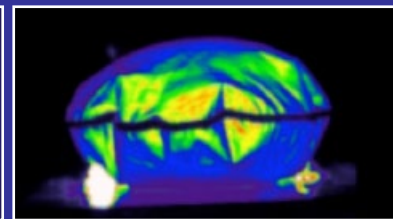
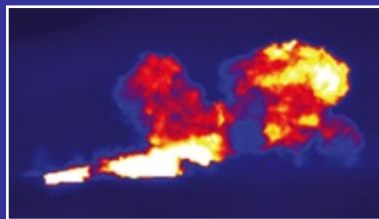
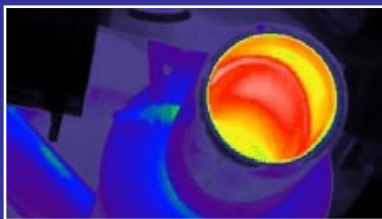
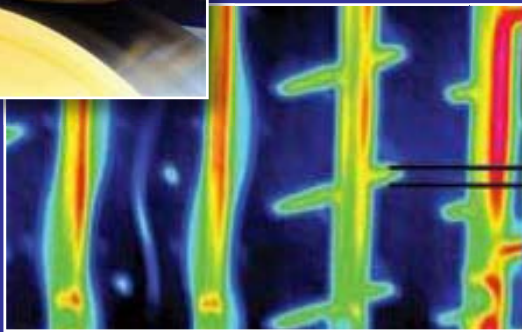


Electrophysics Resource Center  
**Scientific Imaging White Paper**

---

# High Speed Infrared Cameras Enable Demanding Thermal Imaging Applications

Written by Josh White    [jwhite@sofradir-ec.com](mailto:jwhite@sofradir-ec.com)



# High Speed Infrared Cameras Enable Demanding Thermal Imaging Applications

## Introduction

### Contents:

#### Introduction

#### 1. Infrared Spectral Sensitivity Bands

#### 2. Image Resolution and Field-of-View

- 2.1 Detector arrays and pixel sizes
- 2.2 Infrared lens characteristics

#### 3. High Speed Camera Features

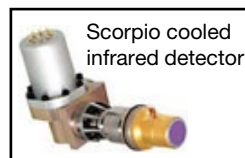
- 3.1 Short exposure times
- 3.2 High frame rates
- 3.3 Dynamic range expansion
- 3.4 Event triggering
- 3.5 Calibration: Non-uniformity correction and radiometry

#### 4. Infrared Camera Applications

- IR Inspection in Design, Test and Manufacturing
- Hyperspectral and Gas Imaging, Remote Sensing
- Target Signature Measurement and Tracking
- Research and Development
- Body Temperature Detection, Medical Imaging
- Non-Destructive Test (NDT)

#### Summary

Recent developments in cooled mercury cadmium telluride (MCT or HgCdTe) infrared detector technology have made possible the development of high performance infrared cameras for use in a wide variety of demanding thermal imaging applications. These infrared cameras are now available with spectral sensitivity in the short-wave, mid-wave and long-wave spectral bands or alternatively in two bands. In addition, a variety of camera resolutions are available as a result of mid-size and large-size detector arrays and various pixel sizes. Also, camera features now include high frame rate imaging, adjustable exposure time and event triggering enabling the capture of temporal thermal events. Sophisticated processing algorithms are available that result in an expanded dynamic range to avoid saturation and optimize sensitivity. These infrared cameras can be calibrated so that the output digital values correspond to object temperatures. Non-uniformity correction algorithms are included that are independent of exposure time. These performance capabilities and camera features enable a wide range of thermal imaging applications that were previously not possible.



(Pictured is Sofradir EC's SSC-640M High Speed Infrared Camera for MWIR imaging.)

Figure 1: At the heart of the high speed infrared camera is a cooled MCT detector that delivers extraordinary sensitivity and versatility for viewing high speed thermal events.

## 1. Infrared Spectral Sensitivity Bands

Due to the availability of a variety of MCT detectors, high speed infrared cameras have been designed to operate in several distinct spectral bands. The spectral band can be manipulated by varying the alloy composition of the HgCdTe and the detector set-point temperature. The result is a single band infrared detector with extraordinary quantum efficiency (typically above 70%) and high signal-to-noise ratio able to detect extremely small levels of infrared signal. As shown in Figure 2, single-band MCT detectors typically fall in one of the five nominal spectral bands shown:

- Short-wave infrared (SWIR) cameras - visible to 2.5 $\mu\text{m}$
- Broad-band infrared (BBIR) cameras - 1.5-5 $\mu\text{m}$
- Mid-wave infrared (MWIR) cameras - 3-5 $\mu\text{m}$
- Long-wave infrared (LWIR) cameras - 7-10 $\mu\text{m}$  response
- Very Long Wave (VLWIR) cameras - 7-12 $\mu\text{m}$  response

