DESIGN AND BREADBOARDING ACTIVITIES OF THE SECOND-GENERATION GLOBAL IMAGER (SGLI) ON GCOM-C

Yoshihiko Okamura(1), Kazuhiro Tanaka(1), Takahiro Amano(2), Masaru Hiramatsu(2), Koichi Shiratama(2)

(1) Japan Aerospace Exploration Agency, 2-1-1 Sengen, Tsukuba, Ibaraki, 305-8505, Japan, okamura.yoshihiko@jaxa.jp, tanaka.kazuhiro@jaxa.jp.

(2) NEC TOSHIBA Space Systems Ltd., 10, Nisshin-cho 1-choume, Fuchu, Tokyo, 183-8551, Japan amano.takahiro@ntspace.jp, hiramatsu.masaru@ntspace.jp, shiratama.koichi@ntspace.jp

ABSTRACT

The Global Change Observation Mission (GCOM) is the next generation earth observation project of Japan Aerospace Exploration Agency (JAXA). GCOM concept will take over the Advanced Earth Observing Satellite-II (ADEOS-II) and develop into long-term monitoring of global climate change. The GCOM observing system consists of two series of medium size satellites: GCOM-W (Water) and GCOM-C (Climate). The Second-generation Global Imager (SGLI) on GCOM-C is a multi-band imaging radiometer with 19 spectral bands in the wavelength range of near-UV to thermal infrared. SGLI will provide high-accuracy measurements of Ocean, Atmosphere, Land and Cryosphere. These data will be utilized for studies to understand the global climate change, especially human activity influence on earth environments.

SGLI is a suite of two radiometers called Visible and Near Infrared Radiometer (VNR) and Infrared Scanner (IRS). VNR is a pushbroom-type radiometer with 13 spectral bands in 380nm to 865nm range. While having quite wide swath (1150km), instantaneous field of view (IFOV) of most bands is set to 250m comparing to GLI's 1km requirement. Unique observation function of the VNR is along-track ±45deg tilting and polarization observation for 670nm and 865nm bands mainly to improve aerosol retrieval accuracy. IRS is a wiskbroom-type infrared radiometer that has 6 bands in 1μm to 12μm range. Swath and IFOV are 1400km and 250m to 1km, respectively.

This paper describes design and breadboarding activities of the SGLI instrument.

1. INTRODUCTION

The global warming has been a growing world wide problem. To address this problem, the 10-year implementation plan for the Global Earth Observation System of Systems (GEOSS) was adopted by the third Earth Observation Summit which was held in Brussels in February 2005. The purpose of GEOSS is to achieve comprehensive, coordinated and sustained observations of the earth environment. The satellite earth observation system is one of the key technologies in GEOSS. To contribute toward GEOSS, JAXA launched the Global Change Observation Mission (GCOM) project. Main mission of GCOM is to establish a system which observes the earth environment for more than 10 years, in order to better understand the global water cycle and climate change mechanism.

The GCOM observing system consists of two series of medium-size satellites which are GCOM-W (Water) and GCOM-C (Climate). GCOM-W will carry the microwave scanning radiometer named Advanced Microwave Scanning Radiometer 2 (AMSR2), and mainly address the global water cycle.[1] GCOM-C will carry the multi wavelength optical imager named Second Generation Global Imager (SGLI), and mainly address the climate change mechanism.[2] To realize above mission objectives, three generations of GCOM satellites (GCOM-W and GCOM-C) are planned to be operated for more than 10 years.

