Introduction of the High Precision Stationary IR Thermometer IT-480 Series

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IT-480 series is infrared radiation thermometer and developed for industrial need temperature control with high accuracy and high repeatability. IT-480 series can measure temperature non-contactly and nondestructively by measuring infrared rays from measurement target, different from conventional contact thermometer. High accuracy and high repeatability were realized by thermopile sensor using MEMS technology of silicon semiconductor process, optical interference filter eliminating influence of atmosphere, and high precision blackbody furnace as calibration standard for temperature measurement. In this paper, we describe the measurement principle and features of radiation thermometer and introduce the high-precision infrared thermometer IT-480 series.

Introduction

The need for temperature measurement is progressively increasing in various industries such as factory automation (FA), safety and security of food, logistics, disaster prevention, and security. Temperature management has been important for alarm applications and quality control of manufacturing. As in recent years, processes based on temperature control have been developed in semiconductor processes and so on. High-accuracy temperature measurement is become more important. Furthermore, it is also expected in the Internet of Things (IoT) application.

Methods of temperature measurement are classified into two types. One type utilizes (or The first one utilizes) thermoelectromotive force and the characteristic change of the sensor element caused by contact to the object directly (typical example: thermocouple type thermometer, thermistor). On the other hand, the second one detects electromagnetic waves radiated from an object (typical example: radiation thermometer).

An infrared thermometer that can measure non-contactly has the advantage of measuring temperature without destroying and affecting the object; and further without degrading the thermometer itself due to the heat of the object. However, since there are noise factors resulting from the measurement principle and emissivity as a characteristic parameter of infrared thermometer, users of infrared thermometers are required to sufficiently understand its measurement principles as compared with the contact-type thermometer. We have continued to develop an infrared thermometer [1] since 1984 and have met the trend of the times. We have been working to disseminate infrared thermometers through customer support by issuing "All of radiation thermometers [2]" and so on.

We have sold the previous model, the IT-450 series, as a built-in infrared thermometer. In order to meet the demand of increasing high-precision temperature measurement in recent years, we developed the IT-480 series which enables more accurate measurements and has achieved improved usability compared with the previous model.

In this paper, we introduce the features of the IT-480 series and describes the measurement principle of the infrared thermometer.

Measurement Principle of Infrared Thermometer

Basic principle and device configuration

Based on Planck's radiation law, all objects radiate electromagnetic waves according (or corresponding) to the temperature of the object. Near room temperature, the radiated electromagnetic waves are in the infrared range. Since the amount of infrared radiation increase in proportion to the temperature of the object, the temperature can be measured by measuring it with an infrared detector. However, since the amount of infrared radiation varies depending not only on the temperature but also on the emissivity for each object. Therefore, it is necessary to optimize the emissivity setting according to the object.

The configuration of the radiation thermometer is shown in **Figure 1**. The infrared rays radiated from the object are condensed by the lens ①, and then filtered by the optical filter ② to let only the necessary wavelength to pass through, and reach the infrared detector ③.

In the infrared detector, an incident electric signal is generated corresponding to the amount of infrared radiation. The signal is processed by a microcomputer ⑥ through an analog to digital converter ⑤ with a signal of a temperature sensor ④ for measuring the reference temperature of the infrared detector itself.

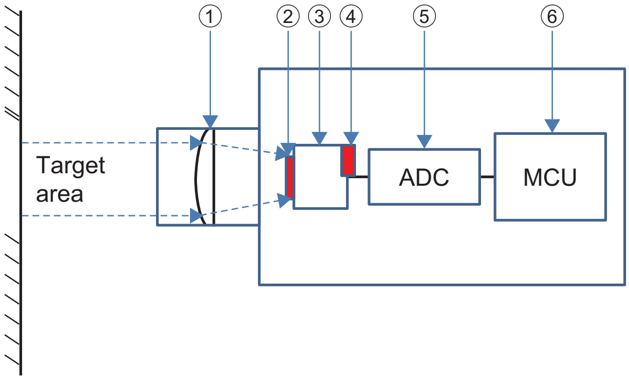

Figure 1 Basic configuration diagram of infrared thermometer

In the microcomputer, the signal is converted into temperature after it being corrected by the reference temperature and the emissivity [3].