### Infrared Camera Spectral Response Characteristics

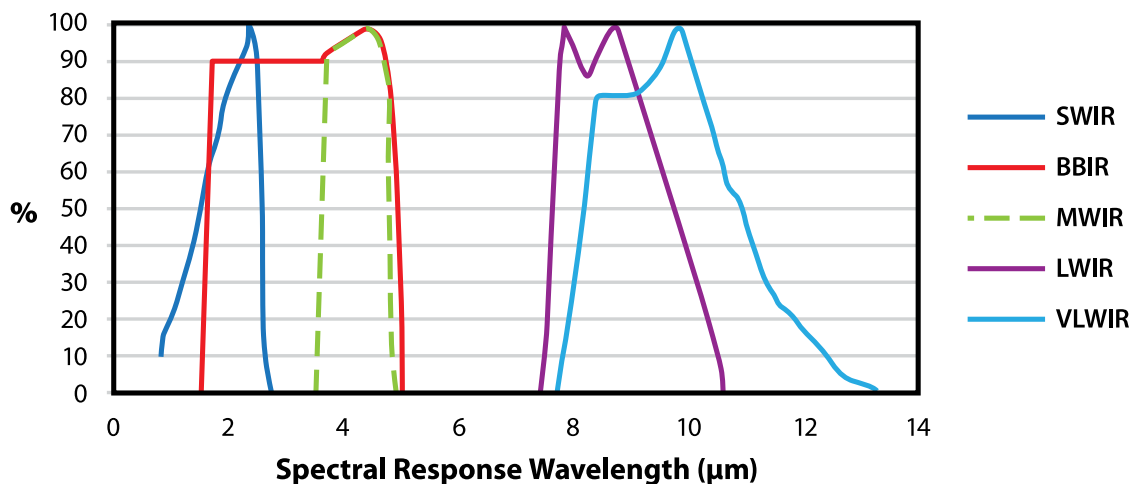


Figure 2: Single-band MCT-based high speed infrared camera spectral response characteristics

In addition to cameras that utilize “monospectral” infrared detectors that have a spectral response in one band, new systems are being developed that utilize infrared detectors that have a response in two bands (known as “two color” or dual band). Examples include cameras having a MWIR/LWIR response covering both 3-5 $\mu\text{m}$  and 7-11 $\mu\text{m}$ , or alternatively certain SWIR and MWIR bands, or even two MW sub-bands.

There are a variety of reasons motivating the selection of the spectral band for an infrared camera. For certain applications, the spectral radiance or reflectance of the objects under observation is what determines the best spectral band. These applications

include spectroscopy, laser beam viewing, detection and alignment, target signature analysis, phenomenology, cold-object imaging and surveillance in a marine environment.

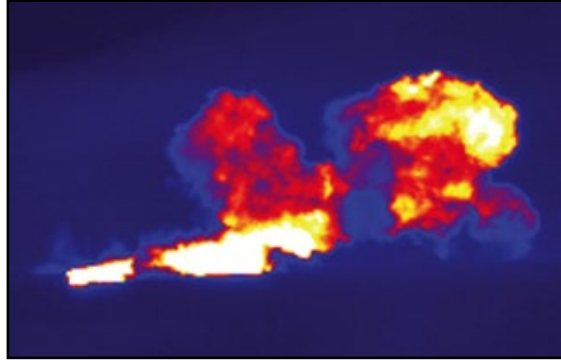


Figure 3: LWIR image of the test firing of a solid rocket booster. High intra-scene dynamic range results in the ability to image the rocket plume (~2500K) and the background (~260K).

Additionally, a spectral band may be selected because of the dynamic range concerns. Figure 3 shows the infrared image obtained with an LWIR infrared camera resulting from the test firing of a solid rocket booster. The intra-scene dynamic range (including the plume and the background) is about 2200K. Such an extended dynamic range would not be possible with an infrared camera imaging in the MWIR spectral range. The wide dynamic range performance of the LWIR system is easily explained by comparing the flux in the LWIR band with that in the MWIR band. As calculated from Planck's curve, the distribution of flux due to objects at widely varying temperatures is smaller in the LWIR band than the MWIR band when observing a scene having the same object temperature range. In other words, the LWIR infrared camera can image and measure ambient temperature objects with high sensitivity and resolution and at the same time extremely hot objects (i.e. >2000K). Imaging wide temperature ranges with an MWIR system would have significant challenges because the signal from high temperature objects would need to be drastically attenuated resulting in poor sensitivity for imaging at background temperatures.

## 2. Image Resolution and Field-of-View

### 2.1 Detector Arrays and Pixel Sizes

High speed infrared cameras are available having various resolution capabilities due to their use of infrared detectors that have different array and pixel sizes. Several common array formats are shown in Figure 4. For applications that do not require high resolution, high speed infrared cameras based on QVGA detectors offer excellent performance. Figure 4a shows a 320x256 array of 30 $\mu$ m pixels. Such cameras are known for their extremely wide dynamic range due to the use of relatively large pixels with deep wells, low noise and extraordinarily high sensitivity.

Figure 4: Infrared detector arrays are available in different sizes, the most common are QVGA, VGA and SXGA as shown. The VGA and SXGA arrays have a denser array of pixels and consequently deliver higher resolution. The QVGA is economical and exhibits excellent dynamic range because of large sensitive pixels.

