FOCUS ON...

C-RED 2 Lite
Temperature stabilized SWIR imaging

C-RED 2 Lite is a 640 x 512 stabilized SWIR camera running at 600 FPS full frame. The camera design optimizes temperature management and enables precise sensor stabilization despite environmental fluctuations. This, in turn, opens the door to quantitative applications such as laser beam profiling, hyperspectral imaging, thermography, *etc.*

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1. Introduction to temperature management

Why is temperature management important?

Monitoring sensor temperature can have distinct goals:

- ✓ **Cooling** is used to decrease the sensor temperature set point. The purpose is to optimize camera performance, in particular the dark current induced noise. Further details can be found in our FOCUS ON... Long Exposure times.
- ✓ **Stabilization** is employed to maintain the sensor at a defined temperature set point with limited fluctuations in time. It is achieved by cooling or heating the sensor with a retro-active feedback. The purpose is to achieve a perfect control over the camera response despite the variations of the environment temperature.

How do we achieve it?

There are multiple means to cool down a sensor, the general idea is always to dissipate heat away from the sensor. In First Light Imaging cameras, this can be achieved through the following means:

- ✓ **Thermoelectric coolers (TEC)** operate by Peltier effect, when an electric current flows through the device, it brings heat from one side to the other. A TEC can be used for either heating or cooling.
- ✓ **Heatsinks** are passive heat exchangers usually made of aluminum or cooper. They are designed to maximize the surface area in contact with the environment (air or liquid).
- ✓ **Airflow** can be induced by an electric fan and create a forced convection. This enables to push hot air away from the heat sinks or the camera core.
- ✓ **Waterflow** also induces a forced convection effect; the cooler the water is, the more efficient the heat dissipation is. Flow can be generated with a passive device or with a chiller device which will actively cool down the water.

These methods can be implemented intrinsically in the camera to dissipate heat away from the sensor or externally to dissipate heat away from the camera. Combining techniques results in optimal temperature management performances. In many cases though, a compromise has to be found between performance and added weight and power consumption.

How about First Light Imaging cameras?

First Light Imaging offers a complete portfolio of InGaAs-based cameras with different intrinsic temperature management options and external cooling means.

- ✓ C-RED 3 (uncooled), which exists in both OEM and housed versions, is dedicated to short exposure times. The design prioritizes compactness and does not offer intrinsic cooling capability. An external water-cooled plate can be added for temperature stabilization.
- ✓ C-RED 2 Lite (stabilized) is a thermoelectrically stabilized camera with multiple options to optimize heat dissipation. This note will describe the camera and its options in details.
- ✓ C-RED 2 (cooled) is a versatile model which includes thermoelectric, air and water cooling. This design enables precise stabilization of the sensor temperature and cooling down to -40°C.

2. Why choose C-RED 2 Lite?

In the C-RED 2 Lite camera, the sensor is stabilized by a thermoelectric cooler (TEC) and integrated in a compact and rugged high-speed SWIR camera.

C-RED 2 Lite camera

The important advantage of the C-RED 2 Lite camera is its temperature management robustness and versatility:

- **Camera "delta T"**. The thermoelectric cooler inside the camera enables to chill the sensor up to 25°C below the temperature of the camera case.
- **Heat dissipation options**. With multiple solutions to cool down the camera case, C-RED 2 Lite is versatile to integrate. The sensor can reach negative temperatures when adequate heat dissipation is achieved.
- **Automatic stabilization**. The algorithm embedded in the camera offers high performance stabilization of the sensor : +/- 0.1°C. This enable you to keep temperature under control. In "automatic" mode, the camera is stabilized at an optimal temperature that covers a large range of the use cases.
- **Control the algorithm**. The "custom steps" and "manual" modes enable fine control over the power consumption and thermal performance.

C-RED 2 Lite does not make any compromise on camera performances:

- **SWIR range**. C-RED 2 Lite has a > 70% quantum efficiency from 900 nm to 1700 nm.
- **High speed.** In full frame, C-RED 2 Lite can run at 600 fps! In windowing (ROI) mode higher frame rates can be reached (up to 32 066 fps). Two-points non-uniformity corrections can be applied on-the-fly without loss of framerate.
- **Large dynamic**. The three capacitors of C-RED 2 Lite (high, medium and low) enable tuning the conversion gain (electrons to ADU factor). While high gain enhances sensitivity, low gain optimizes full well capacity.
- **High Dynamic Range mode**. In HDR mode, the signal from the high and low capacities are linearly combined, allowing the camera to reach a dynamic of 93.6 dB while maintaining the high framerate.
- **High sensitivity.** C-RED 2 Lite typically has a readout noise below 30 e-. Additionally, the dark current-induced noise is kept under control thanks to the precise temperature stabilization.
- **Easy integration.** C-RED 2 Lite can be easily integrated in your system thanks to numerous drilled holes and has a C-Mount/CS-Mount optical interface. C-RED 2 Lite is supported by our multi-camera software First Light Vision. The versatile SDK enables the camera to be interfaced with MATLAB, LabView, Python, *etc.*

3. How to optimize thermal dissipation?

In C-RED 2 Lite, the sensor is stabilized using a thermoelectric cooler. The camera internal design transfers the heat generated on the TEC hot side to the camera case homogeneously. With this design, a delta up to 25°C can be obtained between the case temperature and the sensor temperature.

