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PHOTONICS & IMAGING TECHNOLOGY

Trends in Thermal Imaging

Understanding the New Optical Data Interface

Hyperspectral Imaging — Teaching Robots to See

SPECIAL SECTION:
Technology Leaders in Cameras & Imaging Systems

Supplement to *Tech Briefs*

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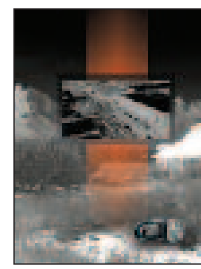
ON THE COVER



New high-performance (1920 x 1200 x 12 μm pixel resolution) thermal imagers are taking infrared image quality to a new level. The main image shows a video still of a farmhouse scene captured with Sierra-Olympic's new Vayu HD 1080p thermal imager. The inset, imaged with the same uncooled microbolometer camera, shows an urban environment with distinctive thermal detail and rich contrast, both important in wide-area security and surveillance applications. To learn more about small-pixel LWIR microbolometer sensors and cameras, see the feature story on page 2.

(*Images courtesy of Sierra-Olympic Technologies, Inc.*)

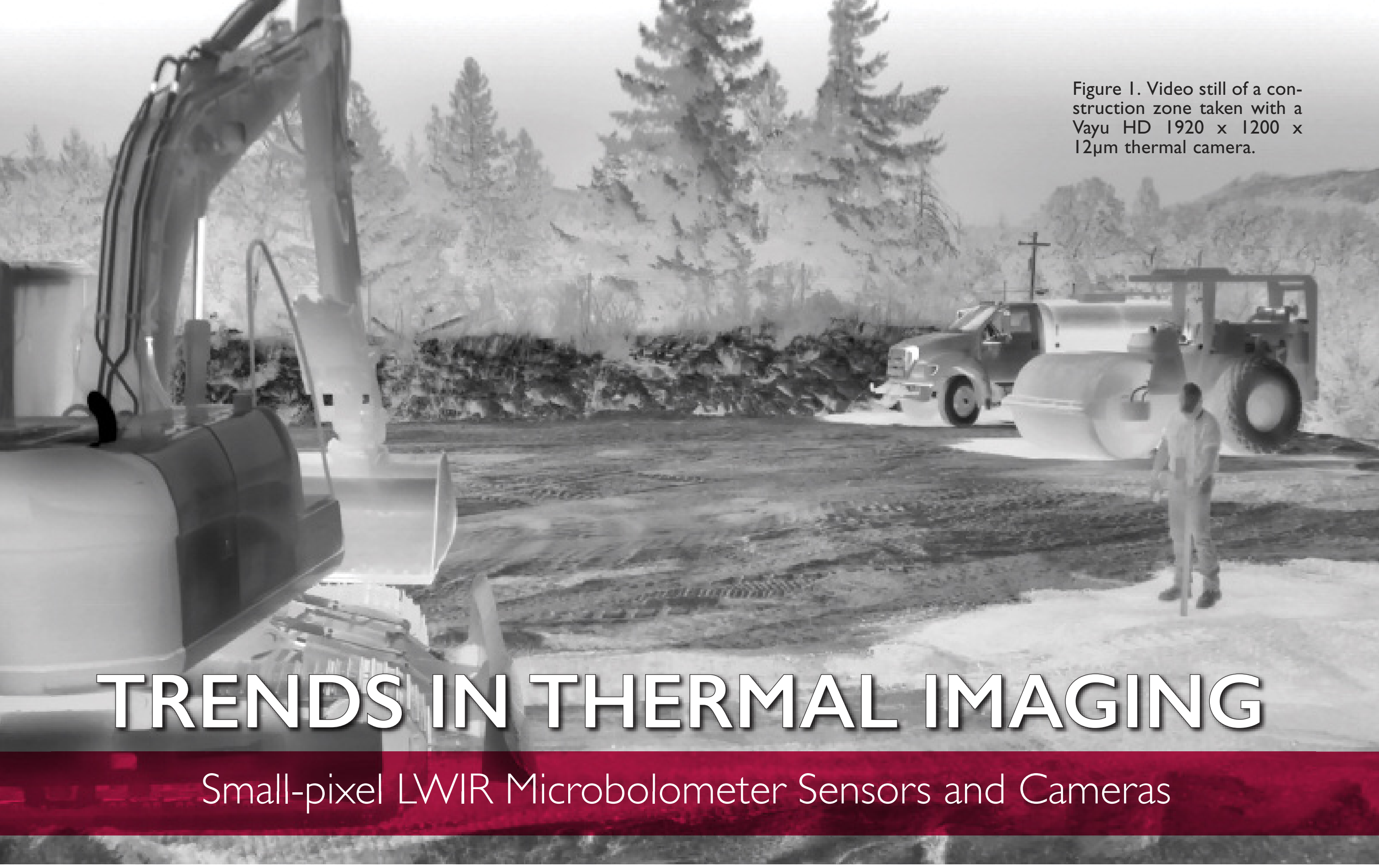


Figure 1. Video still of a construction zone taken with a Vayu HD 1920 x 1200 x 12µm thermal camera.

