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White Paper:

High-speed IR Camera Captures Images without Blur: Results Show Benefits of LWIR Spectral Band

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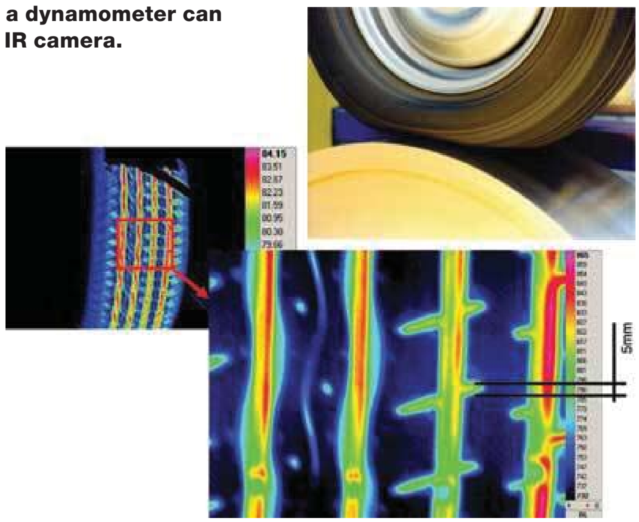
Introduction

Infrared (IR) cameras can image fast-moving objects and measure the temperature of any point on an object without the errors associated with motion blur. One application is in the study of the thermal characteristics of tires in motion. Using a high-speed IR camera to observe tires running on a dynamometer at speeds in excess of 150 mph, researchers can capture detailed temperature data during dynamic testing to simulate turning and braking loads (see Fig. 1).

FIGURE 1: Tires running on a dynamometer can be imaged by an IR camera.



To optimize imaging performance for this application and minimize motion blur requires the careful selection of camera exposure time, frame rate and spectral band. This involves calculations that depend on the linear velocity of the tire, the desired spot size resolution, the anticipated temperature range and the desired thermal sensitivity.

Normal operating temperatures for tires are within the ambient operating specification of a tire, plus a factor for the load-induced heating of the tire under a wide range of load and speed conditions. For our testing, we assumed that the maximum temperature a tire would be about 70°C. Given the uniform material properties of a tire, it is assumed that the temperature resolution or sensitivity required for proper analysis of the tire under various test conditions will be <0.25°C.

Based on a 16-in. wheel and 4-in. sidewall, the circumference of a tire will be 3.1416 × 24 (16 + 4 + 4) = 75.3 in. Assuming a speed of 60 mph, the linear velocity is 1056 in. (26,822 mm)/s. Assuming the resolution desired is 0.2 in. (5 mm) ±15% for acceptable motion displacement, you can calculate the exposure time necessary. You need to integrate the sensor during the period of time it takes the tire to move 0.03 in. (0.2 × 15%). The integration time is determined to be 28.4 µs.

Because the tire temperature is relatively cool, an LWIR camera will perform much better than an MWIR. From Planck's Law, as a target temperature increases, the peak wavelength associated with that temperature shifts toward shorter wavelengths. An LWIR system has its peak sensitivity around room temperature, while a MWIR system has its peak sensitivity around 400°C. Therefore, an LWIR system can better achieve the short exposure and sensitivity performance objectives.

Using a Planck's calculator function one can determine the specific well capacity of the focal-plane array at a given integration time and a given target temperature. At an integration period of 28 µs and an object temperature of 80°C, the LWIR detector's charge capacitor fills to 34%, while an MWIR camera will only fill the charge capacitor to 6%. (The MWIR camera will perform better for higher-temperature testing.) For this particular application, in simple terms there are many more photons in the LWIR than in the MWIR, and more photons will mean better signal (see Fig. 2).

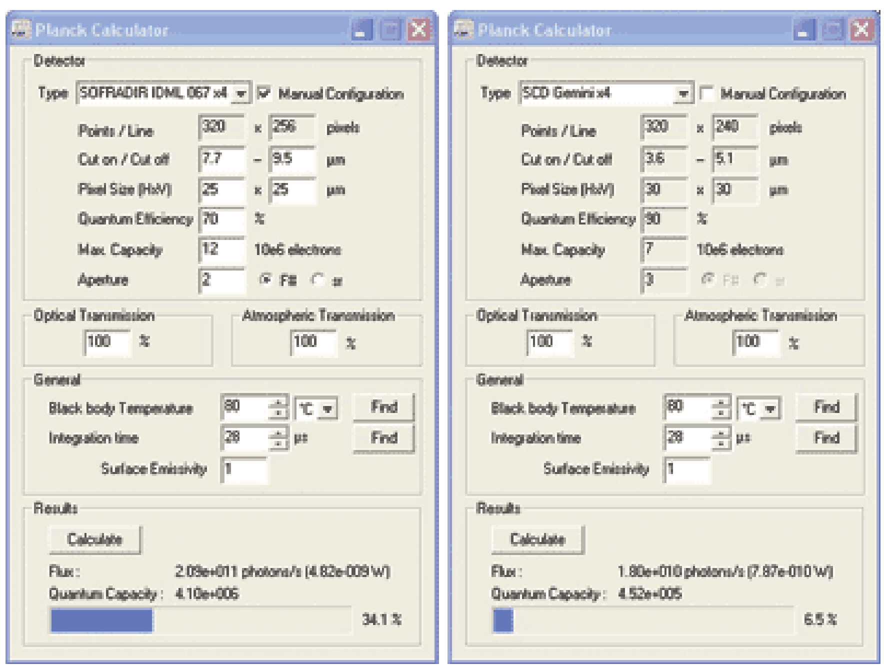


FIGURE 2: A Planck's calculator can determine the specific well capacity of a focal-plane array at a given integration time and a given target temperature. At an integration period of 28 µs and an object temperature of 80°C, the LWIR detector's charge capacitor fills to 34% (left), while an MWIR camera will only fill the charge capacitor to 6% (right).

In addition, high-performance thermal imaging systems have the ability to be synchronized with rapidly occurring events. In this tire-testing example, it is possible to have an optical encoder on the rotating tire that allows precise position location. The TTL signal generated by the optical encoder can be fed into the thermal imaging system to trigger the integration time of the camera. The result is that every time the encoder sends the pulse, the camera integrates and creates an image. This allows a real-time stop image sequence to be created via software.

High-speed infrared imaging can be used to provide important thermal data for rapidly moving objects. For the example of a high-speed tire testing application, an LWIR camera proved superior resulting in sub-125mK performance at an integration time of about 30 μs, with object blur smaller than 1 mm. This level of performance is important in understanding the thermal properties of the tire pattern.

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