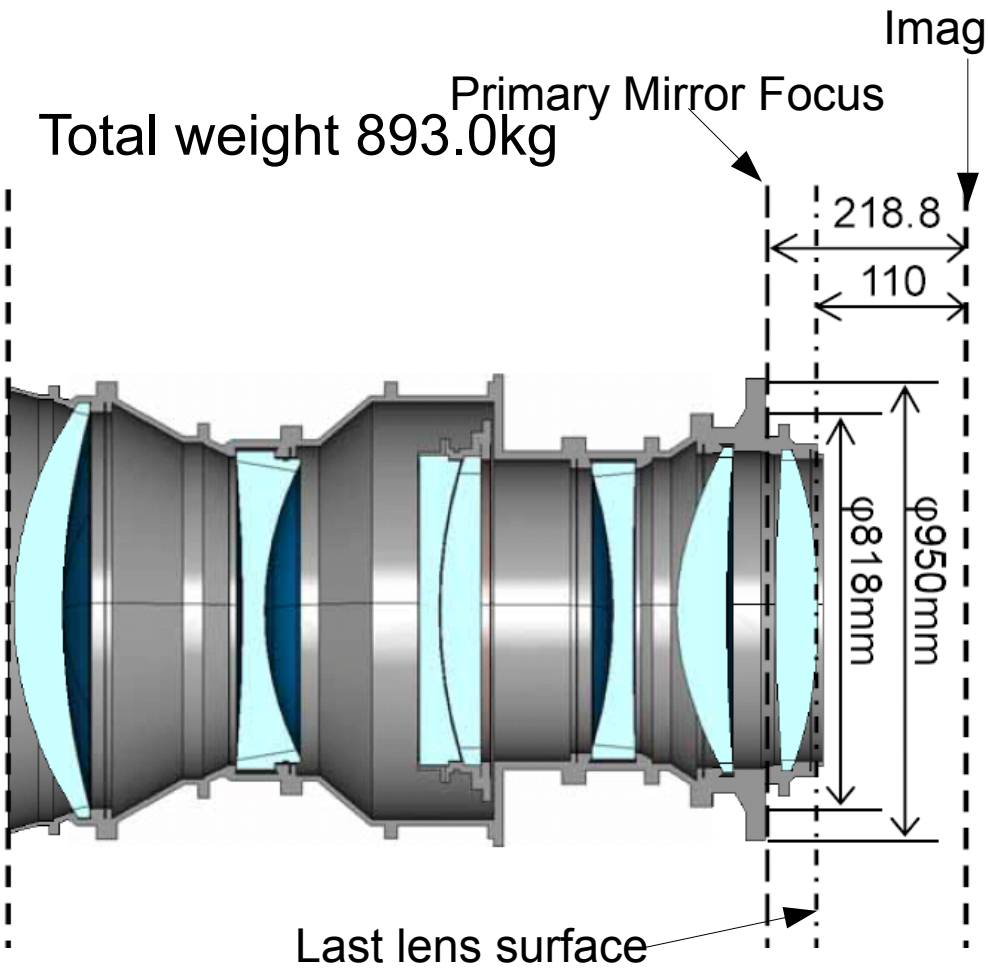


Polishing underway

2010/3E Completion incl. coating

Lens Barrel

Pile of Lens Ring Frames



Each Lens Element is retained by each lens frame.

