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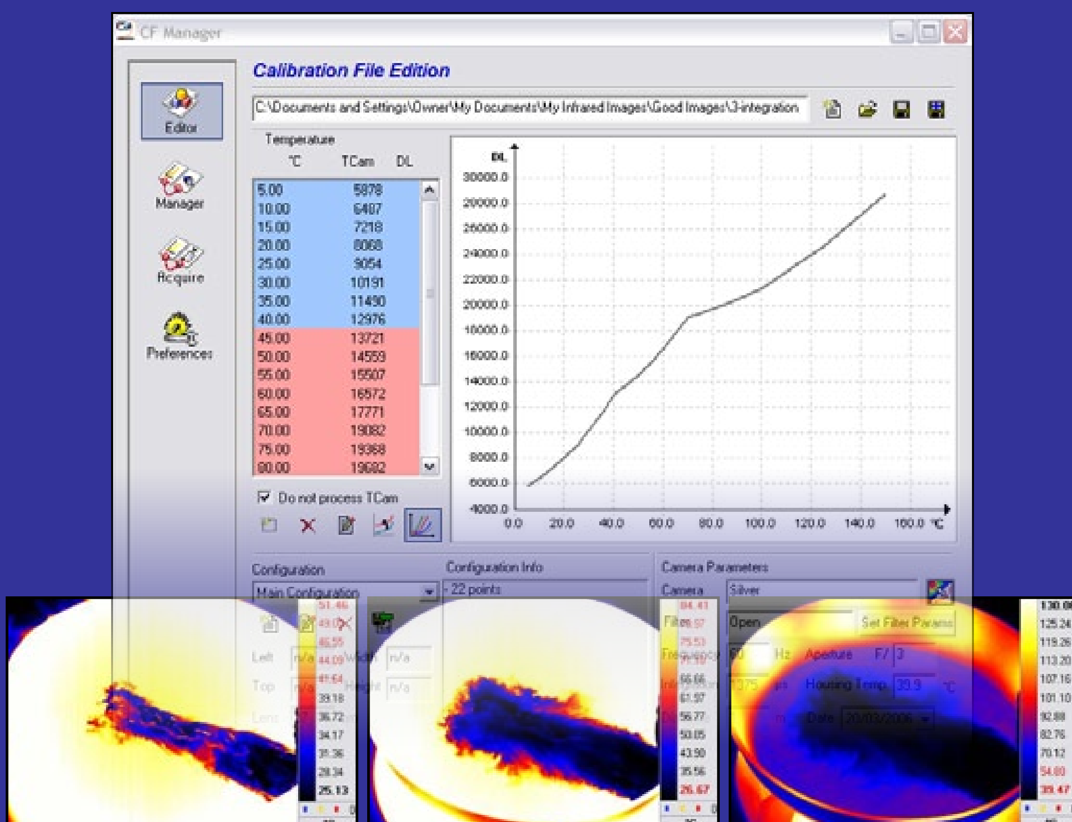
Advanced Techniques for Measuring Temperature or Radiance of Thermally Dynamic Events



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Advanced Techniques for Measuring Temperature or Radiance of Thermally Dynamic Events

Abstract

Today's high performance infrared cameras incorporate high quantum efficiency (QE) (>90% typical) photo-voltaic focal plane arrays, including InSb and MCT, with a spectral response in either the mid-wave band (3-5μm) or the long-wave band (7.7-9.5μm). These cameras feature high thermal sensitivity (typically <20mK), variable integration time control and fast frame rate operation, making them ideal for a wide range of applications. Many applications require the collection of radiometric data of targets with large temperature differences within the scene or of experiments during which dynamic temperature changes occur over a short period of time. This paper introduces new proprietary techniques that enable the collection of radiometric data under dynamic conditions.

Introduction

Each infrared focal plane array pixel is a photo conductor that converts photons into electrons. As infrared radiation is absorbed by the pixel it is converted into electrons which are collected in the pixel's charge capacitor. By adjusting the time the capacitor collects charges, the integration time (IT), we can alter the systems dynamic range and the scene temperature that the system is optimized for. Shortening the integration time enables the imaging of hotter object, while increasing the integration time enables the imaging and measurement of colder objects.

KEYWORDS:
Infrared imaging
Hypercal
CNUC
Recomposer
Non contact temperature measurement
Cascade integration
High speed imaging
Dynamic range optimization
Dynamic range extension
Mid wave infrared camera
Long wave infrared camera

The dynamic range of an infrared camera can be specified in numerous ways however for the purpose of this paper we will refer to dynamic range as the range of apparent black body temperature that a single infrared image frame can quantify without being saturated. Because the systems are designed for high sensitivity their dynamic range is typically limited to about 50°C (nominal integration of 2 milliseconds). Refer to Figure 4 for an example of the target temperature ranges of an InSb-based system at different integration times.