To obtain the lowest sensor temperature setpoint the challenge is to dissipate the heat away from the camera case. **The lower the temperature of the camera case is kept, the lower the temperature of the sensor can be set as well. For this reason C-RED 2 Lite is designed for optimized thermal dissipation.**

First Light Imaging offers a wide range of passive and active thermal management solutions, as well as recommendations to adjust the method to your application. The solutions proposed are ordered from the simplest to the most effective:

Increasing exchange surface

Example of a configuration with increased surface exchange

The effectiveness of passive dissipation is related to the total exchange surface. Any item that increases the surface of thermal exchange will optimize the dissipation, for example:

- ✓ A lens in front of the camera
- ✓ Attaching the camera to a metal board

In such a design, the heat generated in the camera core will dissipate to a larger metal surface. Then, this large surface will exchange heat with the surrounding environment. For example, screwing the camera to the base frame of a large instrument is one way to increase surface exchange.

The larger the contact surface with the camera, and the larger the metal part, the higher the performance gains.

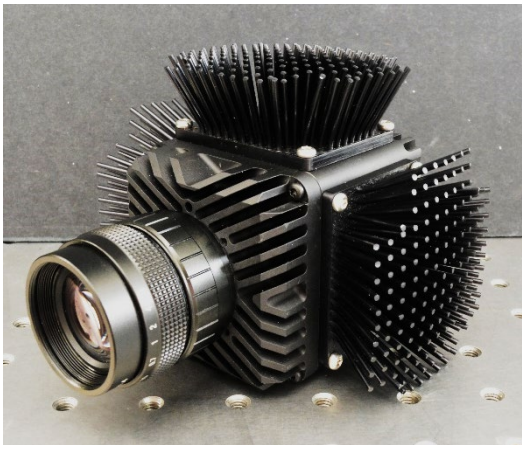
Using passive heat sinks

Further increasing the exchange surface area with the surrounding environment can be achieved with a passive component: heatsinks. It is possible to mount up to three custom heatsinks on the camera.

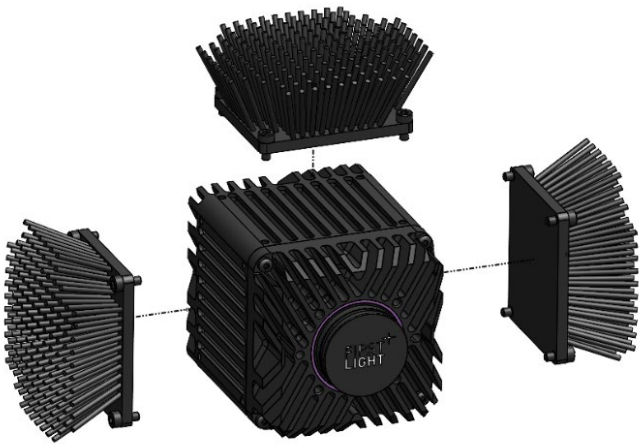
Without forced airflow, the average improvement that can be obtained on the case temperature is the following:

Number of heat sinks	Case temperature decrease
1	- 7 °C
2	- 11 °C
3	- 13 °C

Expected camera case temperature drop compared to the reference scenario of zero heat sinks



Passive heat sinks set-up



Position of the three heat sinks

Using an external fan

An inexpensive way to improve thermal performances is to add an external fan blowing on the camera housing. Any fan can be used for this purpose. For utmost performance, this solution can be combined to the passive heat sinks. Depending on the airflow velocity, the case temperature will significantly decrease. Although very simple to set up, this solution has obvious disadvantages such as vibrations, noise, dust, or atmospheric disturbance.

Example of a configuration with an external fan

Using a hydraulic cooling plate

Hydraulic cooling plate set-up

The finest heat dissipation performance is obtained with the hydraulic cooling plate designed for C-RED 2 Lite. It will provide the highest cooling efficiency, without the drawbacks of forced air convection.

The cooling plate is used in conjunction with a water-cooling system. First Light Imaging recommends using an active system, but a passive one can also be used. With an active system the water temperature is monitored and the camera case can be thermalized at the required temperature.

With the cooling plate, the following sensor temperatures can be reached in a 25°C ambient environment:

Water temperature	Sensor temperature
20°C	-5°C
10°C	-15°C

Expected sensor temperature, as a function of water temperature

When implementing this solution, one should watch out for the dew point. Going below the dew point may damage the camera, as condensation will appear.

First Light Imaging can supply a full cooling pack including the chiller, hoses and spill-free connectors.

Schematic of hydraulic cooling plate installation

4. Conclusion

C-RED 2 Lite is a high-performance camera designed for high flux short wave infrared applications. The camera can reach 600 FPS in full frame. Thanks to this, C-RED 2 Lite is very flexible and can be used for a large scope of applications!

Particular efforts have been put on the thermal management of the C-RED 2 Lite camera. The thermoelectric cooler enables to reach a delta up to 25°C between the sensor and the camera case. Multiple options are then available to cool down the case: increasing the heat exchange surface, adding heatsinks, screwing a hydraulic cooling plate, *etc.* Thermal management ensures that the sensor temperature is stable despite the unavoidable fluctuations of the environment. Depending on your integration constraints and your requirements, you can choose whichever solution is best suited.

C-RED 2 Lite

Stabilized InGaAs camera
600 frames per second (full frame)
640 x 512 pixels
15 µm pixel pitch
30 e- readout noise

- ✓ **Optimized algorithm for precise sensor temperature stabilization**
- ✓ **Guaranteed delta T of 25°C between the sensor and the camera case**
- ✓ **Multiple options to cool down the housing**

For inputs on our key application, check out the FOCUS ON... series !
FOCUS ON... Free Space Optical communications
FOCUS ON... Monitoring weld deposition
FOCUS ON... High speed hyperspectral imaging, *etc.* !

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