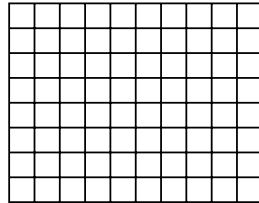


Fig.4a: 320x256x30µm (QVGA)

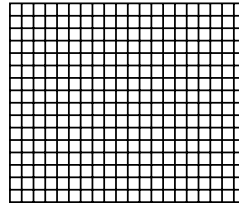


Fig. 4b: 640x512x15µm (VGA)

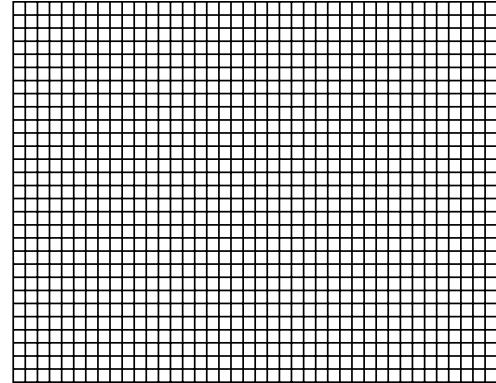


Fig. 4c: 1280x1024x15µm (SXGA)

More recently, the technology of smaller pixel pitch has resulted in infrared cameras having detector arrays of 15 micron pitch, delivering some of the most impressive thermal images available today. For higher resolution applications, cameras having larger arrays with smaller pixel pitch deliver images having high contrast and sensitivity. In addition, with smaller pixel pitch, optics can also become smaller further reducing cost. A 640x512 (VGA format) pixel array is depicted in Fig. 4b and a 1280x1024 (SXGA format) pixel array is depicted in Fig. 4c. A sample image from an SXGA camera is shown in Figure 5.



Figure 5: High resolution image shows spectacular detail and contrast (produced with an infrared camera having 1280x1024x15µm detector and a 50mm infrared lens).

## 2.2 Infrared Lens Characteristics

Lenses designed for high speed infrared cameras have their own special properties. Primarily, the most relevant specifications are focal length (field-of-view), F-number (aperture) and resolution.

**Focal Length:** Lenses are normally identified by their focal length (e.g. 50mm). The field-of-view of a camera and lens combination depends on the focal length of the lens as well as the overall diameter of the detector image area. As the focal length increases

(or the detector size decreases), the field of view for that lens will decrease (narrow). Since the field-of-view depends on the detector physical size, if a lens that is designed to be used on the detector depicted in Fig. 4c is used on either of the detectors depicted in Figs. 4a or 4b, the resulting field-of-view would be half that of the 4c detector.

| Table 1: Diagonal Field-of-View for Common Infrared Lenses |       |       |       |
|--|-------|-------|-------|
| FL (mm)  | MWIR  | BBIR  | LWIR  |
| 9.7  |       |       | 64.7° |
| 13   | 50.6° |       |       |
| 25   | 27.6° | 27.6° | 27.6° |
| 50   | 14°   | 14°   | 14°   |
| 100  | 7°    | 7°    | 7°    |
| 200  |       |       | 3.5°  |
| 250  | 2.8°  | 2.8°  |       |
| 600  |       |       | 1.2°  |

Table 1 shows common lens/camera combinations and their resulting field-of-view for the 4a and 4b sized detectors. Shown are the commonly available lens focal lengths for mid-wave (MWIR), broadband (BBIR) and long-wave (LWIR) imaging. A convenient online field-of-view calculator for a range of high-speed infrared cameras is available at:

<http://www.electrophysics.com/e/camera/index.php>.

In addition to the common focal lengths, infrared close-up lenses are also available that produce high magnification (1X, 2X, 4X) imaging of small objects, as shown in Figure 6.

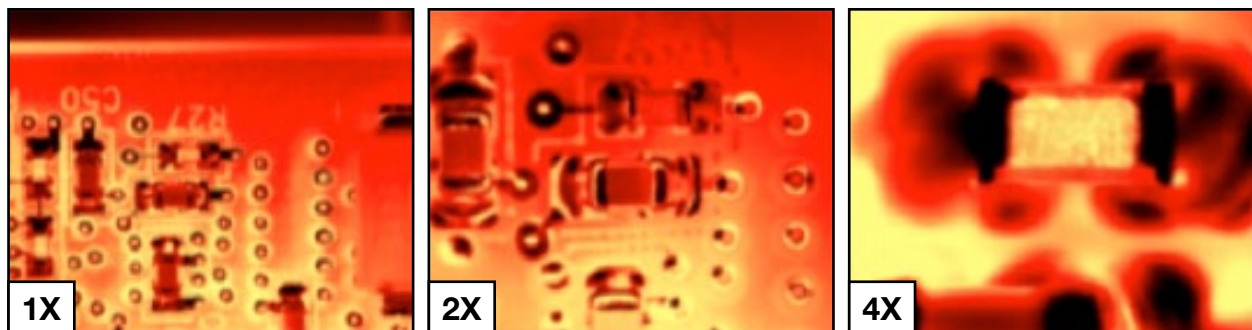
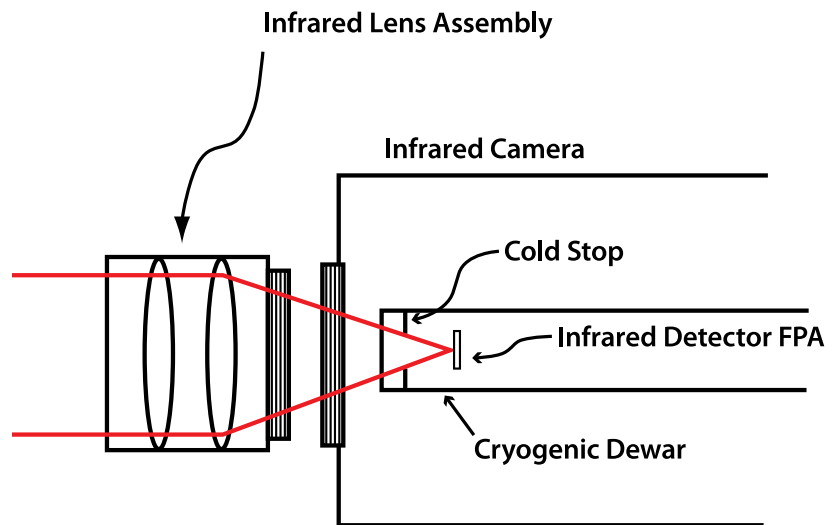


