Optical Sensor Technology Supporting the Greenhouse Gases Observing Satellite (GOSAT, or IBUKI)

HAMADA Kazuo, KANDA Seiji, HIRAMATSU Masaru, ISHIDA Juro

Abstract

Earth observation from satellites has recently been increasing in importance in global environment monitoring for dealing with climate change, monitoring natural disasters such as earthquakes, tsunamis, volcanic activity and torrential rains and collecting security-related intelligence. Since the development of the first satellite-borne optical observation sensor in Japan, NEC has developed a large number of satellite-borne optical sensors. This paper introduces NEC's optical sensors, including the Thermal And Near-infrared Sensor for Carbon Observation (TANSO) mounted on the Greenhouse Gases Observing Satellite (GOSAT, or IBUKI) launched in 2009, the high-resolution OPtical Sensor (OPS) mounted on the Advanced Satellite with New system ARchitecture for Observation (ASNARO) under development, the Hyperspectral Image SUIte (HISUI) and the Second-generation GLobal Imager (SGLI) mounted on the Global Change Observation Mission (GCOM).

Keywords

earth observation, optical sensor, ASNARO, HISUI, SGLI, TANSO

1. Introduction

Since the development of the satellite-borne Multi-spectral Electronic Self-Scanning Radiometer (MESSR) mounted on the MOS-1 marine observation satellite, which was Japan's first Earth observation satellite, launched in February 1987, we at NEC have been providing optical sensors for a large number of satellites, including Earth observation satellites and scientific satellites. We are developing a large variety of sensors, from those with high resolution (below 1 meter) to spectral observation equipment with high precision. For wavelengths, too, we have achieved the development of optical sensors with a wide range of wavelengths, from UV to visible light and IR light. This paper introduces the technical background of the optical sensors NEC is currently developing and an outline of their sensor systems.

2. ASNARO–OPS Optical Sensor Mounted on the ASNARO

NEC has proposed the NEXTAR series of small standard satellite buses featuring low cost, short delivery time and high functionality thanks to new techniques and mechanisms for development, manufacturing and operation. We are currently developing the Advanced Satellite with New system ARchitecture for Observation (ASNARO) (**Fig. 1**), to be launched in FY2012 as the first application of the NEXTAR bus. The ASNARO has been commissioned by the New Energy and Industrial Technology Development Organization (NEDO) and the Institute for Unmanned Space Experiment Free Flyer Foundation (USEF) and is being developed under the guidance of

Fig. 1 Image of the ASNARO flight configuration.

the Japanese Ministry of Economy, Trade and Industry (METI). This section describes the ASNARO-OPS, which is the optical sensor to be mounted on the ASNARO.

The ASNARO-OPS optical sensor is capable of imaging a desired 10 km square on the Earth's surface from orbit at an altitude of 504 km. It uses two bands, including a panchromatic band offering monochrome images and a multi-spectral band offering color images. The two bands can be used to obtain images of a single location simultaneously, with a resolution below 50 cm with the panchromatic band and below 2 meters with the multi-spectral band.

The ASNARO-OPS (**Fig. 2**) employs TMA (three-mirror anastigmat) optics and is composed of a primary mirror (PM), secondary mirror (SM), tertiary mirror and two foldable plane mirrors. The PM (see **Photo**) is made of NTSIC (New-Technology Silicon Carbide), an advanced material with ideal properties for mirrors, such as excellent specific rigidity (Young’s modulus - density) and shape stability (thermal conductivity/ linear expansion coefficient).

To improve the quality of the acquired image, the ASNARO-OPS drives a CCD (Charge Coupled Device) using the TDI (Time Delay and Integration) method. TDI is a technology for maintaining an optimum SNR (Signal-to-Noise Ratio) despite changes in land surface emissivity depending on the imaged location, seasonal variation, ground surface altitude, etc.

