IGRINS-2

New IGRINS for Gemini Telescope

Heeyoung Oh &

IGRINS-2 Team @ KASI and Gemini

GSM 2022, July 25-29, 2022

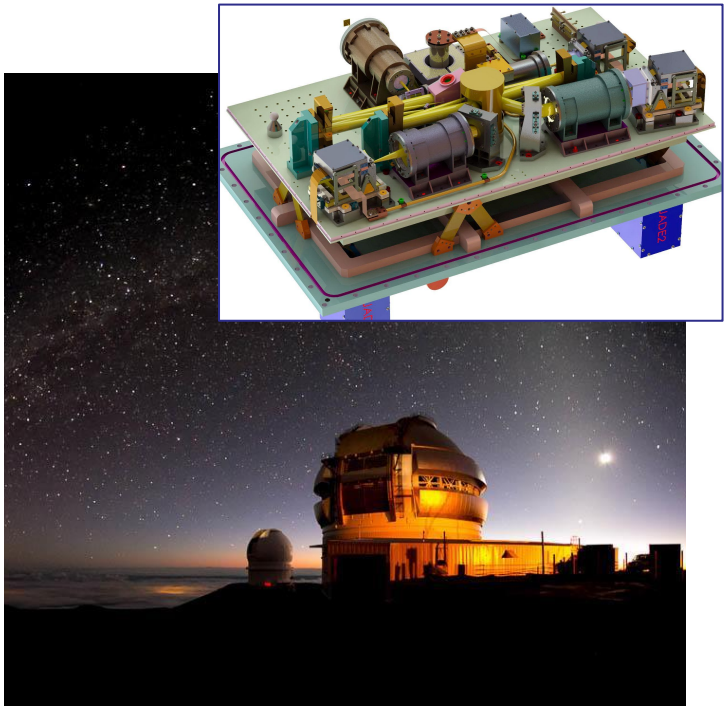
한국천문연구원
Korea Astronomy & Space Science Institute

Gemini Observatory/AURA/NOIRLab

Introduction

- The IGRINS-2 project was initiated as part of the full participant agreement between KASI and Gemini Observatory in July 2018. Specifically, **KASI will provide Gemini Observatory with an instrument very similar to the original IGRINS**.

Gemini's international headquarters @ Hilo



Gemini North

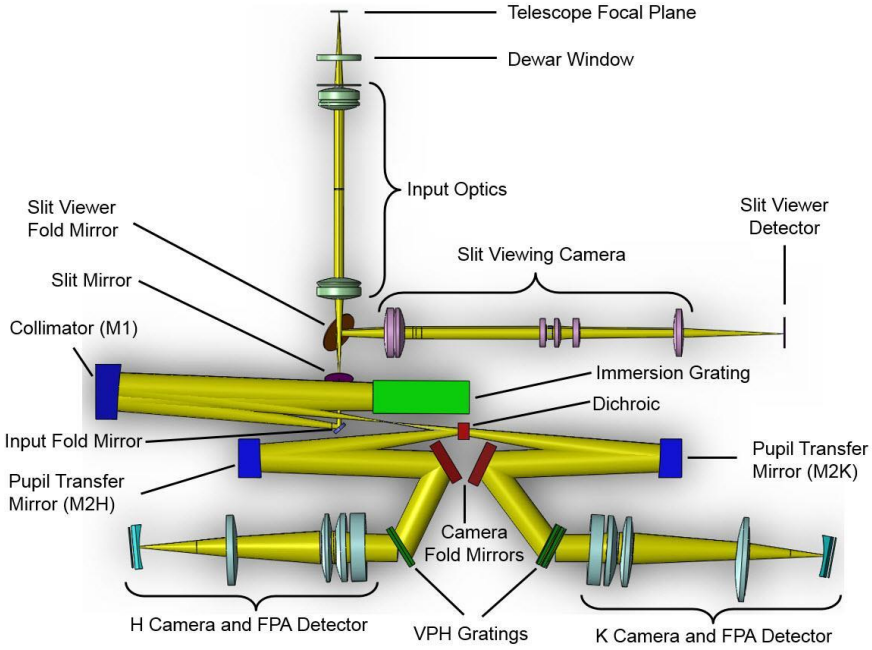
Key Milestone of the Project

Milestone	Date
Kick-off meeting	2020-03-30
Final decision on optical design options	2020-05-30
Critical Design Review (CDR) for upgrade	2020-10-30
Production Readiness Review (PRR)	2021-03-30
Slit-viewing camera lab image acquisition (start)	2022-03-30
Spectrograph integration and test in lab (start)	2022-09-30
Shipping instrument from KASI to Gemini	2023-05-30
Commissioning Readiness Review (CRR)	2023-06-30
Telescope Commissioning	2023-08-30
Operation by Gemini	2023-09-30

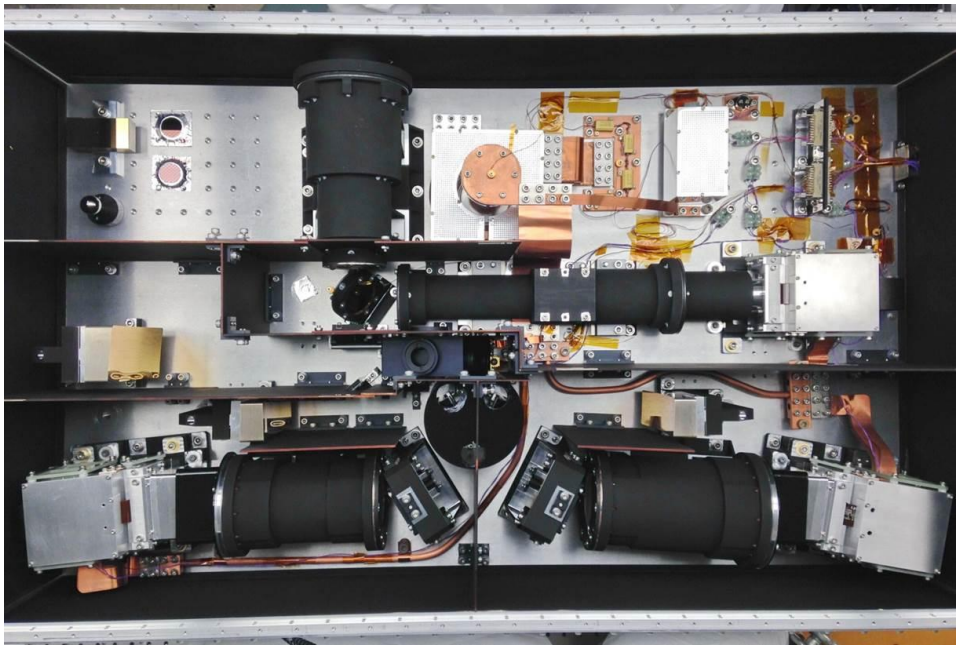
Major Science Requirement

Feature	Requirement
	1.49-2.46 µm
	5″ (5.5″ order spacing)
	3 pixels at 40,000
	0.1″ on the 8.1-m
	50,000
	21,800
	36,000 (32,000)
	<10%
	<0.25% of main line
	0.25% over R/20
	<0.01 e/s
	<2.5%
	<0.01 e/s
	1 km/s (1/2 pixel)
	0.23

Optical Design



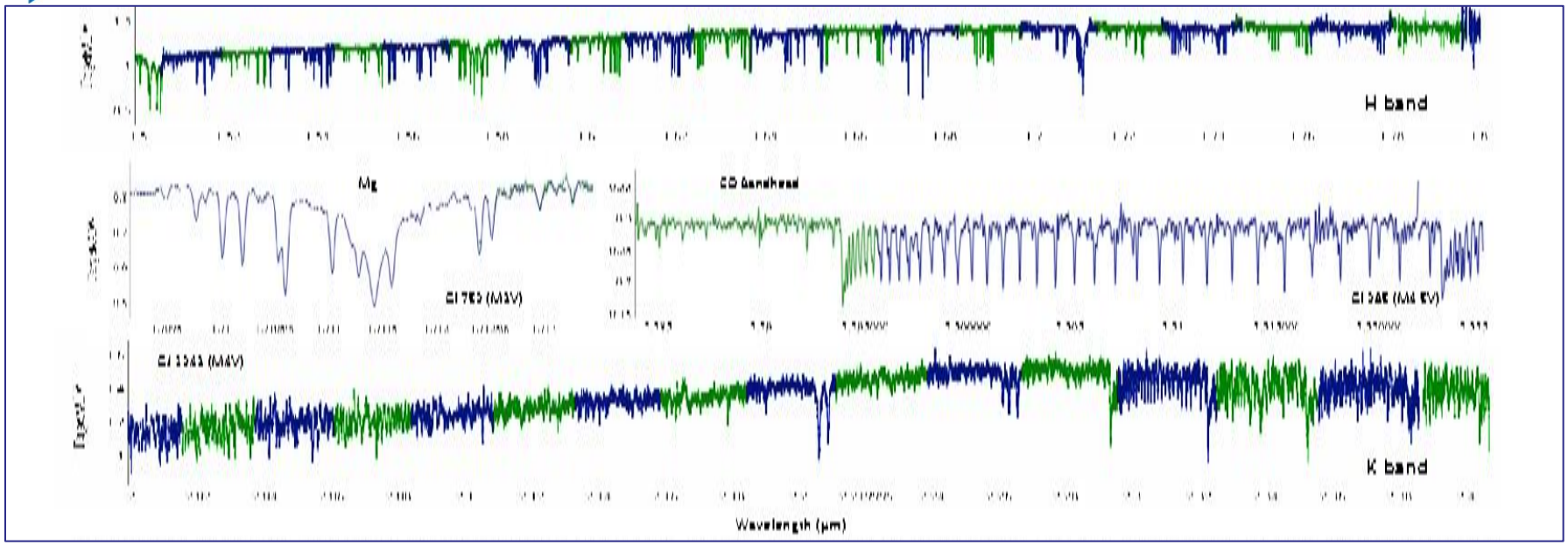
Optical Design



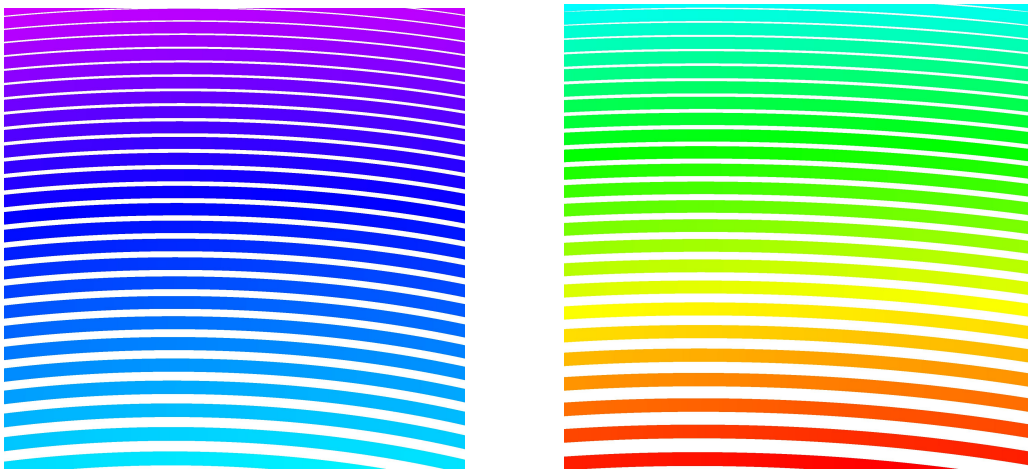
Optical bench Assembly (Original IGRINS)

- *Immersion grating*
- *VPH gratings*
- *H2RG detectors*

Spectral Grasp of IGRINS



Dr. Jae-Joon Lee (KASI) - https://github.com/igrins/plp



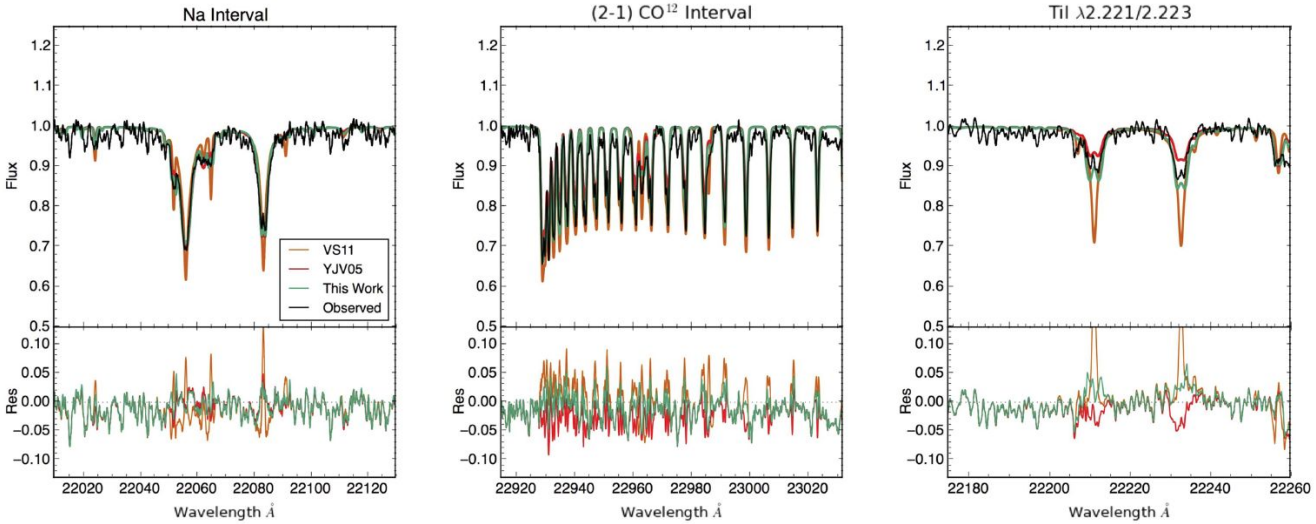
Single shot covers whole H & K bands 1.49-2.46 μm

Science Cases

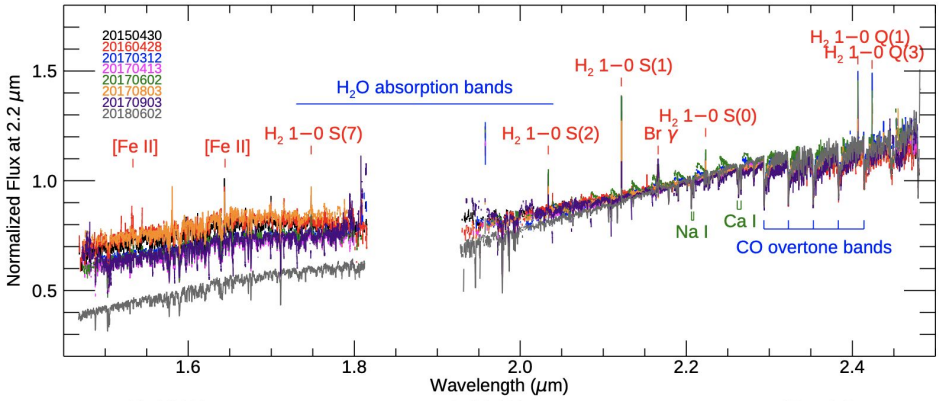
- NIR, high-resolution spectroscopy with high sensitivity.

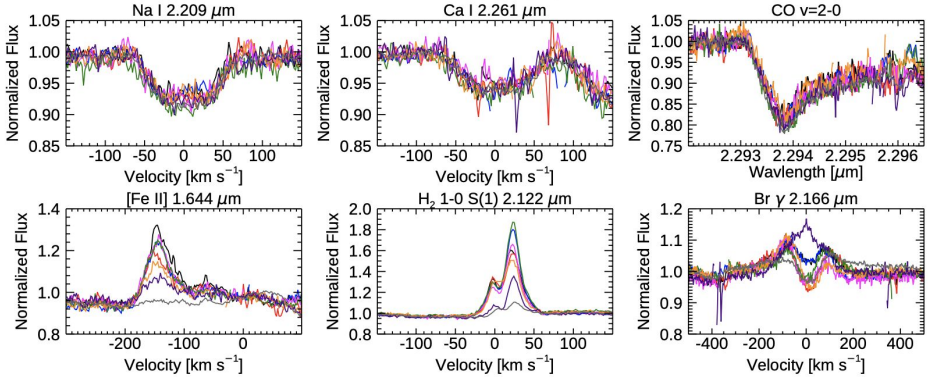
- **Young Steller Objects (YSOs) Evolution**
  - Fundamental stellar properties of T_{eff}, log g, B field
  - < 10 km/s resolved photospheric lines in the majority of YSOs
  - CO, Na, Mg, Ti, Ca, Al, etc.
- **YSO Disks**
  - CO from inner disk, H_2O, accretion features (Br_gamma)
- **Stellar Population and Chemical Evolution**
  - Metallicity from various species, carbon to oxygen ratio of metal poor star
- **RV Studies**
  - Binaries, Brown Dwarf, Yong Planet with ~1 km/s RV precision
- **Interstellar Medium (PNe, Supernova Remnants, PDR)**
  - Ro-vibrational transitions of H_2 in the H and K bands
  - UV-pumping, shocks with H_2 at 2.12 μm, [Fe II] at 1.644 μm
- Galactic Center
- Solar System Bodies

Young Stellar Objects



"Characterizing TW Hydra"
(Sokal et al. 2018)

