# The Development of the Infrared Technology for Meteorological Satellites in Shanghai Institute of Technical Physics

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## Abstract

The requirement of the infrared technology applied on meteorological satellites is the key driving force for the development of infrared technology in Shanghai institute of technical physics (SITP), Chinese Academy of Sciences. The meteorological satellites have become a main detection method for the weather and ocean observation, there are totally 15 meteorological satellites that were launched into both sun synchronous and geostationary orbit and more satellites are under construction to be the second generation ones. The infrared remote sensors are the main payloads on-board on all these satellites. By these infrared remote sensors one can obtain the remote sensing data for ocean colour, water vapour, weather forecasting, and get the atmospheric temperature profile and humidity profile, etc. As the key technology in the infrared remote sensor, the infrared detector technology is developed mainly using the HgCdTe material, meanwhile the quantum well infrared photodetector and type II super-lattice infrared detector are also developed.

## 1. Introduction

Meteorological satellites have become an irreplaceable weather and ocean observing tool, while the infrared detection has become a key technology in the development of meteorologicalsatellites. Because the wind and cloud are the main objects to be observed by the meteorological satellites to explore the weather, the meteorological satellites in China has been named as Feng-Yun satellites. The pronunciation of “Feng” and “Yun” corresponds the Chinese words “wind” and “cloud”, respectively.Up to now, the main observation is on the cloud for the meteorological satellites, and the observation technology to observe the wind is exploring. The infrared technology has been developed in Shanghai Institute of Technical

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Physics (SITP) to observe the cloud in the series of Feng-Yun in Chinese meteorological satellites more than 40 years. The infrared payload on the Feng-Yun series is mainly studied and finished in SITP. Since the first Chinese polar-orbiting meteorological satellite Feng-Yun (FY-1A) was launched in 1988, there are more than 10 meteorological satellites being launched into both sun synchronous and geostationary orbit as listed in table 1.And more satellites are developing as the second generation ones where the infrared payload will play a key role to observe the cloud distribution and evaluation.

Table 1Chinese meteorological satellite

| Launching time | batch | type | duration |
|---|---|---|---|
| 1988.9.7 | FY-1A | Experimental | 39days |
| 1990.9.3 | FY-1B | Experimental | 158days |
| 1999.5.10 | FY-1C | Operational | 7.5years |
| 2002.5.15 | FY-1D | Operational | Working |
| 2008.5.17 | FY-3A | Experimental | Partly working |
| 2010.11.5 | FY-3B | Experimental then operational | Working |
| 2013.9.23 | FY-3C | Operational | Working |
| 1997.6.10 | FY-2A | Experimental | 10 months |
| 2000.6.25 | FY-2B | Experimental | Stop working |
| 2004.10.19 | FY-2C | Operational | Part time working |
| 2006.12.8 | FY-2D | Operational | Working |
| 2008.12.23 | FY-2E | Operational | Working |
| 2012.1.13 | FY-2F | Operational | Working |
| 2014.12.31 | FY-2G | Operational | Working |
| 2016.12.11 | FY-4A | Experimental | Working |

## 2. Infrared payloads in meteorological satellite

Infrared remote sensors are the main payloads on-board each meteorological satellite. As the unique remote sensor on-board the first generation polarorbitingmeteorological satellites (FY-1 series) and the geostationary orbit meteorological satellites (FY-2 series) separately, 10-channel Visible and InfraredScanningRadiometer (VIRSR) and Visible and Infrared

Spin-Scan Radiometer(VISSR) had been developed since 1970s'. The long-term operational ones have been working for over 10 years, and obtain the remote sensing data for oceancolour, water vapour, weather forecasting, etc. The two types of meteorological satellites The main infrared payloads developed in SITP is listed in table 2 and 3 for both the first generation and second generation of meteorological satellites.

Table 2Infrared payloads onboard polar-orbit satellites

| 1st Generation | payload | 2nd Generation | payload |
|---|---|---|---|
| FY-1 01 | 5-channel Visible and Infrared scanning radiometer | FY-3 01 | Visible and Infrared Radiometer |
| FY-1 02 | 10-channel Visible and Infrared scanning radiometer | | Medium Resolution Spectral Imager |
| | | | Infrared Atmo- spheric Sounder |
| | | | Earth Radiation Measurer |
| | | FY-3 02 | Medium Resolution Spectral Imager -II |
| | | | High-spectral Infrared Atmospheric Sounder |
| | | FY-3 03 | Medium Resolution Spectral Imager -II<br>Medium Resolution Spectral Imager -III |
| | | | High-spectral Infrared Atmospheric Sounder -II |
| | | | Earth Radiation Measurer -II |

