WE3.09.1 #2513

INSTRUMENT DEVELOPMENT STATUS AND PERFORMANCES OF HYPERSPECTRAL IMAGER SUITE (HISUI)

-Onboard Data Correction-

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Jun Tanii

Japan Space Systems , Tokyo, Japan

Akira Iwasaki

The University of Tokyo, Tokyo, Japan

Yoshiyuki Ito

NEC Corporation, Tokyo, Japan

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HISUI (Hyperspectral Imager SUIte)

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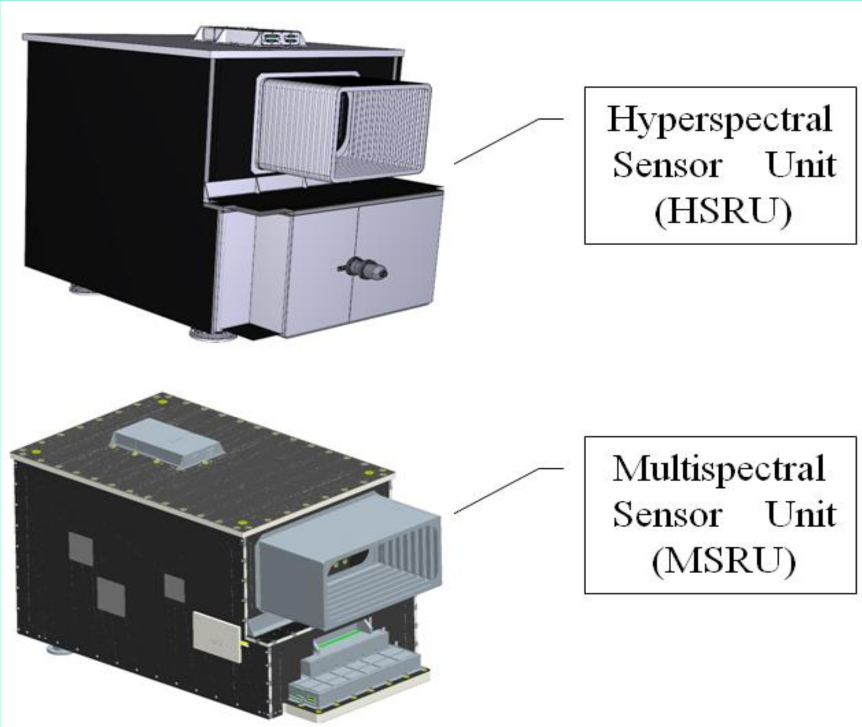
- Japanese earth observation project for resource exploration, vegetation and environment monitoring
- Follow-on mission of ASTER (Advanced Spaceborne Thermal Emission and reflection Radiometer) onboard TERRA
- Consists of 2 instruments
  - Hyperspectral sensor (185 bands from VIS to SWIR)
  - Multispectral sensor (4 bands of VNIR)

HISUI (Hyperspectral Imaging SUIte)

="jade" in Japanese

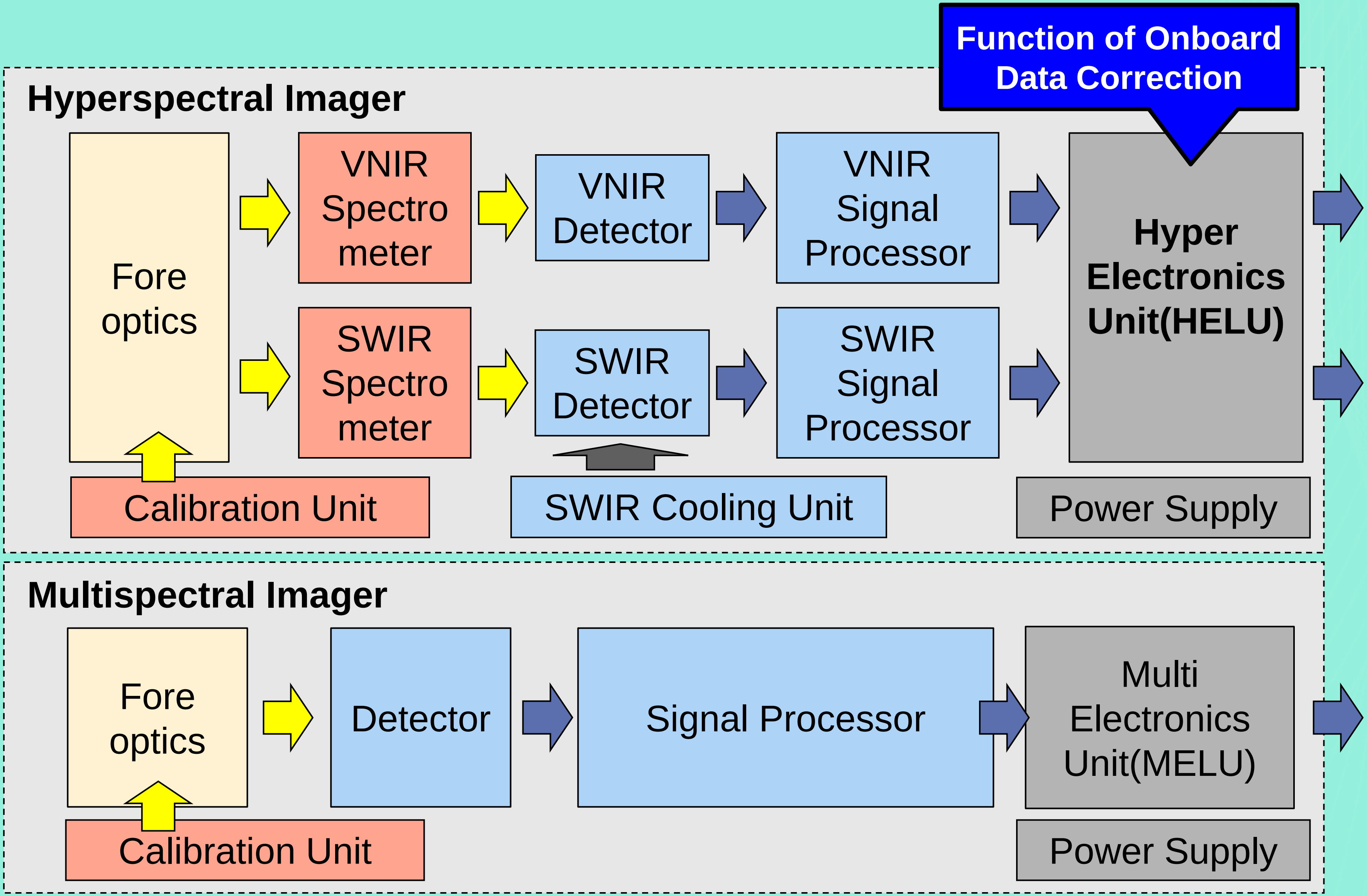
http://www.moonmadness.jp/itoigawahisui.html