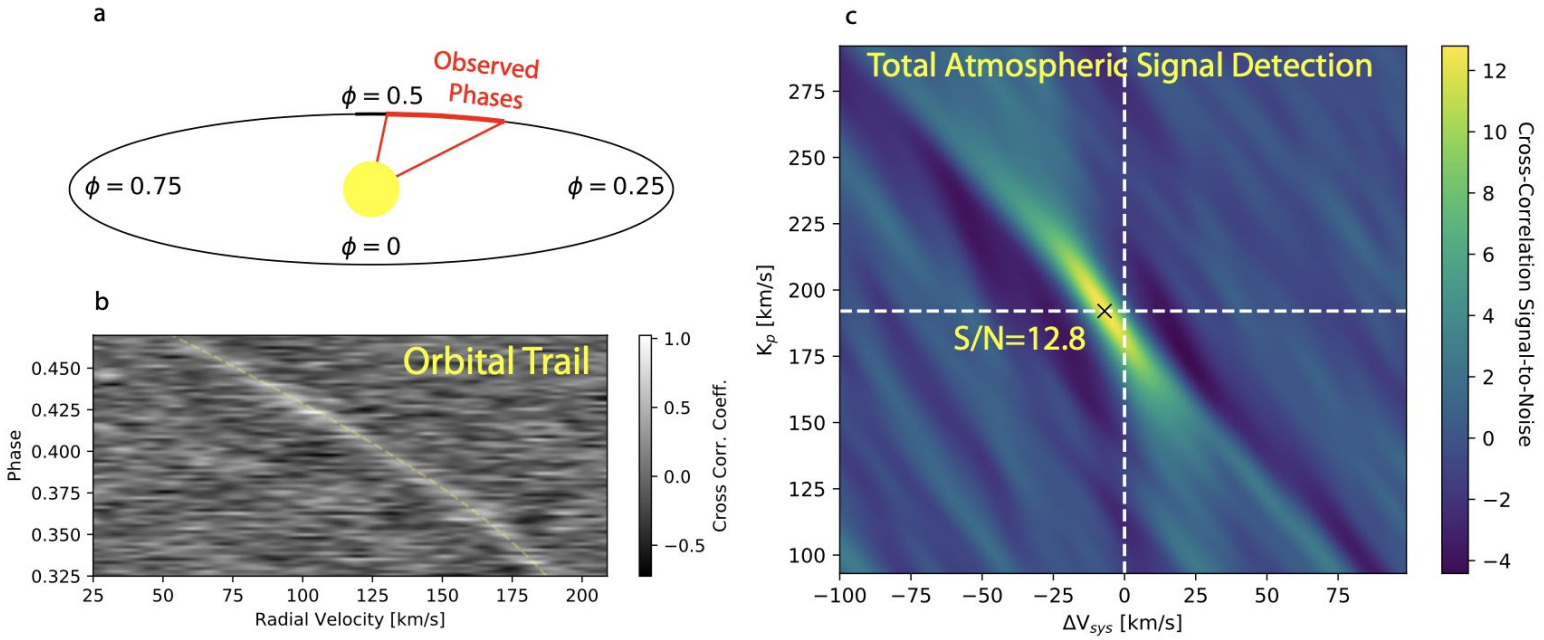




"Evidence of Accretion Burst: The Viscously Heated Inner Disk of the Embedded Protostar IRAS 16316-1540 (Yoon et al. 2021)

IGRINS Science Example

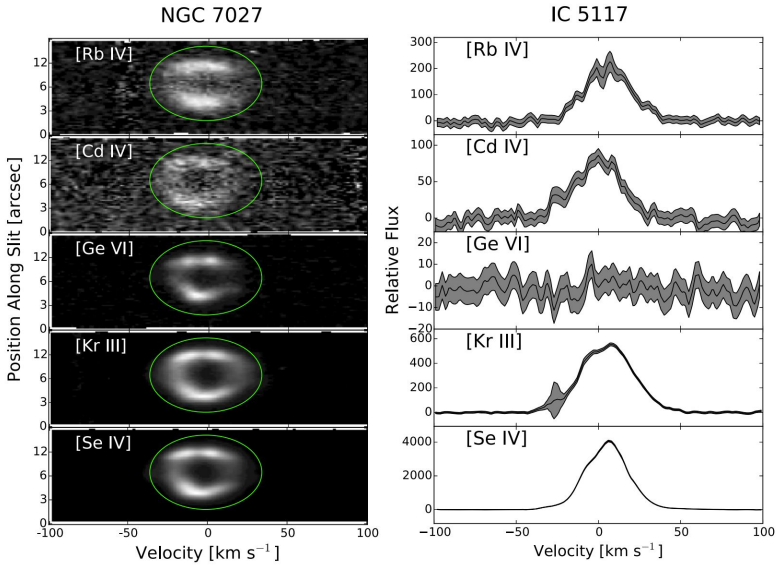
Exoplanet



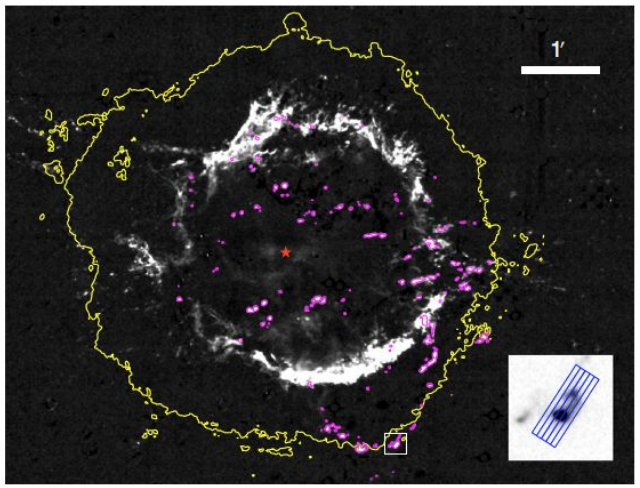
"A Precise Carbon and Oxygen Abundance Determination in a Hot Jupiter Atmosphere" Line et al. (2021, Nature)

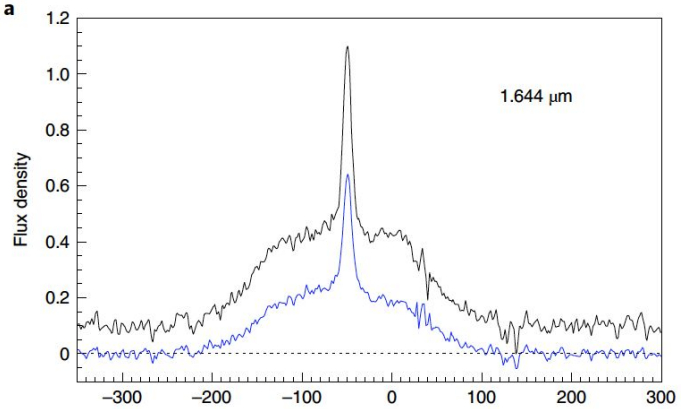
IGRINS Science Example

ISM Studies



"Discovery of Rubidium, Cadmium, and Germanium Emission Lines Planetary Nebulae" (Sterling et al. 2016)





"Detection of pristine circumstellar material from Cas A" (Koo et al. 2020)

IGRINS-2 Development Status

KASI Instrument Team

P.I. Chan Park

Optics

Kang-Min Kim

Mechanics

JaeSok Oh, JG Jang, BH Jang, Chan Park

Electronics

Ueejeong Jeong, YS Yu, HC Seong

Project Manager

Yunjong Kim

Sanghyuk Kim

YoungSam Yu

Moo-Young Chun

In-Soo Yuk

KASI Team

Heeyoung Oh

Hye-In Lee

Systems Eng.

Sungho Lee

Software

UJ Jeong, Jae-Joon Lee

Gemini Team Members

Key members

- Project Manager: Hwihyun Kim (GS)
- Systems Engineering: Brian Chinn (GS)
- Engineering support: John White (GN), Eduardo Tapia (GN)
- Software Engineering: Francisco Ramos (GS), Ignacio Arriagada (GS)
- Science Operation Support: Pablo Prado (GS), Hyewon Suh (GN), Jennifer Miller (GN)

Advisory members

- Project Sponsor/Program Science support: Ruben Diaz (GS)
- Telescope Scientist: Thomas Hayward (GN)

- The instrument specs remain the same
- Reasons for changes
  - It's been 10 year since IGRINS was developed, some products are discontinued
  - To upgrade (within the given schedule)

- Major Change and Upgrade
  - Optics: Slit-view FoV upgrade
    - IGRINS SVC field of view is incomplete (~60%) circle
    - IGRINS-2 will have circular FoV
  - Mechanics: Light tightening
    - One-body radiation shield
    - Connectors, cooler assembly
  - Electronics: MACIE detector controller
    - JADE2, the interface board for the original IGRINS, has been discontinued by Teledyne.
    - MACIE is the new interface board for IGRINS-2

Summary of Design Change/Upgrade

	#	Task Title	Purpose/Reason	IGRINS	IGRINS-2
Optical Design	OP-01	Input fold mirror position	To improve SVC FoV	-	Relative 3 mm movement toward H & K spectrograph
	OP-02	Position of M1 collimator, immersion grating, and all following elements	To improve SVC FoV	-	Relative movement followed by change of input fold mirror
Mechanical Design	ME-01	Optical bench flexure upgrade	To improve instrument flexure	-	Re-optimize the lightweight pattern of optical bench
	ME-02	Radiation shield upgrade	Light tightening	integration of 5 separate plate	Single-body
	ME-03	Shield-bench coupling upgrade	Light tightening	stair shape	Tongue and groove
	ME-04	Interface between cooler assembly and bench	Light tightening	-	Bellows
	ME-05	Connector and cable upgrade	Light tightening	- wire for temp. sensor - flex cables for detector	Hermetic connector
	ME-07	Mechanical upgrade followed by optics change: Positions of input fold mirror, M1 collimator and all following optical elements, slit mirror & mount)	Result of optics change	-	1. Fix M1 collimator position, and making relative movement on input optics, slit mirror, SV fold mirror, SVC, and input fold mirror 2. Design updates for slit mirror and slit mirror mount
	ME-08	Telescope mount and Dewar design update	Result of optics change	-	Tel. mount and Dewar design update to compensate shift of IO toward telescope focus

Summary of Design Change/Upgrade

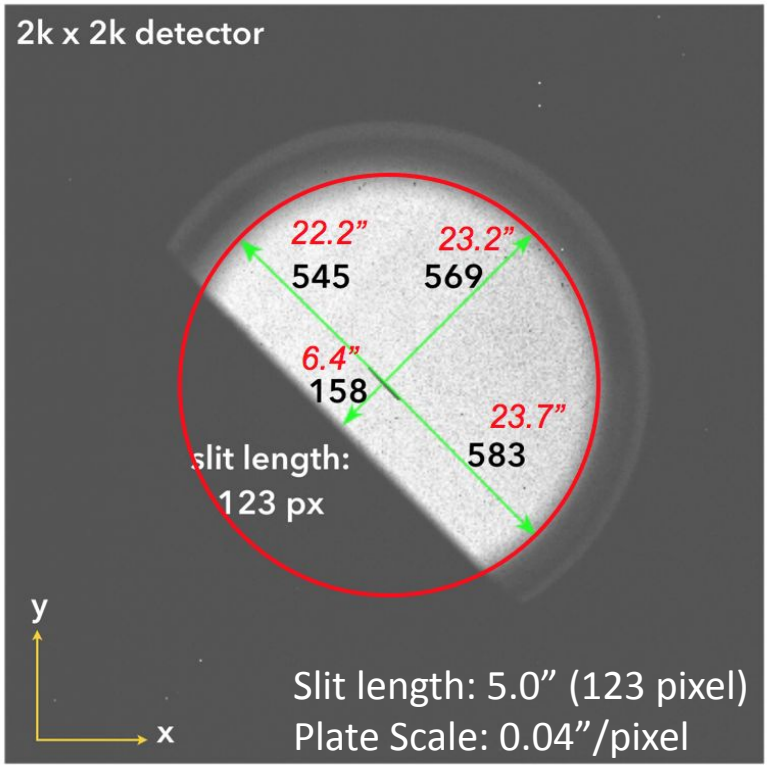
	#	Task Title	Purpose/Reason	IGRINS	IGRINS-2
Electronics	EL-01	Stability test of interface between Sidecar & DCC	Jade2 is discontinued, even SAM	Jade2 (USB2.0)	MACIE (GbE)
	EL-02	Detector Control Computer (DCC)	upgrade	Windows Socket Server	Linux or Windows (OS for running socket server)
	EL-03	Instrument Control Computer (ICC)	to be Gemini facility inst.	iMac	Linux based Computer (Gemini) or iMac *Python code Porting or nothing
	EL-04	Temperature Sensor change	to simplify concept, more heritage	Diode & Cernox	PT100
	EL-05	CTI cold head power supply upgrade	to reduce noise and vibration	helix external power supply (one to two phase)	3 to 2 phase, we will make new power supply box
	EL-06	Location of heat exchanger in electronics enclosure	to reduce risk of coolant leak	top of electronics enclosure	bottom of the electronics enclosure
	EL-07	Vacuum Gauge upgrade	upgrade	Pfeiffer (Sensor, remote controller)	MKS 972B (controller on the sensor) *10^-7 Torr to Atmosphere
	SO-01	Detector control software	to use MACIE	teledyne provided Jade 2 software	MACIE software
Calibration	CA-02	Simplifying Housing and Mounts	to minimize/simplify design by disabling unused func.	-	Replace lamp selector module with a single beam splitter
	CA-03	Adjust cal housing regarding change of Dewar	change of Dewar dimension due to new radiation shield design	-	reduce the distance between cal focus and bottom plate of cal housing by 8mm
Software	SO-02	Observing software	to be Gemini facility inst.	independent software	Upgrade to be compatible with GIAPI
	SO-03	Pipeline	to be Gemini facility inst.	independent code	Upgrade to be adopted to DRAGONS

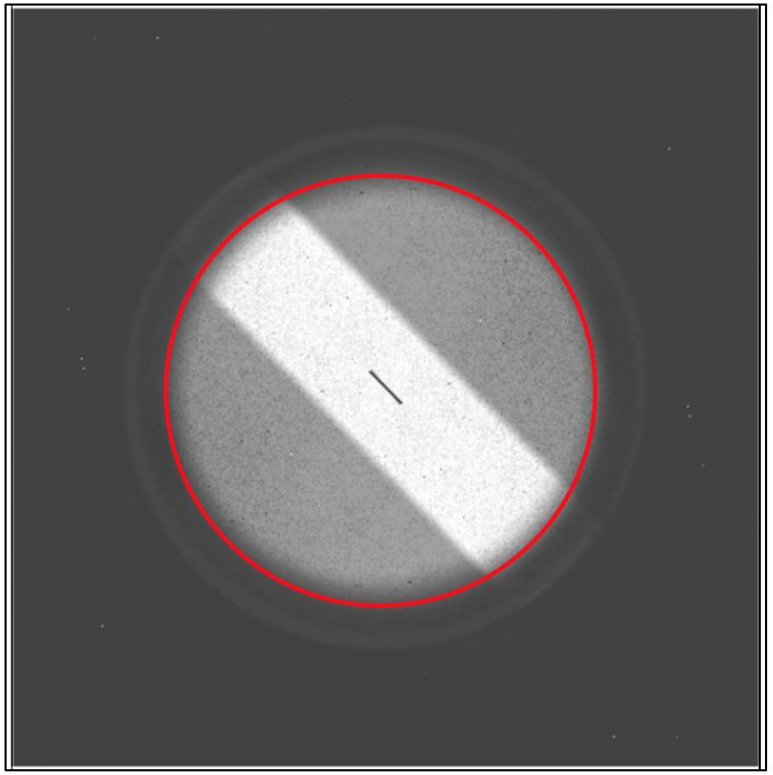
Upgrade of SVC Field of View (1/2)

Original IGRINS:
With current optical & mechanical design, IGRINS SVC field of view is incomplete (~60%) circle in order to secure science beam

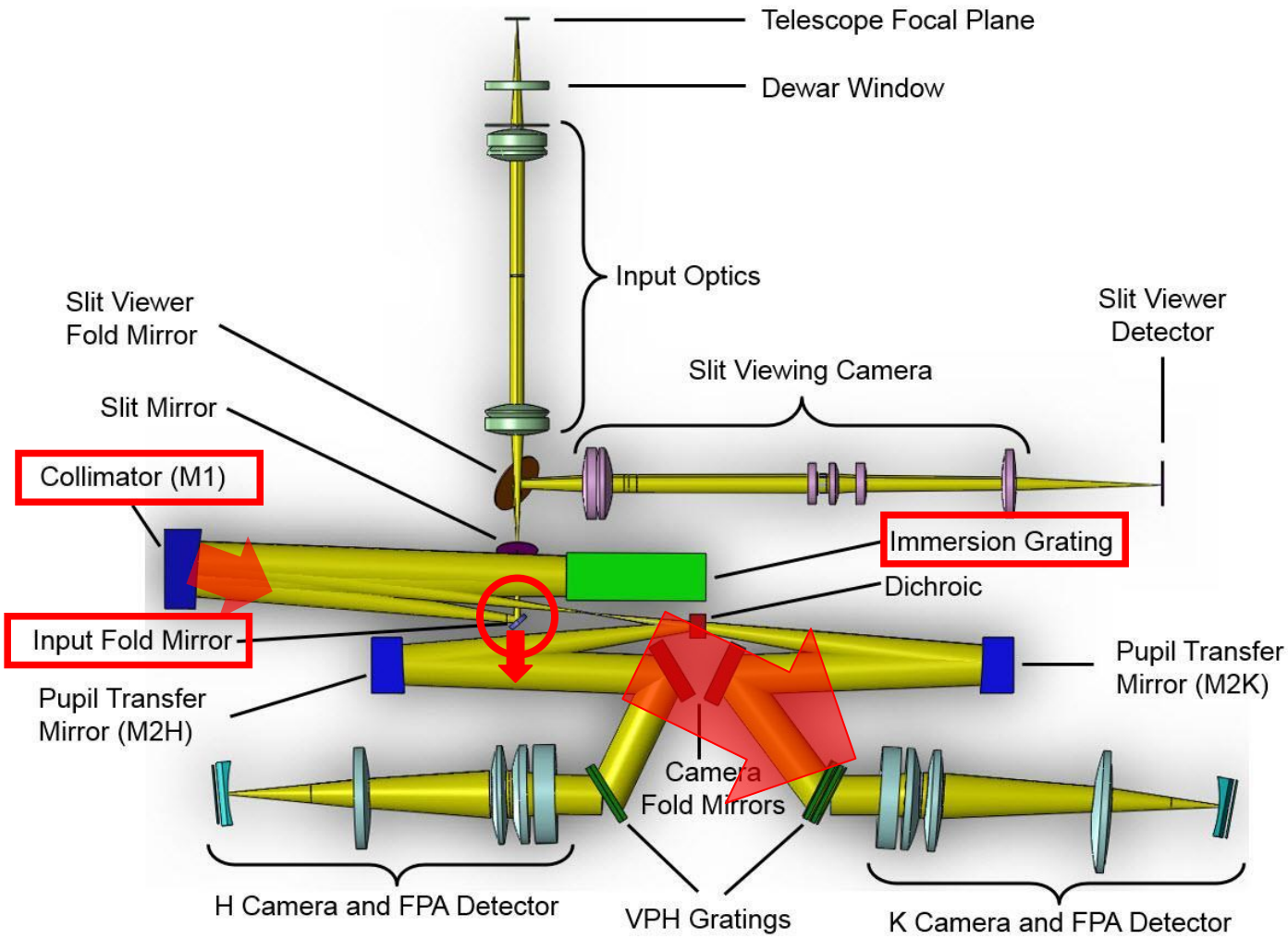
IGRINS-2:
IGRINS-2 with a whole circular field

