DOI 10.5162/SMSI2020/C1.4

Multi-spectral mid-IR Temperature Measurement Using Tuneable Detectors.

Matthew Gillott[1], *Fiona Turner*[1], *Peter Droegmoeller*[1]
[1] *Ametek Land, Dronfield, UK,*
matthew.gillott@ametek.com

Summary:
Most pyrometers for industrial applications use one or two wavelength bands to measure energy in order to determine the target temperature, but this can lead to errors from incorrect or unknown emissivity or non-greyness. Using a tuneable detector based on a Fabry Perot filter, temperature measurement across a greater number of wavelengths can be performed, and potentially eliminate errors arising from atmospheric gasses and surface emissivity.

Keywords: Infrared, detectors, pyrometers, instrumentation, temperature

Introduction

For many years infrared temperature measurement used a single spectral band to determine target temperature. Picking a suitable spectral band allows the measurement instrument to be selected to suit the application and temperature range: longer wavelength detectors are required to measure lower temperatures. There are several drawbacks to single wavelength pyrometers, the main issue being the need to know the emissivity of the target surface for accurate measurement. Furthermore, since the temperature reading is a simple function of the signal received by the instrument, the reading can be significantly altered by the variable atmospheric conditions as well as obstructions in the signal path from a dirty window or dusty atmosphere.

One solution is to use a ratio pyrometer. Ratio pyrometers use two independent signals from two wavelengths and evaluate the temperature of the target using the ratio of the two signals as shown in Fig. 1. This method can determine the emissivity of the target and is less susceptible to obstructions in the signal path. Accurate temperature measurement using a ratio pyrometer no longer has the same issue with surface emissivity as a single wavelength instrument, however the non-greyness of the surface is now an important factor. The non-greyness of a surface is the ratio of emissivities at the two different wavelengths. A grey target has the same emissivity at both wavelengths.

Increasing the number of measurement wavelengths could provide more information about the target, such as being able to determine the non-greyness and account for atmospheric issues such as high CO2 environments. This paper investigates the potential advantages of temperature measurement at multiple wavelengths using a Fabry-Perot interferometer (FPI).

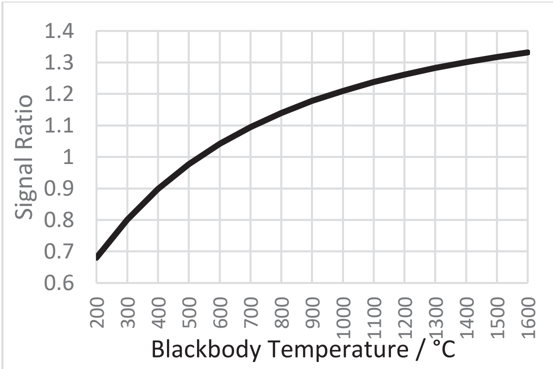

Fig.1 Graph showing the ratio of the infrared radiance from a blackbody at 3.4um to that at 3.8um. The flatness of the curve shows that small errors in non-greyness can lead to large errors in measured temperature.

Experimental Setup

A miniaturised Fabry-Perot interferometer was used to produce a tuneable narrow bandpass filter. The separation of the two reflective surfaces within the interferometer controls the pass band of the filter. In combination with a pyroelectric detector, which provides a relatively even output across multiple wavelengths, a hyper-spectral measurement device was produced. The equipment used in this study utilised an Infratec LFP series detector, which included support electronics for performing closed loop control of the device, ambient temperature compensation and filter stabilisation.

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A test instrument was built using the Infratec detector with custom readout electronics. The custom electronics consisted of three main parts, a power supply, an ADC, an MCU and an ethernet interface for access to the data. The ADC used a 16-bit converter to digitise the output signal from the detector and the MCU performed all the required calculations. The detectors and their respective control electronics were interfaced with using a standard UART serial interface. Commands were issued to the detector board for controlling the detector and filter, for example to set the band pass wavelength. The Infratec control electronics provided an adjustable gain for the output signal from the detector which was utilised to improve the dynamic range of the instrument and adjust the working range of the test instrument. Since the instrument used a pyroelectric based sensor, an optical chopper was used to modulate the signal onto the detector. The MCU provided control for the optical chopper motor and synchronised the readings with each chopper cycle.