TRENDS IN THERMAL IMAGING

Small-pixel LWIR Microbolometer Sensors and Cameras

Most manufacturers of uncooled amorphous silicon (AS) and vanadium oxide (VOx) microbolometer focal plane array (FPA) products have long been producing imaging devices with 17 µm pixel-pitch arrays. Currently, 320 × 240 × 17 µm and 640 × 480 × 17 µm arrays are commonly available as FPA products, sensor cores, and numerous camera products. Several different designs of fixed focal length and continuous zoom optics based on these 17 µm pixel-pitch longwave infrared (LWIR) products are also available. There is general uniformity and compatibility throughout the industry between these camera products and optics which allows customers to choose from a wide array of sensor and optics attributes when developing a new camera product.

The 17 µm pixel pitch, uncooled LWIR industrial base has apparently reached a floor in costs. Now, in pursuit of lower costs and expected larger markets, FPA manufacturers have long been thinking about smaller pixel pitches. The fundamental arguments are evident – smaller pixel pitch renders a smaller diagonal for a given resolution and more FPAs produced per unit area. Additionally, smaller image diagonals and smaller pixel pitches offer smaller optics apertures per desired instantaneous field-of-view (IFOV), thus presenting expected savings in optics costs.

Furthermore, the visible camera industry long ago made 720p arrays (1280 × 720) and 1080p (1920 × 1080) de rigueur, while the thermal imaging industry still considers video graphics array or VGA resolution (640 × 480) to be high resolution. To be fair, there are a number of cooled MWIR 720p resolution devices available, and even some cooled MWIR 1080p devices, but LWIR has generally stalled at VGA resolution. Smaller pixels present opportunities for reasonable image sensor diagonals and reasonable aperture sizes for higher resolution arrays in the uncooled LWIR industry.

To drive down costs and to increase resolutions, the LWIR industry now has a number of smaller pixel-pitch devices available or soon-to-be available for commercial sale. Some 12 µm pixel pitch

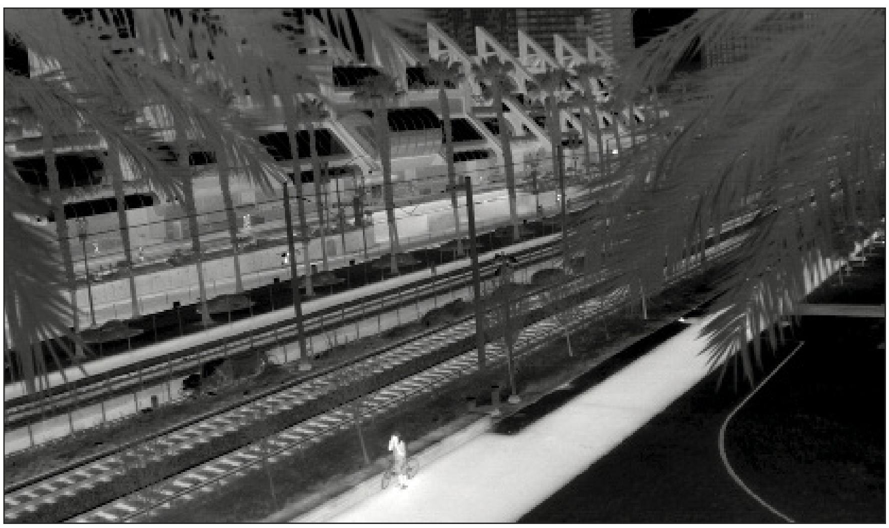


Figure 2. Video still of San Diego trolley tracks and convention center taken with Vayu HD 1080p LWIR thermal imager.

devices have been available in moderate volumes from a small number of manufacturers for about three years. The array sizes range from 60 × 80 up to 1920 × 1200. Clearly, low resolution devices demonstrate very low cost. The high-resolution sensors are not driving low cost, but rather very high performance and stunning image quality (Figure 1 - Video still of construction zone taken with the Vayu HD 1920 × 1200 × 12 µm thermal imager). By the end of 2018, it is expected that most of the U.S., European, and Canadian manufacturers of uncooled microbolometer FPAs will have small pixel offerings with 10 µm and 12 µm pixel pitches.