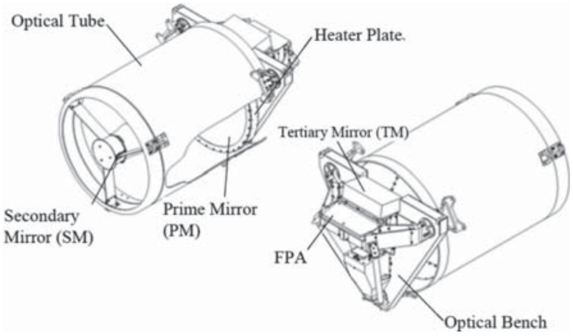


Fig. 2 External view of the ASNARO-OPS.

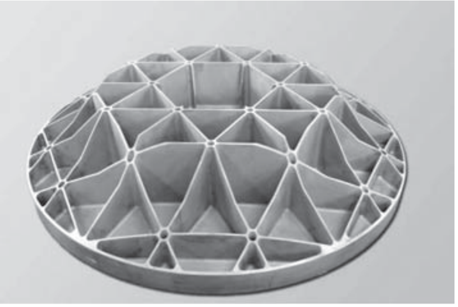


Photo External view of an NTSIC primary mirror.

Fig. 3 Image obtained with ASNARO-OPS (Simulated image).

Aiming at using these advanced technologies as precursors to the compact, lightweight, low-cost Earth-observing optical sensors of the next generation, the ASNARO-OPS flight model is entering the final steps of the manufacturing phase. **Fig. 3** shows a simulation of an image sent from the ASNARO-OPS.

3. Hyperspectral Image SUIte (HISUI)

The Hyperspectral Image SUIte (HISUI) (**Fig. 4**) is a sensor we are developing jointly with the Japan Resources Observation System and Space Utilization Organization (JAROS) under the guidance of METI and commissioned by NEDO. NEC has already succeeded in developing the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensor that was launched in 1999 for oil resource exploration, etc., but the HISUI is intended to further improve resource exploration capabilities and the precision of observations for global environmental conservation. It consists of two sensor elements: a multi-spectral imager with excellent spatial resolution and observation width and a hyperspectral imager with a high identification capability thanks to a high wavelength resolution (**Fig. 5**).

One of the biggest features of the hyperspectral imager is the inclusion of a spectroscopic function dividing wavelengths into 185 bands in addition to traditional imaging functions. This makes it possible to improve the identification of minerals, vegetation, environments, etc. and to obtain highly usable image information over a wide area with high frequency. On the other hand, the multi-spectral imager has four bands in the visible and near-IR regions for obtaining color images in near-natural colors (**Fig. 6** and **Fig. 7**).

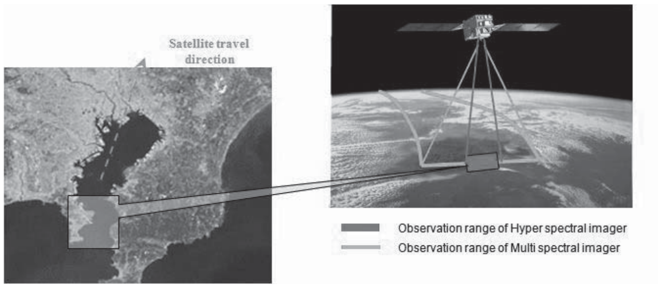
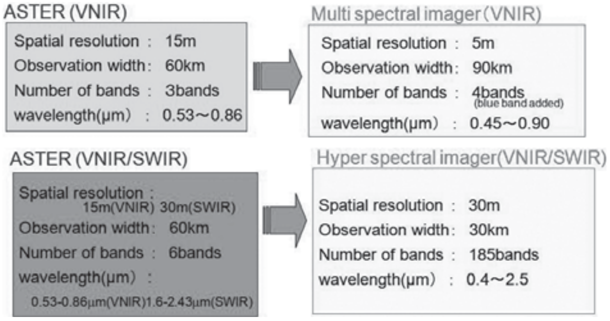


Fig. 4 Image obtained from HISUI data.