Figure 6: Infrared close-up lenses provide a magnified view of the thermal emission of tiny objects such as electronic components.

**F-number:** Unlike high speed visible light cameras, objective lenses for infrared cameras that utilize cooled infrared detectors must be designed to be compatible with the internal optical design of the dewar (the cold housing in which the infrared detector FPA is located). As shown in Figure 7, this is because the dewar is designed with a cold stop (or aperture) inside that prevents parasitic radiation from impinging on the detector. Because of the cold stop, the radiation from the camera and lens housing are blocked, infrared radiation that could far exceed that received from the objects under observation. As a result, the infrared energy captured by the detector is primarily due to the object's radiation. The location and size of the exit pupil of the infrared lenses (and the f-number) must be designed to match the location and diameter of the dewar cold stop. (Actually, the lens f-number can always be lower than the effective cold stop f-number, as long as it is designed for the cold stop in the proper position).

Figure 7: Lenses for cameras having cooled infrared detectors need to be specially designed not only for the specific resolution and location of the FPA but also to accommodate for the location and diameter of a cold stop that prevents parasitic radiation from hitting the detector.



**Resolution:** The modulation transfer function (MTF) of a lens is the characteristic that helps determine the ability of the lens to resolve object details. The image produced by an optical system will be somewhat degraded due to lens aberrations and diffraction. The MTF describes how the contrast of the image varies with the spatial frequency of the image content. As expected, larger objects have relatively high contrast when compared to smaller objects. Normally, low spatial frequencies have an MTF close to 1 (or 100%); as the spatial frequency increases, the MTF eventually drops to zero, the ultimate limit of resolution for a given optical system.

### 3. High Speed Infrared Camera Features: variable exposure time, frame rate, triggering, radiometry

High speed infrared cameras are ideal for imaging fast-moving thermal objects as well as thermal events that occur in a very short time period, too short for standard 30 Hz infrared cameras to capture precise data. Popular applications include the imaging of airbag deployment, turbine blades analysis, dynamic brake analysis, thermal analysis of projectiles and the study of heating effects of explosives. In each of these situations, high speed infrared cameras are effective tools in performing the necessary analysis of events that are otherwise undetectable. It is because of the high sensitivity of the infrared camera's cooled MCT detector that there is the possibility of capturing high-speed thermal events.

The MCT infrared detector is implemented in a "snapshot" mode where all the pixels simultaneously integrate the thermal radiation from the objects under observation. A frame of pixels can be exposed for a very short interval as short as <1 microsecond to as long as 10 milliseconds. Unlike high speed visible cameras, high speed infrared cameras do not require the use of strobes to view events, so there is no need to synchronize illumination with the pixel integration. The thermal emission from objects under observation is normally sufficient to capture fully-featured images of the object in motion.

Because of the benefits of the high performance MCT detector, as well as the sophistication of the digital image processing, it is possible for today's infrared cameras to perform many of the functions necessary to enable detailed observation and testing of high speed events. As such, it is useful to review the usage of the camera including the effects of variable exposure times, full and sub-window frame rates, dynamic range expansion and event triggering.

#### 3.1 Short exposure times

Selecting the best integration time is usually a compromise between eliminating any motion blur and capturing sufficient energy to produce the desired thermal image. Typically, most objects radiate sufficient energy during short intervals to still produce a very high quality thermal image. The exposure time can be increased to integrate more of the radiated energy until a saturation level is reached, usually several milliseconds. On the other hand, for moving objects or dynamic events, the exposure time must be kept as short as possible to remove motion blur.



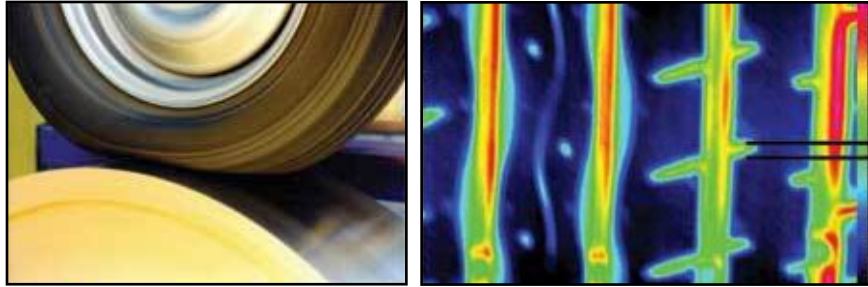


Figure 8: Tires running on a dynamometer can be imaged by a high speed infrared camera to determine the thermal heating effects due to simulated braking and cornering.