Table 3Infrared payloads onboard geostationary satellites

| 1st Generation | payload | 2nd Generation | payload |
|---|---|---|---|
| FY-2 01 | 3-channel scanning radiometer | FY-4 01 | Advanced Geostationary Radiometric Imager |
| FY-2 02 | 5-channel scanning radiometer | | Geostationary Interfering InfraRed Sounder |
| FY-2 03 | Enhanced 5-channel scanning radiometer | FY-4 02 | Advanced Geostationary Radiometric Imager -II |
| | | | Geostationary Interfering InfraRed Sounder-II |

There are four type of infrared sensors which are carried aboard each platform of the second generation polarorbitingmeteorological satellite (FY-3): the Visible and InfraredRadiometer (VIRR), MediumResolution Spectral Imager(MERSI),Infrared AtmosphericSounder (IRAS),Earth Radiation Measurer (ERM). As the results of the three launches of FY-3A, FY-3B and FY-3Csatellites, three groups of these four sensors are currently operating on-orbit andproviding not only the imaging data, but also the sounding data and Earth radiance budget data at the same time. MERSI surveys the earth with a ground pixel resolutionof250-metre and a swath width over 2900 km, thatcould get the global TIR image of 250-meter resolution twice each 24 hours. This specification is distinctive and useful for the environmental monitoring. The global image mosaic from MERSI of FY-3A is shown in Fig.1.As the upgrading sensors of MERSI and IRAS, MERSI-II and High-spectral Infrared Atmospheric Sounder (HIRAS), focusing on imaging and sounding mission separately, are developed and will be launched with FY-3D. They will get more infrared channels and fine spectral data in the near future.

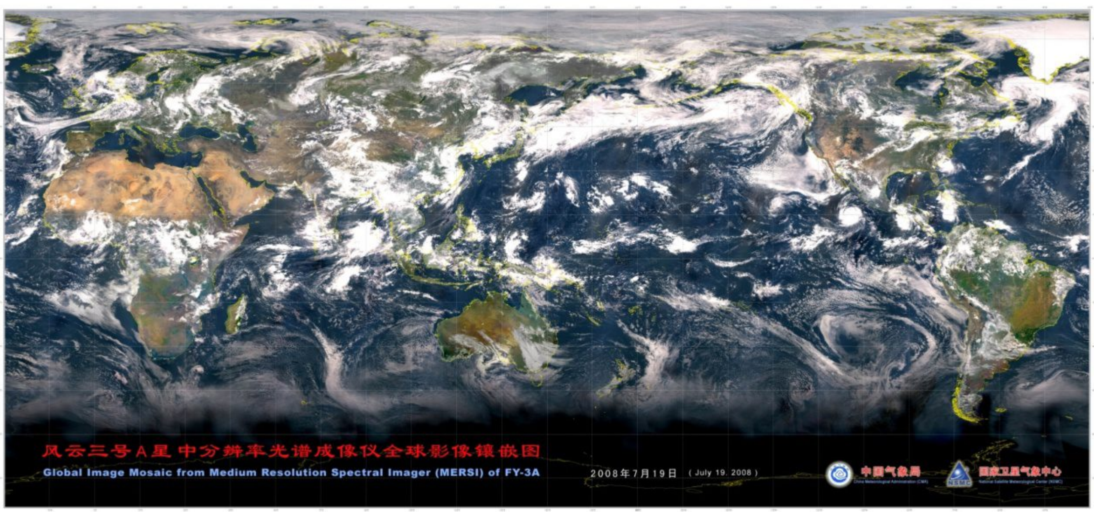


Figure 1.The global image mosaic from MERSI of FY-3A observed in 19 July 2008.

Table 4. Infrared payload comparison among FY-4, GOES-R and Himawari-9

| FY-4(China, 2016/12/11) | GOES-R(USA, 2016/11/19) | Himawari-9(Japan, 2016/11/2) |
|---|---|---|
| Radiometric Imager :<br>Special resolution: | Radiometric Imager :<br>Special resolution: | Radiometric Imager :<br>Special resolution: |

| | | |
|---|---|---|
| Vis/NIR: 0.5-1Km<br>IR: 2-4Km<br>Time resolution: 15min<br>Channel number: 14<br>Detection precision: 0.1K | Vis/NIR: 0.5-1Km<br>IR: 2Km<br>Time resolution: 5min<br>Channel number: 16<br>Detection precision: 0.1K | Vis/NIR: 0.5-1Km<br>IR: 2Km<br>Time resolution: 10min<br>Channel number: 16<br>Detection precision: 0.1K |
| Interfering IR Sounder:<br>Detection band: 700-1130, 1650-2250cm$^{-1}$<br>Channel number: 1650<br>Spectral resolution: 0.625 cm$^{-1}$<br>Special resolution: 16Km | Interfering IR Sounder:<br>No | Interfering IR Sounder:<br>No |

Two type of infrared sensors, advanced geostationary radiometric imager (AGRI) with 14 channels and geostationary interfering infrared sounder (GIIRS), are constructed for the second generation of the geostationary-orbit meteorological satellite (FY-4). The AGRI can obtain the global image very 15 minute as shown in fig.2. The GIIRS can obtain the high resolution IR spectrum with the special resolution of 16Km to get the atmospheric temperature profile and humidity profile. The typical atmospheric temperature profile observed is shown in fig.3. The detail characteristic of AGRI and GIIRS is listed in table 3. Compared with other two newly launched meteorological GOES-R (@2016/11/19) and Himawari-9(@ 2016/11/2), the Radiometric Imager has the similar performance. As a progress, the FY-4 has integrated the both Radiometric Imager and interfering IR Sounder together to improve the data usability for atmospheric analysis.