Infrared detector

In the infrared thermometer introduced in this paper, a thermopile sensor is used as an infrared detector. The thermopile sensor is a sensor in which micro thermocouples are arranged in multiple. That is, similar to the principle of thermocouples, infrared rays are converted into electric signals and outputted by the Seebeck effect (voltage is generated when a temperature difference is given to the contact point of different metals arranged as hot junction and cold junction). As with the thermocouple, the output electric signal is proportional to the temperature difference between the hot junction and the cold junction, so the temperature measurement requires the temperature of the cold junction as the reference temperature. Usually, sensors such as thermistors are incorporated in infrared detectors and measure simultaneously.

Optical filter

Since the infrared rays from the object pass through the atmosphere and reach the infrared detector, there is a problem influenced by a gases such as water vapor or carbon dioxide absorbing infrared rays of a specific wavelength. Since the amount of infrared radiation being absorbed by the atmosphere also increases in proportion to the distance of the atmosphere it has to pass through, the temperature of the object appears lower than the actual temperature.

Even if the distance between the object and the radiation thermometer changes, it is desirable that the measured value is constant as long as the temperature of the object does not change. Our infrared thermometer adopts an optical filter that selectively permits from the region with little infrared absorption by the atmosphere called "atmospheric window", and detects only infrared rays of 8 to 14 μm.

As a result, the total amount of infrared rays reaching the radiation thermometer is stabilized without depending on the distance between the radiation thermometer and the object, so that highly accurate measurements can be performed.

Emissivity

The amount of infrared rays radiated from an object is proportional to the temperature and also varies depending on the emissivity, an inherent parameter of the object. Therefore, it is necessary to investigate it beforehand and to set it to the infrared thermometer when measuring the temperature. Emissivity of representative objects such as skin, water, rubber, plastics etc. is known and can be referred in the literature.

Technology for High Precision Temperature Measurement

In the IT-480 series, we installed our own important technologies related to radiation thermometers for high precision temperature measurement, including the infrared measurement technology that we have cultivated over many years. Thanks to these technologies, we were able to realize the highest precision and repeatability of the industry.

Thermopile sensor (infrared detector)

We developed a sensor that enables high precision and repeatability (**Figure 2**) by adopting a double package structure that suppresses the influence of the ambient temperature change around the infrared thermometer (Patent No. 5658059). In addition, since the sensor chip uses the MEMS technology, this sensor has excellent reliability [4, 5].

Signal correction circuit

A thermoelectromotive force generated between the sensor and the signal processing circuit section, and the offset voltage of the signal processing circuit influences the very small output signal of the sensor. In order to suppress this influence, a capability feature to correct the influence in real time on the sensor and the signal processing circuit was installed.

Optical filter

The IT-480 series adopted the in-house optical filter (**Figure 3**) that we have cultivated over many years. It contributes to the long-term reliability of the infrared thermometer.

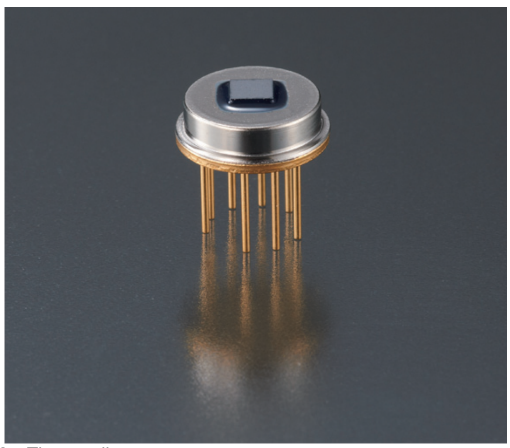

Figure 2 Thermopile sensor

Figure 3 Optical filter

Figure 4 High-precision blackbody furnace

High-precision blackbody furnace

A high precision temperature standard is required to ensure accurate temperature measurement. High-precision blackbody furnace is a very important technology for infrared thermometer. For adjustment and inspection at the time of manufacture of our radiation thermometer and periodical calibration, we use a high-precision blackbody furnace (**Figure 4**) jointly developed with the Institute of Industrial Science and Technology (now National Institute of Advanced Industrial Science and Technology). Our high-precision blackbody furnace has a wide temperature range from -50 to 1000 °C and is excellent in temperature uniformity. This ensures traceability according to national standards.

Specifications and Characteristics of the IT-480 Series

The IT-480 series is a line up intended for four different kinds of visual field characteristics. IT-480S is capable of measuring the temperature of a minute region at a short distance and IT-480F is capable of measuring the temperature of a region of ø55 on an object 2 meters away. The user can select the appropriate one depending on the distance between the object and the infrared thermometer and the size of target. **Figure 5** shows the field of view characteristics. **Table 1** shows the lineup configuration and typical specifications.