There are many applications in which targets heat (or cool) very rapidly and span a temperature range that exceeds the systems nominal temperature dynamic range. Using a single integration time in this instance will potentially result in saturated data. To overcome this, a camera feature called Multi-IT enables the camera to automatically cycle through up to 4 user-selected integration time settings in sequential frames to build a data set that software can process to create a single data set in which each pixel in every image of a recorded sequence is optimized. In the following example an Electrophysics Titanium 520M was operated at 120 frames per second and programmed to run at 3 integration times (1375μs, 600μs and 110μs) while imaging cold liquid being poured into a vessel of hot liquid. The software captured a series of images taken at different exposures sequentially. For a 1 second test, three sequences (one for each integration time), each 40 frames would be created. The first sequence would have data from the longest integration time and would consist of frames 1, 4, 7, 10, etc. The second sequence would be from the 600μs IT with frames of 2, 5, 8, 11, etc. The third sequence would be from the 110μs IT with frames 3, 6, 8, 12, etc.

The following series of images of cold liquid being poured into a cup of boiling liquid were taken at three different integration times. Notice that each image has different temperatures within range.

Image 1: taken at 1375μs integration time.

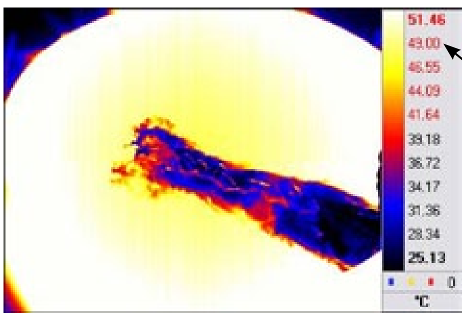


Image is saturated about 50°C

Image 2: taken at 600μs integration time.

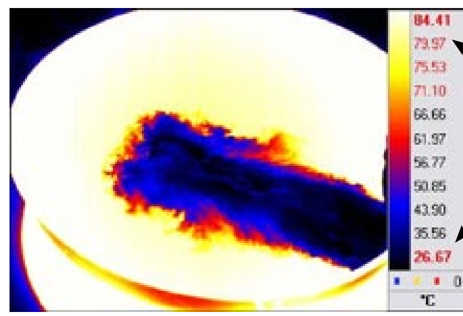


Image is saturated at about 80°C

Image is cold saturated at 30°C

Image 3: taken at 110μs integration time.

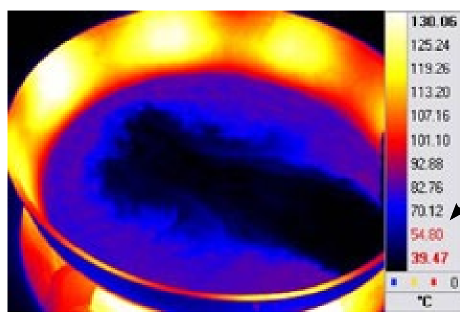
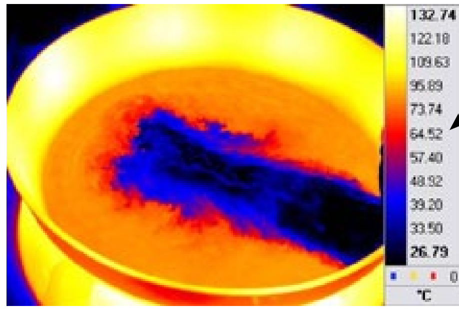


Image is photon-deprived at 60°C

To best maximize the results, the multiple integration times are chosen such that there is ample overlap in between them.

The data set is then reduced into a single sequence file using our Recomposer tool, which provides pixel by pixel analysis in each frame of each sequence and selects the best in-range pixel from the three-integration frame set, based on where its digital value resides within the most linear portion of the calibration curve. Recomposer then compliles this data into a new sequence that encompasses data from all the integration times from the original experiment, hence increasing the dynamic range.

Image 4: Recomposed Image



Hypercal – Eliminates the Need for Unique Integration Time Radiometric Calibrations

Previously or with older technology the user needed to determine what integration settings were necessary to achieve the dynamic range for the data collection by calculating the temperature range they anticipated and perform blackbody calibrations for each integration time prior to collecting data or measuring temperatures. This is potentially very time consuming and requires access to blackbody reference. In addition, if a selected integration did produce the appropriate calibration results another integration time calibration would have to be performed and the test rerun. In addition an NUC, or non-uniformity calibration, was necessary for each integration time. In the case the application required four integration data sets, it would be necessary to perform four radiometric calibrations and four non-uniformity calibrations.