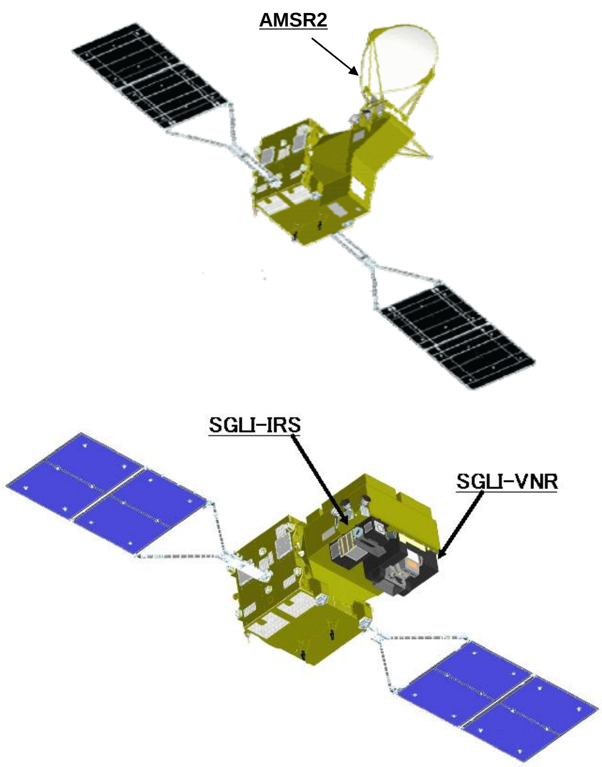

Fig.1. On-orbit configuration of GCOM-W1 (right) and GCOM-C1 (left)

2. OVERVIEW OF SECOND GENERATION GLOBAL IMAGER (SGLI)

Second-generation Global Imager (SGLI) on GCOM-C is a multi-band imaging radiometer in the wavelength range of near-UV to thermal infrared.[3][4] SGLI is a third-generation instrument for this type sensor in Japan. First one is Ocean Color and Temperature Scanner (OCTS) on MIDORI satellite, and second one is Global Imager (GLI) for MIDORI-2. SGLI will observe global environmental factors of earth's multi-sphere: Land, Ocean, Atmosphere, and Cryosphere, in order to monitor the climate change and to better understand the carbon cycle and radiation budget.

SGLI's observation features are as follows.

- Multi-band observation with 19 spectral channels,
- 250m spatial resolution on the land surface and 1km resolution on the ocean surface and the polar region,
- Wide FOV of 1150km for VNR and 1400km for IRS,
- Polarization observation with tilting function.

The main performance requirement of SGLI is shown in Table 1. SGLI has two sensors named Visible and Near Infrared Radiometer (VNR) and Infrared Scanner (IRS). VNR is UV to near infrared (NIR) range sensor, it consists of 11 channel multi-band radiometer: VNR Non-Polarized (VNR-NP), and 3 polarization angle (0, 60 and 120 deg) polarimeter: VNR Polarized (VNR-P). IRS is infrared radiometer from 1μm to 12μm range which has 4 channels in shortwave infrared region (SWI 1.05-2.21μm) and 2 channels in thermal infrared region (TIR 10.8 and 12.0μm).

Table 1 Main Performance Requirements

Item	Requirement
Satellite	GCOM-C1
Orbit	798km Altitude Sun-synchronous
Spectral Bands	VNR-NP : 11CH 380-865nm VNR-P : 2CH 670, 865nm 0, 60, 120deg Polarization IRS SWI : 4CH 1.05-2.21μm IRS TIR : 2CH 10.8, 12.0μm
Scan Angle	VNR-NP : 70deg (Push broom scanning) VNR-P : 55deg (Push broom scanning) IRS : 80deg (45deg rotation mirror scanning)
Instantaneous field of view (IFOV) at nadir	VNR-NP : 250m, 1000m(VN9) VNR-P : 1000m IRS SWI :250m(SW3), 1000m(SW1,2,4) IRS TIR : 500m
Quantization	12bit
Absolute Calibration Accuracy	VNR : ≤3% IRS SWI : ≤5% IRS TIR : ≤0.5K
Life Time	5 Years

Table 2 SGLI Observation Requirement details for bands

CH		λ_c	$\Delta\lambda$	IFOV	SNR	L_{std}(for SNR)
		nm	nm	m		W/m^2/sr/μm
VNR-NP	VN1	380	10	250	250	60
	VN2	412	10	250	400	75
	VN3	443	10	250	300	64
	VN4	490	10	250	400	53
	VN5	530	20	250	250	41
	VN6	565	20	250	400	33
	VN7	670	10	250	400	23
	VN8	670	20	250	250	25
	VN9	763	8	1000	400	40
	VN10	865	20	250	400	8
	VN11	865	20	250	200	30
VNR-P	P1	670	20	1000	250	25
	P2	865	20	1000	250	30
IRS SWI	SW1	1050	20	1000	500	57
	SW2	1380	20	1000	150	8
	SW3	1630(TBD)	200	250	57	3
	SW4	2210	50	1000	211	1.9
IRS TIR	T1	10.8	0.7	500	0.2	300
	T2	12.0	0.7	500	0.2	300
CH		μm	μm	m	K	K
		λ_c	$\Delta\lambda$	IFOV	NEdT	T_{std}(for NEdT)

The sensor requirement was studied based on the previous OCTS and GLI mission experiment of ocean, atmosphere, land and cryosphere researchers and users. The key observation channels such as 670nm and 865nm is observed with both low and high dynamic range independently according to researchers' requirement. Total spectral channels for SGLI is optimized to 19 channels including tilting polarization observation comparing to 36 channels for GLI. On the other hand, the SGLI standard products are increased from 22 products of GLI to 29 products.