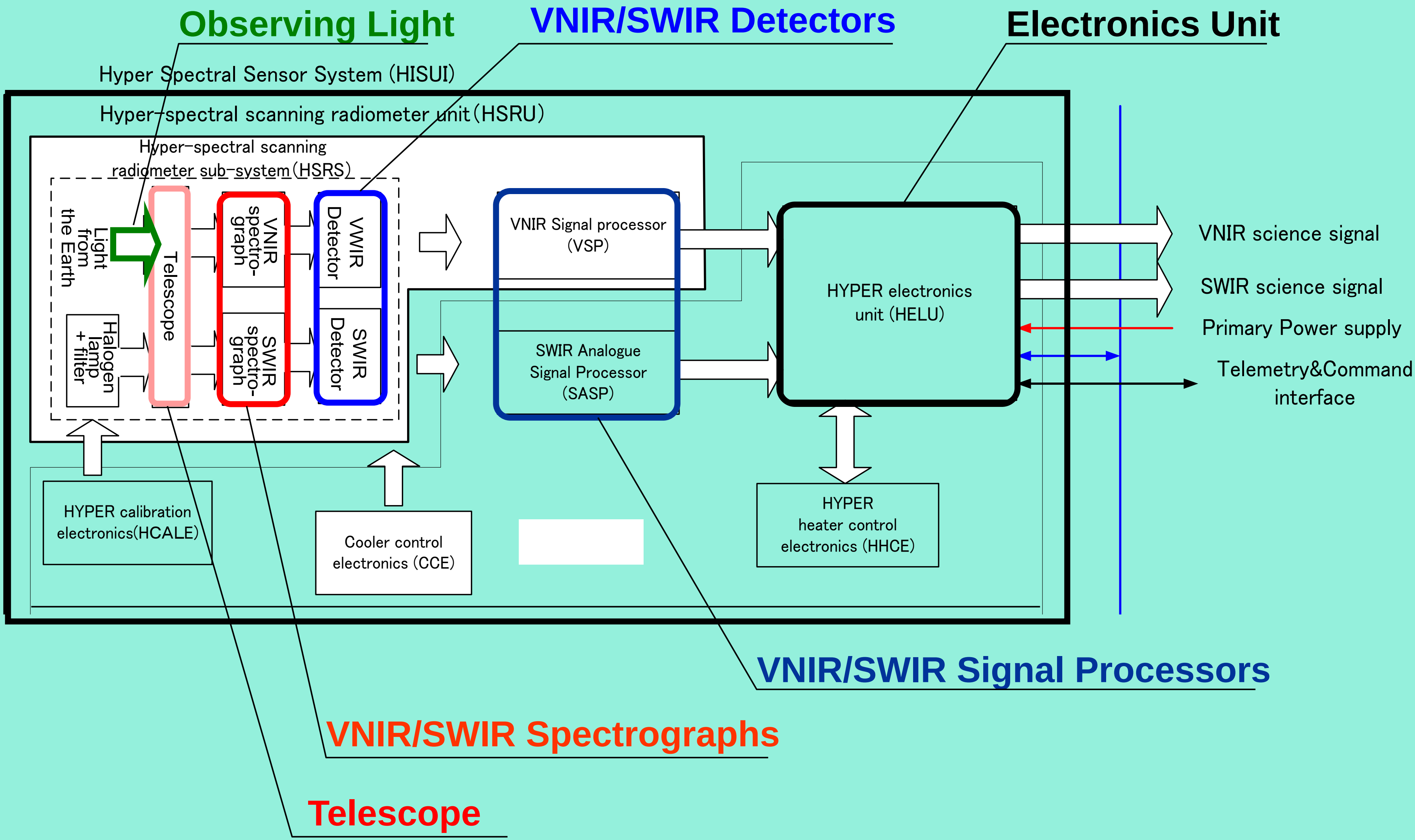
HISUI Specifications

Instrument	Hyperspectral sensor		Multispectral sensor
	VNIR	SWIR	
Spatial Scanning	Push broom type by satellite moving		Same as left
IFOV (Spatial resolution)	48.5 urad (30 m)		8.1 urad (5 m)
FOV (swath width)	48.5 mrad (30 km)		144.7 mrad (90 km)
Observation frequency	< 4.36 ms		< 0.73 ms
Wavelength region and number of bands / Center wave length	400-970 nm (57 bands)	900-2500 nm (128 bands)	Band1:485 nm Band2:560 nm Band3:660 nm Band4:835 nm
	185 bands		
Spectral resolution (sampling) for Hyper Spectral Band width for Multi	10 nm	12.5 nm	Band1:70 nm Band2:80 nm Band3:60 nm Band4:110 nm
Spectral resolution (ILS FWHM)	< 11 nm	< 16 nm	Same as band width
Dynamic range	Saturated at > 70% albedo		Same as left
SNR	>450 (@620 nm)	>300 (@2100 nm)	> 200 (for each band)
MTF	>0.2		> 0.3
Smile and Keystone	< 1 image pixel		N/A
Calibration accuracy (radiometric)	Absolute:±5%, Among bands:±2%		Same as left
Calibration accuracy (spectral)	< 0.2 nm	< 0.625 nm	N/A
Quantization	12 bit		Same as left
Mission life	5 years		Same as left