Hypercal™ is a new technique that automatically creates radiometric calibration data for all integration times between the factory-performed calibration at short and long integration times. Previously, readiometric calibrations were limited to a few integration times. Now, Hypercal allows hundreds or thousands of possibilities. Additionally, our new CNUC™ feature automatically creates non-uniformity correction tables for each integration setting. By automatically generating both radiometric and non-uniformity data we have greatly simplified the set-up of an infrared camera and the collection of radiometric data and eliminated the need for highly specialized black body references.

Figure 1: Calibration Control Tool

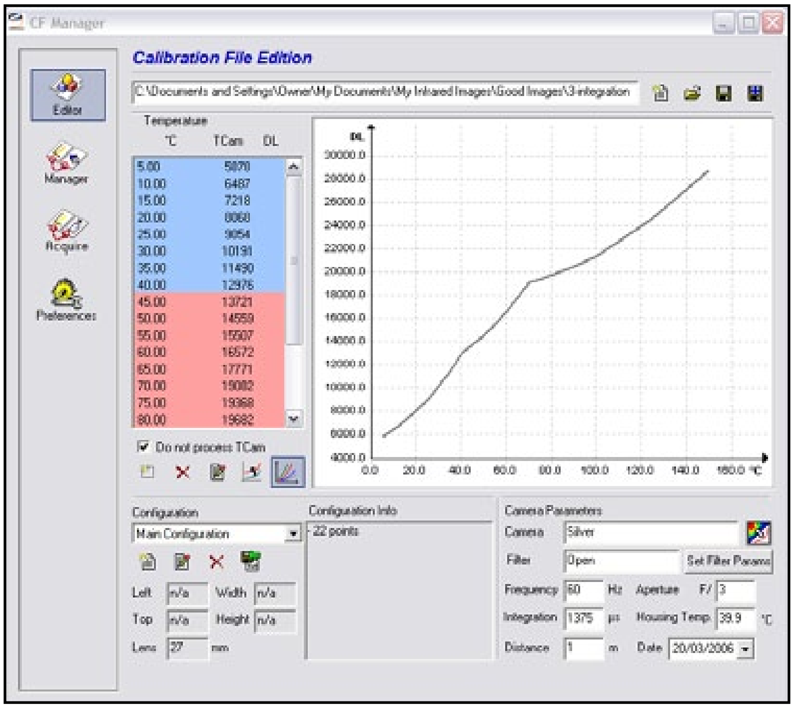
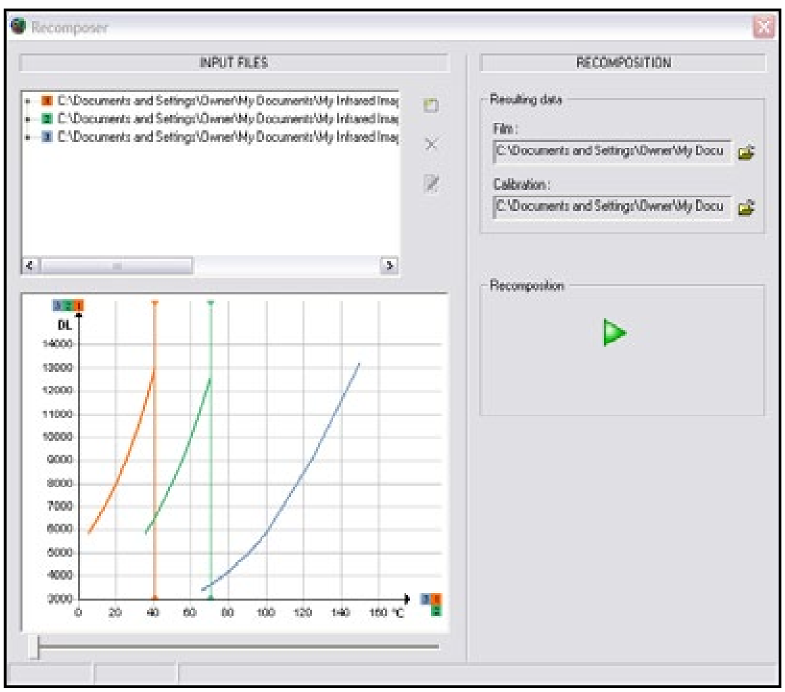


Figure 2: Recomposer Dynamic Range Optimization Tool



Other Considerations

There are other factors to consider when evaluating system configurations for temperature or radiometric data recording and analysis. For example, the effective linear dynamic range of an InSb camera is approximately 50°C when viewing room temperature objects. By adding a neutral density filter you can extend the temperature range, but you will lose some thermal resolution. InSb-based mid-wave (3-5μm) cameras have become a commercial industry standard. However MCT array long-wave cameras with spectral response between 8 and 9.4 μm should be considered for some applications, including for cold temperature measurements and imaging spectroscopy of materials with unique spectral absorption characteristics.

