Thermal Performance Characterization of a 512x512 MWIR SLEDS Projector

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Abstract: In 2014, our team built the world’s first infrared LED scene projector. This system is called the SLEDS projector. It displays 512x512 MWIR images from a DVI computer interface at 100HZ. The projector has been successfully evaluated at multiple user facilities and has logged several hundred hours of operation. Thermal modelling was done to simulate the dissipation of heat in the infrared scene projector (IRSP). Current work is being done at the University of Delaware’s Scene Projection Evaluation and Research (SPEAR) laboratory to evaluate and update the thermal models.

Keywords: thermal performance characterization of a 512X512 projector; Infrared Scene Projection, Infrared LEDs

Introduction

Infrared imaging (IR) systems are widely used in commercial and industrial applications. They operate in a range of wavelength from 0.8 to 20 microns with the most common range being 3 to 5 microns (commonly known as mid-wave Infrared or MWIR). Due to their complexity, IR imaging systems are expensive, sensitive, and high-maintenance devices. To assure proper operation of these systems and to achieve their full performance requires frequent testing and calibration. Infrared scene projectors (IRSPs) are a critical laboratory tool for setup, tests and calibration of infrared imaging systems.

In 2014, a 100 Hz IRSP was completed and has been tested here at the University of Delaware in the Scene Projection Evaluation and Research (SPEAR) laboratory [1, 2]. This system is referred to as the super-lattice light emitting diode (SLEDS) system. Due to the current technology of the IR LEDs, 90% of the input power is dissipated to heat and only the remaining 10% generates light. The high dissipation rate of power causes the IR projector to heat up quickly and causes it to behave abnormally. The focus of this paper is to determine the situations in which the system behaves abnormally and use these observations to improve our future IR projectors.

LED Current Testing

Light emitting diode (LED) output and current have a direct relationship. To increase light output, higher current is needed in each LED pixel, leading to the generation of more waste heat. Since the SLEDS package was not designed with heat removal in mind, the array heats up quickly, adversely affecting the emission. To better understand and negate this effect, further work is needed in evaluating and improving our models.

For testing, breakout pads were added to corner pixels allowing for monitoring of voltage and current. In the SLEDS system, the pixel current is driven by the voltage level on a drive transistor, controlled by a digital to analog converter (DAC). In order to get an accurate reading for the voltage and the currents at each DAC count (DAC output level), the voltages and the currents were measured 10 times and the mean value was used. A Keithley was programmed and used and to measure the voltage, and python code was developed that could accurately read the current. Figures 1 and 2 illustrate the results of this test. The block of 9 pixels shows a more averaged and expected result [3].

![Figure 1. Current per pixel as a function of DAC Count.](image1)

![Figure 2. Voltage as a function of current for a small block of pixels.](image2)

Luminance Testing

The intention of the next test was to measure the effect of heat over time on a single pixel. Four different duty cycles and nine different brightness levels were used. For each test,
9000 frames were collected and every 1000 frames the DAC count is increased.

A FLIR IR camera was used to capture the raw images, and Python code was used to sum the background in each of the images and graph the data. Figure 3 show the result for each duty cycle. All the zeros and off frames have been removed for clarity.

Figure 3. Time versus normalized luminance. Each graph shows a different duty cycle, at the same DAC counts. The last graph includes all duty cycles in 1 with background subtraction.

As the duty cycle tests were being performed, an interesting phenomenon was observed, when the system is not properly cooled down, the luminance increases over time at the same DAC count. This behavior is counter-intuitive because the pixels’ luminance should decrease with heating effects. Figure 4 show these observations.
Figure 4. The top graph shows time versus luminance at 166K, in which there is an increase over time without changing the DAC output. The bottom graph shows the same test done at 77K.

Luminance Reduction
Previously it had been observed that pixels decrease in brightness with time. To confirm this and determine its extent, the system was operated for 120 seconds continuously.

For this test a group of about 75 pixels were lit up and kept on for 120 seconds. The starting intensity was at 6666₁₆ and after each test it was increased by 3333₁₆ until the full brightness of FFFF₁₆ was reached.

The luminance versus time data were captured using the FLIR camera and the raw images were processed using python code and the results are shown in Figure 5. After each test, to ensure removal of heat generated from the previous test, the system was allowed to cool down for 5 minutes before running the next one.

Figure 5. Time versus normalized luminance. The diameter is in pixels and represents the size of the area lit up. The intensity in DAC counts increases with each test.

The results indicate that as the DAC count increases the change happens quicker and pixels lose luminance faster. The suspected reason for this behavior is the poor performance of the current cryostat in cooling the SLEDS array. Also, the thermal impedance between the array and the cold finger was too high. These issues are being corrected in future SLEDS systems [4, 5].

Stair Step Test
In order to better understand the previous tests, stair step tests were conducted and compare for similarity to the duty cycle tests. Each DAC count was recorded one frame at a time to presumably remove all thermal effects.

The stair step test includes the DAC count of each pixel, the data that was processed from each individual raw image, and the measured current for each frame. Originally it was decided to use one of the corner pixels to measure the voltage of the pixel while being tested. However, due to the wire bonding around the pixel, there was no clear image due to reflections. As a result, one of the pixels in the middle was used to complete this test. Figure 6 and Table 1 illustrate the results.
Figure 6. Time versus normalized luminance. The DAC count is changed and reset to record luminance without thermal effects.

Table 1. This table shows a better representation of the data in the figure above and will be used as a testing reference.

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Conclusion
The research described in this paper, while on-going, demonstrates the successes achieved under the SLEDS system. Although there are still some unanswered questions about the behavior of the system we have ample information to verify thermal modelling and improve future systems.

Acknowledgements
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References