HISUI Functional Block Diagram

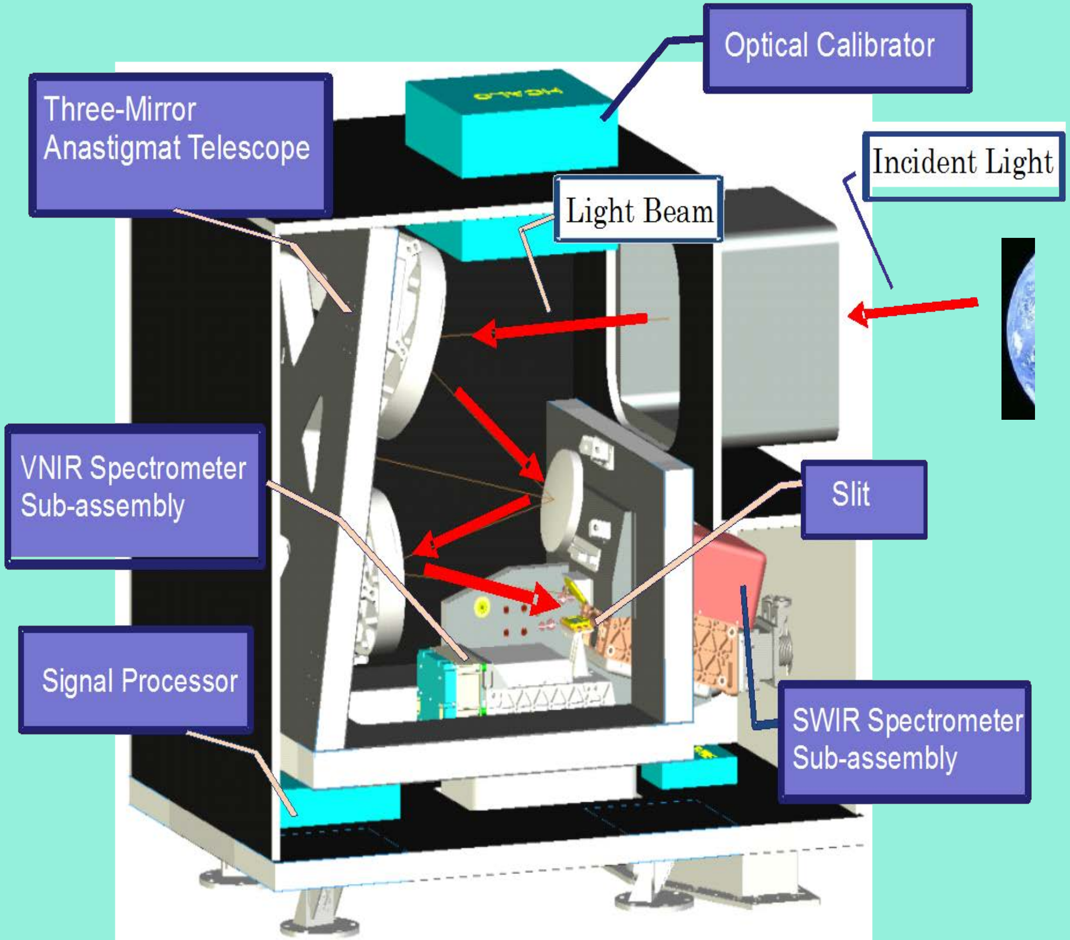


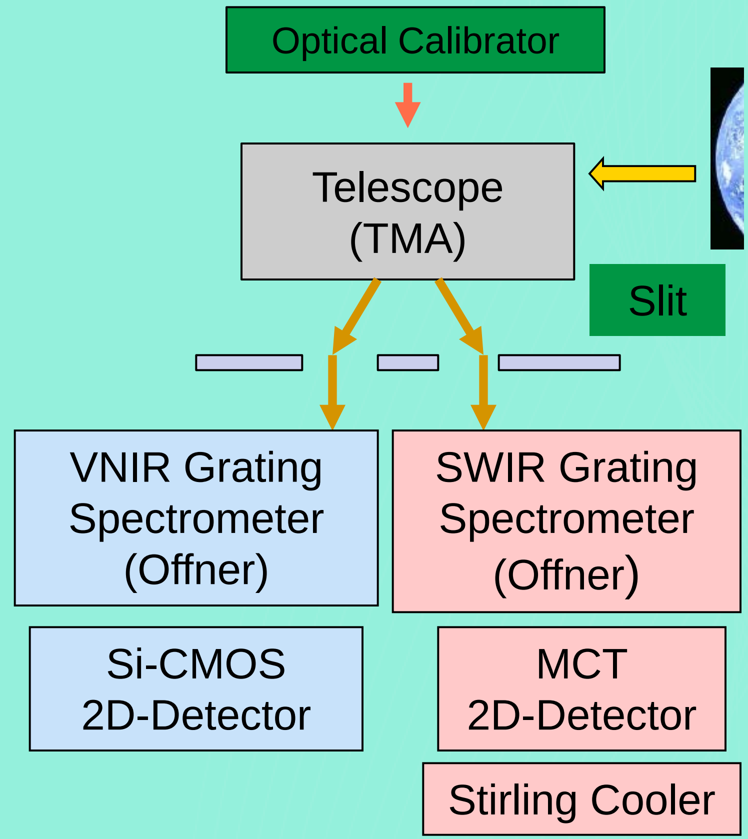
HISUI Hyperspectral Sensor Function Diagram



1. HISUI Instrument Overview

Hyperspectral Sensor Unit





Design of Hyperspectral Sensor Unit

Design for The Telescope and Spectrograph

- Telescope
  - TMA (off-axis three mirror anastigmat type)
  - The diameter of telescope is approximately 30cm and the F-number is 2.2. It is matched for the ground sampling distance(GSD) of 30 meters.
- Spectrograph
  - Two Aberration-corrected Offner type Grating spectrographs

    VNIR spectrograph and SWIR spectrograph

    High diffraction efficiency

    Equal interval of Spectral Sampling

    Minimize the wavelength shift/ smile/ keystone
  - Robust in alignment against temperature change
  - Stable temperature control within +/-1K in orbit to minimize the wavelength shift.

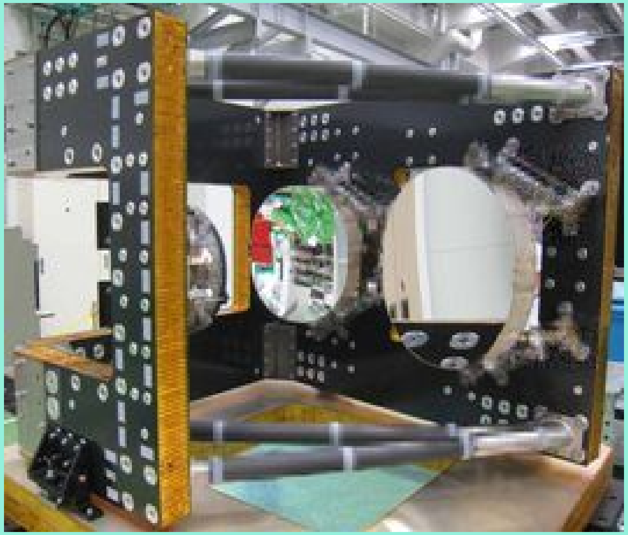
Design of Hyperspectral Sensor Unit

Design for The Telescope and Spectrograph

- Detector
  - VNIR detector: 2Dimentional backside illuminated silicon CMOS
  - SWIR detector: 2Dimentional PV-MCT

- Cooler and Dewar
- SWIR detector is integrated inside the dewar
- and cooled down to 145K using Stirling-type cryocooler.

Flight Model of Hyperspectral Sensor Unit



Optical Calibrator

Telescope (TMA)

Slit

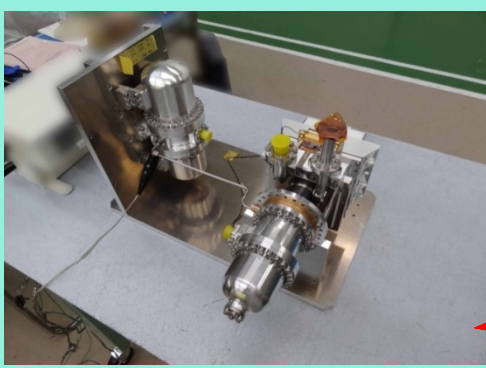
VNIR Grating Spectrometer (Offner)

SWIR Grating Spectrometer (Offner)

Si-CMOS 2D-Detector

MCT 2D-Detector

Stirling Cooler



Onboard Data Correction and Compression

Function of HELU (Hyper Electronics Unit) for Digital Data

- **Data correction** of items as follows;
    - Offset-Gain-Non linearity
    - PRNU (Photo Response Non-Uniformity)
    - Smile distortion (using weight-coefficients during the binning)
- In order to reduce data size,
    - data binning in spectral direction

      4 pixels in VNIR 2 pixels in SWIR
    - lossless **data compression**

- Observation Mode:

  With Onboard Data Correction and Data Compression
- Calibration Mode:

  Without Onboard Data Correction nor Data Compression

  (Onboard Calibration with Lamps, Vicarious Calibration, ……)

Flow of Onboard Data Correction in HELU

Sensor Data (12bit DN) before correction and binning
VNIR: 228 Channels (2.5nm interval)
SWIR: 256 Channels(6.25nm interval)

↓

Radiometric correction
offset-gain-(non)linearity, PRNU

↓

Binning (including smile correction using Weight Function)