- To achieve better target acquisition & guiding
- To better utilize detector area

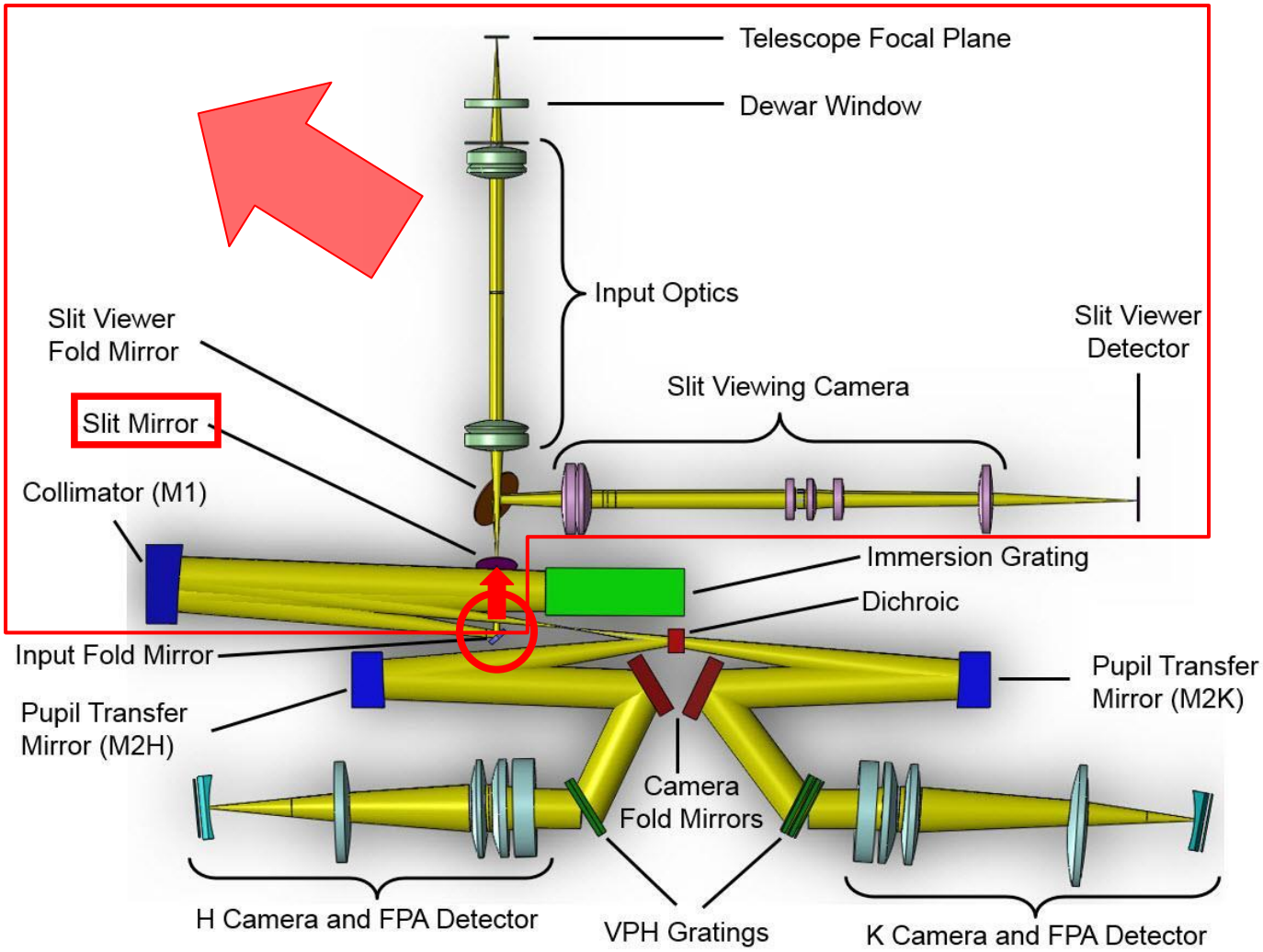




Upgrade of SVC Field of View (2/2)

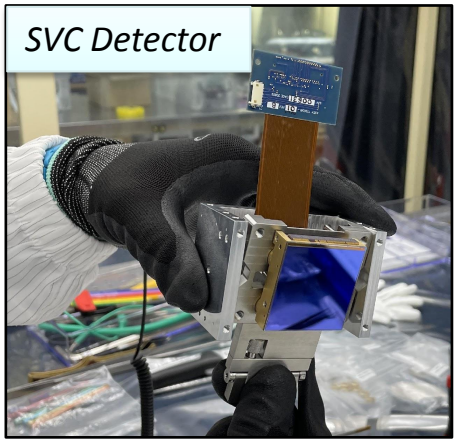


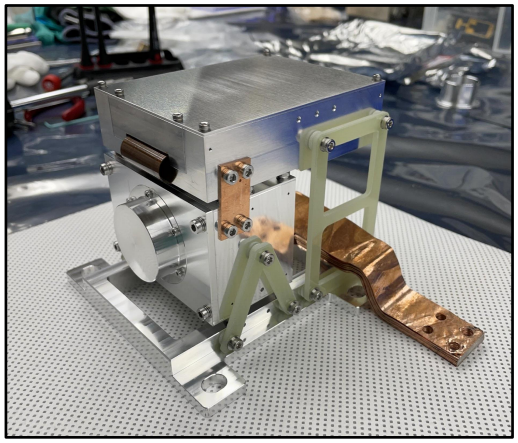
Application of Solution Option 1

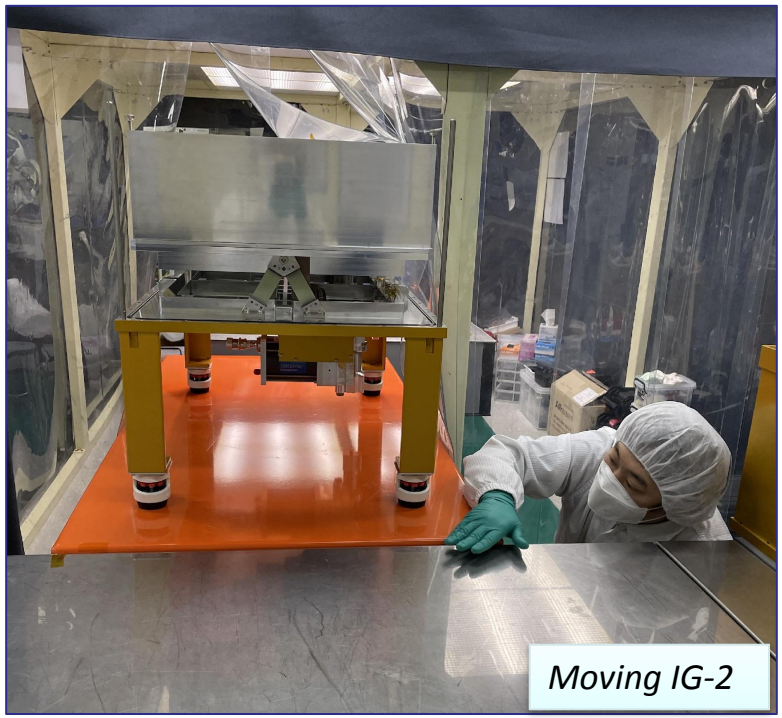


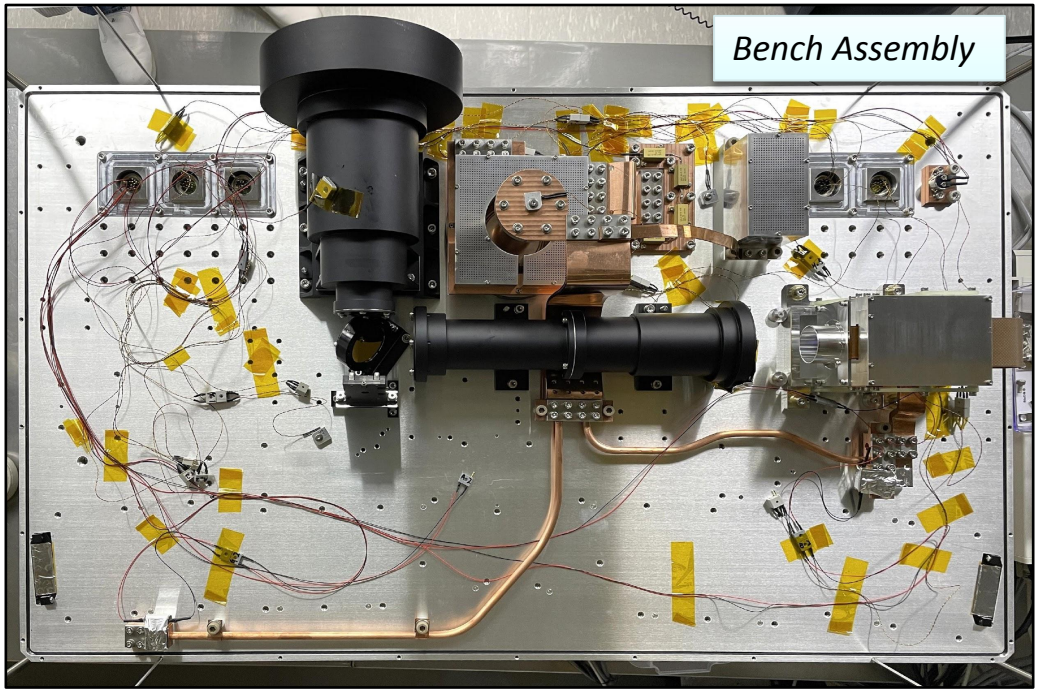
- Solution option is applied by changing the relative physical location of IO and SVC in the mechanical part

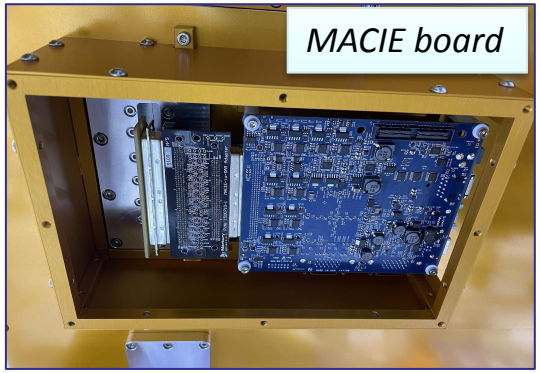
KASI Lab Activity (1/3)


SVC Detector

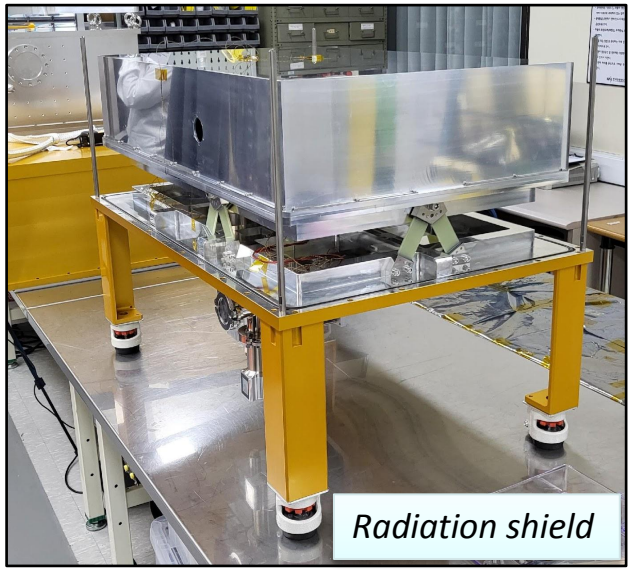



Moving IG-2

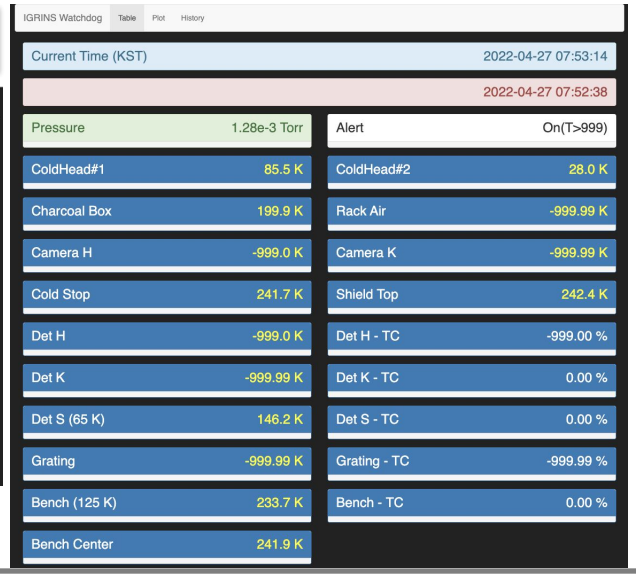

Bench Assembly


MACIE board

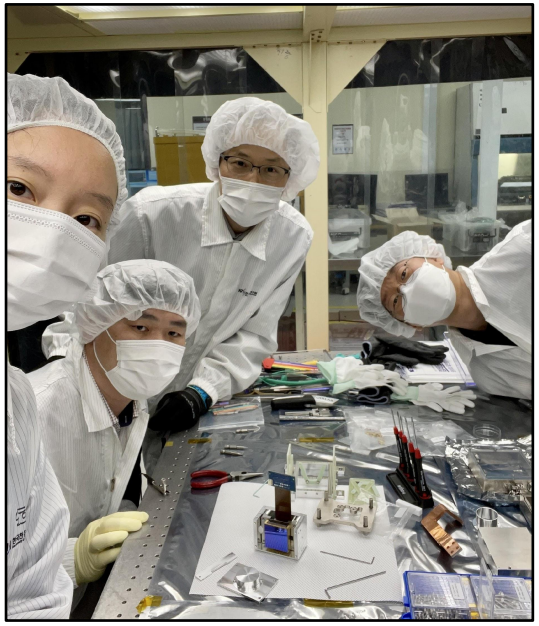
KASI Lab Activity (2/3)

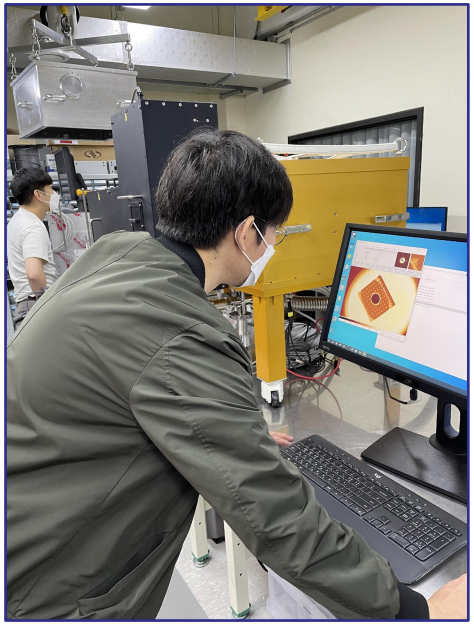


Web monitoring

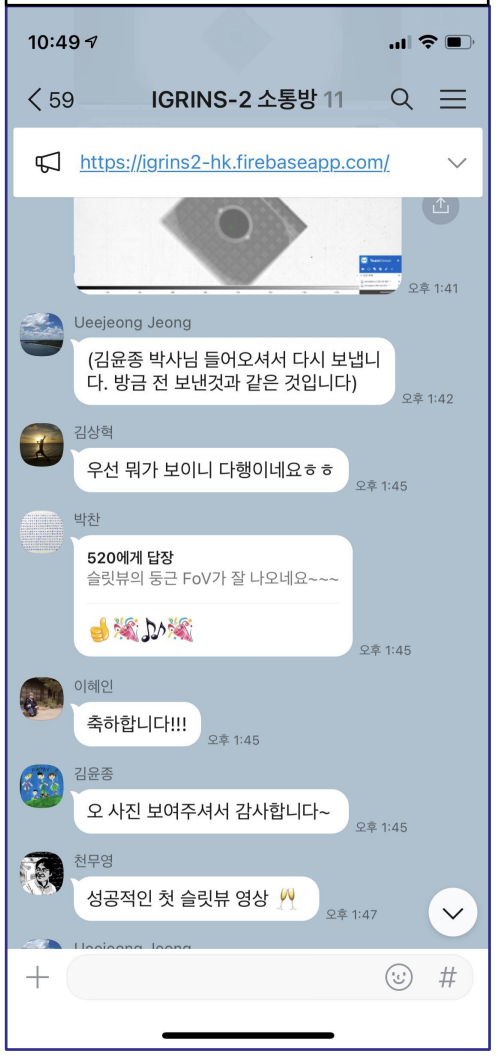


KASI Lab Activity (3/3)