Compared to the previous model IT-450 series, USB connection function, USB bus power operation, detachable power supply / current output cable have been adopted while the function of laser sighting has been adopted in the longrange type. In addition, by using the application software for Windows, it is easy to change the setting. Regarding the temperature measurement performance, for example, in the case of 200 degree C measurement, the accuracy has been improved from the measurement accuracy of ±2.2 degree C in the previous model to ±1.0 degree C in the IT-480. In addition, the reproducibility is

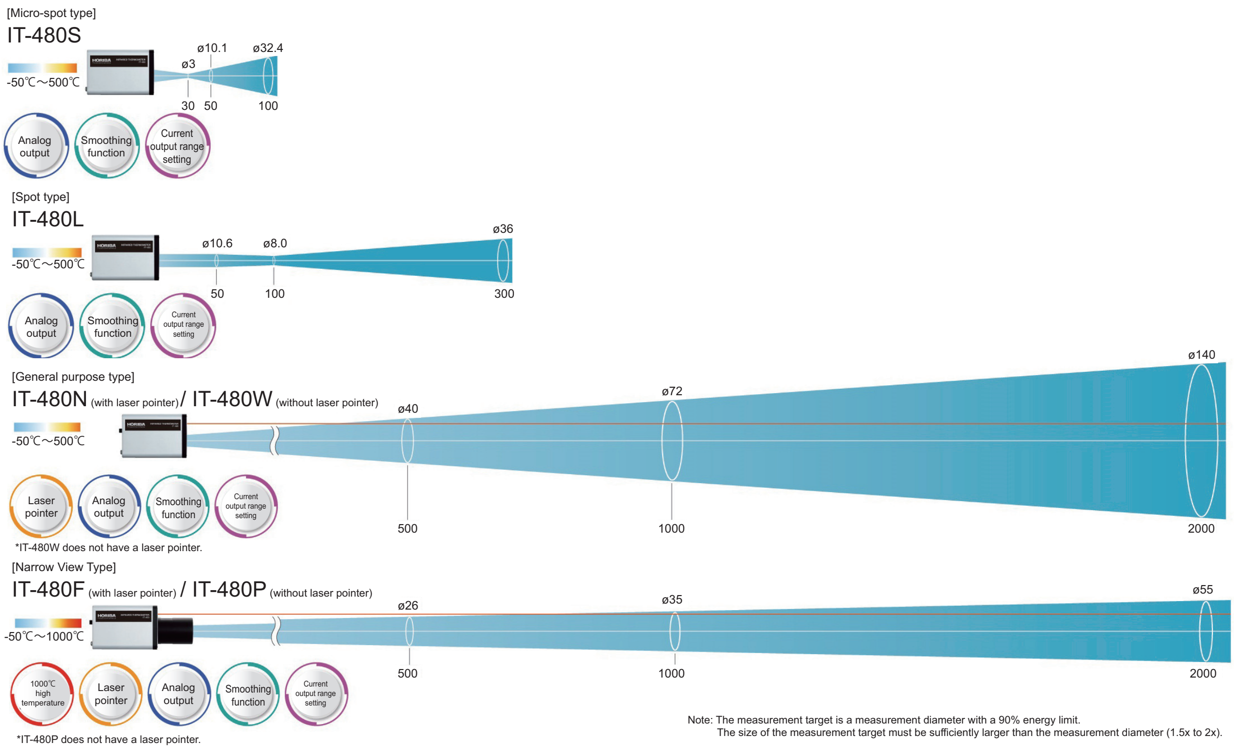

Figure 5 IT-480 Series Lineup

Table 1 IT-480 series specificationure

	Micro-spot type	Spot type	General purpose type	Narrow view type
Lineup	IT-480S 	IT-480L 	IT-480N (with laser pointer) IT-480W (without laser pointer) 	IT-480F (with laser pointer) IT-480P (without laser pointer) 
Spectral response	8μm to14μm			
Measured temperature range	-50°C to 500°C			-50°C to 1000°C
Output	USB (resolution = 0.1°C) Current (4 mA to 20 mA, resolution =0.24μA, non-insulated)			
Current output range	-50°C to 500°C (factory setting 0°C to 500°C)			-50°C to 1000°C (factory setting 0°C to 500°C)
Accuracy	[USB Output] Within ±(-8%rdg+1)°C [-50°C to 0°C] Within ±1°C [0°C to 200°C] Within ±0.5%rdg°C [200°C to 500°C] [Current Output] Difference from USB data is within ± (0.1% output range)°C			[USB Output] Within ±(-8%rdg+1)°C [-50°C to 0°C] Within ±1°C [0°C to 200°C] Within ±0.5%rdg°C [200°C to 1000°C] [Current Output] Difference from USB data is within ± (0.1% output range)°C
Repeatability	0.5°C or less			Within 1°C [-50°C to 0°C] Within 0.5°C [0°C to 500°C] Within 1°C [500°C to 1000°C]
Respose Time	Current output 0.14 s or less (95% response, moving average count is 1.)			
Measurement diameter	ø3 mm/ distance 30 mm	ø8 mm/ distance 100 mm	ø72 mm/ distance 1000 mm	ø35 mm/ distance 1000 mm
Temperature drift	Within ±0.5°C/°C [-50°C to 0°C] Within ±0.25°C/°C [0°C to 500°C]			Within ±0.5°C/°C [-50°C to 0°C] Within ±0.25°C/°C [0°C to 500°C] Within ±0.5°C/°C [500°C to 1000°C]
Emissivity	Factory setting: 0.950 (Setting range is 0.100 to 1.999.)			
Ambient temperature/ humidity	Temperature: 0°C to 55°C Humidity: 35% to 85% (No condensation)			
Power supply	USB bus power /12 V DC to 24 V DC			
Power consumption	30 mA or less (at 24 V DC)		30 mA or less (at 24 V DC, laser: OFF) 40 mA or less (at 24 V DC, laser: ON)	
Material of the body case	Aluminum			
Mass	Approx. 95 g (Body only. Excluding cable and metal brackets)			Approx. 115 g (Body only. Excluding cable and metal brackets)
Sight	Setting gauge		Laser (Class 1)	

improved from 1.0 degree C in the previous model to 0.5 degree C in the IT-480 series. Furthermore, as in the previous model, it is possible to issue traceability certificates according to national standards.

About the New Function of IT-480 Series

Laser marker

It is difficult to confirm the actual measurement area since the infrared thermometer measures invisible infrared rays radiated from the object. To overcome this, the IT-480 series adopts an installation gauge imitating the measurement area that can be attached to the front of the equipment for the short distance measurement type, and the laser pointing for the long distance measurement type. As a result, it is possible to visually confirm the measurement area.

