Technical Note

MIKRON INFRARED
A LUMASENSE TECHNOLOGIES Company

PhotriX™ Series Spectral Wavelength and Bandwidth Advantages

Introduction:

When evaluating the wide range of available industrial radiation pyrometers for your temperature measurement application, it is very important to consider the effects of detector spectral wavelength and bandwidth sensitivity. Mikron's PhotriX™ infrared thermometer system has been designed with narrow bandwidth detectors, at shorter wavelengths, to help minimize the effect of emissivity errors and improve accuracy. These detectors provide excellent signal to noise ratios, enabling precise high-speed measurements over a wide range of target materials, down to temperatures as low as 30°C.

Discussion:

Overview of Detectors:

Radiation based temperature sensors can be broadly classified into two main groups; thermal detectors and quantum (photon) detectors. The first category includes bolometers and thermopiles that convert absorbed electromagnetic radiation into a temperature change in the detector element. The temperature change then affects a measurable physical property of the detector material such as electrical resistance. These devices typically have a response time on the order of a second and have a very low detectivity that require a broader bandwidth to collect enough energy for a measurable signal. This mostly restricts the use of thermal detectors to industrial applications at lower temperatures where the radiation flux is larger in the infrared (4-20um) of the Planck spectrum (See Figure 1) and a fast response time is not needed.

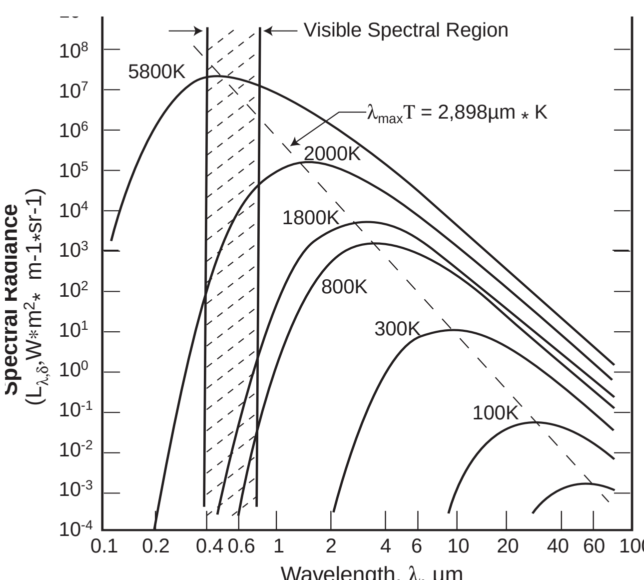

Figure 1

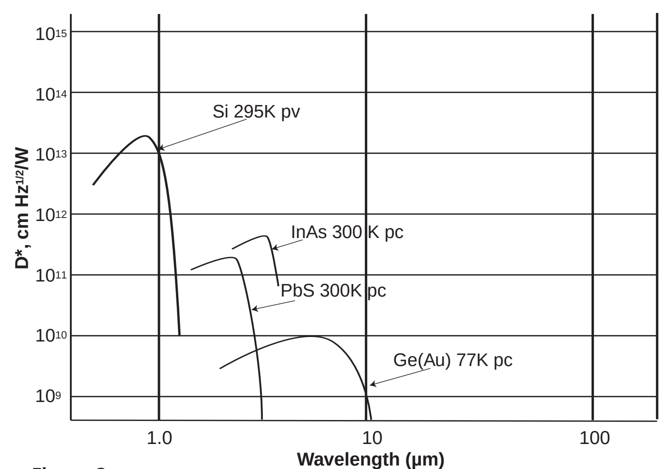

Figure 2

Quantum detectors are much more sensitive and respond to individual photons via mechanisms such as the photoelectric, photoconductive or photovoltaic effect. Typical spectral detectivities of these devises are up to 10^6 times that of the thermal detectors, and response times on the order of nanoseconds are common. A large variety of doped semiconductor materials have been developed to produce radiation sensors with reduced bandwidths, covering the Planck spectrum from visible to far infrared (See Figure 2). Mikron's PhotriX Optical Pyrometers belong to this class of detectors, and are constructed with sensitive proprietary sensors. Due to the wide variety of detector options available, it is important to consider the advantages, restrictions and competing factors when selecting a sensor for your application.

Selection of Wavelength and Bandwidth:

Absorption/Transmission spectra:

The first consideration in any application must always be to examine the absorption/transmission spectrum of the target material. Any obstructions, such as surrounding gases, quartz or glass windows, will also effect the measurements. The detector wavelength should be chosen to maximize the absorption of the target material while minimizing the influence of any obstructions. Figure 3 shows the transmittance as a function of wavelength

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Spectral Response (nm)	Temperature Range (°C) Min	Max
880 nm	195	3000
900 mn	190	3000
700-1650 nm	15	2800

Table 1

for a variety of obstruction and target materials. Notice, for example, that the transmission of silicon drops rapidly below 1 micron and therefore, a silicon wafer would only be opaque to a pyrometer selected with a wavelength below this value.