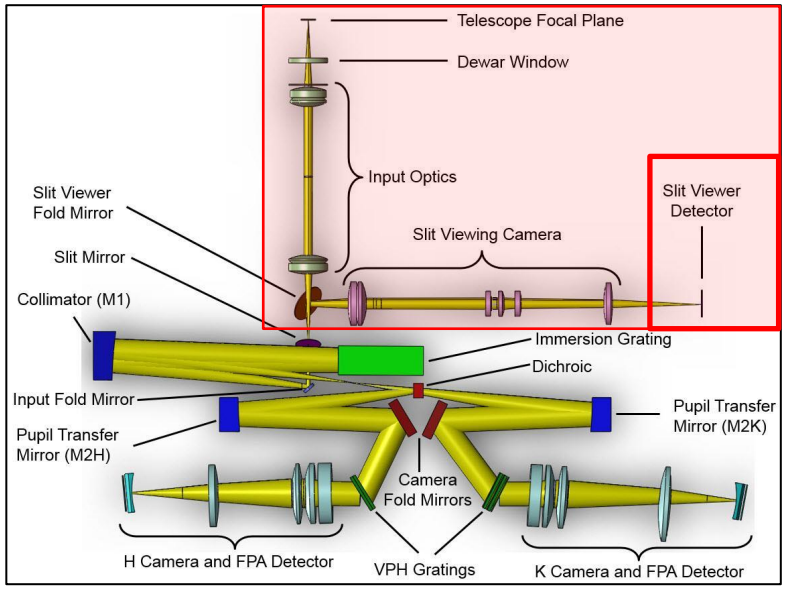


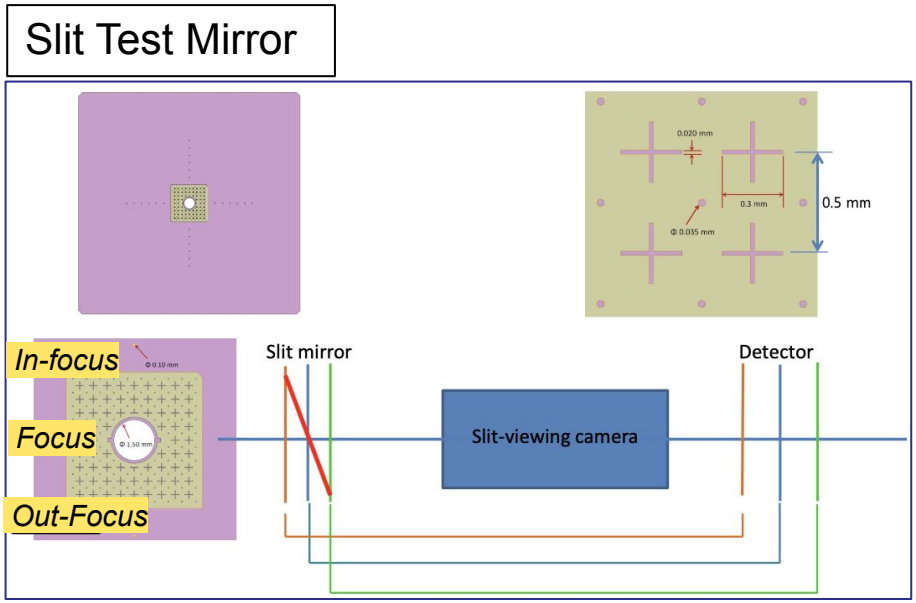


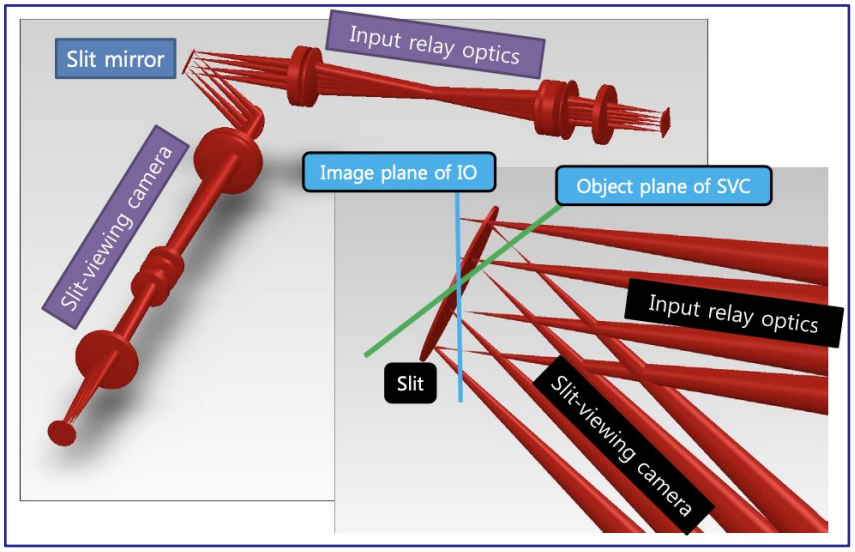
KASI team communication chat

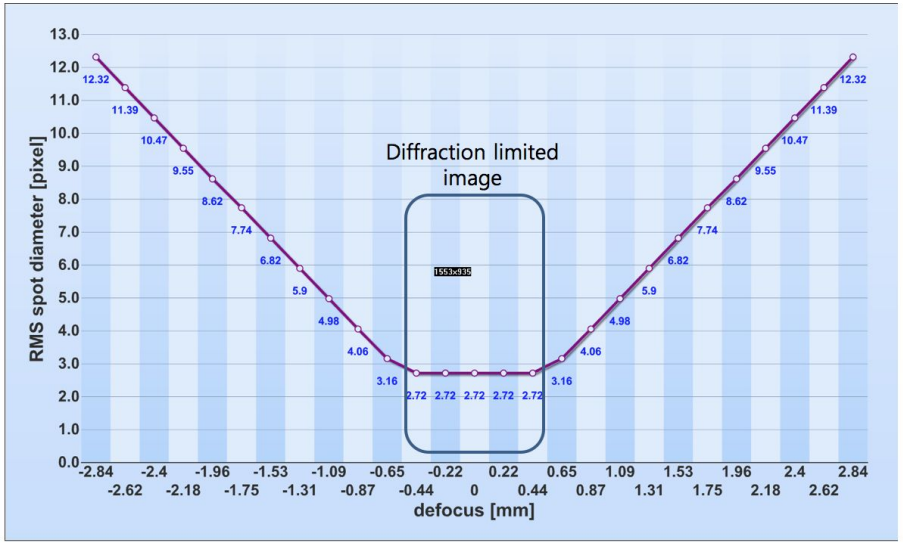


Alignment of SVC Detector: Method

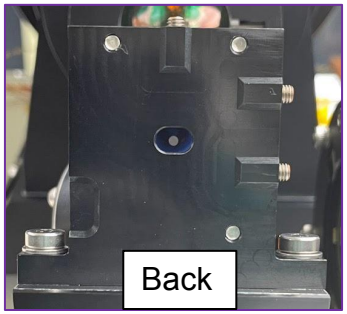


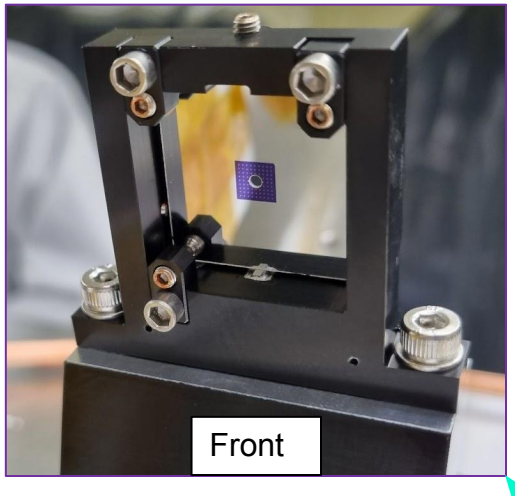




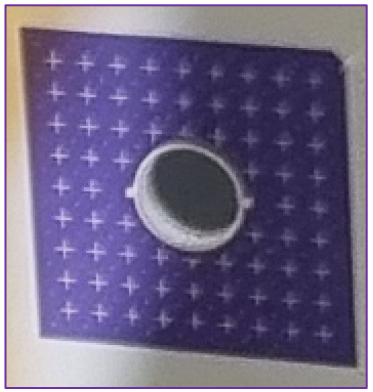


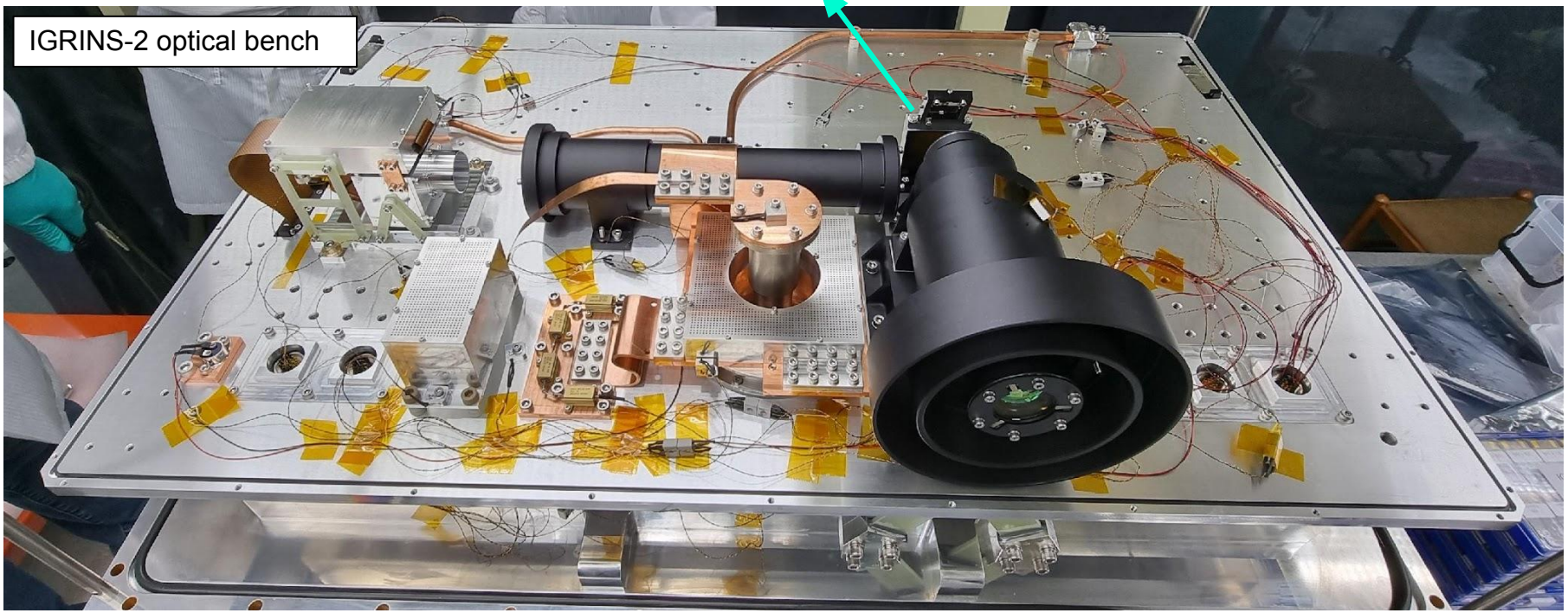
Alignment of SVC Detector: Setup





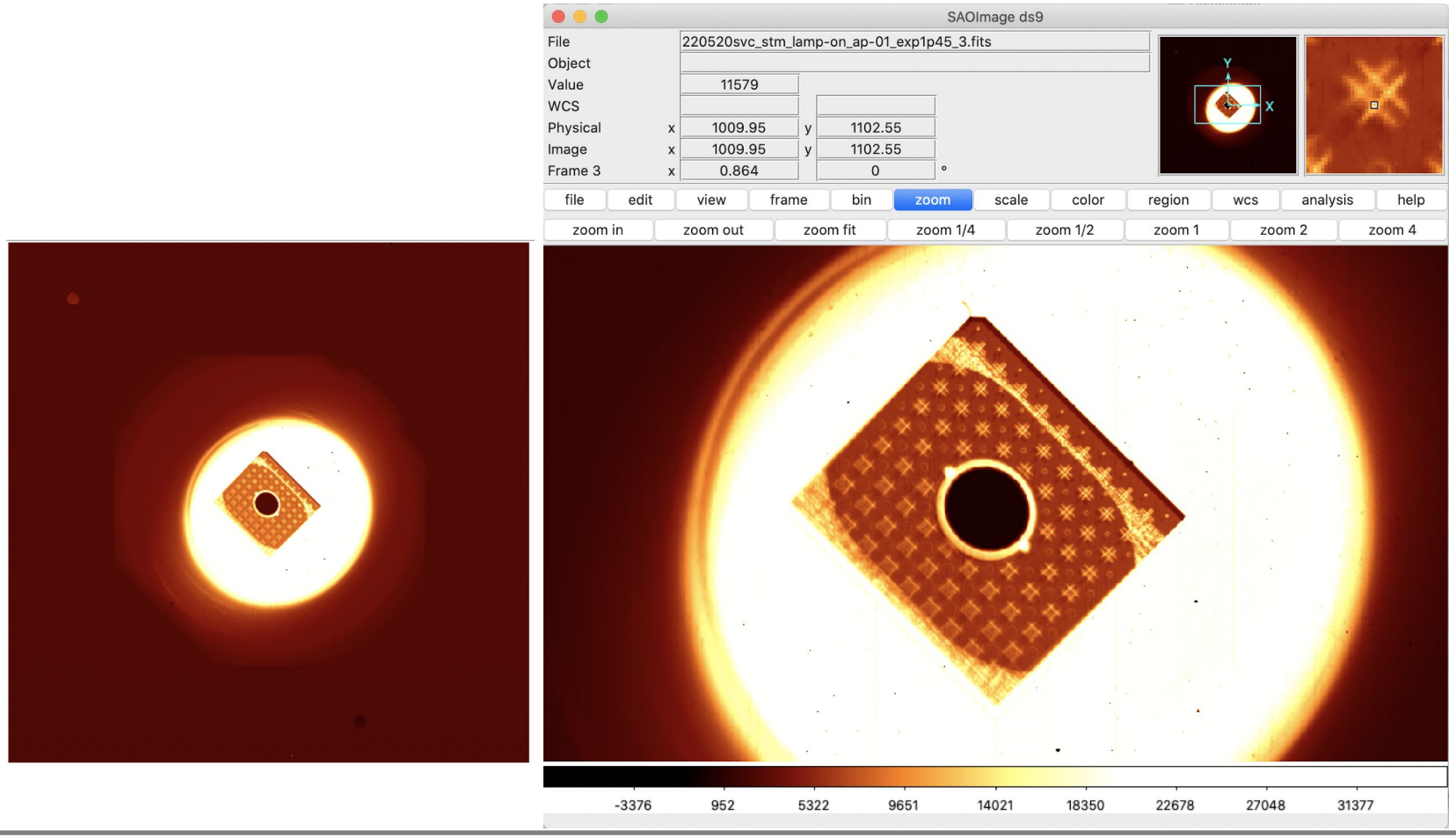
Slit test mirror





Alignment of SVC Detector: First SVC Image

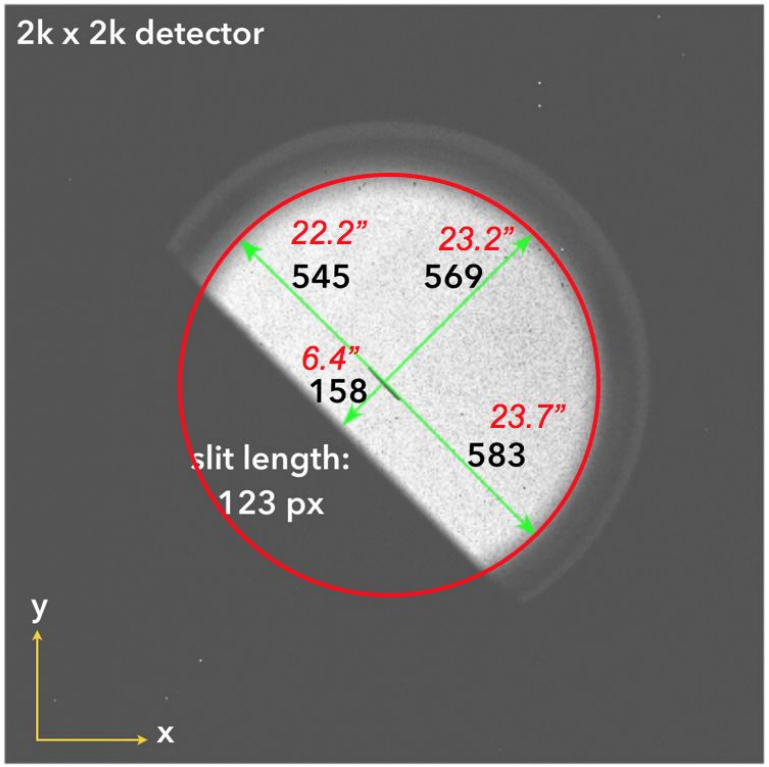
- In May 2022, we got first SVC image of IGRINS-2!
  - @ operating temperature including detector and bench
  - Minimum exposure (1.45s) with fowler mode
  - 20W THL source (<5% input aperture)



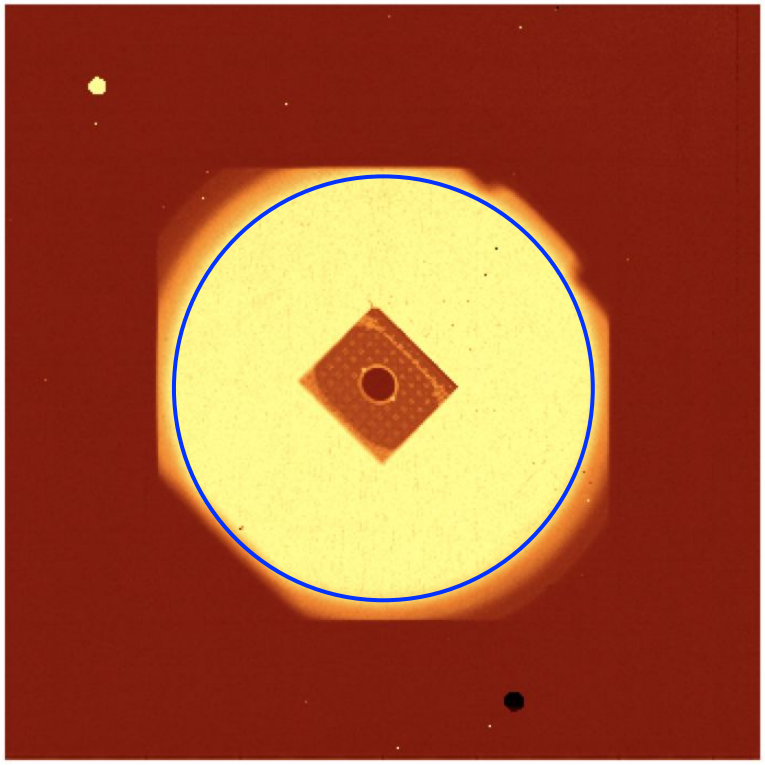
Alignment of SVC Detector: SVC FoV

- Circular shape of the SVC field is successfully confirmed.

