WHITE PAPER

Detecting and Visualizing Hydrocarbon Gas Leaks with MWIR Cameras

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Midwave-infrared (MWIR) cameras are utilized by the oil and gas industry to detect and visualize emissions of hydrocarbon gases such as methane, propane and butane. These special infrared cameras are optimized to capture images below the red end of the visible color spectrum at the peak absorption wavelengths of the gases, which are often odorless and invisible to the naked eye.

Using MWIR cameras to detect emissions helps guarantee the safety of people working in and around the oil and gas equipment. Other benefits to quickly identifying leaks and leaky equipment that may need repair include increasing efficiency and reducing economic losses. Early detection also reduces any potential detrimental effect of gas emissions to the atmosphere and lessens the likelihood of fines incurred from environmental agencies.

To identify hydrocarbon leaks in process control equipment, hand-held MWIR cameras are able to detect leaks typically within a 1-25 meter range with a standard 25mm fixed-focal-length optic, and up to several dozen meters with the use of telephoto lenses. When a larger inspection area is required, fixed-mounted MWIR cameras on motorized pan and tilt positioners can provide continuous monitoring in 360° for large radius of coverage. If operators need to image transmission and distribution systems such as remote pipelines, MWIR cameras mounted on aerial platforms such as fixed-wing aircraft and/or helicopters can remotely detect leaks up to 500 meters line-of-sight with the appropriate lens.

Unlike CCD or CMOS imagers that image light in visible wavelengths, sensors used in MWIR cameras detect infrared radiation emitted by objects in the 3-5µm spectral range. Traditionally, these photon-sensitive focal plane array (FPA) detectors have been manufactured from indium gallium arsenide (InGaAs), lead selenide (PbSe), mercury cadmium telluride (MCT), and indium antimonide (InSb). InSb-based midwave-infrared imagers are the most common types of detectors used in optical gas imaging cameras due to their superior price/performance ratio. However, a typical InSb MWIR FPA detector has the disadvantage that it must be cooled to liquid nitrogen temperatures (down to 77K) to become photoconductive and suppress the noise that would otherwise deteriorate performance. This is achieved by integrating the focal plane array into a cryogenic cooler which consequently leads to an increase in the size, mass, power consumption and cost of the camera.

SWAP this for that

The requirement to reduce the size, weight and power (SWaP) of MWIR cameras for optical gas imaging has led to the development of sensors that can operate at higher temperatures compared to InSb-based designs, increasing the mean time to failure (MTTF) of such cameras. More specifically, the proprietary XBn Hot Midwave IR detector - based on bulk InAsSb technology - has an operating temperature of approximately 150K. This leads to a corresponding reduction in the SWaP of the cooler assembly; it consumes less electrical power and takes less time to cool down.

Sierra-Olympic Technologies (Hood River, Oregon) developed a new optical gas imaging camera core based upon an XBn Hot Midwave IR detector. The incorporation of a 640 x 512, 15-micron pixel-pitch MWIR detector array into the Ventus OGI camera has resulted in a camera with a weight of 580 grams, including the lens (**Figure 1**).

The XBn Hot Midwave IR detector is housed in a vacuum-sealed vessel known as a dewar. The dewar is then incorporated into an integrated detector/cooler assembly (IDCA) which is comprised of an optical window, a cold shield and a cold filter. The focal plane of the detector is attached to an electrical split-Stirling cooler to enable heat to be conducted away.

Reducing the weight of the camera was possible because the split-Sterling linear cooler is lighter than its cryogenic counterpart while providing a smaller footprint and longer life. The Sterling cooler lowers the temperature of both the FPA detector - protecting the IR detector from thermal background stray radiation - and the spectral cold filter mounted in front of the detector which limits the radiation reaching the FPA.

In the Ventus OGI camera, a cold shield was used to protect the detector from unwanted heating by IR or thermal radiation reflected within the dewar. The f/1.5 cold shield allows the maximum amount of IR energy from a scene to enter through the lens before impinging on the detector.

Lenses for infrared cameras with cooled detectors must be compatible with the internal optical design of the cold housing in which the IR detector array is located. To focus the energy onto the detector and to match the aperture of the cold shield, an f/1.5 lens with manual focus was developed using specialized optical coatings that restrict IR energy to a wavelength range optimized for the narrow band pass cold filter. Marrying the characteristics of the lens and filter enables the camera to detect gas plumes more effectively.

Camera characteristics

The XBn Hot Midwave IR detector in the Ventus OGI camera can operate at higher temperatures than comparable InSb based designs with no compromise to sensitivity, integration time, pixel resolution, and speed of digital data output of the camera.

Typically, the sensitivity of an MWIR camera is defined as the ratio of the temporal noise to the responsivity. Known as the noise equivalent temperature difference (NETD), it represents the minimum temperature difference that a camera can resolve and is expressed in units of mK. The sensitivity of Sierra-Olympic's optical gas imager is less than 30mK, a figure which is comparable to both InSb and MCT based designs.

To achieve a good NETD, the MWIR detector used in the Ventus OGI camera requires an integration time between 1ms-1s. While faster integration times are considered an important characteristic when capturing images at high speed, the integration time of the new camera does not represent a technical limitation in the optical gas imaging marketplace.