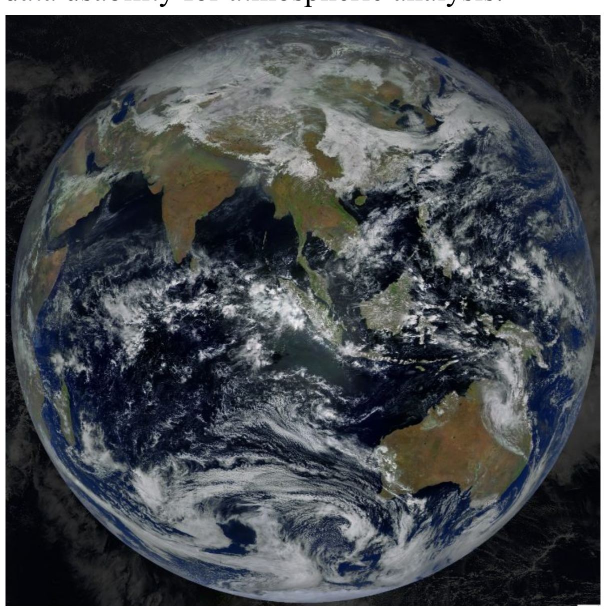

Figure 2. The image obtained by advanced geostationary radiometric imager on FY-4

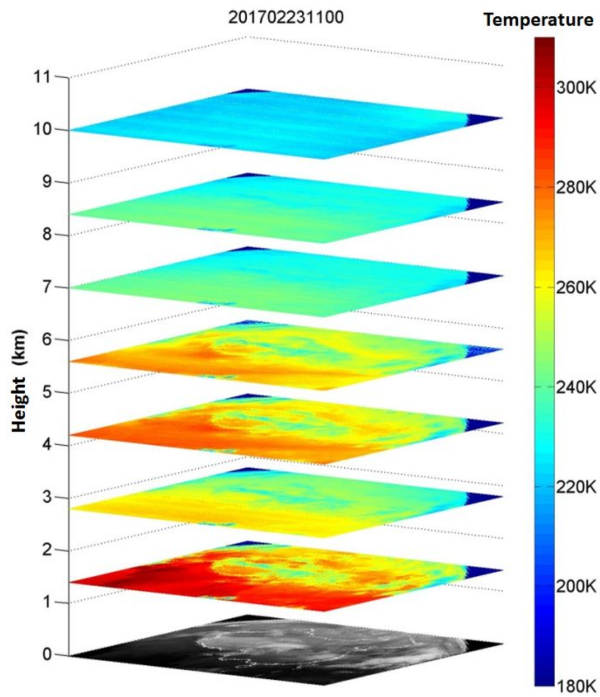

Figure 3. The 3 dimensional temperature profile obtained by geostationary interfering infrared sounder on FY-4

## 3. Infrared detector for the payloads in meteorological satellite

Up to now, the main infrared detector used on the Feng-Yun meteorological satellite is HgCdTe photo-detector. The very long wavelength HgCdTe detector has been developed for the geostationary interfering infrared sounder on FY-4. It has the following characteristic: format: 32×4, cutoff wavelength: $\lambda c$=15.3μm, Detectivity: $5.05\times10^{10}$ $cmHz^{1/2}/W$, Responsivity: $1.42\times10^{4}$ V/W, Non-uniformity: 5.47%, Crosstalk: 4%, and operation temperature: 65K.

In order to get the large format of long wavelength focal plan array for IR payload in meteorological satellite, two type of quantum infrared photo-detectors has also been developed. One is the type II super-lattice long wavelength IR photo-detector. It has the format of 320×256 with the average peak detectivity (@10.6μm) of $3.4\times10^{10}$ $cmHz^{1/2}$ $W^{-1}$ at 65K. The second is the quantum well IR photo-detector. It has the format of 320×256 with the average peak (@15μm) detectivity of $1.4\times10^{10}$ $cmHz^{1/2}$ $W^{-1}$ at 50K.

# 4. Conclusion

The infrared payload technology has been developed in SITP, it has shown it high impact on the Chinese meteorological satellite. It will continue its important role in the roadmap of Chinese meteorological satellite. The high performance infrared detector will be the key technology for the infrared payload in the FY3 and FY-4 meteorological satellite to be launched in 2018, 2019, and 2020.