One relevant application is the study of the thermal characteristics of tires in motion. In this application, by observing tires running at speeds in excess of 150 mph with a high speed infrared camera, researchers can capture detailed temperature data during dynamic tire testing to simulate the loads associated with turning and braking the vehicle. Temperature distributions on the tire can indicate potential problem areas and safety concerns that require redesign. In this application, the exposure time for the infrared camera needs to be sufficiently short in order to remove motion blur that would reduce the resulting spatial resolution of the image sequence. For the set-up shown in Figure 8, for a desired tire resolution of 5mm, the desired maximum exposure time can be calculated from the geometry of the tire, its size and location with respect to the camera, and with the field-of-view of the infrared lens. The exposure time necessary is determined to be shorter than  $28\mu\text{s}$ . Using a Planck's calculator, one can calculate the signal that would be obtained by the infrared camera adjusted with specific F-number optics. The result indicates that for an object temperature estimated to be  $80^{\circ}\text{C}$ , an LWIR infrared camera will deliver a signal having 34% of the well-fill, while a MWIR camera will deliver a signal having only 6% well fill. The LWIR camera would be ideal for this tire testing application. The MWIR camera would not perform as well since the signal output in the MW band is much lower requiring either a longer exposure time or other changes in the geometry and resolution of the set-up.

The infrared camera response from imaging a thermal object can be predicted based on the black body characteristics of the object under observation, Planck's law for blackbodies, as well as the detector's responsivity, exposure time, atmospheric and lens transmissivity.

### 3.2 Variable frame rates for full frame images and sub-windowing

While standard speed infrared cameras normally deliver images at 30 frames/second (with an integration time of 10 ms or longer), high speed infrared cameras are able to deliver many more frames per second. The maximum frame rate for imaging the entire camera array is limited by the exposure time used and the camera's pixel clock frequency. Typically, a 320x256 camera will deliver up to 275 frames/second (for exposure times shorter than 500 $\mu$ s); a 640x512 camera will deliver up to 120 frames/second (for exposure times shorter than 3ms).

The high frame rate capability is highly desirable in many applications when the event occurs in a short amount of time. One example is in airbag deployment testing where the effectiveness and safety are evaluated in order to make design changes that may improve performance. As shown in Figure 9, a high speed infrared camera reveals the thermal distribution during the 20-30 ms period of airbag deployment. As a result of the testing, airbag manufacturers have made changes to their designs including the inflation time, fold patterns, tear patterns and inflation volume. Had a standard IR camera been used, it may have only delivered 1 or 2 frames during the initial deployment, and the images would be blurry because the bag would be in motion during the long exposure time.

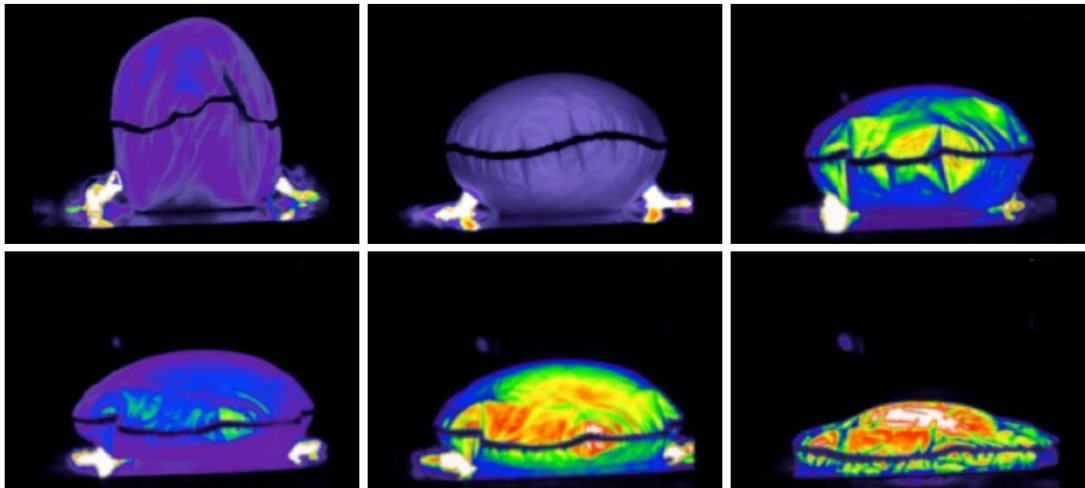


Figure 9: Airbag effectiveness testing has resulted in the need to make design changes to improve performance. A high speed infrared camera reveals the thermal distribution during the 20-30ms period of airbag deployment. As a result of the testing, airbag manufacturers have made changes to their designs including the inflation time, fold patterns, tear patterns and inflation volume. Other sequences are available for viewing online at: [www.electrophysics.com/e/PH\\_site/ph-multimedia-ctr.html](http://www.electrophysics.com/e/PH_site/ph-multimedia-ctr.html).

Even higher frame rates can be achieved by outputting only portions of the camera's detector array. This is ideal when there are smaller areas of interest in the field-of-view. By observing just "sub-windows" having fewer pixels than the full frame, the frame rates can be increased. Some infrared cameras have minimum sub-window sizes. Commonly, a 320x256 camera has a minimum sub-window size of 64x2 and will output these sub-frames at almost 35Khz, a 640x512 camera has a minimum sub-window size of 128x1 and will output these sub-frame at faster than 3Khz.