Basic instantaneous field of view (IFOV) is set to 250m comparing to GLI's 1km requirement. Using this higher resolution with wide FOV (1150km for VNR and 1400km for IRS), it is expected that the human activity influence on earth environments can be studied.

3. INSTRUMENT DESIGN

3.1 VNR

Visible and Near Infrared Radiometer (VNR) is push broom scan radiometer which has 13 channels in the region of 380nm to 865nm. VNR instrument configuration is shown in Figure 2.

VNR-NP instrument is divided into three 24deg pushbroom type telescopes configured in cross track direction to realize the wide FOV (70deg) requirement with wide spectral range (380nm to 865nm). Each telescope has refractive telecentric optics and 11 channels CCD on which 11 channels bandpass filter assembly is mounted.

To realize VNR-P polarization observation, three linear polarization channels (0, 60 and 120 deg) are set for two pushbroom telescopes which is dedicated for 670nm and 865nm observation. Tilting operation around Y axis ±45deg is required for VNR-P in order to observe with scatter angle requirement from aerosol observation. Observation scatter angle is calculated using satellite orbital position, sun and observation point direction. The scatter angle direction between 60 and 120 deg is required for the aerosol retrieval over the land surface.

VNR has large deployable diffuser plate made of Spectlalon for the solar calibration and inner light source using light emitting diodes (LEDs) to achieve the high calibration accuracy. In addition to the onboard calibration, lunar calibration with the spacecraft maneuver is planed for long term trend evaluation.

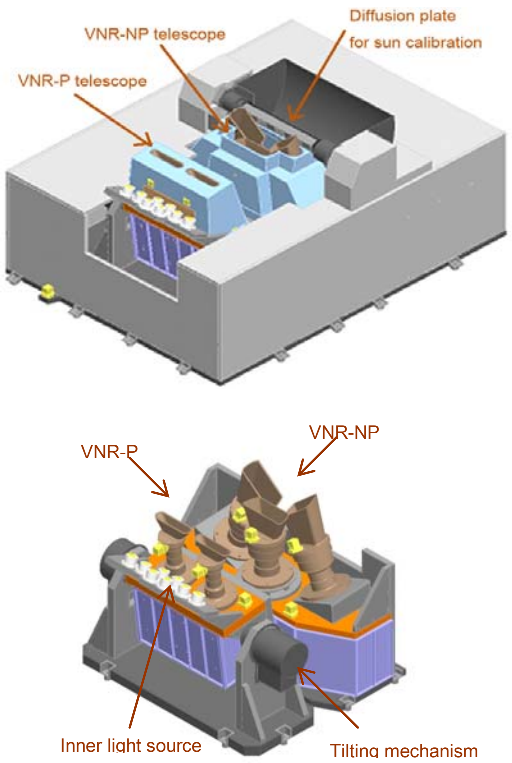

Fig. 2 VNR instrument 3D draw and its inner configuration

3.2 IRS

Infrared Scanner (IRS) is wiskbroom scan radiometer which has 6 channels in the region of 1.05µm to 12µm. IRS instrument configuration are shown in Figure 3.

The 45deg tilted scan mirror is rotated around X axis continuously to realize to scan the 80 deg earth observation, onboard calibrator (blackbody, solar diffuser, and inner light source) and deep space in short time. Compared with the double-sided mirror employed on GLI and MODIS, constant incident angle to the scan mirror is advantage for the calibration uncertainty.

The observation light is directly focused onto the focal plane using the Ritchey-Chretien type telescope without any relay optics. The infrared spectral range is divided by the dichroic filter for the shortwave infrared (SWI) and thermal infrared (TIR) regions in order to optimize the detector requirement.