Original IGRINS



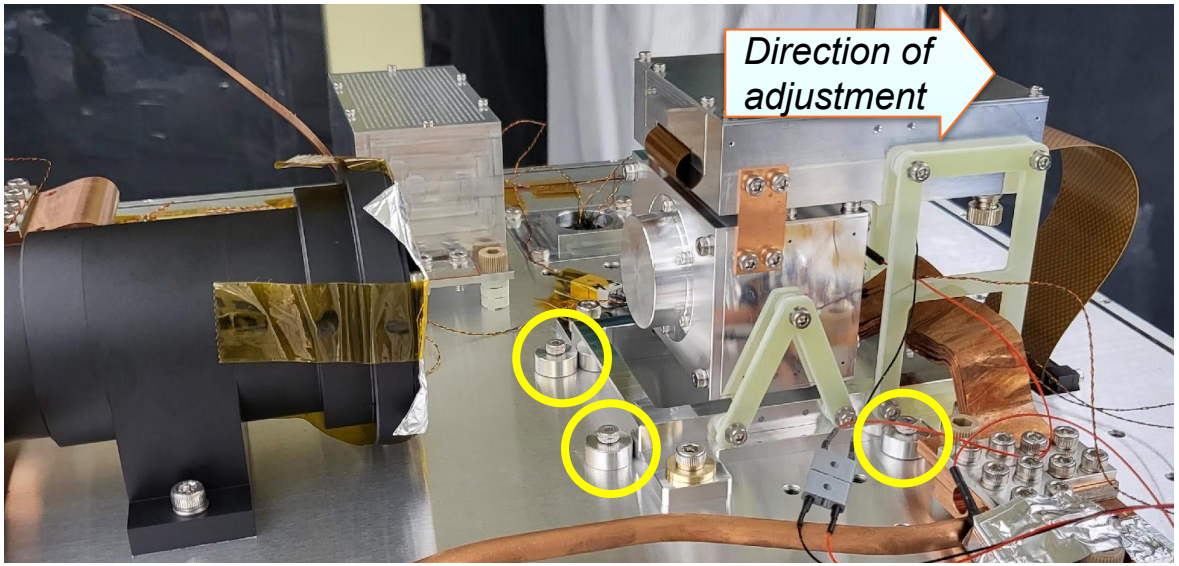
IGRINS-2



Alignment of SVC Detector: Adjustment

- The direction of adjustment is the direction that **moves the detector away from the slit mirror**.
- □ The direction of adjustment is the same as we did with the original IGRINS.

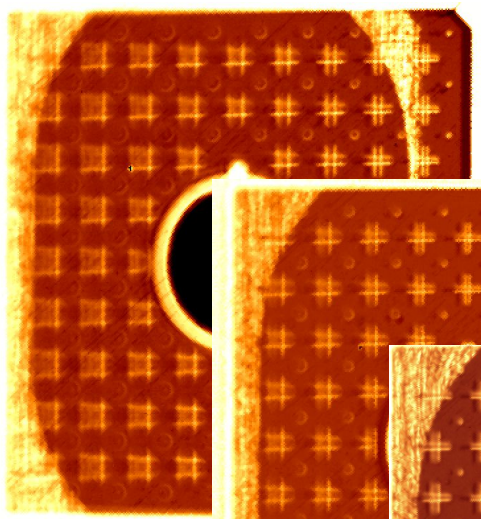
- Adjustment at each cooling cycles: **0 mm** □ **1 mm** □ **1.7 mm** □ **1.8 mm** (final value)



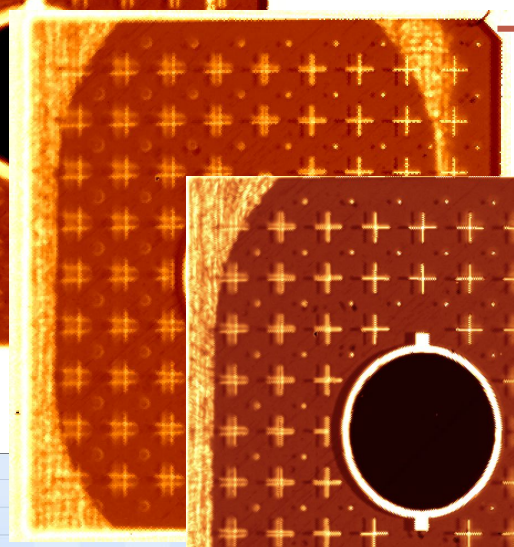
Detector mount bumpers allowing focus adjustment

Alignment of SVC Detector: Summary

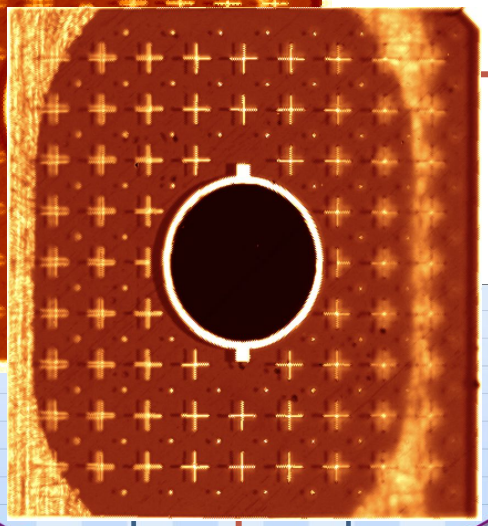
- Image measurement to find the value for the final adjustment.



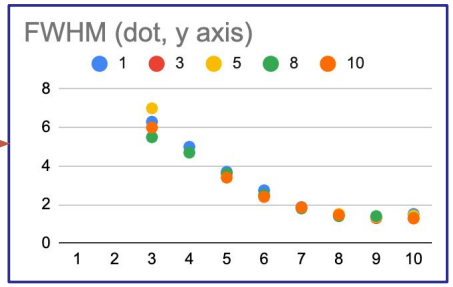
First image

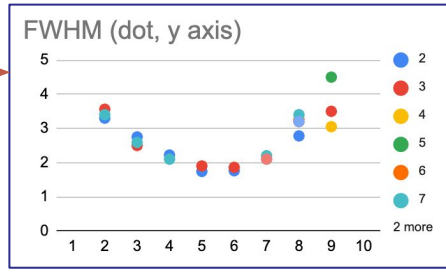


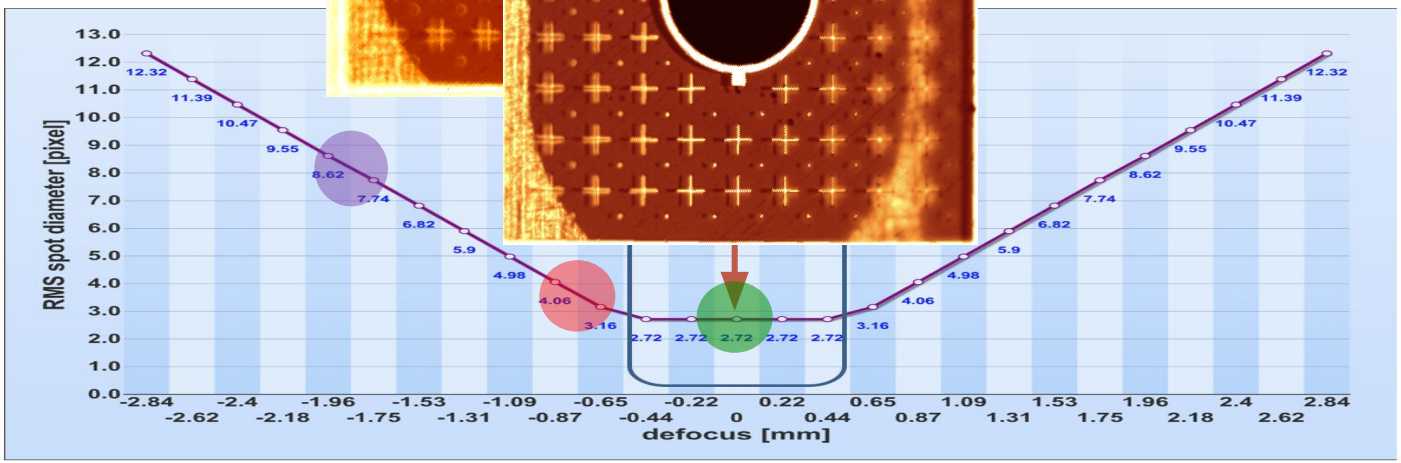
1 mm adjustment



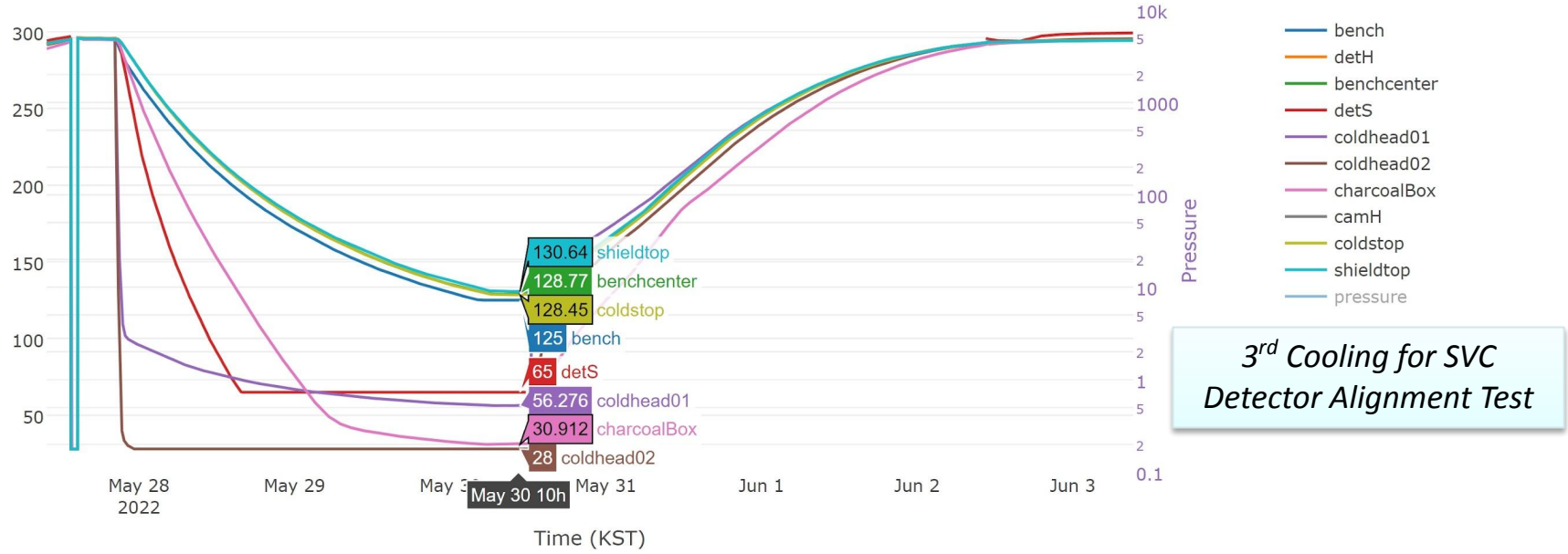
1.8 mm adjustment (final)



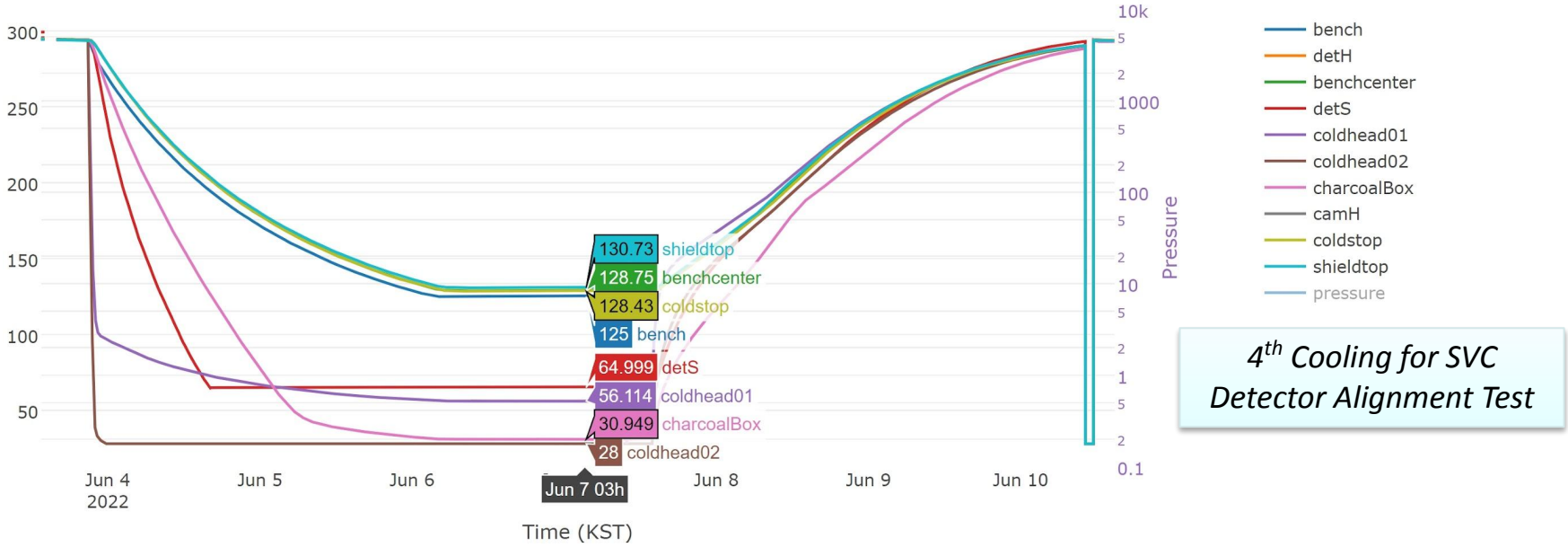




Cooling Test

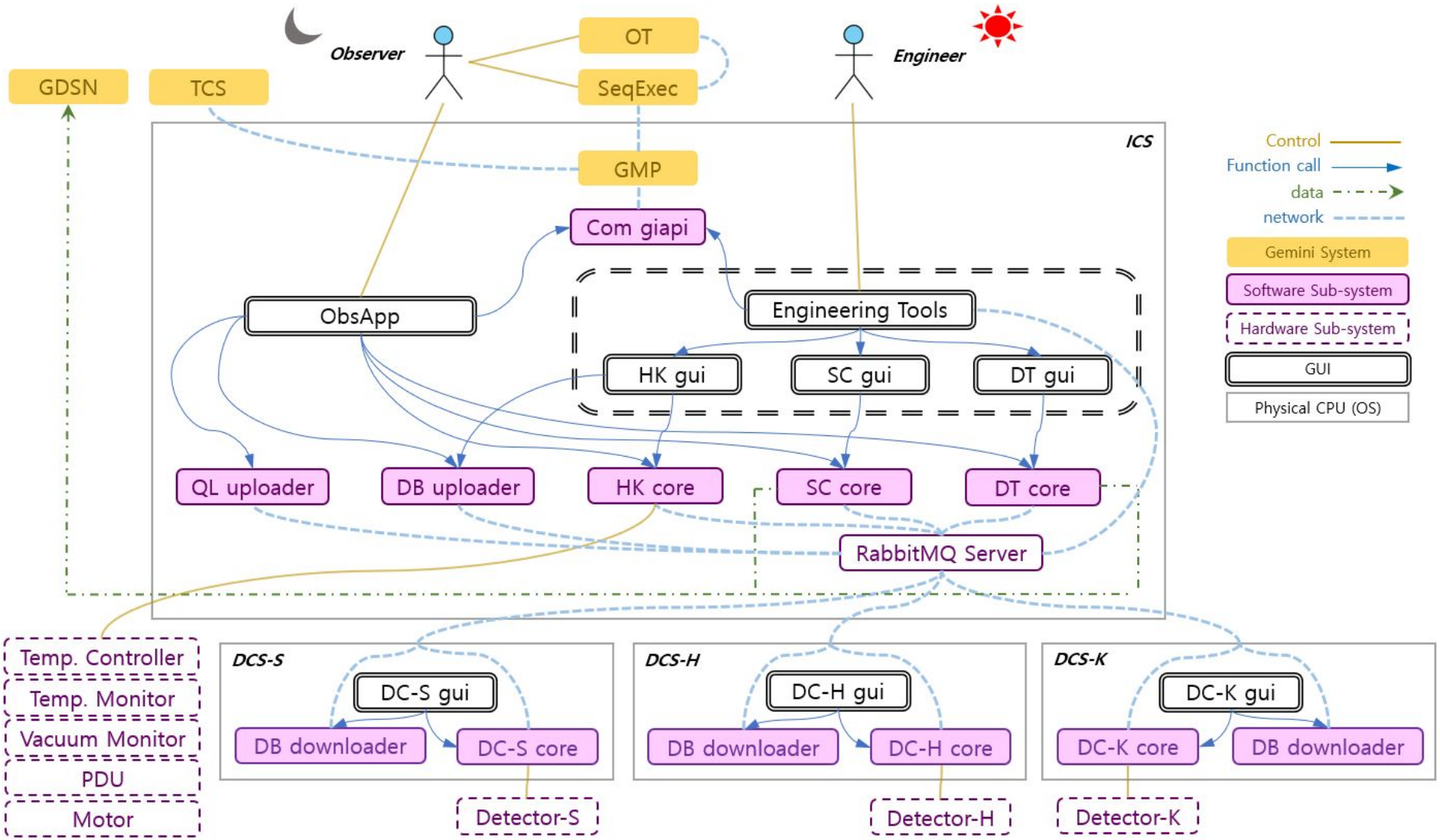


3rd Cooling for SVC Detector Alignment Test



4th Cooling for SVC Detector Alignment Test

Software Development



Reviews and Meetings: Virtual to Real

Kick-off meeting

CDR


The team finally met in person at SPIE!