Figure 3: Effective Temperature Range for LWIR Camera

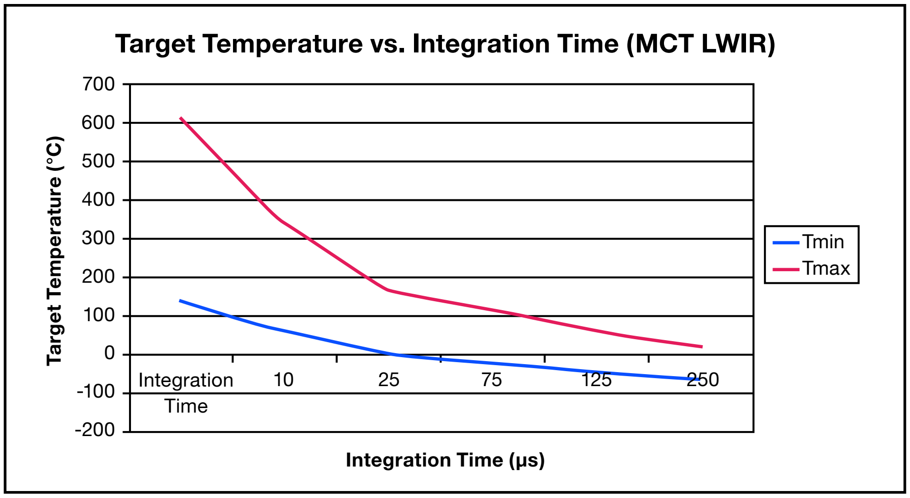
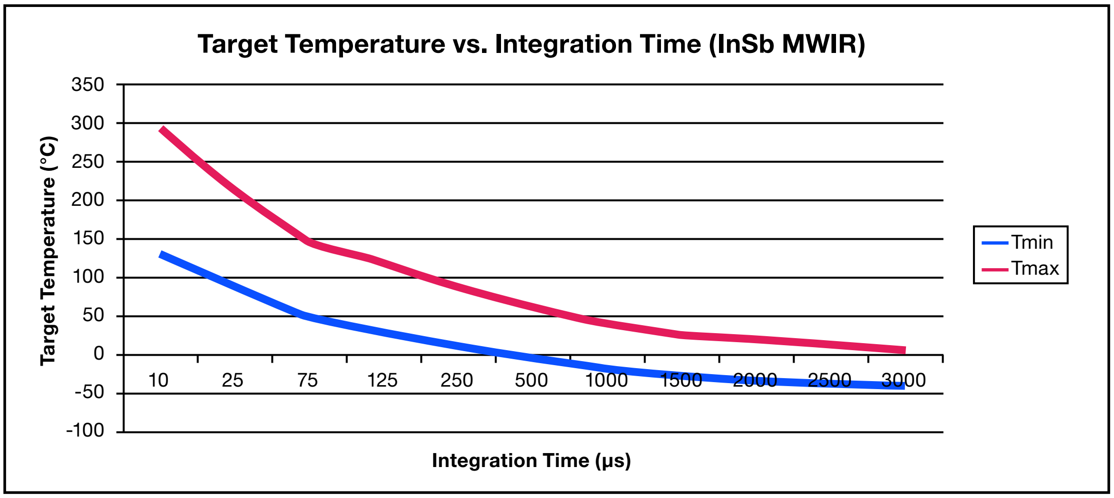


Figure 4: Effective Dynamic Range for MWIR Camera



Summary

- Variable detector integration expands the effective dynamic range of high quantum efficiency cameras.
- Advanced software tools like Recomposer automatically extract data from up to four separate data bins and combine them into one data set.
- New advances in calibration like Hypercal and CNUC have eliminated the need for user-performed radiometric calibration at user-determined integration settings and individual NUC calibrations.
- Selection of wavelength is also a consideration when analyzing the application dynamic range requirements and matching them to the performance of a camera model.

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Edition: 04-11 rev04