The SWI detector is 4 channels InGaAs photo-diode array cooled to -30 deg C using peltier thermo electronic cooler. The TIR detector is 2 channels photo-voltaic type HgCdTe (PV-MCT) array cooled to 55K by stirling-cycle cooler. The bandpass filters corresponding to the spectral channels are mounted on the focal plane in the detector packages.

The solar diffuser made of Spectlalon, inner light source using light emitting diodes (LEDs) for SWI channels and high emissivity blackbody for TIR channels are employed as the onboard calibrator. Those calibration sources and deep space window arranged around the scan mirror make it possible to obtain calibration data every scan.

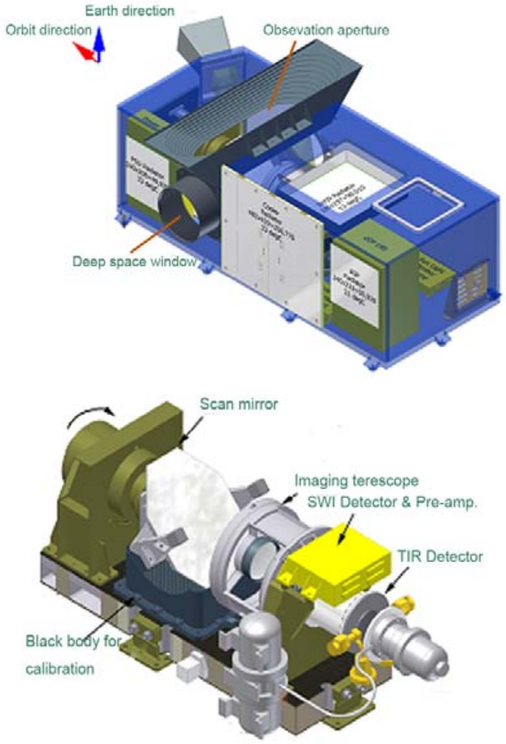

Fig. 3 IRS instrument 3D draw and its inner configuration

4 BREADBOARDING ACTIVITIES

4.1 SGLI breadboarding activities

The SGLI bread boarding activities have been conducted by NEC TOSHIBA Space Systems Ltd. since the beginning of 2006. The purposes of the two years "front-loading" activities are as follows;

- Minimize the technical risk in following development phase,
- Validate feasibility of the technical challenges and critical components,
- Assess and demonstrate the observation performances by sensor system level such as signal to noise ratio (SNR), alignment and calibration accuracy.
- Establish techniques of the sensor integration and calibration test methods

The SGLI system design which was reflected the preliminary test manufacture results of critical technologies was finished in June 2007 and manufacture and tests of the BBM components have been finished. SGLI BBM systems integration and tests are now conducted and will be finished in autumn 2008.

4.2 SGLI-BBM components and key technical issues

The Major SGLI-BBM components and those key technical issues are shown in Table 3. The highlight results of some BBM components manufacture and evaluation are shown below.

Table 3 Major SGLI-BBM components and key technical issues

Major BBM components		Key technical issues and BBM evaluation
VNR	Optics	Imaging performance for wide FOV and wide spectral range Suppression of polarization sensitivity
	Bandpass filters Polarization filters	Spectral performance (in-band, out-band) High-precision mechanical processing and assembly technology
	CCD	Realization of 11 line CCD Radiometric performance (SNR, Sensitivity, Output stability)
	Readout circuits	Low noise design, Output stability
	Onboard calibrator	Light level accuracy and stability Environment resistance of LEDs
IRS	Scan mirror assembly	Scanning accuracy and stability Bearing life time
	Optics	Imaging performance
	Detector (SWIR, TIR)	Radiometric performance (SNR, Sensitivity, Output stability)
	Bandpass filters	Spectral performance (in-band, out-band)
	Mechanical cooler	Cooling performances (TIR: 55K, temperature stability)
	Readout circuits	Low noise design, Output stability
	Onboard calibrator	SWI: Light level accuracy and stability TIR: high emissivity of blackbody calibrator

(1) VNR focal plane (CCD and filter assembly)

VNR detector adopts dedicated 11 line linear CCD detector with 6000 pixels on each line. The bandpass filters corresponding to 11 spectral channels are assembled and mounted just in front of the CCD focal plane. To minimize the parallax effects on observation, the line interval is minimized to 1mm or 2mm considering severe spectral performance requirement. The channel order is also specified from mission requirement. Fig. 4 shows the 11 line CCD and bandpass filter assembly.