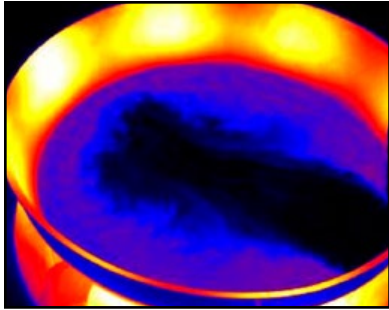
Because of the complexity of digital camera synchronization, a frame rate calculator is a convenient tool for determining the maximum frame rate that can be obtained for the various frame sizes.

### 3.3 Dynamic range expansion

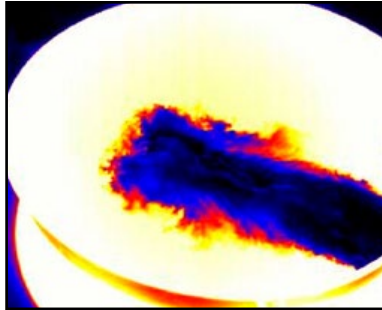
One of the complications of having a very high sensitivity infrared detector is that the overall scene dynamic range will be limited. For example, if a raw count corresponds to 5 mK/digital count, a 14-bit signal range will deliver less than 80°C in dynamic range. This range is further reduced because of pixel non-uniformity. As a consequence, the range of object temperatures that can be viewed in one frame may be too narrow for the application.

To increase the apparent dynamic range, a unique solution can be implemented which allows the user to artificially expand the dynamic range without sacrificing the high sensitivity performance of the camera. (This mode is sometimes called Dynamic Range ExtendIR, DR-X, superframing, multi-IT). When the dynamic range expansion mode is engaged, the camera sequentially captures multiple frames, each frame having a different exposure time. The short sequence includes frames that are highly sensitive (because of long exposure times) and also less sensitive frames for imaging objects at higher temperatures (because of shorter exposure times). For the method to be effective, the overall time for the frame sequence must be short enough to avoid motion blur. If this is the case, then camera software combines the frames into one image frame having the entire dynamic range for the sequence.

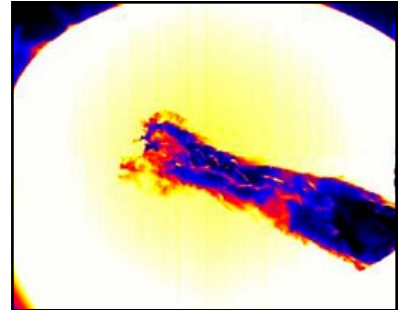
As an example, consider the following sequence of images showing the process of mixing a cold fluid to a flask of boiling liquid. If an exposure time was selected based on the full temperature range, the thermal resolution of the cooler objects will be poor. Conversely, if the exposure time is selected to improve the thermal resolution of the cold fluid, the hotter objects may cause saturation. As a result, with dynamic range expansion, multiple integration times can be selected that span the entire scene dynamic range.



Exposure time 110µs / Frames 1,4,7 /  
Object Temperature Range 65-150°C

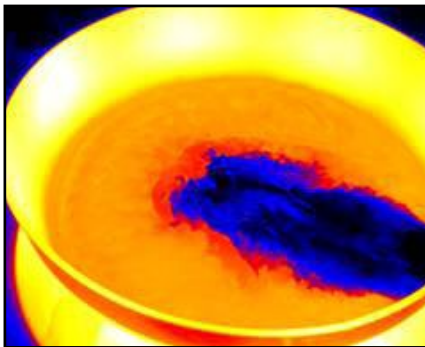


Exposure time 600µs / Frames 2,5,8 /  
Object Temperature Range 35-70°C



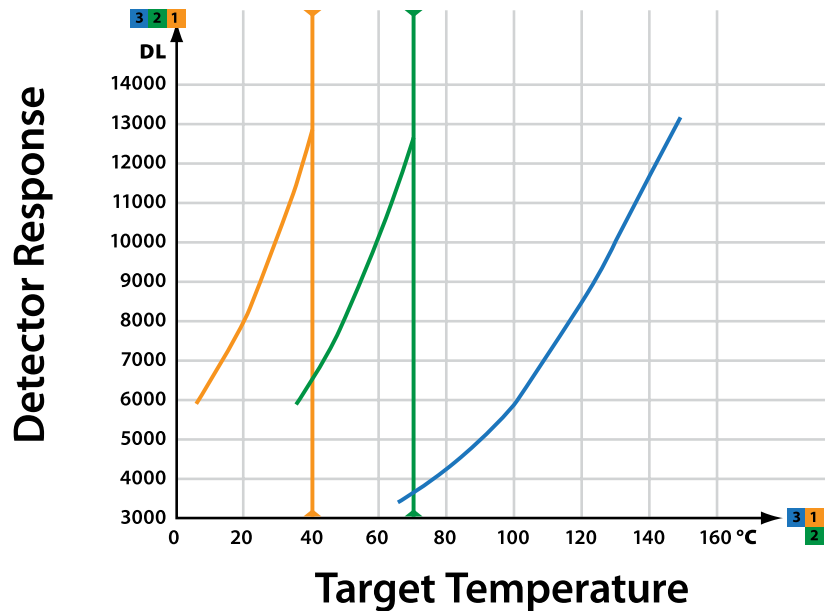
Exposure time 1375µs / Frames 3,6,9 /  
Object Temperature Range 5-40°C