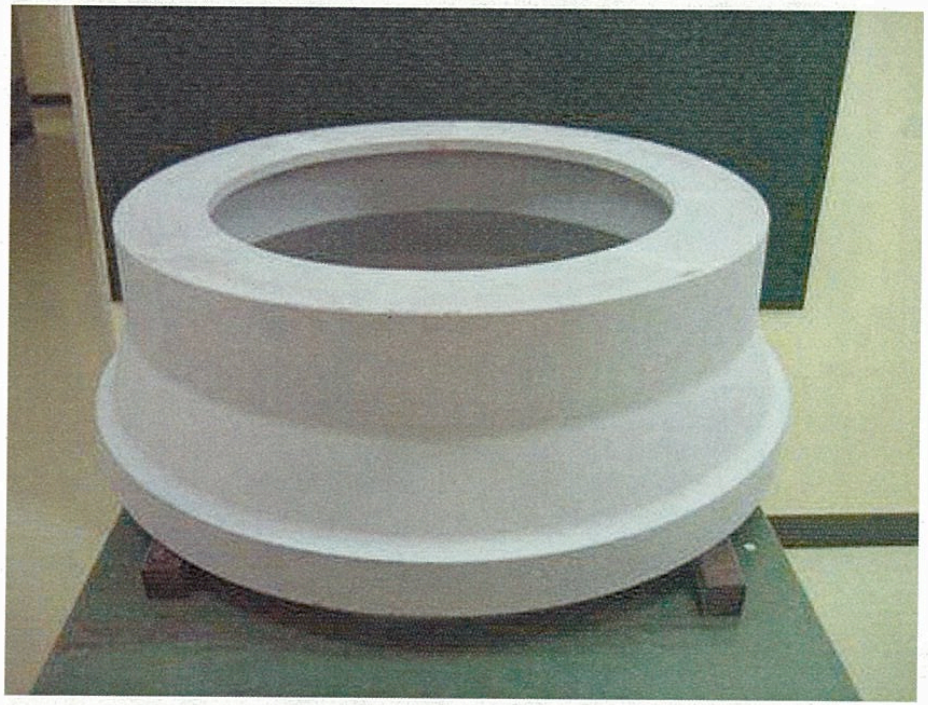
The lens frames are stacked and formed the lens barrel assembly.

Lens Frame Material
CORDIERITE

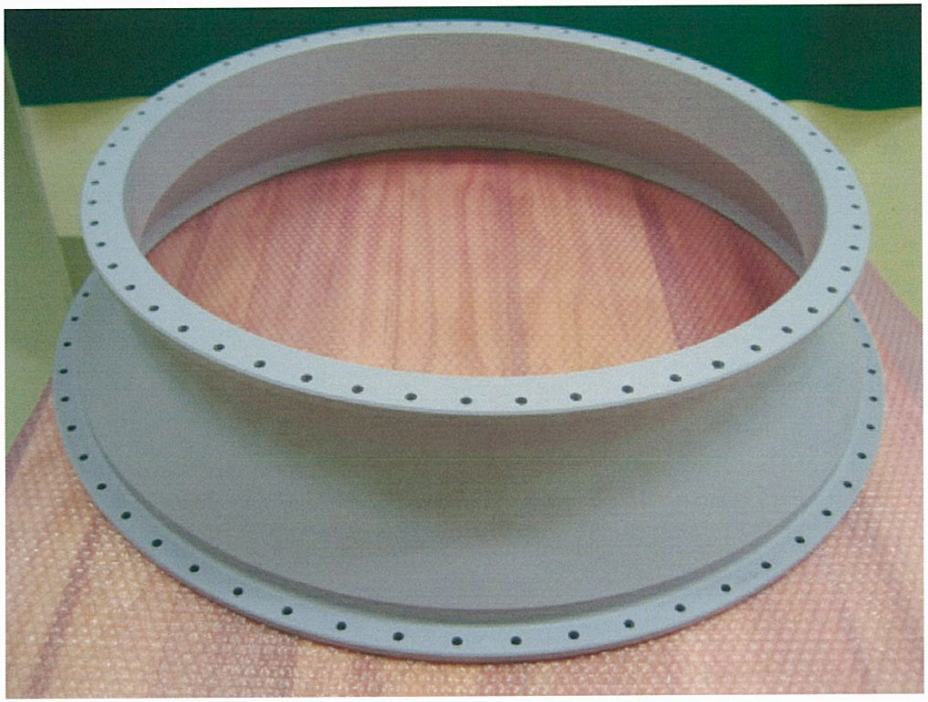
Feature

- Low CTE (< |0.1| ppm)
- High Young's modulus (~ 140 Gpa)
- mass density ~ 2.7 kg/m^3