To achieve the high radiometric requirements of VNR, CCD performance such as SNR, linearity, output stability is important. As different dynamic range is required channel by channel, the integration time of CCD is controlled for each line independently. As a result of the BBM activities, the dedicated 11 line CCD with required performances were manufactured and the radiometric tests with the readout circuits (pre-amp and analog signal processor) show the feasibility of the high radiometric performances of VNR.

As for the 11 line bandpass filter assembly, not only the spectral performance (in-band and out-band) but also high-precision mechanical processing and assembly technology are essential. As a result of the BBM manufacture, processing and assembly technology was established.

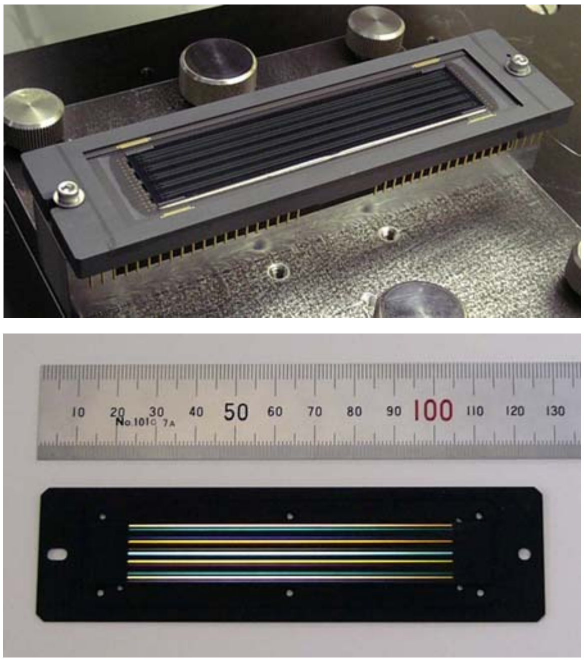

Fig. 4 11 line CCD and bandpass filter assembly

(2) SWI detectors

The SWI detector is 4channels InGaAs photo-diode (PD) array with 4 channel filters. Because of high SNR requirement especially at 1.6-2.2micron range, SWI detectors are cooled to -30 deg C using peltier thermo electronic cooler. Multi PD elements are aligned in the along track direction on chip for each channel (SW1, 2 and 4: 5 detector elements, SW3: 20 elements) because of 1km resolution requirement to SW1, 2and 4 and 250m resolution requirement for SW3. Both InGaAs detector for SWIR region and peltier cooler have good heritage in many space applications including previous GLI sensor.

As the incident flux from the earth target in the SWI region is relatively low, realization of the high SNR requirement is the key technical issue. As a result of the BBM activities, the SWI detector with 4 channel filters was manufactured and achieved its required performances. To assess the total radiometric performances of SWI channels, performance tests and evaluation for the combination of SWI detector, pre-amp (trans impedance amplifier), and analog signal processor has been conducted.

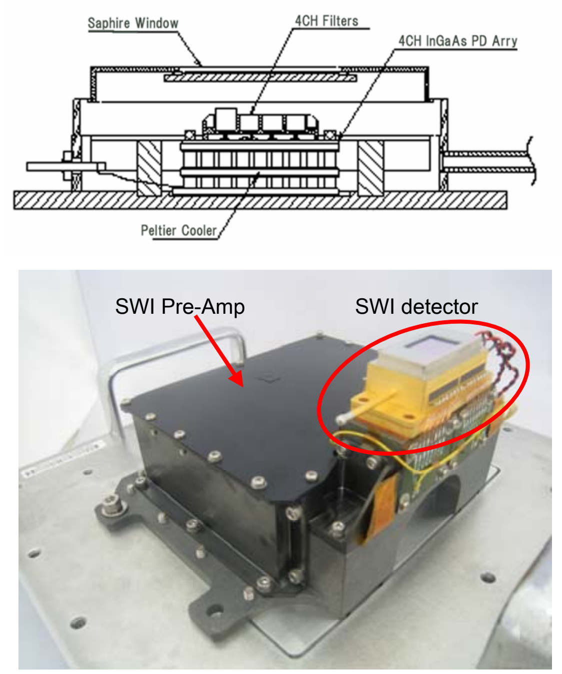

Fig. 5 SWI detectors cross-section drawing and SWI detection unit

(3) TIR detectors

TIR detector is 2channel PV MCT array (each channel detector has 10 elements) developed by SOFRADIR. This detector includes two detection circuits for detection at 10.8 µm and 12.0 µm, hybridized on a Readout Integrated Circuit (ROIC) based on the CMOS technology and 2 channel filters are mounted on the focal plane. Detailed design and developing results of the TIR detector are descried in Aurelien et. al. (2007).[5]