ASTER (VNIR)
Spatial resolution : 15m
Observation width: 60km
Number of bands : 3bands
wavelength(μm) : 0.53~0.86

Multi spectral imager(VNIR)
Spatial resolution : 5m
Observation width: 90km
Number of bands : 4bands (blue band added)
wavelength(μm) : 0.45~0.90

ASTER (VNIR/SWIR)
Spatial resolution : 15m(VNIR) 30m(SWIR)
Observation width: 60km
Number of bands : 6bands
wavelength(μm) : 0.53-0.86μm(VNIR)1.6-2.43μm(SWIR)

Hyper spectral imager(VNIR/SWIR)
Spatial resolution : 30m
Observation width: 30km
Number of bands : 185bands
wavelength(μm) : 0.4~2.5

Fig. 5 Performance comparison between HISUI and ASTER.

The hyperspectral imager aims in particular to offer observation data of the highest quality in the world, with a higher SNR and a higher wavelength determination precision compared to competing projects in overseas countries (**Fig. 8**). For this purpose, we have put emphasis on implementing a bright telescope for obtaining a larger amount of observation light, a spectroscope with extremely high efficiency and a sensor/signal processor system with low noise. In addition, we also endeavor to guarantee stable physical information on the observation target, such as scattering intensity and wavelength, in order to make observation data easy to use by refining the in-orbit calibration technology we have cultivated with optical sensors in the past.

The HISUI is presently in the manufacturing/test stage of the evaluation model. We will begin manufacturing of the flight model in FY2012, aiming at a launch around FY2014.

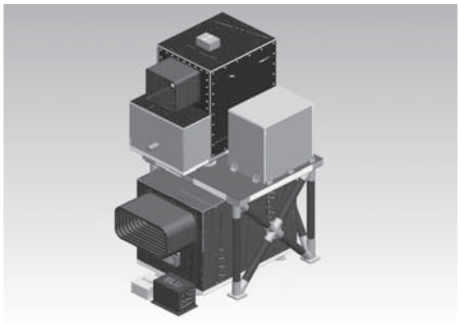


Fig. 6 Image of a hyperspectral imager (Top) and a multi-spectral imager (Bottom).

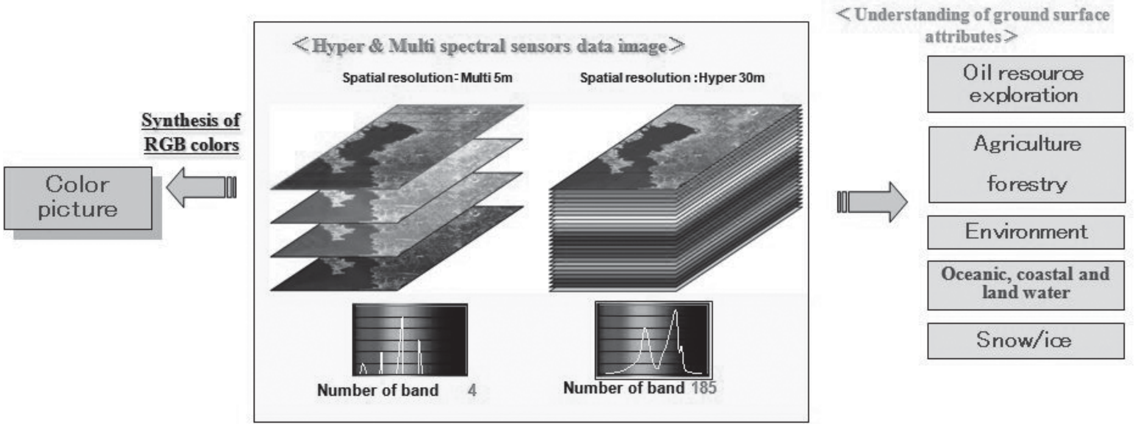


Fig. 7 The spectroscopy of a hyperspectral imager.