The small pixel, uncooled LWIR sensors have truly revolutionized the thermal imaging industry, more so with low- and medium-resolution sensors. The most striking examples are items with resolution as low as 60 × 80 pixels offered as a component at the same large electronics distributors where one commonly buys connectors and power regulators. These low- and moderate-resolution devices have been built into $300 products that plug into a mobile phone, and/or plug into hand-held cameras that look and feel like a typical digital camera. Most are readily available from the large online and big box retailers. At $300, every electrician, heating, ventilation, and air conditioning (HVAC) professional, and home inspector can own one or two for more complete and competent professional services that now include thermal imaging. Most of these items have 12 µm pixels, and have very low-cost optics – either molded chalcogenide optics or wafer-scale micro optics. These low- and moderate-resolution imaging products are currently available from FLIR Systems and Seek Thermal.

Small pixel, uncooled microbolometer FPAs for "performance applications", that is, VGA resolution of 640 × 480 or higher, are still not common. There are small pixel VGA devices available, as well as very high-resolution sensors. As an industry, however, small pixel VGA is still in early development. There are not many small pixel optics available, and there are very few small pixel cameras available for purchase with standard video interfaces. The only VGA resolution, or higher, uncooled microbolometer cameras available are end-user items, such as rifle scopes and commercial cameras with 1920 × 1200 × 12 µm resolutions with very advanced features (Figure 2 - Video still from Vayu HD of San Diego's trolley tracks and convention center).

Figure 3. Sierra-Olympic's high-definition thermal 1080p LWIR imager, the Vayu HD..

Figure 4. The Vayu HD with environmental housing.

In 2018, however, it is expected that there will be broad introduction and availability of numerous camera cores based on small pixel LWIR sensors. Camera cores with 320 × 240 are currently available. Similar camera cores with VGA resolution of 640 × 480 are expected in mid-2018. The VGA cores will represent the bulk of commercial developmental items going forward because of the imaging system advantages. The sensor cores are reported to have a much lower cost, and the optics planned for small pixel LWIR compatibility are expected to be lower cost, as well. With customers typically clamoring for lower cost systems, these new products will fulfill this need.

Sensor performance with small pixel LWIR is still to be determined. Inherently, with small pixel collection area per pixel, one would expect lower noise equivalent temperature difference (NETD) values per unit optical F#. Most manufacturers are planning on low F# optics for best performance. For long focal length optics, there may be a crossing point where no material savings are realized. For example, if a F1.4 optic with a 17 µm pixel device delivers an acceptable NETD, a F1.0 optic might be required for a 10 µm or a 12 µm sensor, and the cost savings will be lost with the larger aperture optic. But for most medium- to short-range applications, where short optical effective focal lengths (EFLs) are acceptable, smaller apertures should translate into cost savings. For those FPA manufacturers that can maintain sensitivity per unit F# when going from 17 µm pixels to a small pixel device, the savings will be the greatest.

At Sierra-Olympic, our experience with 12 µm pixels and the currently-available long focal length, high F# optics, indicates that longer detection ranges are realized with smaller pixels per unit effective focal length (EFL) and F#. It can be expected that small pixel LWIR sensor cores will be matched to currently available long-range LWIR optics with reasonable F#, and offer better detection, recognition, and identification than the 17 µm device fitted to the same lens. One can expect to see long EFL systems that deliver horizontal field of views (HFOVs) that were formerly available only with cooled MWIR systems. These uncooled LWIR systems will be lower cost, and have more favorable export control profiles than some MWIR systems.

The greatest challenge and reward in small pixel LWIR will be in true high-definition (HD) systems. These systems are just becoming available, and Sierra-Olympic has plans for product introductions in the commercial 720p and 1080p resolution families in uncooled LWIR – based on small pixels. A commercially-available product exists with 1080p resolution (Figure 3). The new LWIR HD camera delivers standard HD-SDI video, IP video over Ethernet, and standard digital. A major challenge in camera development with the 1080p LWIR sensor is the optic. First, there are no commercially-available optics for the sensor, so each optic is custom. Next, designing for modulation transfer function (MTF) performance on small pixels and large diagonals is a challenge for the optics designer and manufacturer. Additionally, customers expect the standard features of athermalization and environmental sealing (Figure 4). The company has achieved this in its first 1080p optical designs.

Camera system considerations are also important. Both the HD sensor and the supporting processors consume a relatively high amount of electrical power. Building rugged, conductively-cooled, sealed systems drives the camera size and weight. Overall, the HD LWIR camera will be larger and consume more power than a typical VGA resolution sensor. It is expected that the HD LWIR camera systems based on the small pixel LWIR FPAs will benefit markets in wide-area security/surveillance, marine and airborne navigation, thermal imaging in natural resource applications, and video production.

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