Measurements were performed using a Land R1500T blackbody calibration source as a target of controllable temperature. The test instrument was focussed on the blackbody from a distance of 1m using focused optics.

Results

The chopped signal output becomes sinusoidal in shape due to the slow response time of the pyroelectric detector, so measurements were made of the peak-to-peak signal intensity variation. For a given detector illumination, the signal intensity could be altered either by adjusting the on-board amplifier gain or speed of the chopper. Graphs were plotted of signal intensity against temperature for each wavelength as shown in Fig. 2. From this data, a function was generated to convert the reading from the detector into a temperature.

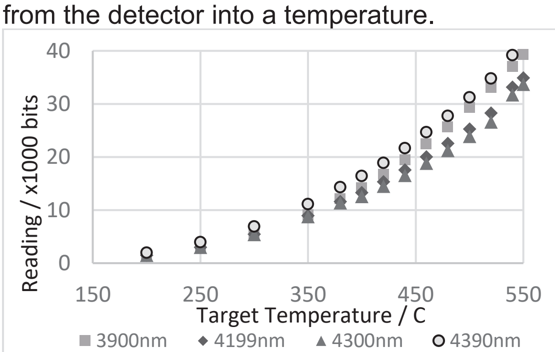

Fig.2 Graph showing the output reading determined by the MCU across several wavelengths and temperatures

The noise was estimated as the standard deviation of 100 readings for each wavelength and temperature combination, as shown in Fig. 3. This chart shows that the noise of the system is viable for taking single wavelength measurements with approximately 1°C accuracy. Further improvements could also be made by performing more signal processing.

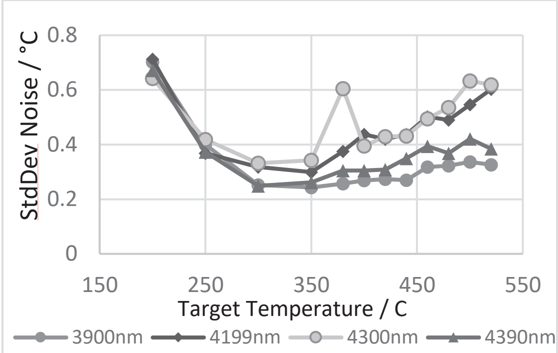

Fig. 3 Graph showing noise of temperature readings across multiple wavelengths and target temperatures

In Fig.4, the signal ratio at the two wavelengths is compared with a theoretical model. The data shows that whilst the shape agrees with that of the theoretical model, the errors in measurement could result in large temperature errors due to the flatness of the curve.

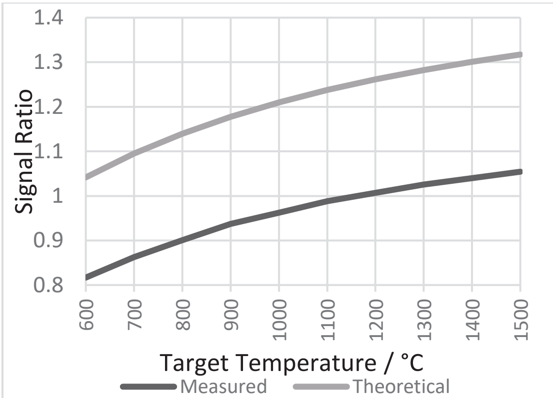

Fig. 4 Graph of ratio of signals at 3.4um to 3.8um for both the test instrument and the model.

Conclusion

The accuracy of the LFP series detector has been measured. Whilst the errors may be too large in the current state for ratio-type measurements, other applications could be possible such as material or surface condition determination. Emissive hot gasses could also be detected and measured independently of the target.