↓

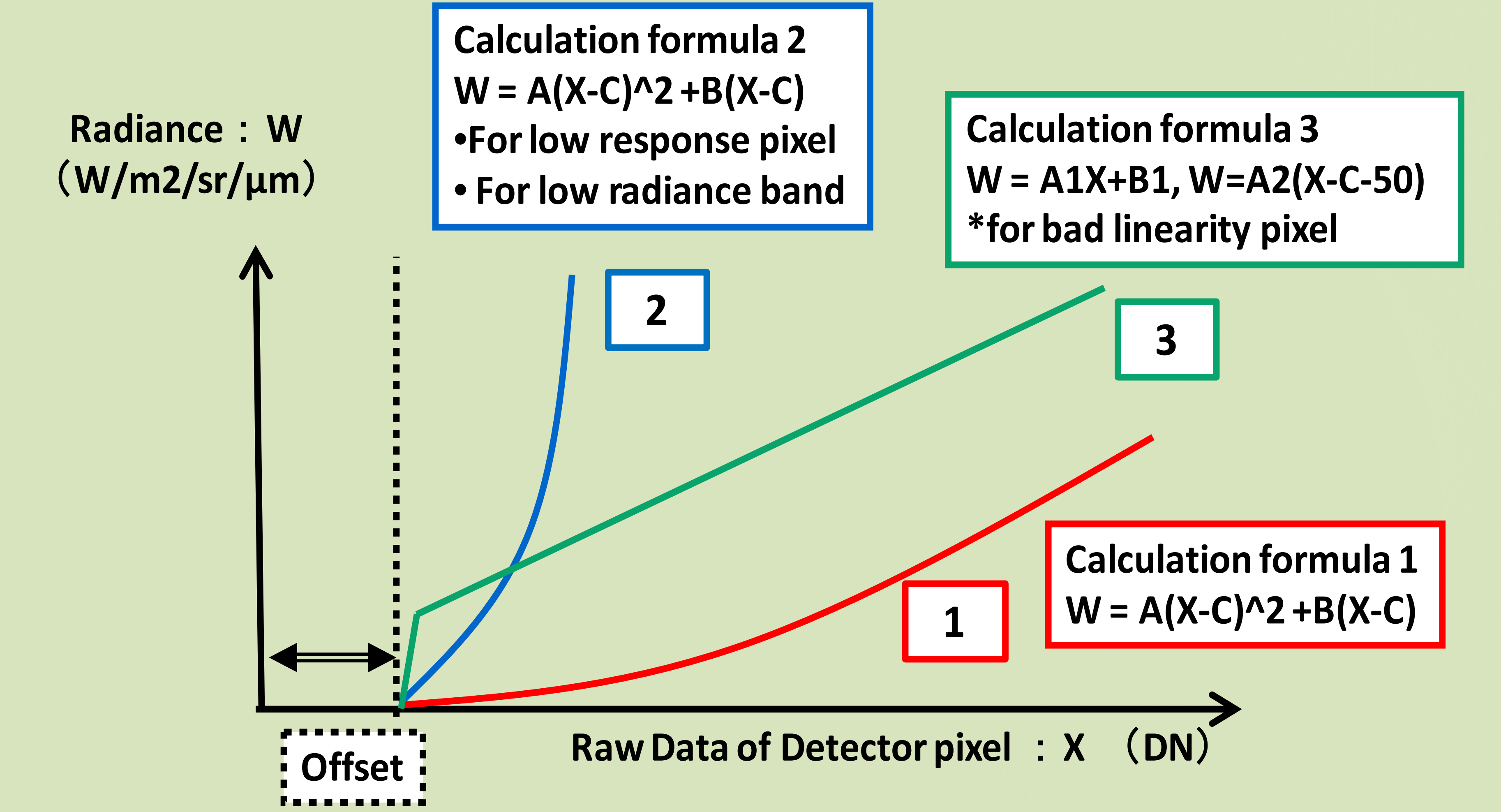
Corrected Radiance data of each band(12bit DN)
VNIR :57bands (10nm interval),
SWIR: 128bands(12.5nm interval)

↓

Down Link

Onboard Radiometric Correction

Formulae for non Linearity/Offset Correction

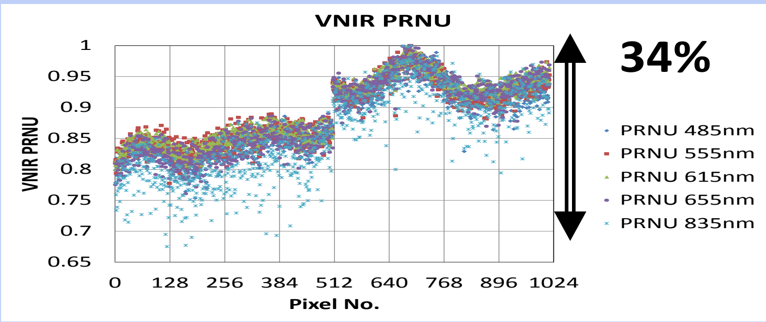


Onboard Radiometric Correction

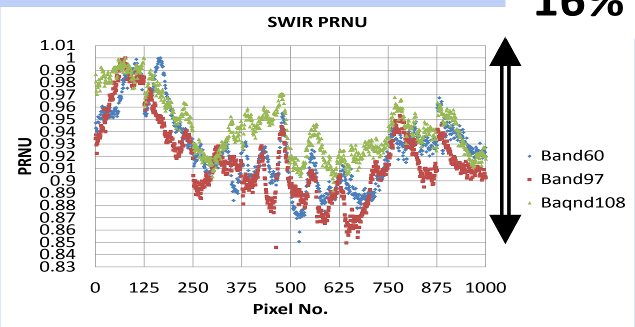
Examples of PRNU/Gain Correction

VNIR

SWIR

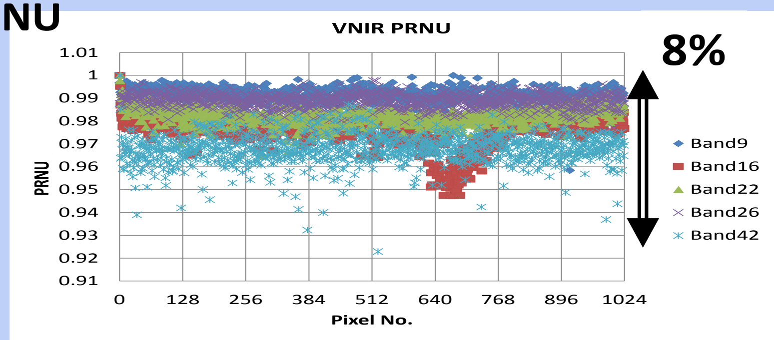


16%



Raw Data

PRNU



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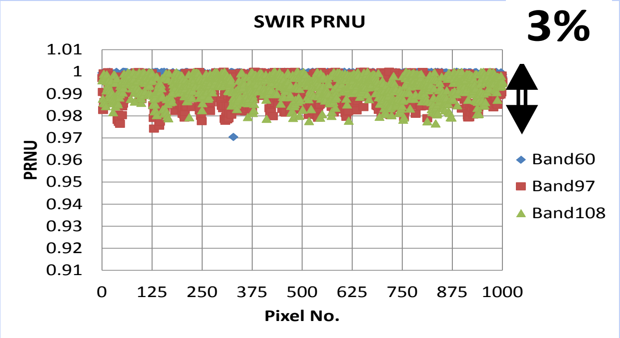