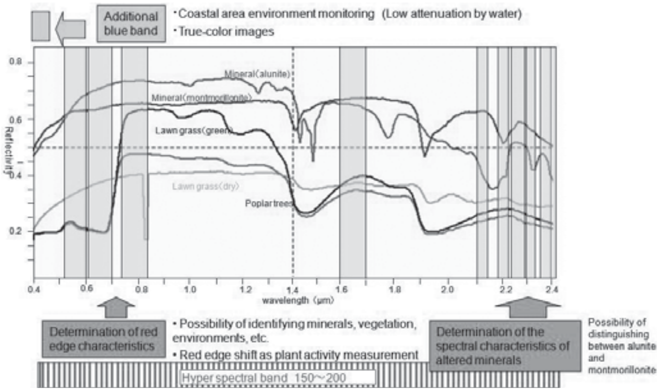


Fig. 8 Comparison of wavelengths obtained with HISUI and ASTER.

4. SGLI Mounted on the Global Change Observation Mission

We, as the main contractor, are currently developing the Second-generation GLobal Imager (SGLI), aiming at installation on the first climate change observation satellite (GCOM-C1, **Fig. 9**) of the Global Change Observation Mission (GCOM). The SGLI is a broad-area, multichannel optical radiometer and is the third-generation successor of the Ocean Color and Temperature Scanner (OCTS) mounted on the Advanced Earth Observing Satellite 1 (ADEOS-I, or MIDORI) and the GLobal Imager (GLI) mounted on the ADEOS-II (MIDORI-2). The SGLI covers a broad wavelength range from the UV to the thermal IR domains. It is a sensor system observing an area on the Earth's surface more than 1,000 km wide every day to monitor the land surface, atmosphere, ocean and snow ice involved in global-scale climate change, as well as the effects of human activities on them. It is under development with a launch scheduled in FY2014.

Since the SGLI needs to cover a wide range of wavelengths, it is composed of two sensors, including a Visible and Near-infrared Radiometer (VNR, **Fig. 10**) and an Infrared Scanner (IRS).

With the VNR, we adopted a multi-element CCD sensor that can handle multiple bands with a compact size and can image an area of 1,150 km width at a time. For this purpose, we developed a new image sensor collecting 11 (for 11 bands) one-dimensional CCDs into a single chip. In addition to these 11-band image sensors, the VNR also uses two bands to observe polarization in three directions (**Table 1**).

With the IRS, we adopted a large, high-sensitivity sensor to

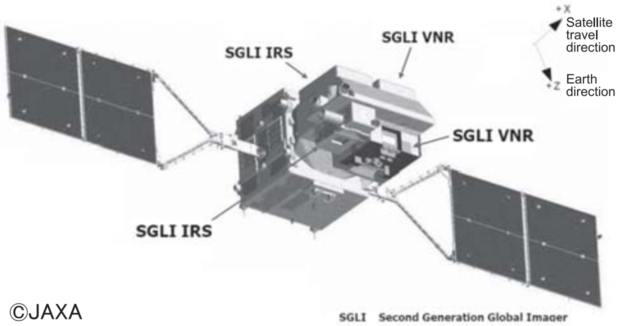


Fig. 9 Overall view of the GCOM-C1.

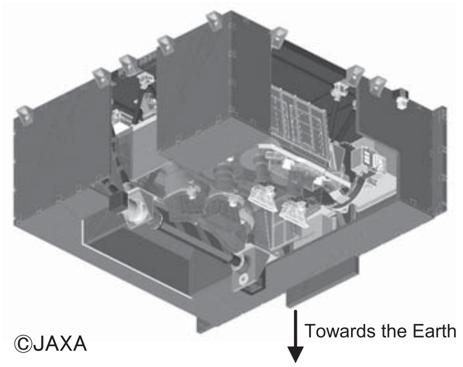


Fig. 10 External view of the VNR.