The spatial resolution of the MWIR camera - which refers to the size of the smallest possible feature that it can detect - is determined by the pixel pitch of the imager. The 640 x 512 pixel XBn focal plane array used in the Ventus OGI features a 15-micron pixel pitch, but sensor manufacturers are currently developing devices with a 10μm XBn pixel pitch which are also designed to operate at 150K with performance similar to the 15μm pixel pitch design.

To support various applications, the 30 frames-per-second (fps) Ventus OGI is available with a number of different output options. Interfaces to the camera currently include a 14-bit Camera Link interface, NTSC or PAL analog video, and an RS-422 serial interface for camera control. A custom option is available to provide users with an H.264-encoded IP stream or GigE Vision interface that delivers both video and camera control.

Software support

The processing and visualization of image data is a crucial part of identifying fugitive emissions. To meet this need, a sophisticated software tool is provided with advanced processing functions. A document API (application programming interface) aids developers in integrating downstream software.

In certain instances, there may be only a slight temperature difference between a target and the background image. Generally, it is preferable to have a 5 degree C temperature difference between a gas plume and the background. When this is not the case, dynamic contrast enhancement and noise reduction tools can help the user better visualize the plume. Automatic Gain Control (AGC) can adjust the brightness and contrast on localized areas of the image based on the distribution of thermal intensities. The contrast of the foreground and background images can be adjusted independently. In the case mentioned above, the foreground boost could increase the contrast of the gas plume, while the background boost would reveal more details of the equipment and surrounding area.

Most gas imaging cameras use monochrome or grey scale palettes to visualize the images that are captured. **Figure 2** is a frame capture of a gas leak from a midwave infrared OGI camera; hot areas in the image are highlighted in white, while cool areas are displayed as black. However, several other visualization options are available when using the Ventus OGI. Users can invert the polarity of the monochrome image where black becomes hot and white becomes cool. Alternatively, they can choose from a range of rainbow, ironbow, or sepia palettes which assign different colors to different infrared intensities.

Unmanned drones

The design of the Ventus OGI camera represents a leap forward in the development of MWIR cameras, making it the smallest, lightest and efficiently-powered OGI camera available. Weighing 580 grams with a lens and sized at 146.6 x 70.9 x 73.1mm, the Ventus OGI represents a significant improvement over previous designs that can be up to twice as large and much heavier.

The low SWaP Ventus OGI camera, recently EPA 0000a CERTIFIED, is well-suited for use on multi-rotor or fixed-wing unmanned aerial vehicles (UAVs) where it can be employed to survey areas in gas processing plants that may be difficult to access. Enabling a camera to fly over and around stacks and pipe racks also eliminates the need for personnel to carry out manual tasks, creating greater efficiency and lowering the cost of operations management.

Aerial surveillance is also an excellent way to perform checks on long sections of pipelines (**Figure 3**). Traditionally, this has been a task performed by manned helicopters that require both a pilot and a camera operator. With the Ventus OGI, lengthy surveillance procedures can now be carried out by unmanned drones which perform more consistently and are less expensive to operate.

Figure 1: Sierra-Olympic Technologies optical gas imaging camera core is based around an XBn Hot Midwave IR detector. The incorporation of the 640 x 512, 15-micron pixel-pitch MWIR detector array into the Ventus OGI camera, has enabled the company to produce a camera with a weight of only 580 grams - including the lens.

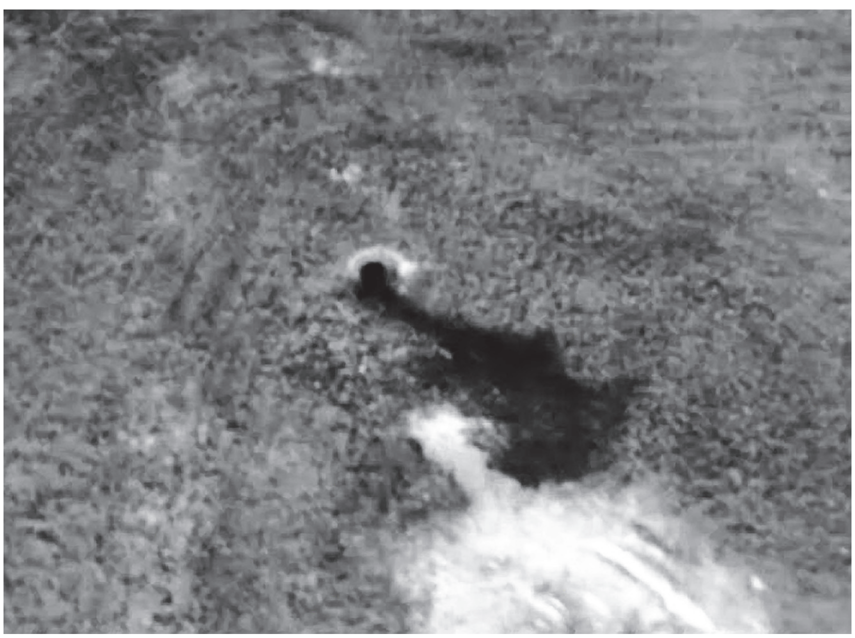

Figure 2 - The dark, billowing plume rising above the ground surface is a gas leak coming from a buried gas pipeline. Image captured using an MWIR OGI camera.

Figure 3: The new Ventus OGI camera is likely to find a home mounted on drones to perform checks on long sections of pipelines.

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