Corrected Data

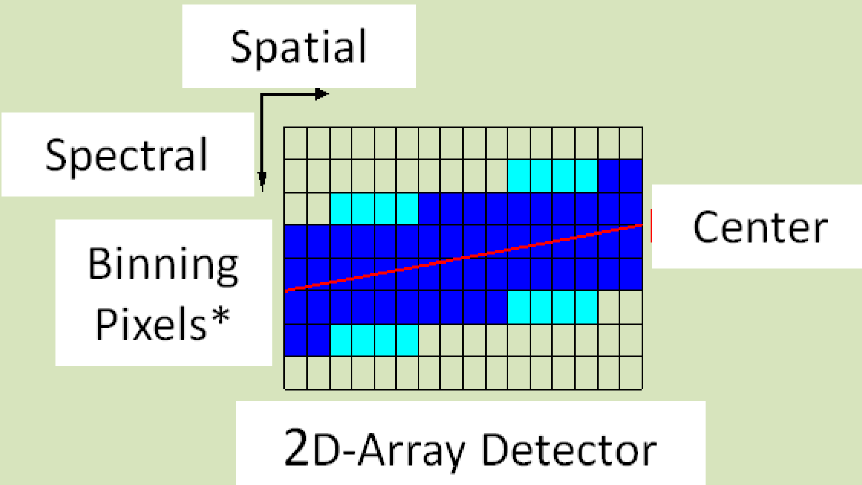
Detector pixel No

PRNU: Photo **R**esponse **N**on-**U**niformity

(*) Based on the data of Evaluation Model of the sensor

Onboard Spectral Correction

Concept of Binning/Smile Correction



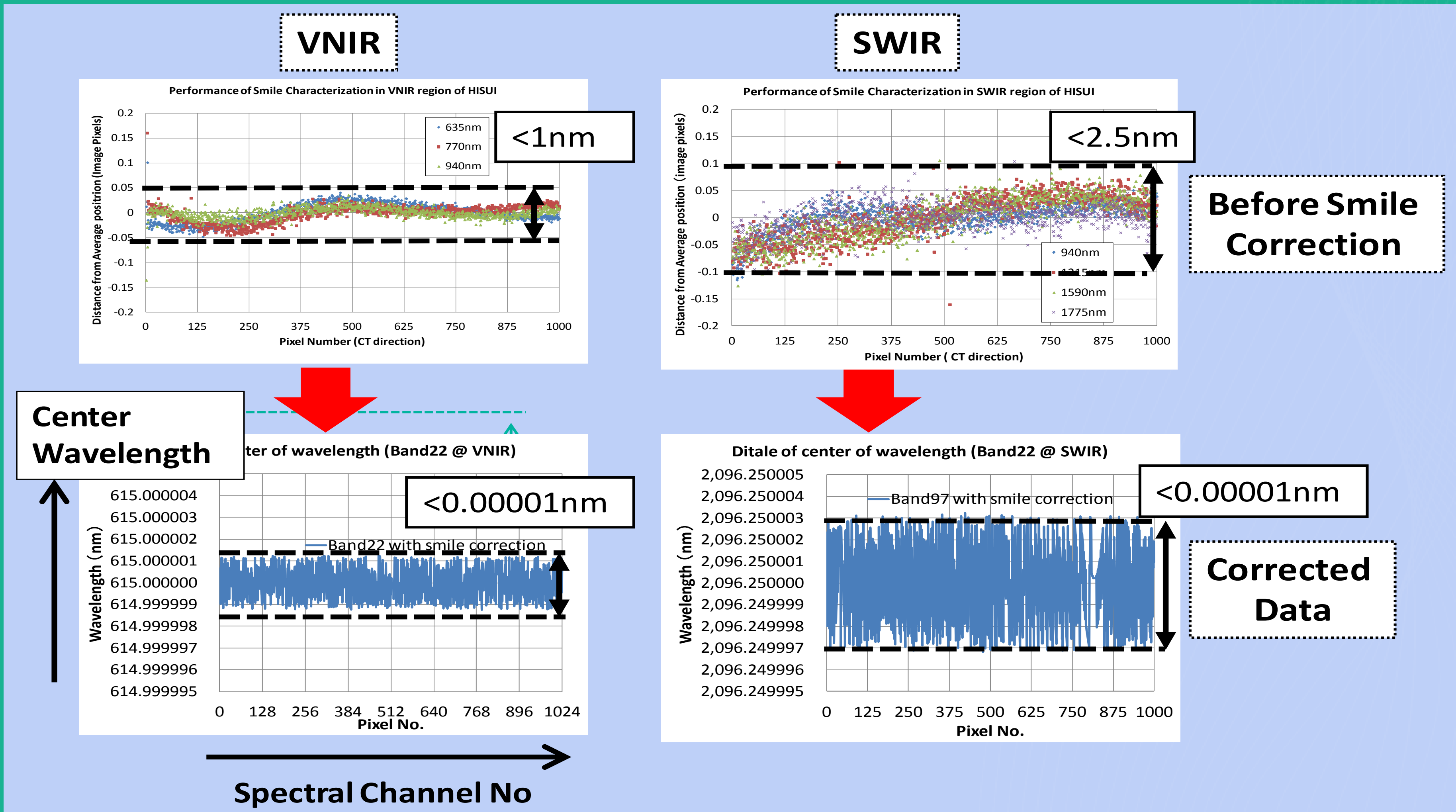
$$p = \frac{w_1 x_1 + \cdots + w_n x_n}{w_1 + \cdots + w_n}$$

p : Radiance data after smile correction
w_n : Weight function of pixel No (n)
X_n : Radiance data of pixel No(n) after radiometric correction
n : VNIR =1- 6, SWIR =1-4
(*) Binning is executed along spectral direction

(*) Based on the data of Evaluation Model of the sensor

Onboard Spectral Correction

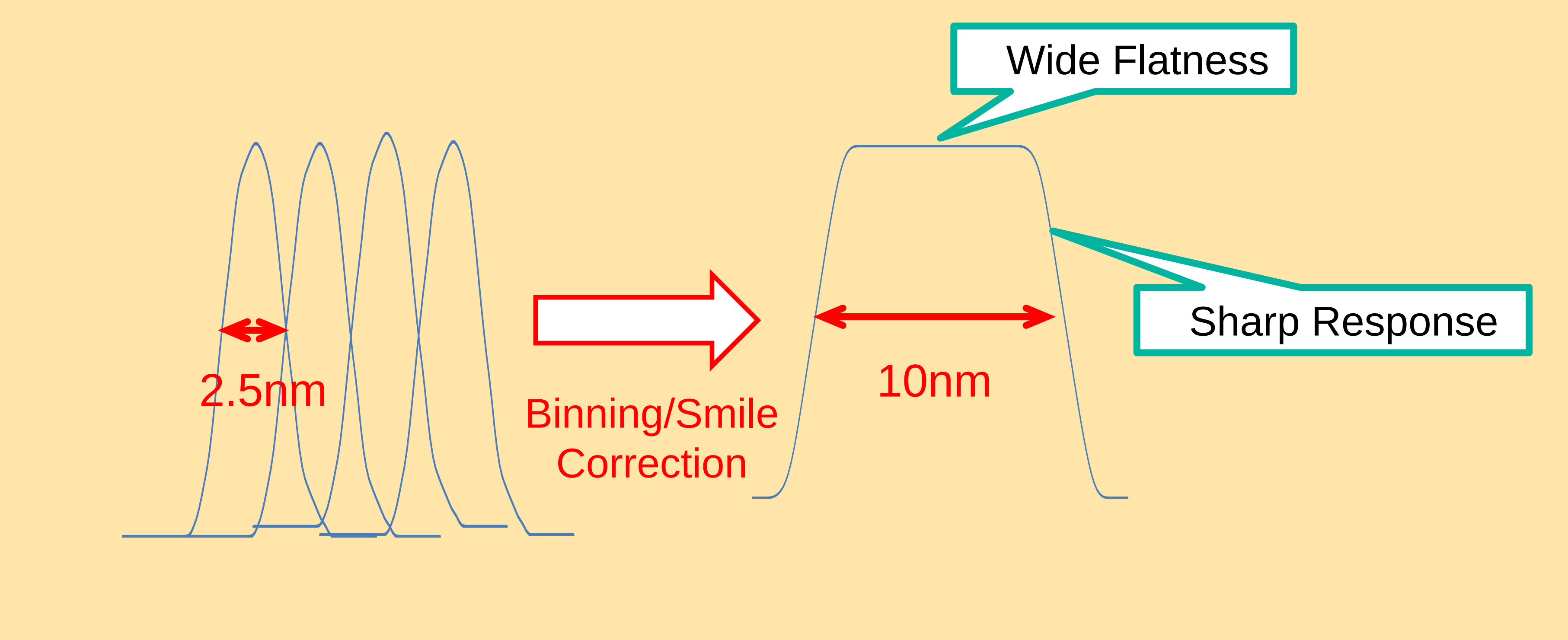
Examples of Binning/Smile Correction



(*) Based on the data of Evaluation Model of the sensor

Onboard Spectral Correction

Concept of Binning and Spectral Response



data binning in spectral direction
4 pixels in VNIR
2 pixels in SWIR

Summary of Onboard Data Correction

Items	Performance after onboard correction	Performance before onboard correction*
Smile	<10-5nm@VNIR <10-5nm@SWIR	<1nm@VNIR <2.5nm@SWIR
Linearity	<5%@VNIR (over99.99% data) <5%@SWIR (over99.99% data)	<5%@VNIR (over99.97% data) <5%@SWIR (over99.99% data)
PRNU	PRNU<13%@VNIR (over99.7 data) PRNU<20%@SWIR (over99.7 data)	PRNU<34%@VNIR (over99.7 data) PRNU<33%@SWIR (over99.7 data)

(*) Based on the data of Evaluation Model of the sensor

Spectral Performance

Spectral Performance :

Wavelength Shift/ Smile/ Keystone

Before Launch

- Spectrometer Performance
- Misalignment of Assembly

To measure

- Onboard correction parameter Table

(install into Onboard Data Processor of HELU)

Launch/In Orbit

- Offset :Launch Vibration Condition
- *Variable* :Onboard Thermal Vacuum Condition

Correction Parameter Table: install into Ground Data Processing System

Spectral Performance

Wavelength shift of Flight Model (expected)

VNIR <0.06nm

SWIR <0.11 nm

including launch and space environment conditions

Onboard spectral calibrator monitors the wavelength shift.