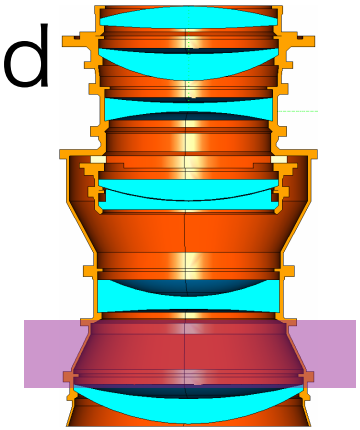
Lens Barrel from Kyocera



Sintered



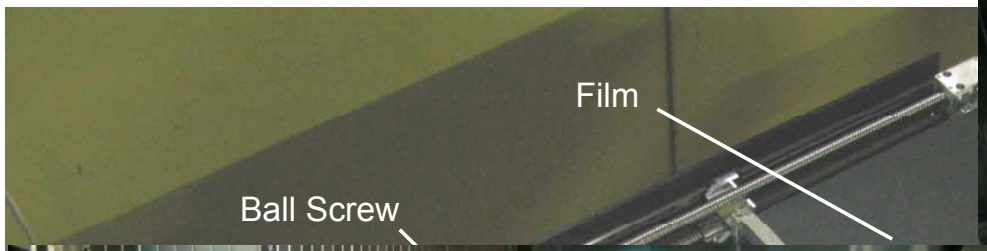
Machined