To realize the low noise requirement, the advanced

PV-MCT detector is cooled to 55K using the dedicated dewar assembly and stirling-cycle coolers. The stiring cycle cooler has many space application heritages such as ASTOR-F and SELENE. The active balancer is used for SGLI to cancel the mechanical disturbance from the cooler compressor and dispressor.

The TIR detector dewar assembly and stirling-cycle cooler have been manufactured. To assess the total radiometric performances of TIR channels, total TIR system including detector, dewar, cooler, and analog signal processor were integrated and performance tests and evaluation have been conducted.

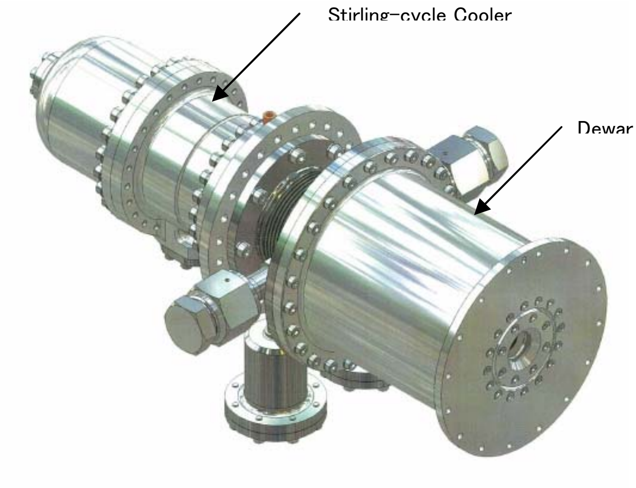

Fig. 6 TIR detectors(top) and TIR detection unit(bottom)

4.3 SGLI-BBM System level testing

The important feature of the SGLI-BBM is to assess and demonstrate the observation performances by sensor system level, while generally only component level tests are conducted in BBM activities. The manufactured BBM components have been integrated into VNR-NP telescope, VNR-P telescope, and IRS sensor system as indicated in Figure 3 and 5. The BBM System level testing is now being conducted including following tests;

- Radiometric tests such as SNR, linearity, output stability,
- Geometric tests such as MTF and alignment,
- Tests for polarization observation performance,
- Spectral response tests for VNR total telescopes,
- Tests combined with the onboard calibrators,
- Stray light evaluation.

5 CONCLUSION

SGLI is a multi-band imaging radiometer in the wavelength range of near-UV to thermal infrared which is required high radiometric performances. To validate feasibility of the critical components and to assess the required high performances, SGLI BBM activities have been conducted since 2006. The SGLI system design and BBM components manufacture and testing have been finished. These results give a prospect to achieve the observation performances. In addition, to confirm the SGLI system level performances, SGLI BBM systems tests are now conducted and will be finished in autumn 2008.

REFERENCES

[1] K. Imaoka, M. Kachi, A. Shibata, M. Kasahara, Y. Iida, Y. Tange, K. Nakagawa, and H. Shimoda, "Five years of AMSR-E monitoring and successive GCOM-W1/AMSR2 instrument", Proc. SPIE vol.6644, 2007.

[2] Y. Honda, H. Yamamoto, M. Murakami, and N. Kikuchi, "The possibility of SGLI/GCOM-C for global environment change monitoring", Proc. SPIE vol.6361, 2006.

[3] Y. Okamura, K. Tanaka, and Y. Tange, "Current status on design of the Second-generation Global Imager (SGLI)", Proc, Technical report of the Institute of Electronics, information and communication engineers Japan, 2007.

[4] M. Hiramatsu, K. Tanaka, Y. Okamura, T. Amano, and K. Shiratama, "Design Challenge on Forthcoming SGLI Boarded on GCOM-C", Proc. SPIE vol.6644, 2007.

[5] A. Dariel, P. Chorier, N. Reeb, B. Terrier, M. Vuillermet, and P. Tribolet, "Development of a long wave infrared detector for SGLI instrument", Proc. SPIE vol.6644, 2007.