Table 1 Main specifications of the SGLI VNR.

VNR Main Specifications	
Unpolarized observation system	11 bands between 380 and 8,698 nm (UV to near IR), resolution 250 m, scanning width 1,150 km
Polarized observation system	2 bands including 673.5 and 868.5 nm, 3 polarization directions, resolution 1 km, scanning width 1,150 km

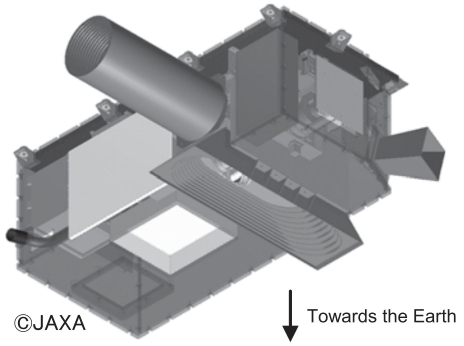


Fig. 11 External view of the IRS.

Table 2 Main specifications of the SGLI IRS.

IRS Main Specifications	
Shortwave IR system	4 bands between 1.05 and 2.21 µm, resolution 1 km (250 m for land and coastal areas with the SW3 band), scanning width 1,400 km
Thermal IR system	2 bands including 10.8 and 12.0 µm, resolution 500 m, scanning width 1,400 km

scan images by rotating a plane mirror (**Fig. 11**). Using IR rays makes observation possible regardless of day or night conditions on the ground surface, and observation is scheduled to continue for five years after the launch. The sensors used in observation are cooled to reduce noise. In particular, the thermal IR measuring system is designed to maintain a very low temperature of 55 K (-218°C) using a mechanical refrigerator (**Table 2**).

5. Thermal And Near-infrared Sensor for Carbon Observation (TANSO) Mounted on GOSAT

The Thermal And Near-infrared Sensor for Carbon Observation (TANSO, **Fig. 12**) was launched on January 23, 2009 on the Greenhouse Gases Observing Satellite (GOSAT, or IBUKI) in order to measure the global concentration distribution of greenhouse gases and to clarify the absorption/emission amounts of greenhouse gases on the Earth. The TANSO determines gas concentrations by measuring the absorption spectra of greenhouse gases such as CO_2 present in the shortwave IR domain (1.6 and 2.0µm) and the thermal IR domain (14.3µm) using a kind of spectroscope called a Fourier interferometer.

Since the TANSO uses reflected light and thermal radiation light from the Earth as its light source, it is capable of global observation. It can drastically improve observation area and frequency, for example changing the previous observation method based on ground observation of about 286 points (as of May 2000) to the coverage of 56,000 points around the entire Earth in three days. For observation precision, too, its extensive use of the latest technologies, such as the Fourier interferometer, which achieves a high wavelength resolution and high SNR, and the pointing mirror, which directs the observation point with high precision, makes it possible to achieve a relative precision of each measuring session of no more than 1% as of October 2010. This makes possible the land area measurement of CO_2 vertical column amounts in a 1,000-km mesh with a 3-month average relative precision of 1%.

In addition, it is expected that the use of TANSO data can reduce the estimation uncertainty of the CO_2 absorption/emission amounts that have previously been obtained using ground observation data only. This reduction of estimation uncertainty is particularly large in South America, Africa and Asia, where the amount of ground observation is small (**Fig. 13**). [*1]

The TANSO has already completed its initial operations, and its ground processing algorithm is currently being studied for further improvements in precision. The application of this advanced ground processing to calibrated observation data is

