FLIR

TECHNICAL NOTE

Cooled versus uncooled cameras for long range surveillance

PTZ-35x140 MS: a thermal imaging camera with two uncooled micro bolometer detectors for mid to long-range surveillance.

Long-range surveillance in low-light conditions or total darkness is a perfect application for thermal imaging technology. This type of surveillance is often required at borders or for large perimeters where most threats occur at night.

There are however a multitude of choices of thermal imaging camera systems for mid to long-range surveillance in the commercial marketplace. An often asked question is. "Should I use a cooled or an uncooled thermal imaging system and which one is the most cost effective?"

The security market is an industry that is very price sensitive and competitive. A case has to be made for a purchase of any one particular high-value thermal imaging camera system for long-range surveillance. Certainly when there are other, seemingly equivalent systems out there at lower cost.

This technical note describes the two classes of long-range thermal imaging camera systems available on the market today: the cooled and uncooled systems. The component costs for these two classes of system can be quite different, making it extremely important to decide which way to go.

Cooled thermal imaging cameras

A modern cooled thermal imaging camera has an imaging sensor that is integrated with a cryocooler. This is a device that lowers the sensor temperature to cryogenic temperatures. This reduction in sensor temperature is necessary to reduce thermally-induced noise to a level below that of the signal from the scene being imaged.

Cryocoolers have moving parts made to extremely close mechanical tolerances that wear out over time, as well as helium gas that slowly works its way past gas seals. Eventually a rebuild for the cryocooler is required after 8,000-10,000 hours of operation.

Cooled thermal imaging cameras are the most sensitive type of cameras to small differences in scene temperature. They can detect the smallest of temperature differences between objects. They can be produced to image in the midwave infrared or MWIR band of the spectrum where the thermal contrast is high due to blackbody physics. Thermal contrast is the change in signal for a change in target temperature. The higher the thermal contrast, the easier it is to detect targets against a background that may not be much colder or hotter than the target.

Generally speaking, the images from MWIR cameras pointed at nighttime scenes of interest show quite vivid contrast compared to other infrared wavebands. Cooled cameras also can be designed to work in the longwave infrared or LWIR band.

Uncooled thermal imaging cameras

An uncooled infrared camera is one in which the imaging sensor does not require cryogenic cooling. A common detector design is based on the microbolometer, a tiny vanadium oxide resistor with a large temperature coefficient on a silicon element with large surface area, low heat capacity and good thermal isolation.

Changes in scene temperature cause changes in the bolometer temperature which are converted to electrical signals and processed into an image. Uncooled sensors are designed to work in the Longwave infrared or LWIR band from 7 to 14 microns in wavelength, where terrestrial temperature targets emit most of their infrared energy.

Cryocooler

Long-range surveillance in total darkness is a perfect application for thermal imaging technology

Uncooled cameras are generally much less expensive than their counterparts, the cooled infrared cameras. The sensors can be manufactured in fewer steps with higher yields relative to cooled sensors, less expensive vacuum packaging, and uncooled cameras do not require cryocoolers, which are very costly devices.

Uncooled cameras have fewer moving parts and tend to have much longer service lives than cooled cameras under similar operating conditions. Security applications often require continuous operation of cameras to avoid the possibility of missing any threats. Cooled cameras will generally require servicing after 1-2 year of operation, while an uncooled camera might work continuously for years.

Cooled of uncooled? What to choose?

All these advantages of uncooled cameras beg the question: Under what circumstances is it appropriate to use cooled cameras? The answer is that when standoff ranges get out to 5km or greater, thermal imaging systems based on cooled cameras can quickly become more cost-effective.

Note the emphasis on the word "systems" – the camera is only one component of an imaging "system". One of the biggest cost drivers of a long-range uncooled camera system is the lens. As effective range requirements increase, the lenses for uncooled camera systems become so bulky and expensive that it can often be cheaper to specify a cooled camera with an equivalent focal length lens instead.