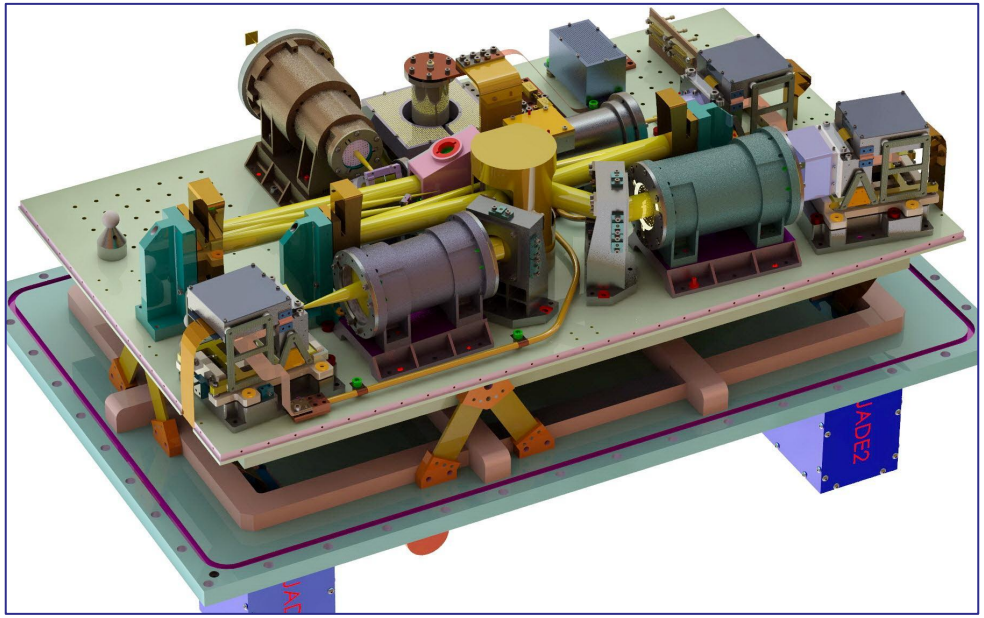
Plan and Considerations

- We have about a year before shipping
  - We are now on schedule!
  - We are preparing to proceed to AIT Phase B (spectrograph camera alignment).
  - Documentations, test report

- Detector Procurement
  - Three detectors: SVC, H, and K detectors
  - SVC detector, and K-detector is installed on IGRINS-2
  - Another science grade will be delivered in Jan. 2023

- More Face-to-face interaction
  - Few Gemini members will visit KASI after GSM 2022
  - Possible visit of Gemini team in October 2022

Thank you!



Backup Slides

Alignment Flow : Phase A

Initial Cooling Test Done

A1. Part Inspection (IO, SVC) [KASI/300K]

A2. Integration (IO, SVC) [KASI/300K]

A3. Interferometer Test (IO) [KASI/300K]

A4. Interferometer Test (SVC) [KASI/300K]

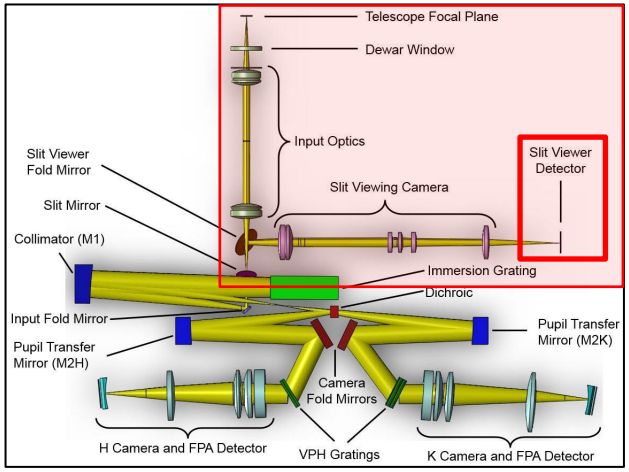
A5. Detector Alignment (SVC) [KASI/130K]

A6. Performance Measurement (IO+SVC) [KASI/130K]

SVC Detector Mount Assembly [KASI/300K]

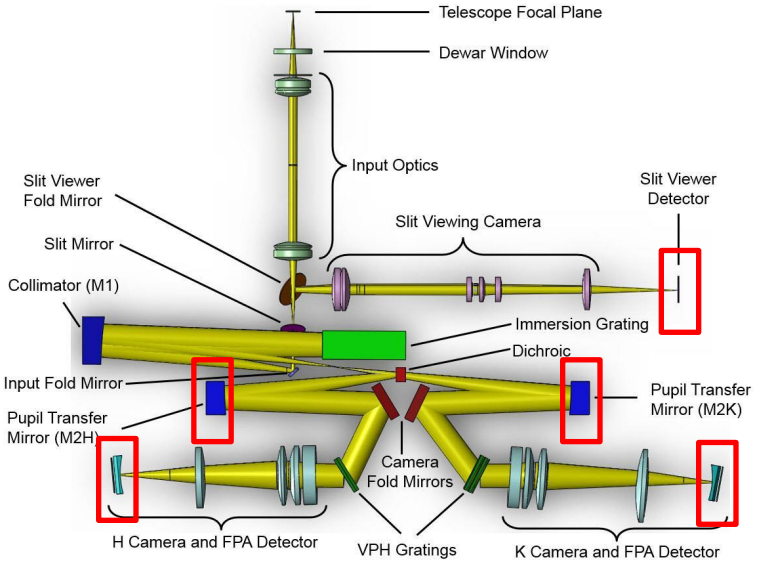
Test SVC Detector [KASI/130K]

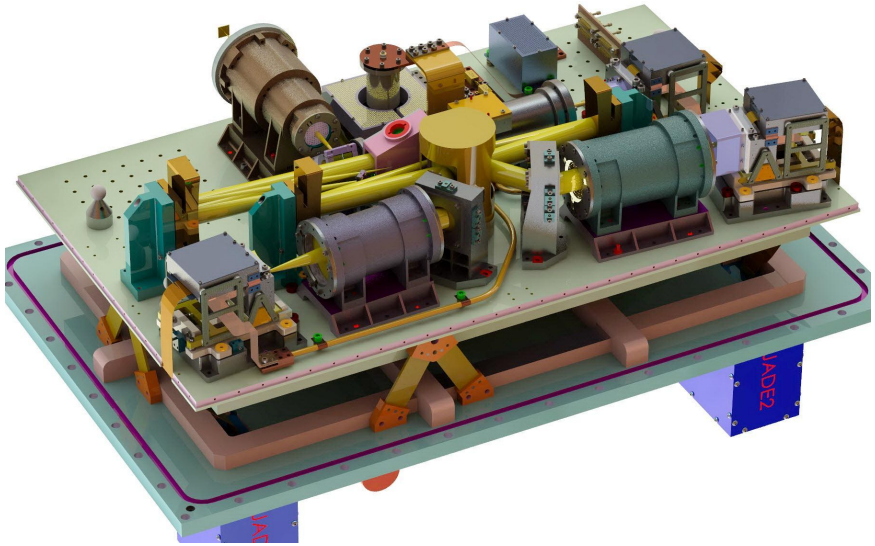
We are now here



- *Alignment Flow: Phase A*

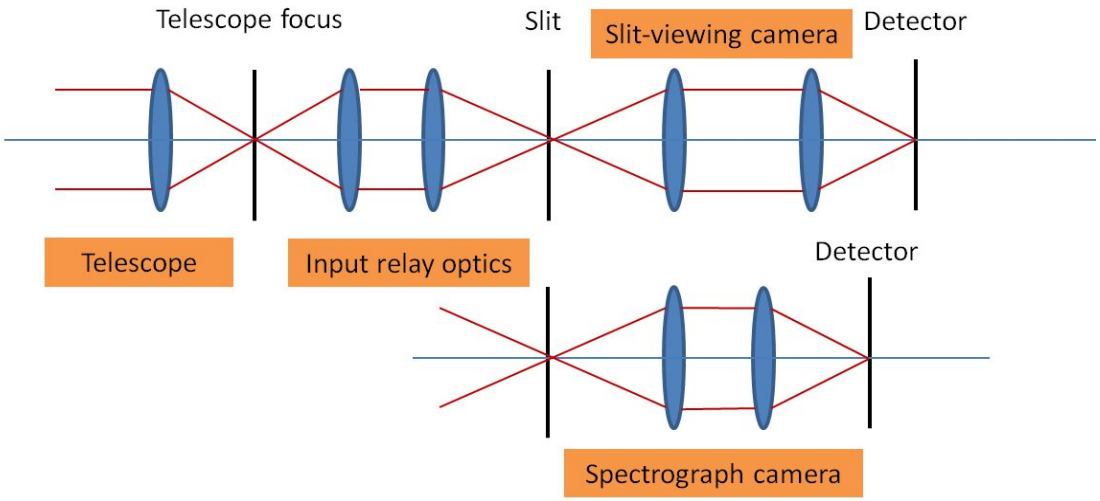
Alignment Concept





Fabrication Type	Component	Mount requirement
Compensators	• Pupil transfer mirror • Slit-viewing camera detector • H-band camera detector • K-band camera detector	Parts that provide position adjustments.
As-built performance	• Input relay optics • Slit-viewing camera • Slit mirror, Fold mirrors • Dichroic mirror • Collimating mirror • H-band camera • K-band camera	No need position adjustment, should perform as built.
“Impossible” parts	• Immersion grating • H-band VPHG • K-band VPHG	Parts requiring characterization and adjustment before installation.

Alignment Phase A: Slit-view camera



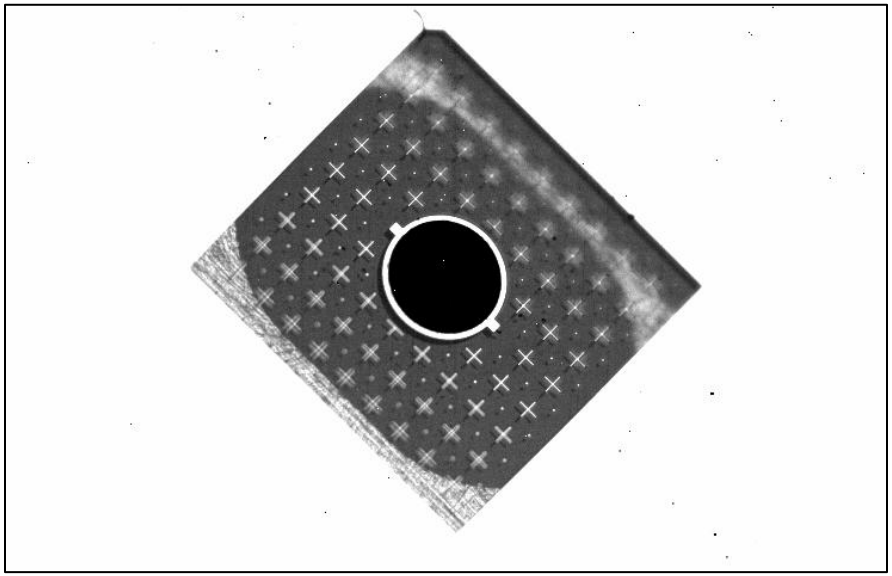
- **Two types of camera systems**: slit-view camera & spectrograph camera
- The focus of spectrograph will reply on the slit-view camera during the Observation

□ **Phase A.** Align slit-view camera first

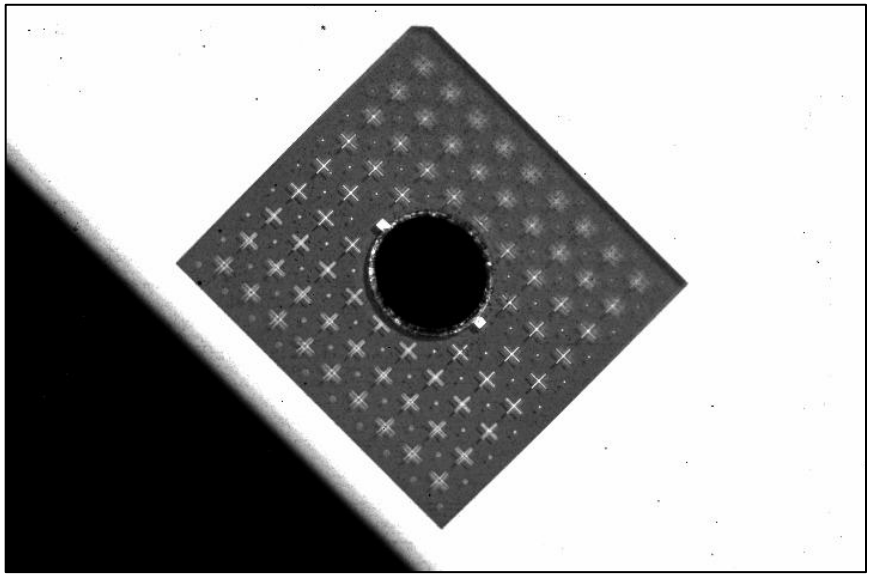
□ **Phase B.** Sync the focus of spectrograph cameras with slit-view camera

Summary of SVC Alignment

IGRINS-2

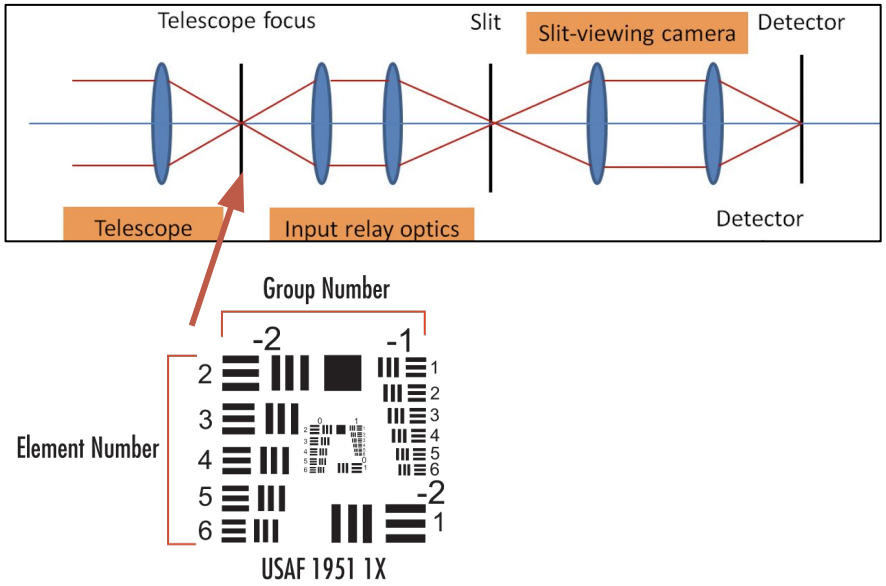


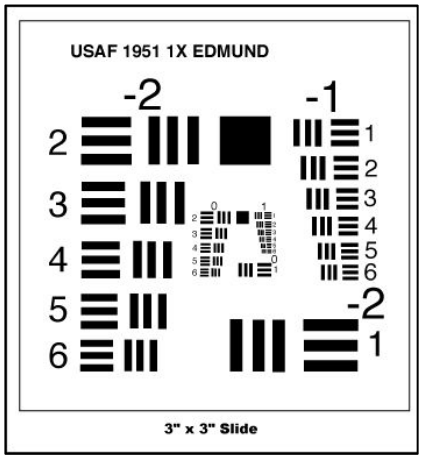
Original IGRINS



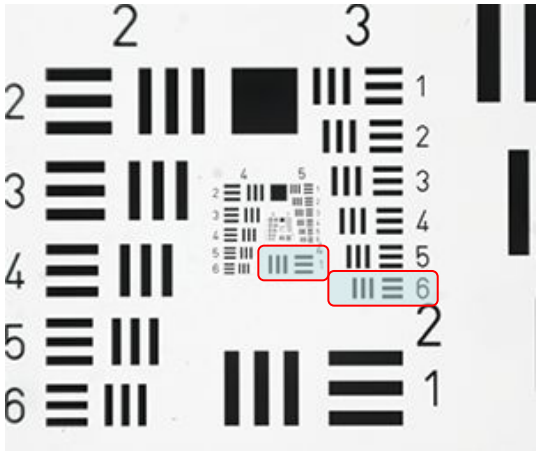
- The image of the slit-test mirror taken with “aligned” SVC detector -- IGRINS-2 and the original IGRINS.