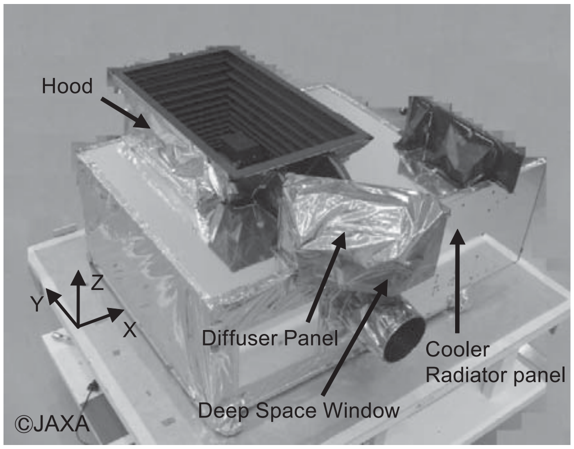


Fig. 12 External view of the TANSO.

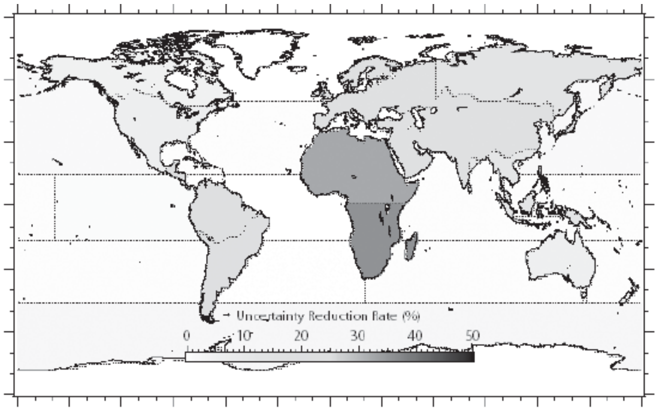


Fig. 13 Uncertainty reduction rate of CO_2 absorption/emission amounts.

[*1] Interim result as of October 2010 announced by the National Institute for Environmental Studies (NIES).

expected to make it possible to regularly distribute information on average CO_2 and methane concentrations with higher precision.

6. Conclusion

In the above, we introduced the technical background and system outline of the optical sensors we are developing. We would like to express our deep gratitude to METI, JAXA and other organizations for their kind guidance in the development of these optical sensors.

At NEC, we have long been developing optical sensors incorporating advanced technologies as the front-runners of satellite-borne optical sensors. In the future, too, we will contribute to the implementation of an affluent, safe and secure society through the development of more advanced optical sensors.

Authors' Profiles

HAMADA Kazuo
Manager
Technology Operations Unit
NEC TOSHIBA Space Systems, Ltd.

KANDA Seiji
Engineering Expert
Technology Operations Unit
NEC TOSHIBA Space Systems, Ltd.

HIRAMATSU Masaru
Senior Expert
Technology Operations Unit
NEC TOSHIBA Space Systems, Ltd.

ISHIDA Juro
Senior Expert
Technology Operations Unit
NEC TOSHIBA Space Systems, Ltd.

Information about the NEC Technical Journal

Thank you for reading the paper.
If you are interested in the NEC Technical Journal, you can also read other papers on our website.

Link to NEC Technical Journal website

Japanese

English

Vol.6 No.1 Space Systems


NEC

NEC Technical Journal

Space Systems

NEC Tackles the Global Business of Space Solutions

Vol. 6 No. 1

Vol.6 No.1

April, 2011

Special Issue TOP

◇ Papers for Special Issue

Progress with the implementation of NEC's Roadmap

Technologies/Products supporting roadmap implementation (Satellites/Space station)

Technologies/Products supporting roadmap implementation (Satellite ground system)

Technologies/Products supporting roadmap implementation (Satellite Bus)

Technologies/Products supporting roadmap implementation (Communication)

Technologies/Products supporting roadmap implementation (Observation sensors)

Technologies/Products supporting roadmap implementation (Fundamental technologies)

Technologies/Products supporting roadmap implementation (Guidance control computer)

Asteroid probe MUSES-C (HAYABUSA)

◇ NEC Information

NEWS