USB bus power drive

Since the previous model IT-450 series is designed for industrial use, an external power supply of 12 to 24 V and 4-20 mA current output was adopted.

In addition to the above specifications, the IT-480 series can use USB bus power.

The USB bus power and dedicated application software enable temperature measurement without using external power supply and 4-20 mA detection device (**Figure 6**). The user can configure it with a notebook PC or a tablet PC as in **Figure 6**, and utilize highprecision temperature measurement in various activities including research and development without any space limitations.

IT-480 dedicated Windows application

In order to make full use of the USB function of the IT-480 series, we have released a free IT-480 dedicated Windows application software. With this application software, the user can change settings such as emissivity and current output range of 4-20 mA, measure temperature simultaneously up to eight IT-480 units and display a graph. There is high expectation for it not only for industrial applications but also for various activities such as research and development. It also has an automatic emissivity setting function and it is possible to easily optimize the emissivity, an essential parameter for handling the infrared thermometer.

Figure 6 Cooperation with personal computer

Emissivity setting function

Correct emissivity setting is indispensable for highaccuracy temperature measurement. Cases that are commonly encountered in using a radiation thermometer are that the temperature cannot be matched with a contact type temperature measuring instrument such as a thermocouple and high accuracy measurement cannot be performed as specified. This occurs when using the infrared thermometer without optimizing the emissivity setting.

By setting appropriately, it is possible to match thermocouples and infrared thermometers with high accuracy. As explained in the measurement principle, the emissivity can be referred to the literature if it is a representative object. If it is unknown, it can be inferred by Windows application software dedicated to the IT-480 series. The usage method is described below. Measure the known temperature of the object with a thermocouple or like, and measure the temperature with the IT-480. Next, Input each temperature value to the application software dedicated to the IT-480 series. The optimum emissivity is automatically calculated so that the measured value by the radiation thermometer could meet the known temperature. By utilizing this function, it is possible to easily carry out the high-precision and repeatability measurement of the IT-480 series at anytime.

Conclusion

The installation and built-in high-precision infrared thermometer IT-480 series is a culmination of proprietary technologies cultivated through our long-standing infrared thermometer product development. We will continue to improve precision, reduce the size and develop infrared thermometers that detect infrared at wavelengths other than 8 to 14 µm.

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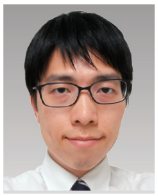

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