SVC performance: Test method using USAF target





#55-622 from Edmond Optics

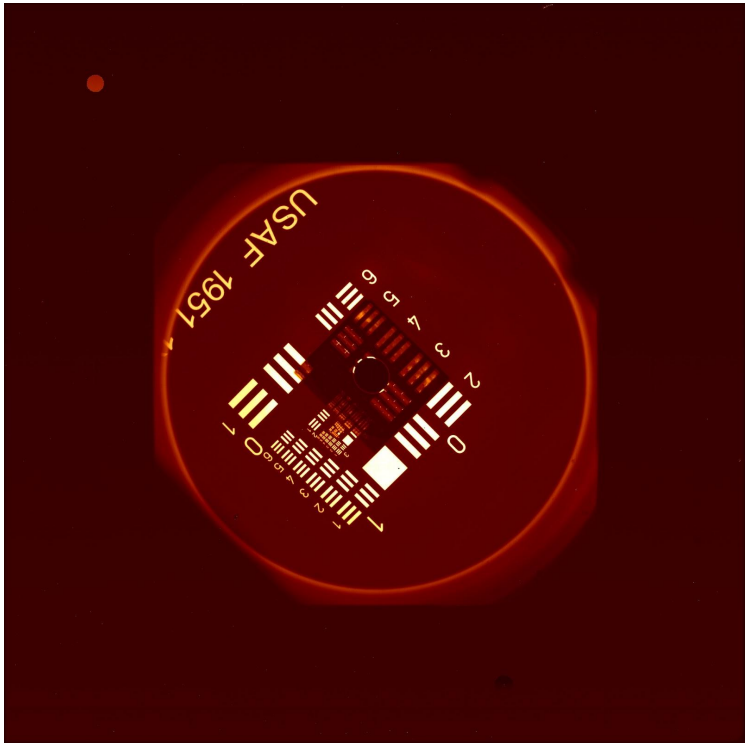


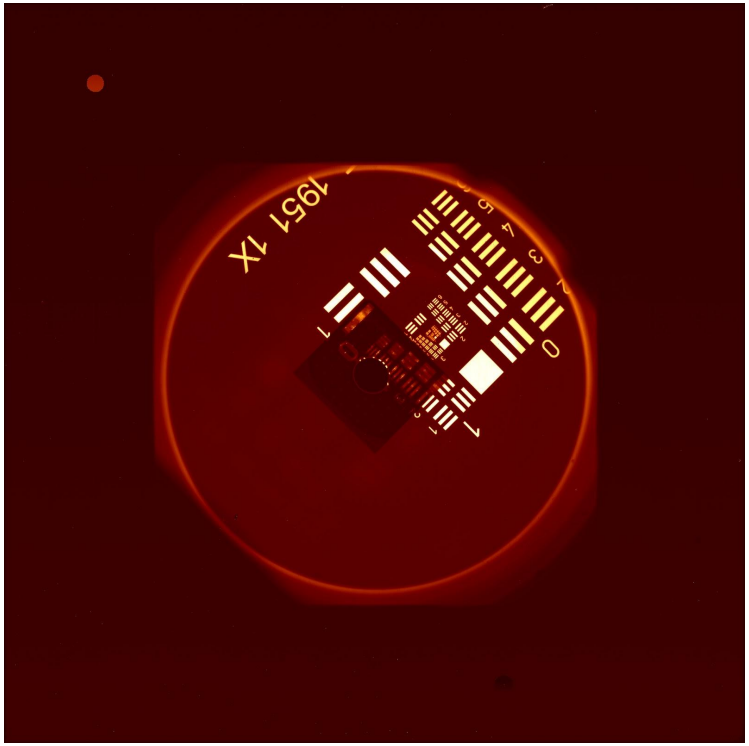
Center zoom-in

- Requirement: RMS spot diameter of SVC focus ~48 micron
- Expected resolution at SVC focus: ~20.8 lp/mm

- Magnification factor from Tel. focus to SVC detector: 0.705
- Expected [lp/mm] object to be resolved at the location of Tel focus (=USAF target in Cal box): 14.7 lp/mm
- USAF element we want to resolve is:
  - Group number=3, Element=6: 14.3 lp/mm (required)
  - Group number=4, Element=1: 16.0 lp/mm (over spec)

SVC performance: USAF target image



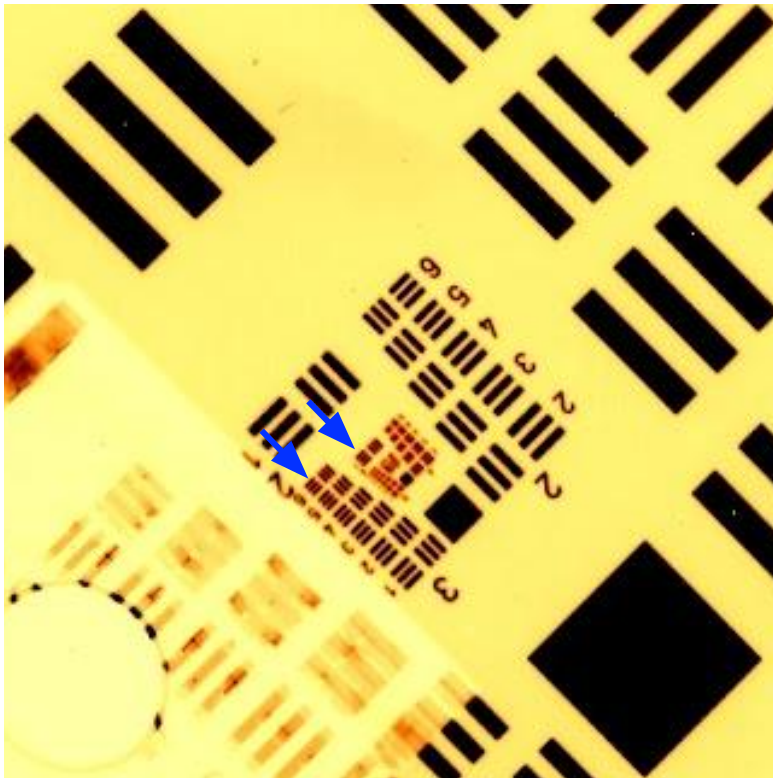


- “Focused” USAF target images by IGRINS-2 SVC.
- The USAF target is imaged at two different area of the SVC field.

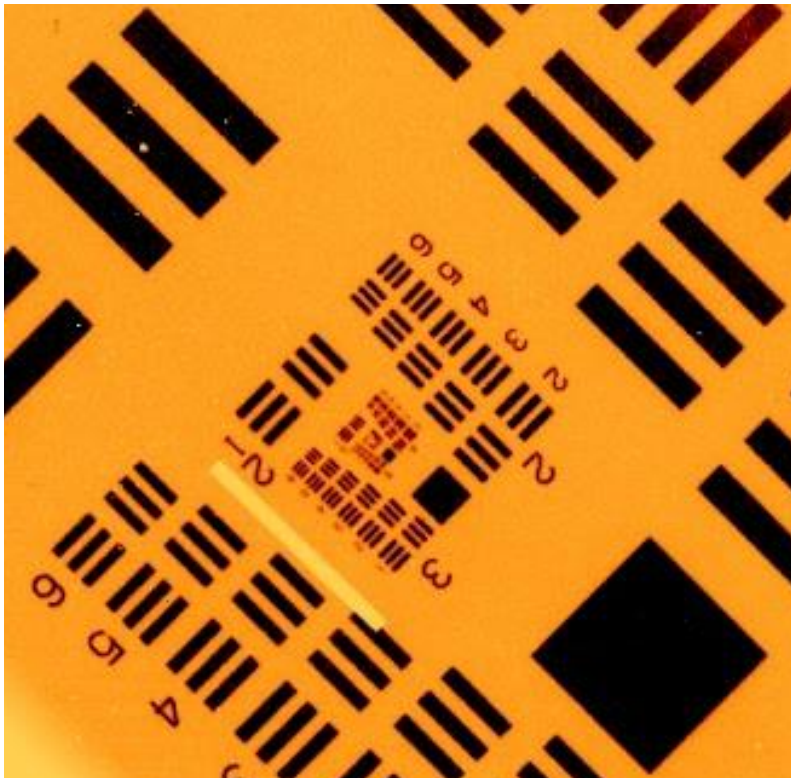
*Central area of the field is shown dark due to the slit-test mirror feature.

SVC performance: USAF target image

IGRINS-2



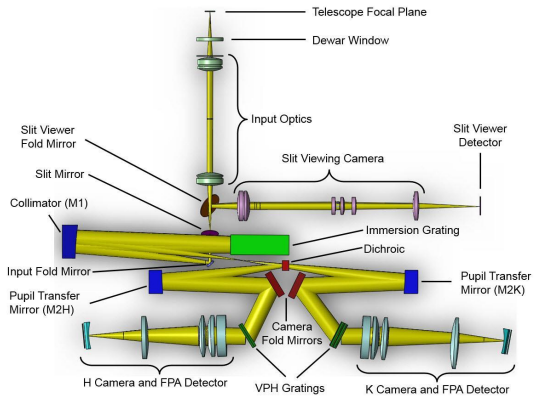
Original IGRINS



- The part pointed by the arrows are the goal elements.
- The imaging performance of the IGRINS-2 SVC is comparable to that of the original IGRINS.
- Image quality will be further analyzed.

Status of Lens Procurement

Part List		Material	Price	Quantity	2021	2022
Input Optics	Warm Window	ZnSe	$3,554	1	0	1
	Cold Window	Sapphire	$1,946	1	0	1
	L1	S-FTM16	$2,031	1	0	1
	L2	CaF2	$2,369	1	0	1
	L3	CaF2	$2,200	1	0	1
	L4	S-FTM16	$1,862	1	0	1
SVC	L1	S-FTM16	$2,877	1	0	1
	L4	S-FTM16	$2,369	1	0	1
	Ks-Filter	Infrasil-301	$16,923	1	0	1
	Slit Viewer Fold Mirror	Zerodur	$3,215	1	0	1
H-Camera	H1	CaF2	$4,315	2	1	1
	H3	Infrasil-301	$4,062	2	1	1
	H4	Infrasil-301	$4,400	2	1	1
	FF-H	Infrasil-301	$21,154	1	0	1
	Pupil Transfer Mirror M2H	Al6061-T6	$33,846	1	0	1
	Camera Fold Mirror H	Zerodur	$2,877	1	0	1
K-Camera	K1	CaF2	$4,400	2	1	1
	K3	Infrasil-301	$4,231	2	1	1
	K4	Infrasil-301	$5,077	2	1	1
	FF-K	Infrasil-301	$21,154	2	1	1
	Pupil Transfer Mirror M2K	Al6061-T6	$33,846	1	0	1
	Camera Fold Mirror K	Zerodur	$2,877	1	0	1
H*K Common Part	Input Fold Mirror	Zerodur	$2,538	1	0	1
	Collimator M1	Al6061-T6	$33,846	1	0	1
	Dichroic	Infrasil-301	$16,923	2	1	1
Calibration Optics	L1	S-FTM16	$3,046	1	0	1



- The lens maker company has shipped those lenses made last year.
- The company is manufacturing lenses list in 2022.
- All lenses in 2022 are spare part. Lead time does not affect the final schedule.

4. Mechanical System

Sanghyuk Kim

Mechanical Parts Procurement Status

Item	Price (USD)	Delivery	Status
Test Dewar Assembly	55,000	2021.07	Done
Vacuum Chamber	35,000	2021.09	Done
Input Optics Assembly	25,000	2021.11	Done
Slit Viewing Camera Assembly	17,000	2021.11	Done
Optical Bench Assembly	30,000	2021.11	Done
Radiation Shield Assembly	15,000	2021.11	Done
Cooler Assembly	15,000	2021.11	Done
Slit Mirror and Slit Fold Mirror Assemblies	8,000	2021.11	Done
SVC Detector Mount prototype	13,000	2021.11	Done
2021 Sub-total	213,000		Calculated as 1USD = 1,150KRW
H&K Camera Assemblies	54,000	2022.07	Manufacturing in progress
H&K and SVC Detector Mount Assemblies	70,000	2022.04	Done
Mirror Mounts (Off-axis, dichroic, fold)	45,000	2022.07	Manufacturing in progress
Grating Mount Assemblies	35,000	2022.08	Manufacturing in progress
2022 Sub-total	204,000		Calculated as 1USD = 1,150KRW
Telescope Mount Assembly	13,000	2023.02	Final design in progress
Total	430,000		

Summary

- The procurement of the mechanical part is on schedule.
- In April, the cooling test without the opto-mechanical components was finished, and after that, we completed the integration of the optomechanical components for the SVC alignment test.
- The SVC detector alignment started at the end of April.
- We are working on assembling H and K detector mounts, and they will be installed on the optical bench in June.
  - H-detector mount: with Sci. grade H2RG
  - K-detector mount: detector mount only
- The telescope mount design will be updated in accordance with the design change of the ISS plate and the BWA.

5. Electronics System

Mooyoung Chun

Status of IGRINS-2 Electronics

Procurement of H2RG detector – Eng-A & 1st Science Grade FPA arrived, 2nd SG FPA on Jan. 2023
Tunning of H2RG detector – Course tunning of 1st Sci. grade & Slit Viewer is done. See next slides

Waiting for delivery

- *Lakeshore Temperature controller 335 (Aug.) – To make a shorter cool-down time*
  - *IEEE488 to RS232 converter (Aug.) – For interface of LS temp. controller 335*
- *Lantronix Device Server EDS3008PR (June) – To compare how often the communication error occurs, EDS8PR(current one) and EDS3008PR*

Ready to order

- *Temp. Controlled(TC) Rack (Aug.) – When BWA design is fixed, TC rack will be ordered.*
- *Patch panels for TC rack (Aug.) – All connectors which line go to outside of RC rack are located at patch panel. Design of patch panels are finished, but we will order them with TC rack.*

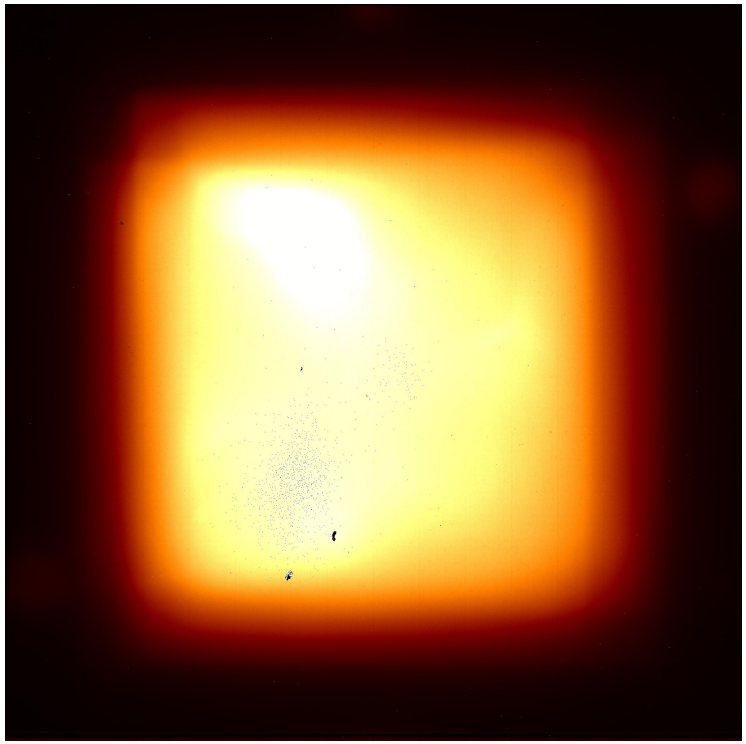
INITIAL TUNING RESULT

- *Science A grade detector (#21662)*
- *Reference level ~ 8,000 ADU*
- *Enhanced clocking / global reset*

a single CDS image

(max. ~5,000 ADU)

Bias	Voltage	Hex Reg Addr	Hex Reg Value
Vreset	0.2502 V	6000	804a
Dsub	0.587 V	6002	80e0
VBiasGate	1.8645 V	6004	b520
VrefMain	1.2176 V	602c	81b0



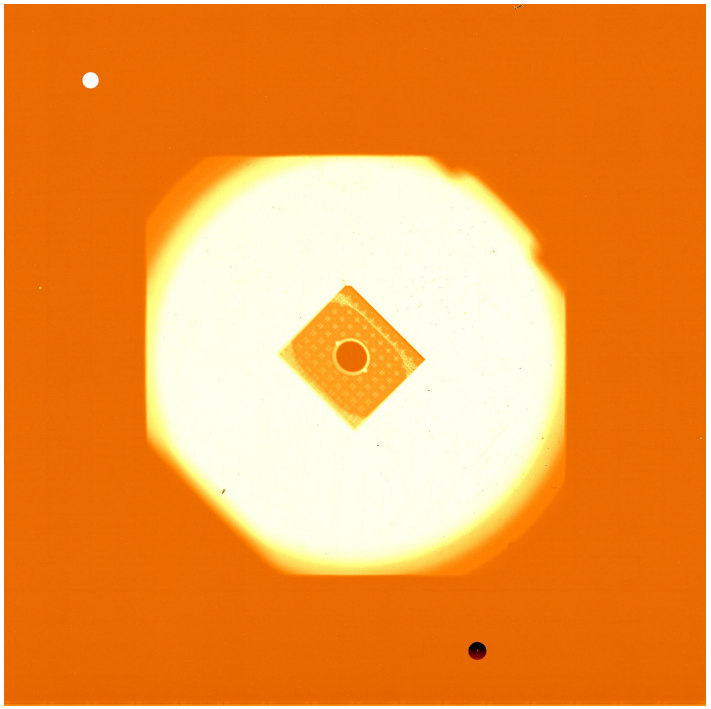
INITIAL TUNING RESULT

- *Engineering A grade detector (SVC)*
- *Reference level ~ 8,000 ADU*
- *Enhanced clocking / row-by-row reset*

a single CDS image

(max. ~1,300 ADU)

Bias	Voltage	Hex Reg Addr	Hex Reg Value
Vreset	0.2502 V	6000	804a
Dsub	0.7154 V	6002	8120
VBiasGate	1.8645 V	6004	b520
VrefMain	1.1496 V	602c	820a