Temperature Resolution, Signal/Noise Ratio and Response Time:

The temperature resolution (precision) of a radiation detector is limited by the combined noise of the sensor, electronics and radiation noise, which increases with lower temperatures. This sets a lower limit to the temperature range as the signal associated with the incoming radiation falls to the point where the noise is of similar magnitude, and the Signal to Noise Ratio (SNR) approaches unity. For lower temperatures, the Planck spectrum peaks at longer wavelengths, producing larger signals. In addition, as the spectral bandwidth is relaxed the signal is increased, and the noise is decreased yielding a larger SNR. It then follows, that a larger bandwidth, and/or a longer wavelength will be advantageous for lower minimum temperatures. Most industrial pyrometers operate under these conditions.

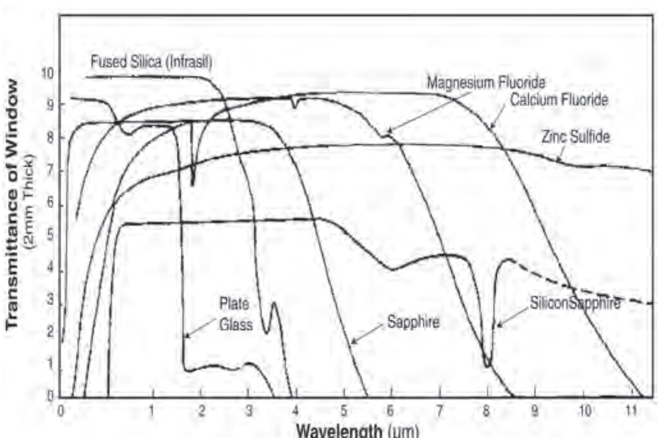

Figure 3

Many of the semiconductor radiation sensors available today have excellent noise performance (10^{-13} to 10^{-15}A), which provide excellent SNR, with short wavelengths and narrow bandwidths, allowing precise measurements at low temperatures. As mentioned above, these quantum detectors generally have very fast response times. This is advantageous for measurement of rapidly changing temperatures (or rapidly moving processes) when the accompanying increased noise is within acceptable limits.

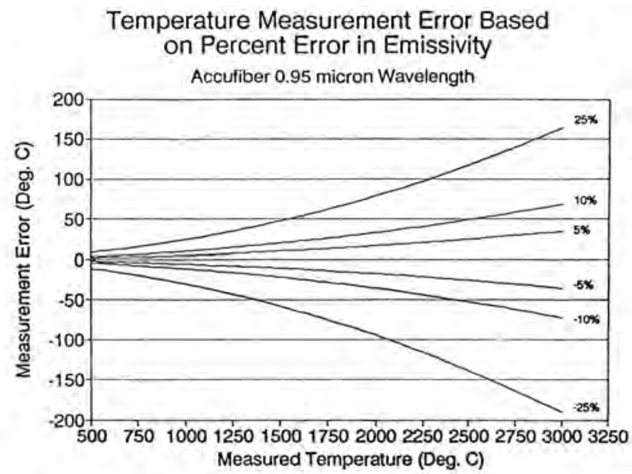

Figure 4

Emissivity Errors and Accuracy:

To obtain accurate temperature results from a radiation pyrometer it is necessary to know the effective emissivity ,e, of the target. Obviously, the best solution is to measure the emissivity in-situ, which is possible only with advanced, and expensive, radiation pyrometers. Baring this possibility, the emissivity must be estimated from tables, or inline/offline measurements. In all cases, a mistake in the measurement, or estimation of, e will manifest itself in an inaccurate temperature measurement. The temperature error 'dT' can be minimized by selecting a radiation pyrometer with a shorter wavelength 'l' as can be seen by the expression; $dT = dT^2 l\ de/e$ which is derived from the Planck equation. Figure 4. shows the expected temperature error as a function of wavelength and temperatures for a set of constant emissivity curves. In addition, a narrow spectral bandwidth detector has advantage that the emissivity is more likely to be a constant over the region. For a large bandwidth region the emissivity function may be quite complicated as it will vary with wavelength. The PhotriX's detectors have all been chosen with short wavelengths and narrow bandwidth sensors to provide more accurate temperature measurements.

Summary:

There are competing factors that must be considered when selecting the wavelength and bandwidths for radiation pyrometers. In general, the greatest accuracy is achieved by keeping the bandwidth as narrow as possible, and wavelength as short as possible, while maintaining constraints set by the required SNR. The PhotriX optical pyrometers have been designed with superior short wavelength, narrow bandwidth detectors, that have an extremely low noise performance to maximize the SNR. This provides outstanding precision, low temperature ranges, very fast system response, and minimizes effects of emissivity errors.