Spectral Performance :
Wavelength shift of evaluation model

	VNIR	SWIR	Remarks
Specification	**<10nm**	**<12.5nm**	**<1 pixel**
Normal Temp. & Pressure	<1.0nm	<2.5nm	
After Onboard Correction	$<10^{-5}$nm	$<10^{-5}$nm	
After Launch Vibration Test	Negligible	Negligible	Offset
Thermal Vacuum Test	<0.058nm	<0.106nm	Variable
Total	**<0.06nm**	**<0.11nm**	Expected Value Onboard
Onboard Calibrator	**0.2nm**	**0.625nm**	

Conclusions

- Onboard Data Correction of Hyperspectral Sensor of HISUI
- The validation tests of Onboard Data Correction function have been completed using the data of functional evaluation model of Instrument.
- The smile performance after correction is very well.
- The method of Onboard Data Correction has been established.
- Status of HISUI Instrument
- Analyzing test results, FM is expected to achieve the spectral performance better than specifications.
- The critical parts of FM, such as the telescope, the spectrographs and the detectors, have been manufactured and the integration & tests of the sensor is proceeding .

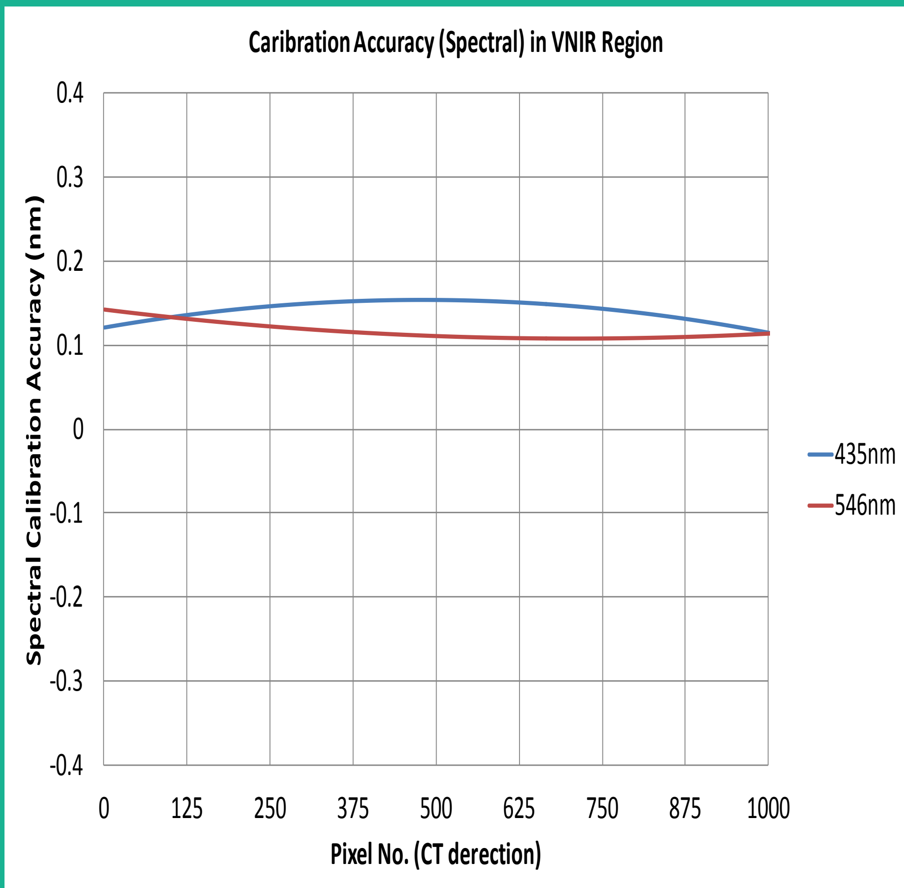
Acknowledgements

- HISUI project proceeds under the contract with METI (Ministry of Economy, Trade and Industry).

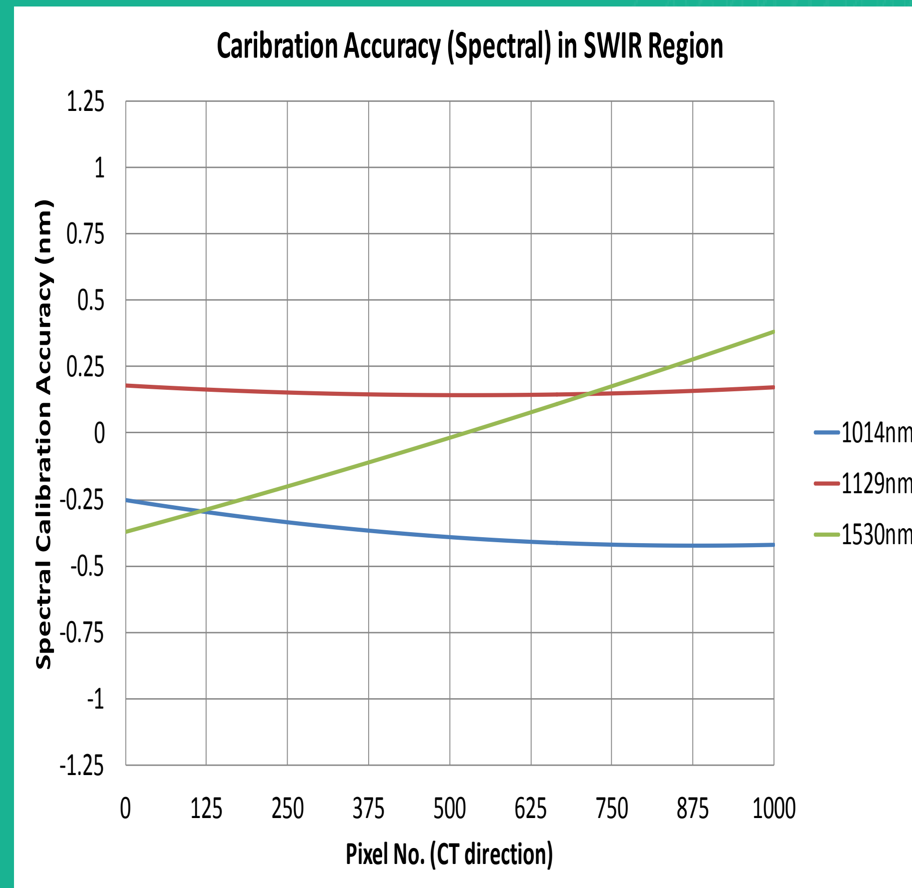
Thank you very much for your attention !