In this example, three exposure times have been selected (1375µs, 600µs, and 110µs) to cover a wide scene temperature. The camera then cycle through each exposure time at the full frame rate. If the camera is operating at 240 frames/second, the first frame will be at the first exposure time, the second frame will be at the second exposure time, the third at the third exposure time. The fourth frame will begin the sequence again at the first exposure time. The system will effectively generate three sequences, three frames apart, each at a rate of 80 frames/second with the three exposures times. Through image processing, the sequential frames can be recombined into one complete sequence making a pixel by pixel determination as to the apparent signal, further increasing the dynamic range. The resulting image is shown below (with a 5-150°C object temperature scale):



The exposure times correspond to different camera sensitivities as shown in Figure 10. In operation, the camera is programmed to select the appropriate exposure time frame by frame. The resulting data will either be multiple sequences created from multiple integration times, or a combined sequence that takes the most appropriate data based upon the scene. In addition, the user can choose to vary the number of frames per integration time, as well as have the option to utilize an internal filter mechanism for attenuation or spectral data.

Figure 10: Detector response due to different exposure time selections



Certain applications require very wide thermal dynamic ranges, which may not be possible with a single integration time. The high speed infrared camera's dynamic range expansion mode will allow the user to cycle through exposure times at the fastest rate possible for the camera.

### 3.4 Event Triggering

In order to capture high speed events, infrared cameras must be properly synchronized. In the tire-testing example in Section 3.1 above, 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 infrared camera to trigger the start of the recording sequence for the camera. The result is that every time the encoder sends the pulse, the camera exposes the infrared detector for a certain exposure time creating an image. This allows a real-time stop image sequence to be created via software.

In addition to the ability to accept an external TTL trigger, infrared cameras have other capabilities that improve their ability to capture high speed events. For example, certain trigger features permit the infrared camera to synchronize the trigger with the desired image capture. Because digital image frames are captured in real time, a pre-trigger permits the software to identify the beginning of a desired sequence that actually occurs before the trigger signal! Post-trigger delays are also available for aligning the frame capture with an event that follows the trigger after a programmable delay.

In addition, most high speed thermal cameras today have the ability to provide a trigger output to allow external devices to be synchronized with the thermal camera. Therefore the camera can slave or be slaved. Having both a trigger input and output is useful in an application that involves using multiple cameras to view the same target from different angles. In this case, the data can be assembled – via software – into a 3-dimensional rendering of the thermal profile.

### 3.5 Calibration: non-uniformity correction and radiometry

One of the challenges in obtaining the best data from a high performance infrared camera system was in maintaining a proper calibration. Calibration often refers to two different operations. One, non-uniformity correction, is necessary to calibrate the sensor for optimal image quality. The other calibration has to do with determining the temperature of objects based on their image brightness.

Non-uniformity correction is required to assure that the infrared detector array delivers the best possible image quality. Each pixel in the detector array inevitably has a slightly different gain and offset value. In addition, some pixels may have other anomalous properties that deviate from the norm. The gain and offset for all the pixels in the array need to be adjusted so that each pixel performs identically to the others. Variations can occur for a variety of reasons, including detector non-uniformity and optical affects such as the lens illumination non-uniformity that attenuates the apparent radiance near the edge of the image. Anomalous pixel signals must be replaced with nearest neighbor averages as is appropriate for the application.

To correct for the gain and offset, a calibration called Non Uniformity Correction (NUC) must be created. The process typically requires that the user expose the detector to a “cold” and “hot” blackbody source. An algorithm then corrects the detector signal non-uniformity. A similar process called Bad Pixel Replacement (BPR) is required for any pixels that are considered “bad” which means they deviate from certain thresholds set for evaluating uniformity or due to noisy behavior.

Non-uniformity correction is complicated because there are variations in pixel performance for each integration time. Therefore, this process would need to be performed for every integration time that the user selects. As high performance cameras can operate from 1us to >10ms, this means that in theory 10,000 calibrations need to be made. However, because of the linear response of the detector, recent advances have been possible to make this process transparent to the user. A process called TrueThermal allows the

user to select any integration time and the camera will automatically reference a look up table of both NUC and BPR properties that were established either at the factory or at the user's site. In this situation, once a user selects the appropriate integration time, the camera system applies a predefined NUC and BPR table to allow instant and seamless operation.

Once the sensor is calibrated for uniform image quality, the camera can be calibrated for radiometry, or temperature measurement. If an infrared camera is properly calibrated, the object temperature can be determined based on the radiance signal in the thermal images, the background ambient temperature, possible atmospheric effects and the objects emissive properties. It is often particularly useful to be able to use the infrared camera to measure the temperature of objects (such as projectiles) traveling at high speeds. This finds applicability in several important situations, including: tracking of missiles, spacecraft and other objects, in determining the trajectory of bullets and projectiles and automatically identifying their origin based on trajectory information, and in creating thermal signatures for military targets.

Some users require that the thermal data be calibrated for radiometry. Again, this radiometric data will be dependent upon a specific integration time and must include the NUC and BPR corrections. In the past, for each integration time, a unique radiometric calibration would be required. Today, the TrueThermal calibration function facilitates the process, not only correcting for NUC and BPR, but also applying the appropriate radiometric calibration table to the data. This now allows the user to, in real time, change integration times and have fully corrected data for NUC, BPR and radiometric calibration.