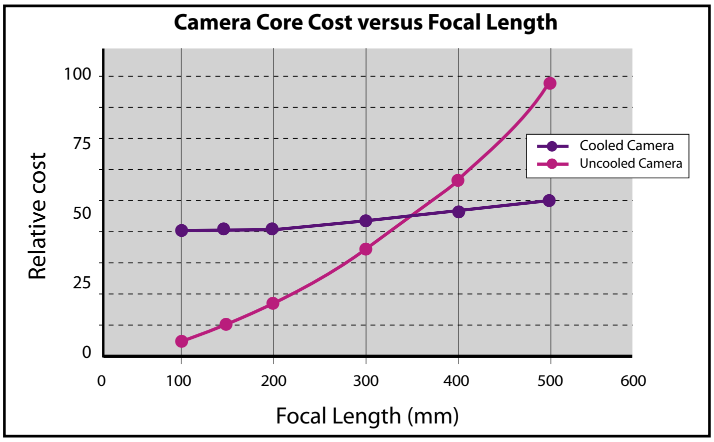
The HRC-40 x 490 is an example of a thermal imaging camera with cooled Indium Antimonide (InSb) detector.

The cooled system cost is high at short focal lengths where the lens cost is a relatively small fraction of the system cost. The system cost does not increase rapidly with focal length, while the uncooled system cost does. This difference in cost is driven by the lens, and the crossover point (currently around 350mm for typical systems) is changing in the rapidly emerging global IR optics market.

Why are lenses so much more expensive for uncooled systems at long focal lengths?

It has to do with another crucial lens parameter, the f/number. The f/number determines the light gathering power of the lens and therefore affects the sensitivity of the camera system.

As the focal length of a lens is increased, the diameter of the front lens element must be increased to keep the system f/number constant. An uncooled camera must be run at a low f/number (typically 1.4-2) to have comparable sensitivity to a cooled camera. Higher f/numbers reduce uncooled camera sensitivity and there is no "knob" that one can turn to compensate for the reduction in the light signal transmitted through the lens.



Cost model for cooled and uncooled cameras, lenses included.

The f/number of an optical system is the ratio of the focal length of the lens to the diameter of the front lens element. An f/2 lens with a 500mm focal length must therefore have a 250mm diameter front lens element. That front lens element is very expensive and approaches the limits of manufacturability for germanium, in part due to the difficulty of making a large enough optics-grade blank out of raw germanium material.

In contrast, a cooled camera system can be operated at f/numbers of f/4 and higher without significantly compromising system sensitivity. This is because the exposure time or integration time of a cooled camera is a parameter or "knob" that can be increased to make up for reduced light throughput.

The integration times needed to operate with f/5 lenses are less than 10msec, enabling 50/60Hz and higher video frame rates, which are standard for the security industry. An uncooled camera cannot have its integration time increased – it is continuously integrating IR light from the scene. An f/4 lens with a 500mm focal length need only have a 125mm diameter front optic, which is much less expensive than a 250mm optic. Longer focal length lenses for cooled systems are commercially available (up to 1000mm) at f/4, and very long focal length lenses (several meters or more) at f/7.5 have been constructed.

Conclusion:

Long range thermal infrared surveillance applications require long focal length lenses, and the cost of lenses increases rapidly with focal length for uncooled camera systems and rather slowly for cooled systems. As a result, even though the cost of a cooled camera core is much higher than an uncooled core, the system cost (core plus lens) for uncooled surpasses cooled system cost at a focal length on the order of 350mm. Useful imaging of man-sized targets at multi-km ranges requires focal lengths that exceed 350mm. Therefore, multi-km imaging of man-sized targets is less expensive with a cooled camera system, at least for the initial system cost.

It is important that the system designer factors in the 8,000-10,000 hour lifetime of cryocoolers into the cost model to arrive at the best solution. If the cryocooler needs a servicing every 2 years, and the cost is 10% of the total system, then the 4-year cost of the cooled system is really 1.2X the initial system cost.

Having more than 50 years of experience with thermal imaging cameras and producing both cooled and uncooled systems, FLIR Systems can always provide you with the necessary information to make a well-informed decision based on your particular application.

Acknowledgement to Dr. Austin Richards Ph. D. for authoring the article and to Pierre Boulanger for his contribution.

For further information please contact:

FLIR Commercial Vision Systems B.V.
Charles Petitweg 21
4847 NW Teteringen - Breda
The Netherlands
Phone : +31 (0) 765 79 41 94
Fax : +31 (0) 765 79 41 99
e-mail : flir@flir.com
www.flir.com