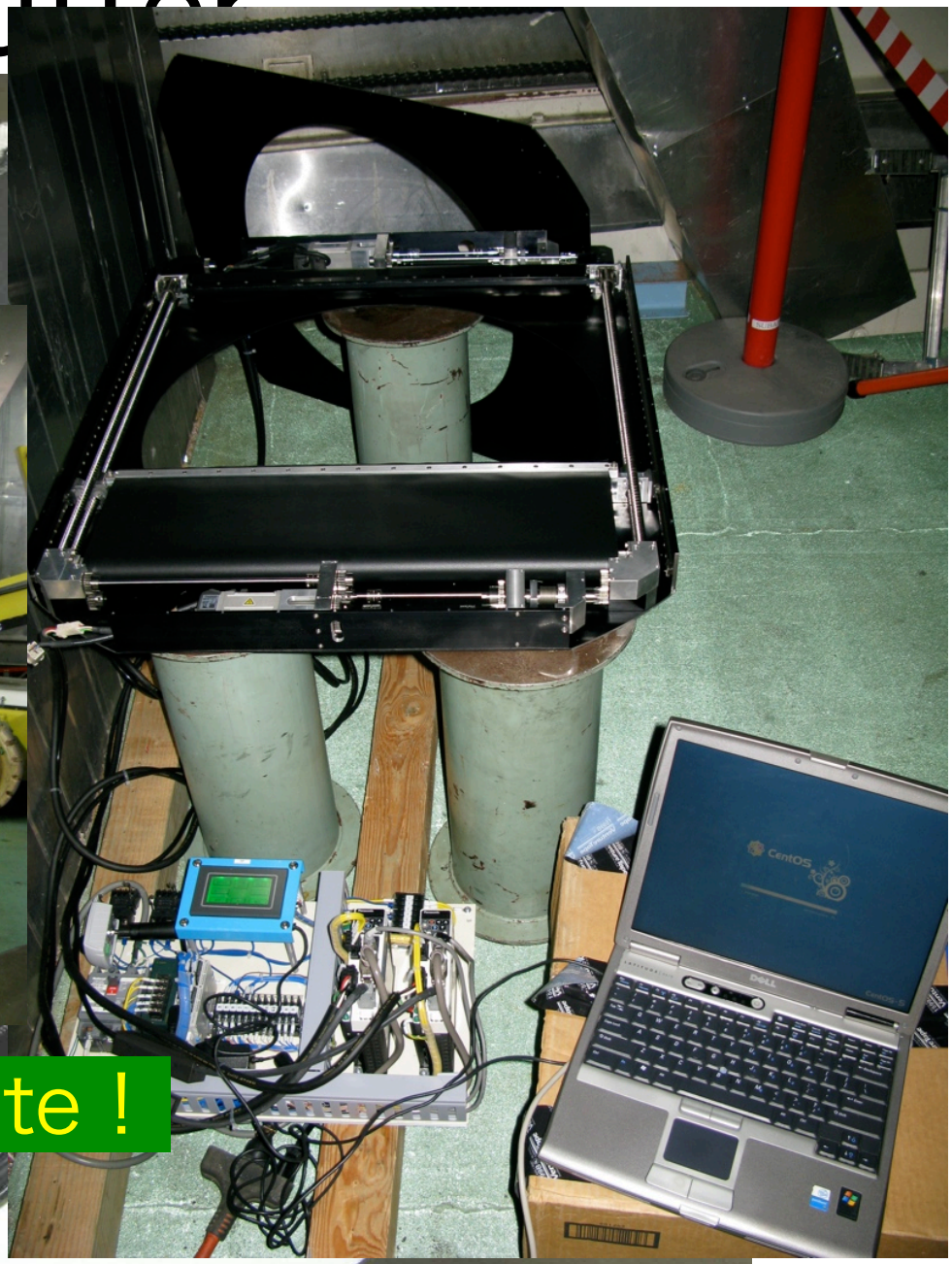


2009/11 completion 18 parts

Shutter 600 mm phi

Shu





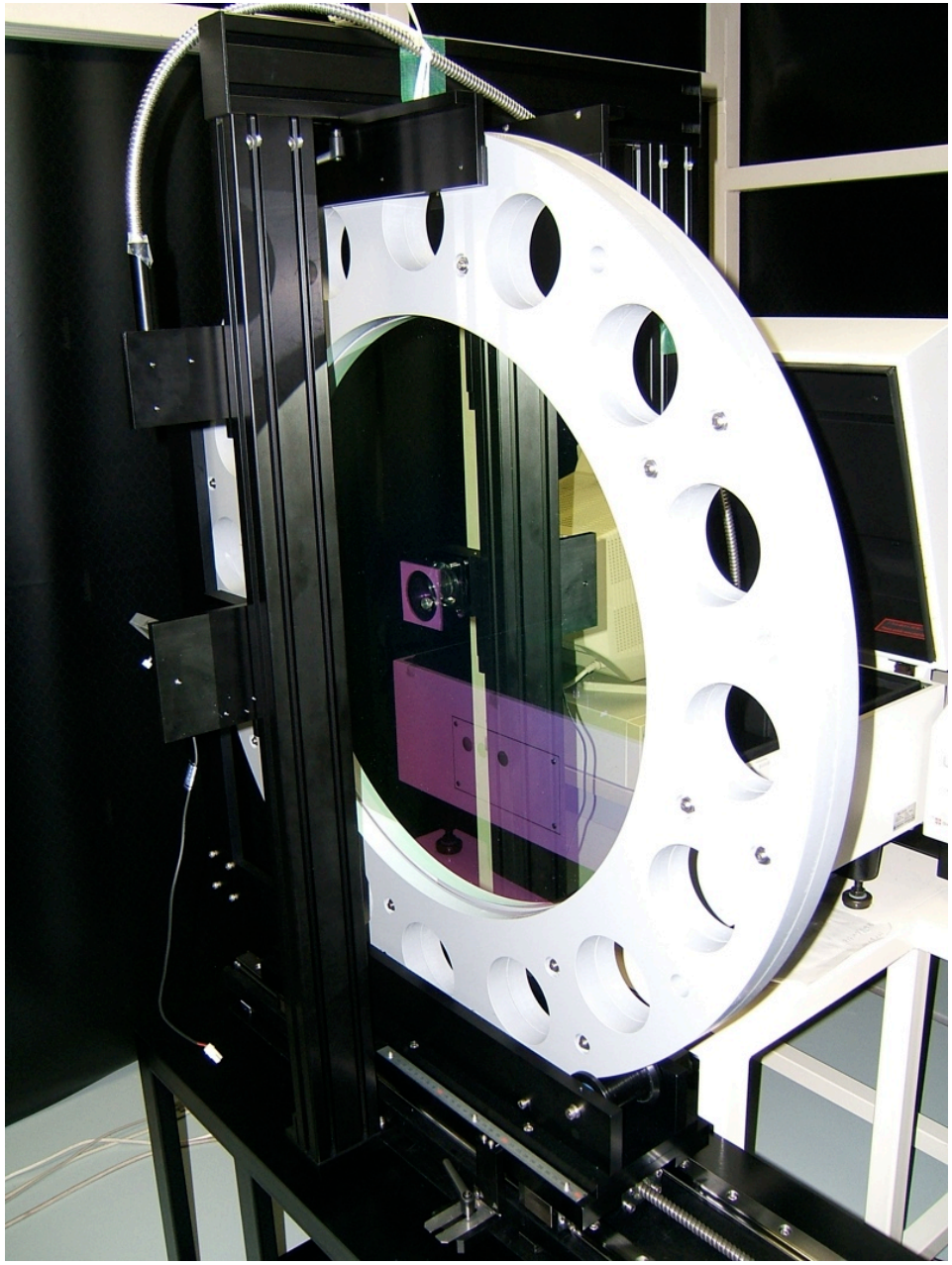
Durability test on site !