## 4. Infrared Camera Applications

***IR Inspection in Design, Test and Manufacturing:*** Thermal imaging has become an extremely valuable technology in many industries as a tool to inspect and test different designs and processes. The thermal signatures can be a result of electrical, electro-mechanical, chemical or other causes. Thermal images reveal heat dissipation, thermal conductance, non-uniformities as well as other important diagnostic factors.

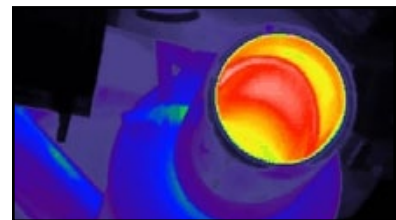


Figure 11a: Automotive Exhaust

**Hyperspectral and Gas Imaging, Remote Sensing:** Broadband infrared cameras are very useful for hyperspectral imaging (which involves the accumulation of a spectral set of times), gas imaging (which occurs at a sometimes very narrow portion of the infrared spectrum) and remote sensing (imaging the backscatter, reflection and emission differences of various materials). Powerful image processing software is available to facilitate the analysis of the resulting infrared images.



Figure 11b: Gas Plume Detection

**Target Signature Measurement and Tracking:** The spectral characteristics of vehicles, weapons and countermeasures have been found to be important for many applications. Broad spectral range, high resolution and high sensitivity are key features of infrared cameras for these applications. We offer multi-spectral imaging systems with a wide range of optics. In addition, we offer powerful data acquisition systems featuring real-time image capture and radiometric analysis.

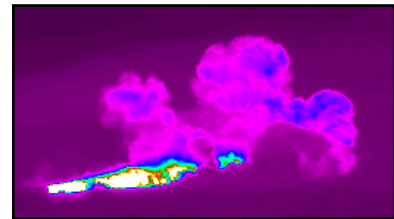


Figure 11c: Solid Rocket Motor Testing

**Research and Development:** Thermal imaging is used extensively in engineering and scientific research centers around the world. Thermal imaging provides insight into critical information about an object's thermal and spectral characteristics. In certain

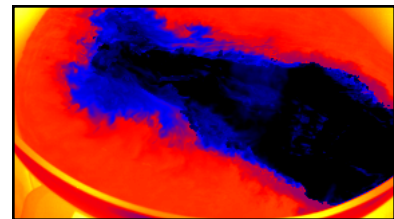


Figure 11d: Materials Measurement

circumstances, information can be obtained on high-speed events (available with high frame-rate cameras) as well as circumstances requiring large dynamic range (available with variable integration cameras). Key to the use of these imagers is often application-specific software that permits the detailed analysis of both two-dimensional images as well as arrays of image sequences.



**Medical Imaging, Body**

**Temperature Detection:** Many physiological conditions produce variations in body temperature and temperature distribution across the human body. As an example, the installation of thermographic cameras at airports has become a key Swine Flu and SARS screening tool for many areas around the world. Thermography has also been used as a screening tool for applications such as breast cancer and pain management.

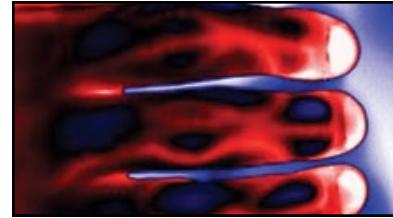


Figure 11e: Medical Imaging  
(human hand)

**Non-Destructive Test (NDT):**

Thermal imaging is a non-invasive technique which when applied with specific stimulus provides a view into subsurface defects in difficult test samples. Inspection of composite aircraft parts is gaining wide acceptance in airframe manufacture and service.

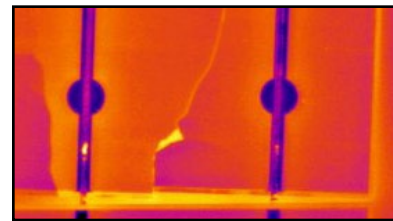


Figure 11f: Solar Cell Inspection

Advanced materials are finding their way into automotive and consumer products and thermographic NDT is a fast and wide area screening technique that is very cost effective.

## Summary

Because of the impressive performance of MCT detector technology, high performance infrared cameras have become available that enable a wide variety of demanding thermal imaging applications. A selection of infrared cameras are available having mid-format to large-format detectors and with spectral sensitivity ranging in the short, mid and long-wave spectral bands. The cameras owe their versatility to certain features that include: high frame rate imaging, adjustable exposure time, event triggering enabling the capture of temporal thermal events, dynamic range expansion, non-uniformity correction and radiometric calibration. These performance capabilities and camera features enable a wide range of thermal imaging applications that were previously not possible, including: IR Inspection in design, test and manufacturing, hyperspectral imaging, gas detection, remote sensing, target signature measurement and tracking, R&D, medical imaging and NDT.

For more comprehensive White Papers  
visit our online Knowledge Center.  
**[www.electrophysics.com/infrared-cameras](http://www.electrophysics.com/infrared-cameras)**



373 Route 46, Fairfield, NJ 07004 Phone: 973-882-0211 Fax: 973-882-0997  
[www.electrophysics.com](http://www.electrophysics.com)

© 2010 Electrophysics Corp. All rights reserved.  
An ISO 9001 Certified Company.