Spectral Performance

Test Data of Evaluation Model（Spectral Calibration Accuracy at Normal Temp.）



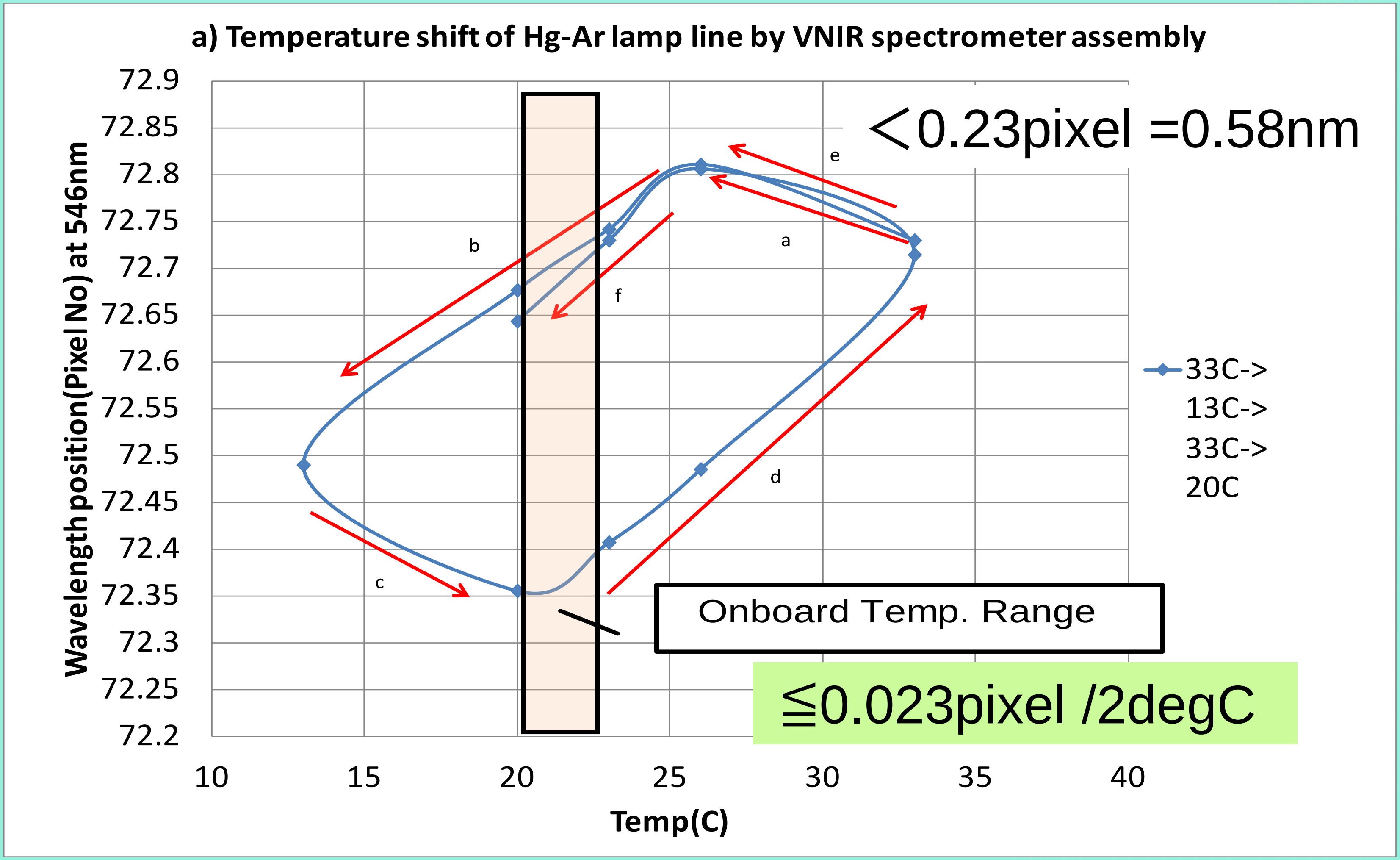
VNIR



SWIR

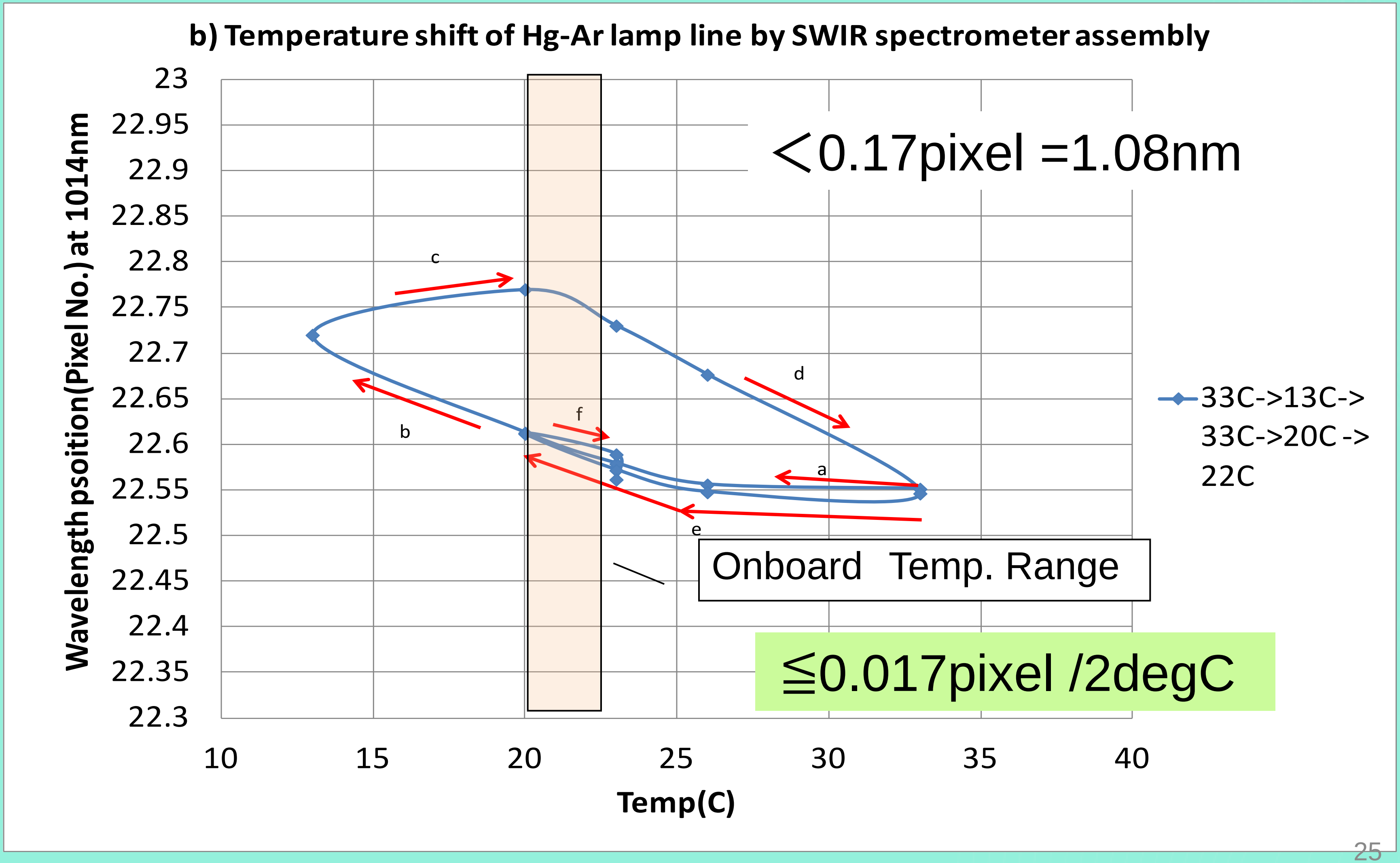
Spectral Performance

VNIR :Wavelength Shift vs. Temp. (Thermal Vacuum Test)



Spectral Performance

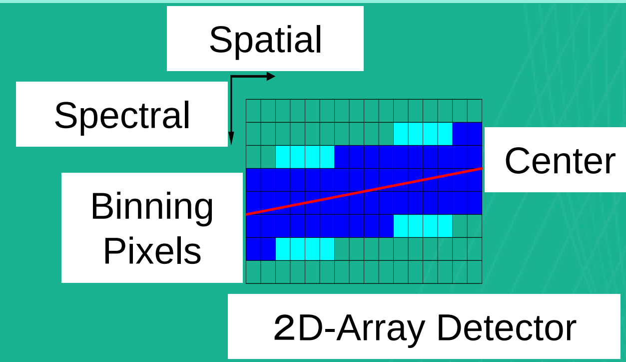
SWIR :Wavelength Shift vs. Temp. (Thermal Vacuum Test)