Filter

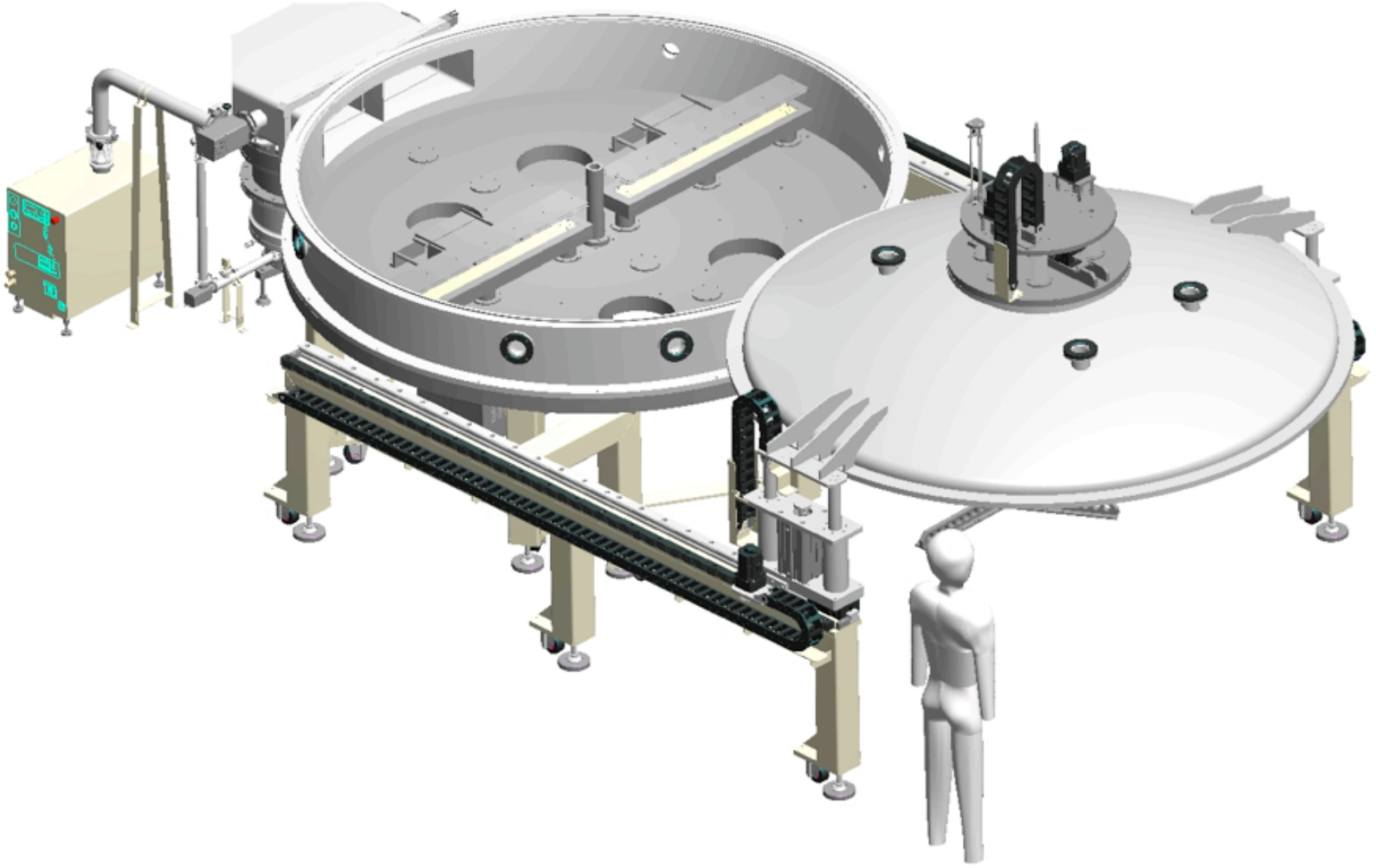
Prototyping

- Optics coating Japan
- Asahi Spectra
- Barr

They all look promising.