Observing Software

Hye-In Lee

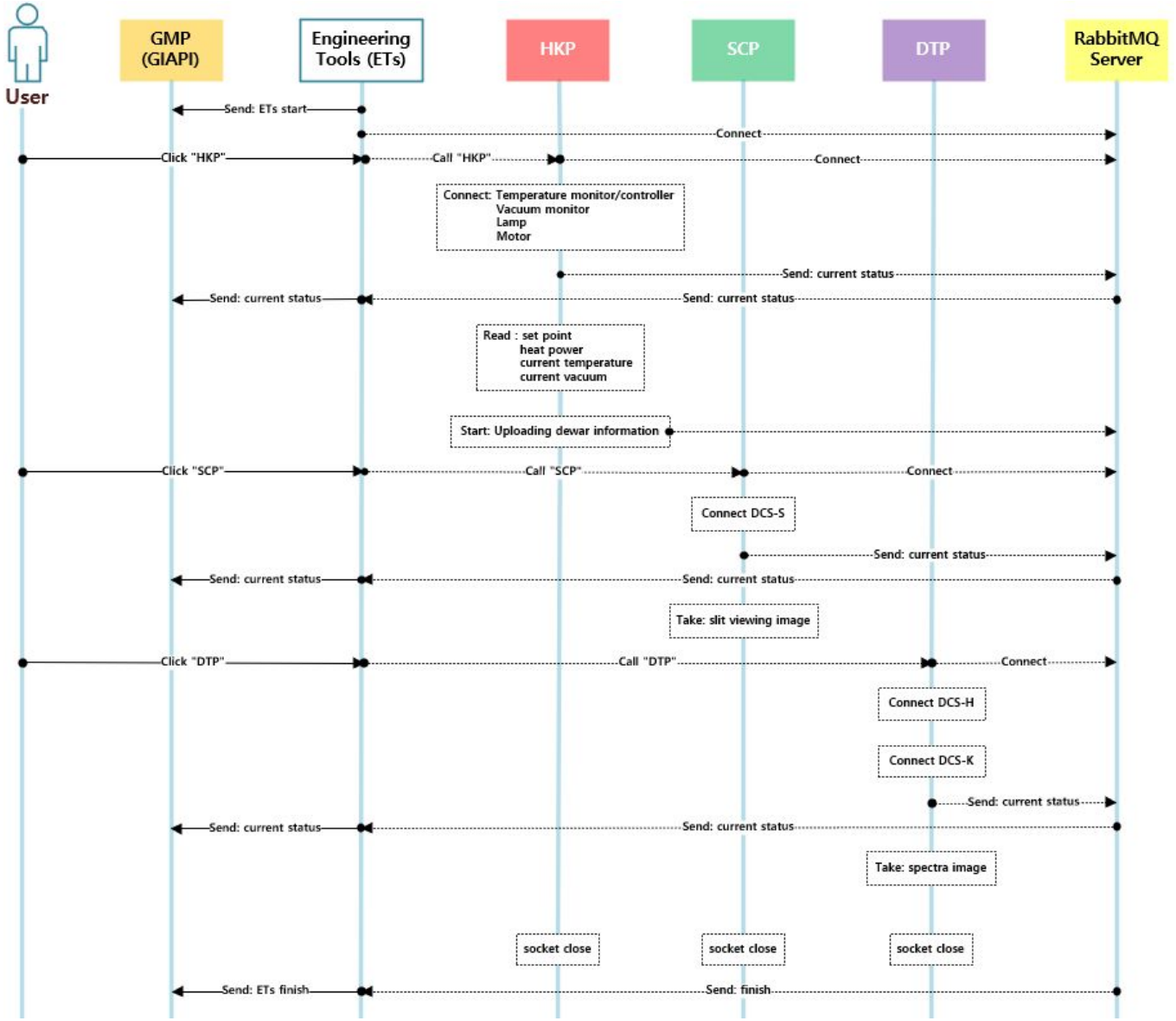
1. Development Plan
2. Design
3. Test & Development
4. Summary

1. Development Plan

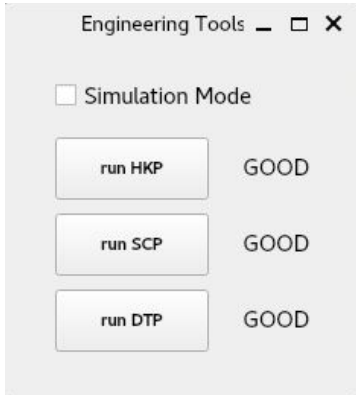
period	Meeting (GIAPI & DRAGONS)	Design	Test & Development
2022.04		• Observing mode & Engineering mode • Header for DCS	• [D] DCS - cli, core • [D] HKP – upload HKP db for web-app • [T] HKP - communication test
2022.05	• DRAGONS meeting – FITS structure (1 header / expanded S, H, K images) • Control software meeting – ObsApp		• [D] DCS – download HKP db for header • [D] DCS – include HKP db in header • [T] HKP – communication test
2022.06	• Control software meeting – ObsApp and Engineering Tools	• Engineering Tools, HKP, SCP, DTP – GUI, architecture • HKP, SCP, DTP – operation scenario	• [T] HKP – communication test • [D] DCS – cli, core
2022.07	• Discussion - Communication information, ObsApp GUI	• Engineering Tools – function design	• [T] HKP – communication test • [D] DCS – GUI • [D] ICS - RabbitMQ related coding
		• GIAPI review	• [T] HKP – communication test • [D] DCS – GUI • [D] SCP, DTP – cli, core
2022.08			• [T] DCS – communication test / sub-system test • [D] HKP – modify HKP db for web-app • [D] SCP, DTP – GUI • [D] ICS - related coding with simulation
2022.09			

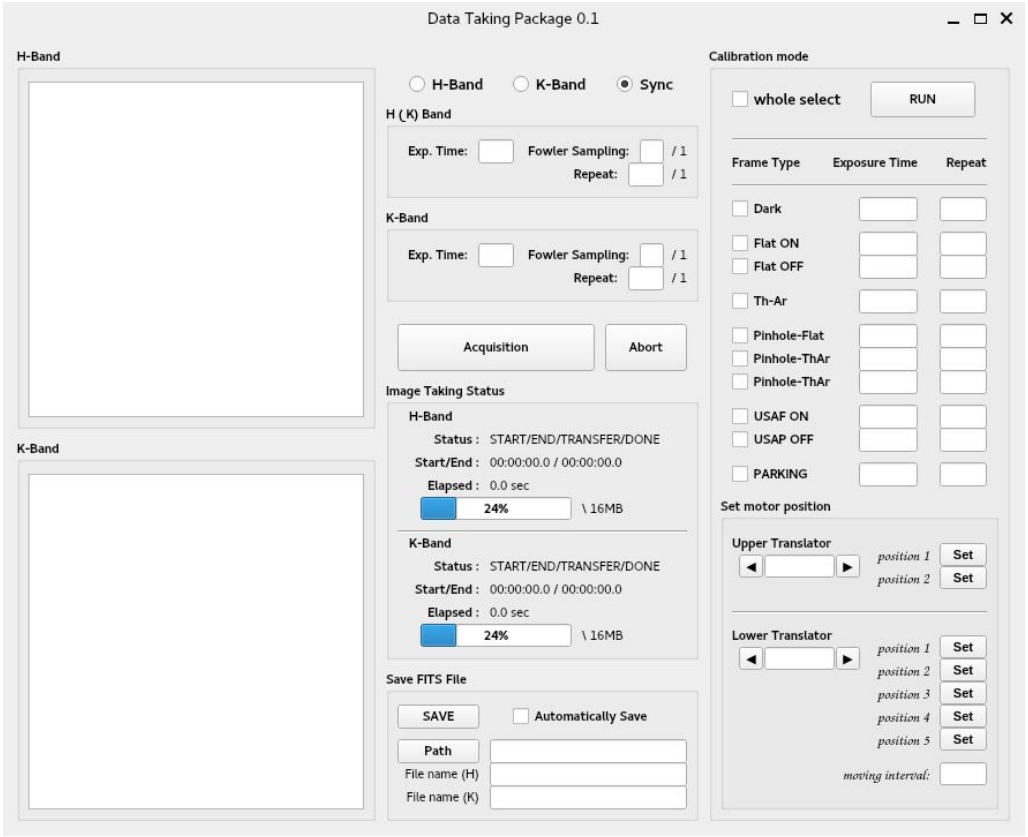
* [D] development / [T] test

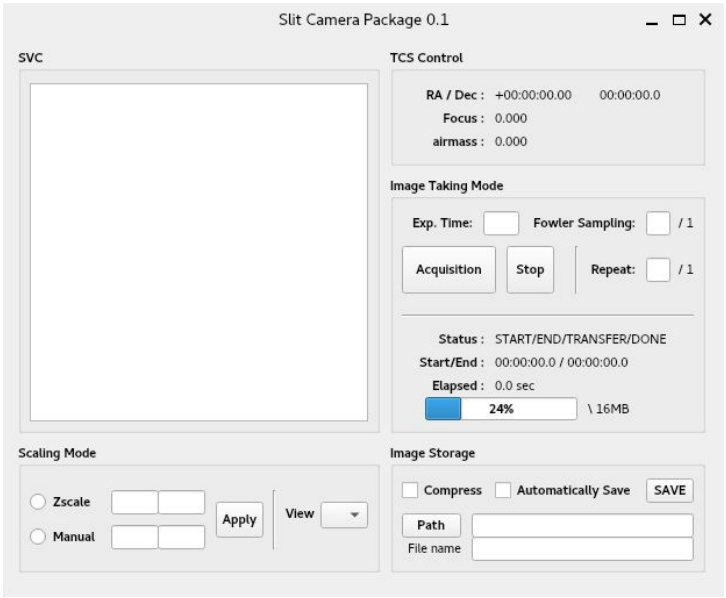
2. Design - Scenario for Engineering Tools



2. Design - GUI


Engineering Tools
Simulation Mode
run HKP
GOOD
run SCP
GOOD
run DTP
GOOD


Data Taking Package 0.1
H-Band
K-Band
H-Band
K-Band
Sync
H (K) Band
Exp. Time:
Fowler Sampling:
/ 1
Repeat:
/ 1
K-Band
Exp. Time:
Fowler Sampling:
/ 1
Repeat:
/ 1
Acquisition
Abort
Image Taking Status
H-Band
Status : START/END/TRANSFER/DONE
Start/End : 00:00:00.0 / 00:00:00.0
Elapsed : 0.0 sec
24%
\ 16MB
K-Band
Status : START/END/TRANSFER/DONE
Start/End : 00:00:00.0 / 00:00:00.0
Elapsed : 0.0 sec
24%
\ 16MB
Save FITS File
SAVE
Automatically Save
Path
File name (H)
File name (K)
Calibration mode
whole select
RUN
Frame Type
Exposure Time
Repeat
Dark
Flat ON
Flat OFF
Th-Ar
Pinhole-Flat
Pinhole-ThAr
Pinhole-ThAr
USAF ON
USAP OFF
PARKING
Set motor position
Upper Translator
position 1
position 2
Set
Lower Translator
position 1
position 2
position 3
position 4
position 5
moving interval:


Slit Camera Package 0.1
SVC
TCS Control
RA / Dec : +00:00:00.00 00:00:00.0
Focus : 0.000
airmass : 0.000
Image Taking Mode
Exp. Time:
Fowler Sampling:
/ 1
Acquisition
Stop
Repeat:
/ 1
Status : START/END/TRANSFER/DONE
Start/End : 00:00:00.0 / 00:00:00.0
Elapsed : 0.0 sec
24%
\ 16MB
Scaling Mode
Zscale
Manual
Apply
View
Image Storage
Compress
Automatically Save
SAVE
Path
File name

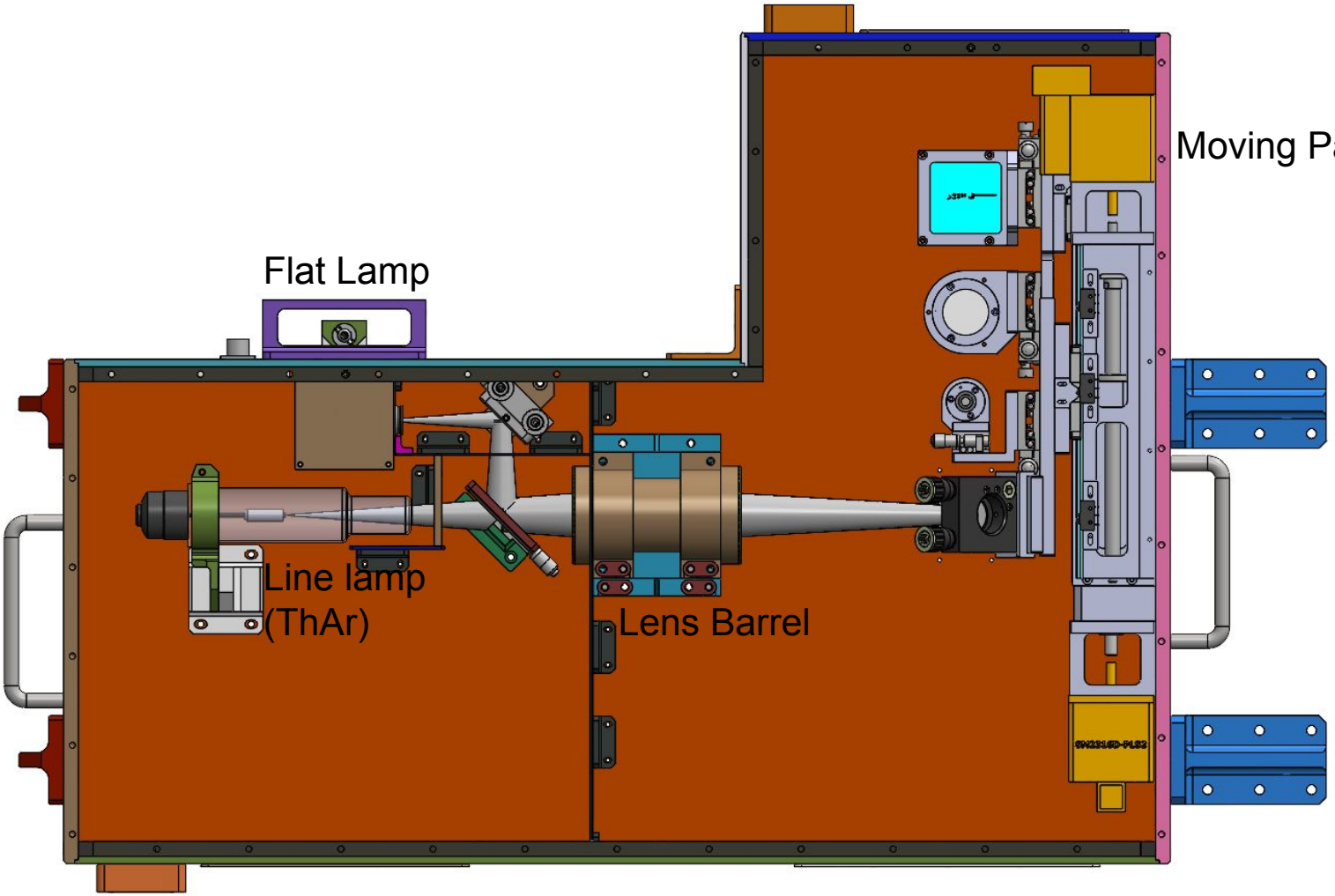
7. Calibration system

Heeyoung Oh
& IGRINS Team

Schedule after PRR

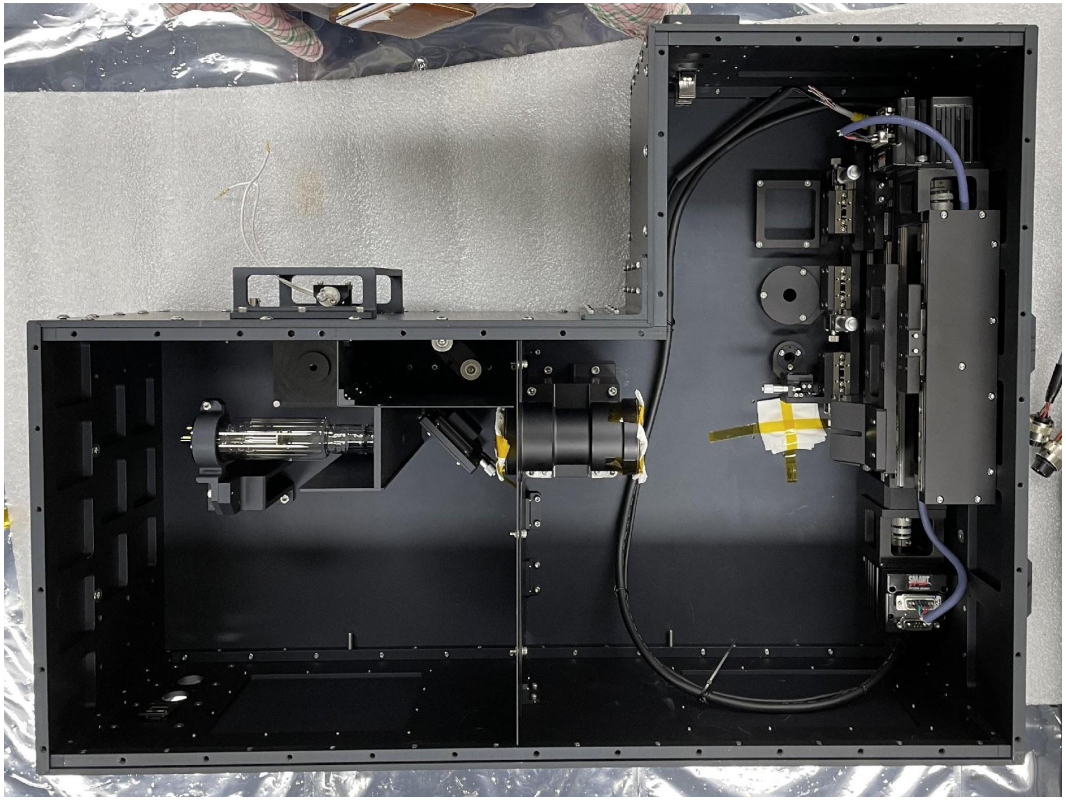
Month	Items	Check List	Status update
March 2021	✔ PRR Meeting		
April-May 2021	✔ Order of commercial parts ✔ Prepare for procurement of fabrication		▪ ~70% of commercial parts has been delivered to KASI ▪ Documentation for the fabrication is being done / done for: ○ Non-moving part (done) ○ Moving part (being prepared) ○ Lens barrel (90% done)
June 2021-August 2021	✔ Inspection of commercial parts ✔ Start procurement of fabrication		▪ 100% of commercial parts has been delivered. ▪ Among 3 contracts for fabrication ○ Non-moving part (done) ○ Moving part (under delivery) ○ Lens barrel (under delivery)
September 2021	✔ Inspection of fabricated part ✔ Prepare assembly and test	▪ Alignment telescope ▪ Lab space	▪ All of fabricated parts has been delivered and inspected.
October-December 2021	✔ Assembly ✔ Alignment ✔ Moving part test	▪ Electronics connection ▪ Command line software for motors	▪ Assembly done ▪ Moving part test done ▪ Initial alignment done
January 2022-March 2022	✔ Prepare SVC test	▪ Dewar assembly ▪ Initial test of dewar vacuum and cooling ▪ IO, SVC assembly and test	▪ Ready for SVC test
March 2022~	✔ Use for SVC test		▪ SVC test started

Calibration System Configuration



Top view of the system

Assembly of Calibration Box



Top view of the assembled calibration box