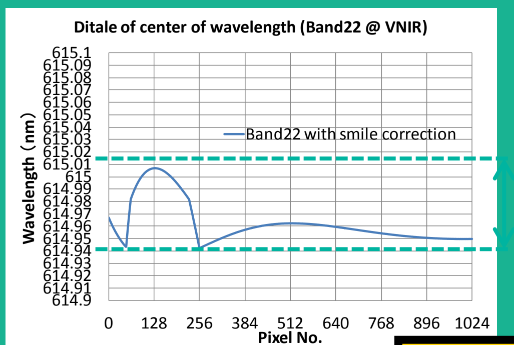


Spectral Performance After Onboard Correction

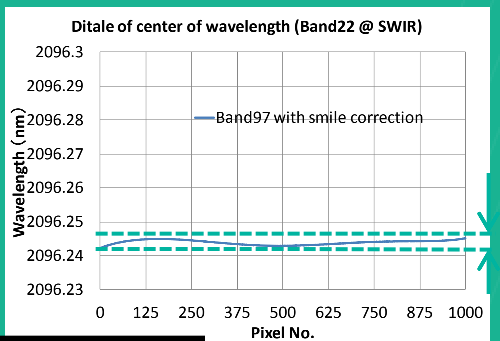
Onboard correction

- Using the weighting function at the binning



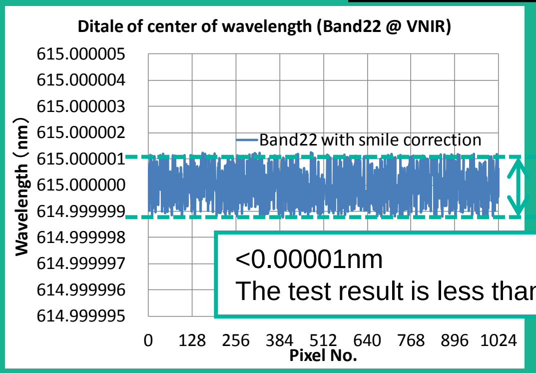


<0.06nm

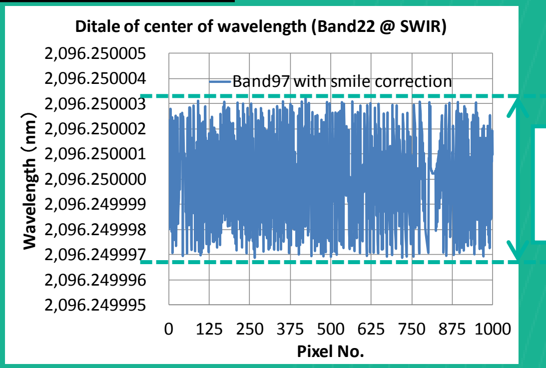


<0.008nm

Optimize the weighting function

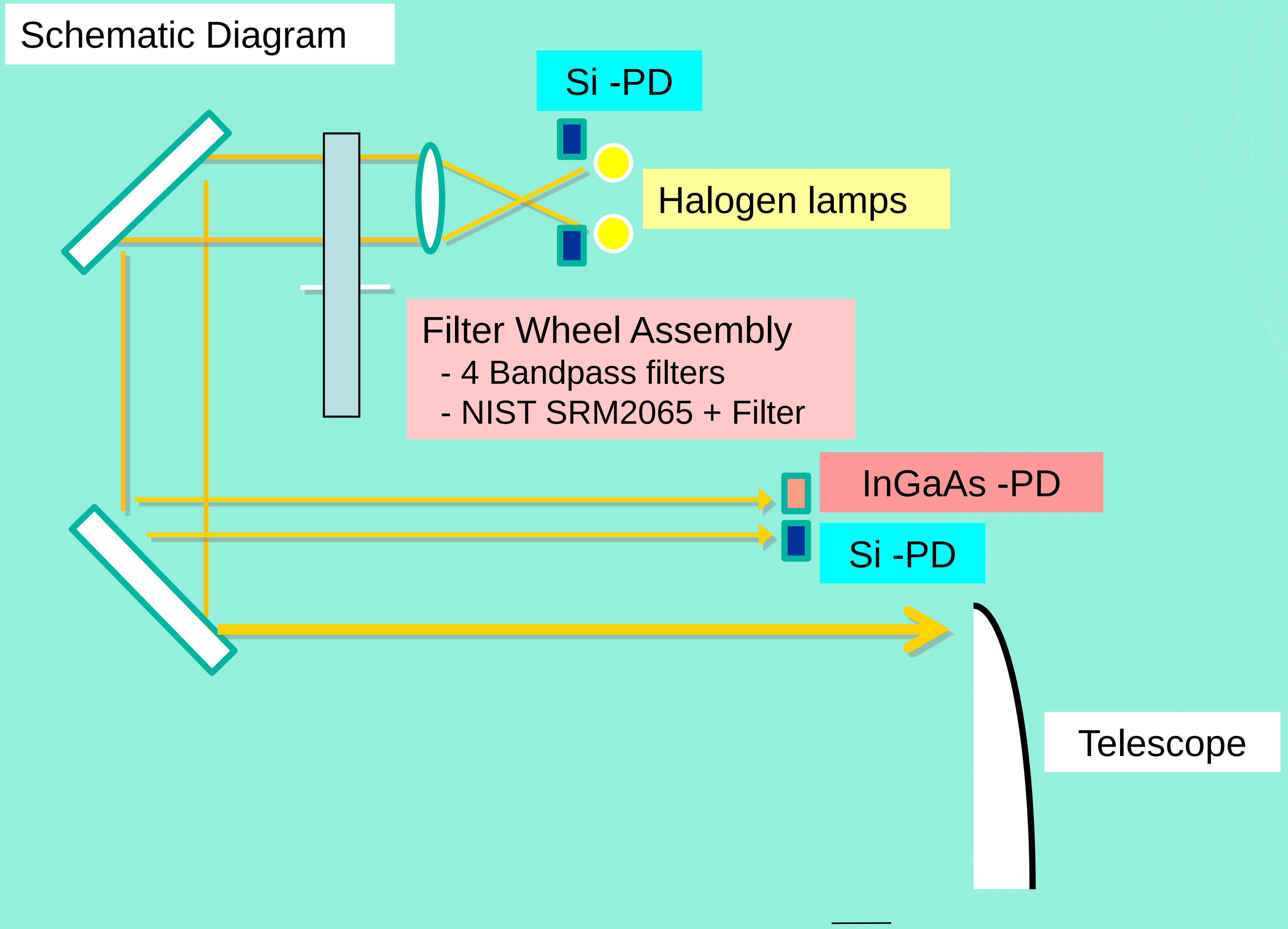


<0.00001nm
The test result is less than 0.000002nm



<0.00001nm
The test result is less than 0.000003nm

Onboard Calibrator of Hyperspectral sensor



Onboard Calibrator of HISUI

Onboard Calibrator of HISUI

- HISUI has Optical onboard calibrators .

Instrument	Hyperspectral Sensor	Multispectral Sensor
Light Source	Two halogen lamps	Two halogen lamps
Detector to monitor	•Si-photodiode for VNIR •In-Ga-As-photodiode for SWIR	Si-photodiodes
Filters	Band pass filters Spectral calibration filter	4 band pass filters The band pass wavelength of filter is matched to the spectral band for observation.
Spectral Calibration Accuracy (Target)	0.2nm (VNIR), 0.625nm (SWIR)	N/A