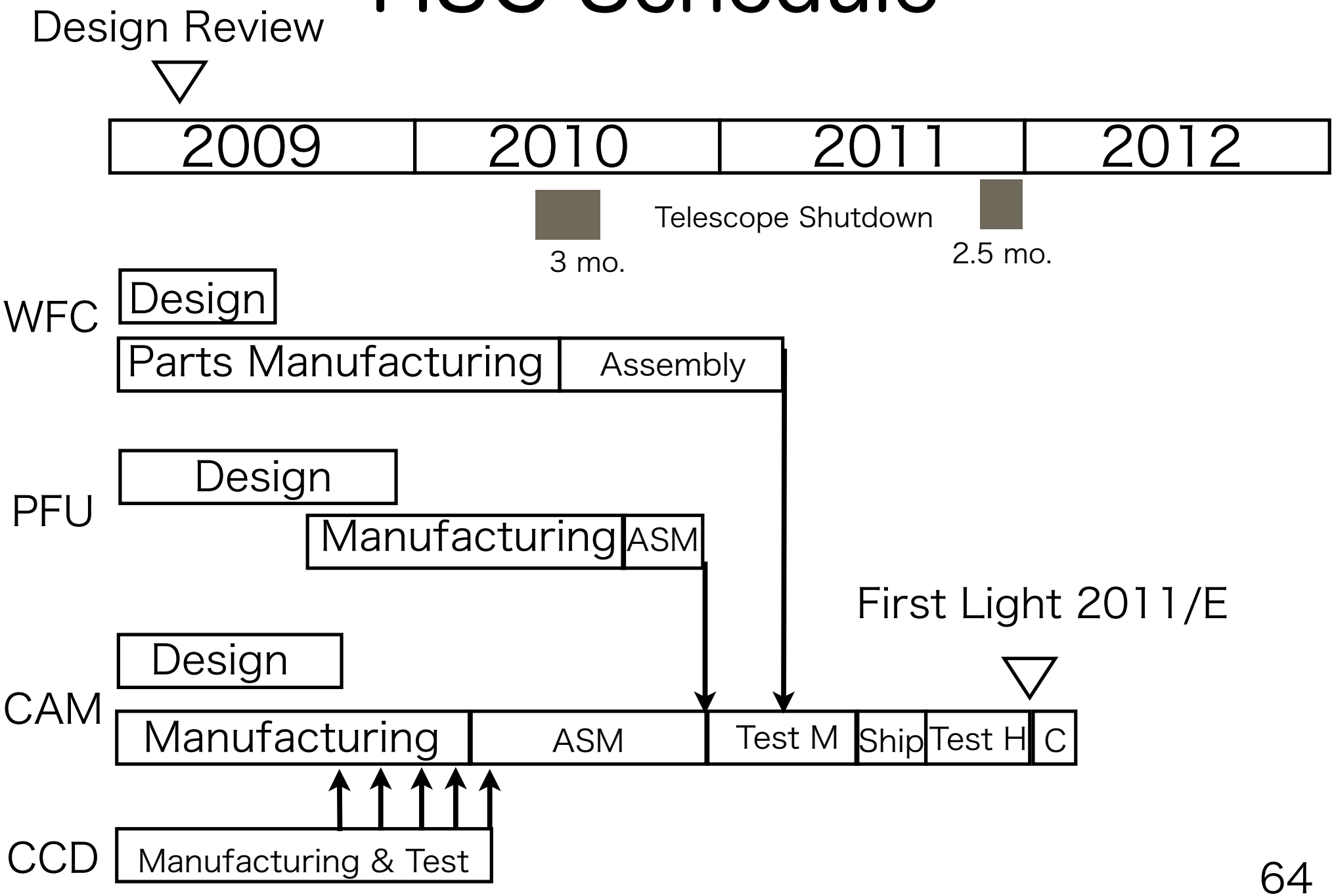


Asahi Spectra



New sputtering coating facility is being built.

HSC Schedule



Summary

	Suprime-Cam	HSC
1.	Large Aperture	
2.	Wide Field of View	Wider
3.	Superb image quality	keep it
4.	High QE in red	Higher

No fatal technical risk remains

Budget crisis being settled by stimulus money

2011/E First Light

Thank you