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Thermography – Past, Present and Future

Termografia - przeszłość, teraźniejszość i przyszłość

ABSTRACT

Infrared thermography is one of the fastest growing inspection techniques nowadays. This article provides an overview of the existing equipment solutions on the market of infrared thermography. It also presents the latest announcements of new products and points the path of future development of this technology.

Keywords: *thermography, development, thermographic camera*

STRESZCZENIE

Termografia podczerwono to jedna z najszybciej rozwijających się dziś technik inspekcyjnych. W artykule tym przedstawiono przegląd istniejących na rynku rozwiązań sprzętowych stosowanych w termografii podczerwonej. Zaprezentowano także najnowsze zapowiedzi nowych produktów oraz przedstawiano ścieżkę przyszłego rozwoju tej technologii.

Słowa Kluczowe: *termografia, rozwój, kamera termograficzna*

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1. Perspective from the past

The technology of infrared thermography has evolved greatly since Sir William Herschel discovered infrared radiation in 1800. While Sir Herschel did discover infrared energy, and he used a thermometer to identify it, he did not discover how to measure it. That credit goes to Max Planck who developed the blackbody equations for the measurement of infrared radiation. The most important point of this is to understand that infrared cameras do not measure temperature; they measure radiosity: a visualization of the distribution of infrared radiation that is received by the camera's detector. Thermography requires knowledge of the electromagnetic spectrum and the relationship between heat, electromagnetic wavelengths and their interaction with varying materials.

The difficulty of using infrared cameras is generally blamed on emissivity. Emissivity is the ratio of the quantity of infrared radiation emitted by a material to the amount emitted by a perfect emitter, that is, by a blackbody. The most significant problem with using infrared cameras is usually the user's lack of technical knowledge of how materials interact with infrared radiation. This ignorance is reinforced by television and movies portrayal of infrared cameras defying the laws of physics. The problem is that the viewing public has no basis for understanding that many of these portrayals are fiction. Infrared cameras can not see thermal images of people through the walls of buildings. Infrared cameras are powerful tools when used by people with the proper knowledge and training. To illustrate this point, consider a well known powerful tool, a stethoscope. A doctor's stethoscope is fairly inexpensive, only about $250. It is a simple instrument to use, yet it requires a great deal of knowledge and training in order to interpret the sounds. Just as I want a trained professional interpreting the sound of my heart with a stethoscope, I want a trained professional interpreting the images produced by an infrared camera. In the not too distant past, infrared cameras were large and very expensive. A high performance system only 15 years ago cost in the range of $25,000 to $50,000 or more. It would often require a day of preparation in order to use the infrared camera system the following day. The typical system included liquid nitrogen, large heavy batteries, an array of electronic instruments and computer equipment all on a rolling cart. Most of today's infrared cameras are handheld and use long wavelength uncooled microbolometers, developed in 1995, replacing most of the liquid nitrogen cooled detectors. The dominant characteristics of today's infrared camera are the size of the detector array as measured in pixels, and its thermal sensitivity. A simple infrared camera benchmark could be characterized by a 320x240 pixel detector and a thermal sensitivity of about 80-100 mK. These were then, and still are today, higher performance characteristics. The distinction is relevant. Infrared thermographic technology is becoming more specialized and more general at the same time.

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2. Present Perspective: specialized applications

By specialized, I refer to technological advances in our understanding and application of the detection in the infrared portion of the electromagnetic spectrum. One of the most advanced examples is the development of gas imaging cameras for identifying fugitive gases.

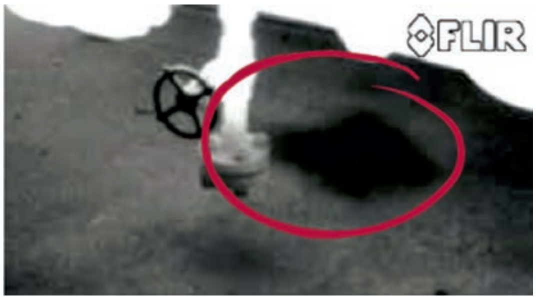

Fig. 1. Captured gas leak from production site
Rys. 1. Wykryty wyciek gazu w instalacji linii produkcyjnej

These infrared cameras blend the spectral characteristics of specific gases with their detectable thermal characteristics. In simple terms, specific gases absorb radiation at certain specific wavelengths. So by observing specific wavelengths where the gases absorb, the infrared camera system is able to produce a visual image of the thermal image of the gas. Different gases have different spectral characteristics, so it is not possible to detect all fugitive gases with a single detector. Several cameras are produced with different detectors, each with the ability to "see" certain specific gases. And these instruments have the added utility of being able to be used for traditional infrared inspections as well.

In exactly the same way, infrared cameras are available with a wide range of detectors and filters for specific materials and applications.

Glass is an example of a material that is familiar to nearly everyone but one that has very unique spectral characteristics. Glass is commonly thought of as being transmissive, that is, light passes through it. This is true in the 0.4 – 0.7 microns wavelength where we see, but glass is also very reflective at certain wavelengths and is totally opaque at other specific wavelengths.

What we find from the spectral characteristics is that if we are working with a glass manufacturing company and it is important to accurately measure the temperature of the glass, then it is essential to use the wavelengths where the glass is opaque and not transmissive or reflective, approximately 4.8 – 5.2 microns. We find that it is essential to understand how the wavelengths of radiation affect the detectability of heat differently with different materials and processes.

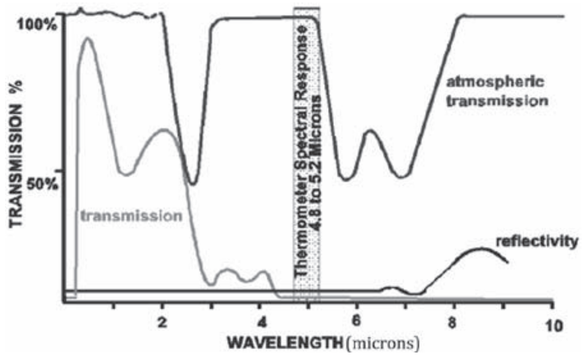

Fig. 2. Temperature measurement with infrared thermometers, Land, Inc.
Rys. 2. Pomiar temperatury przy użyciu termometrów działających w zakresie podczerwieni, Land, Inc.

So on one hand, we must have a detailed knowledge of the detectability of heat in various materials. We also need to understand the nature of heat and how it moves in various materials.

Another specialized infrared technique, based on this understanding, is flash thermography. This technique is broadly applied to inspecting composite materials for defects such as disbonds and voids. The materials used for composite materials are often thermally opaque and good thermal conductors. A pulse of heat is applied to the composite material and the surface is monitored with the infrared camera. We are interested in mapping the rate of change of temperature at the surface. Composite materials would have a uniform rate of thermal conductance in a homogenous material. When a delamination or void occurs, this anomaly is a resistance to the rate of thermal conductance. So mapping the rate of change of temperature at the surface can reveal subsurface defects such as delaminations and voids that would not be detectable with xray.

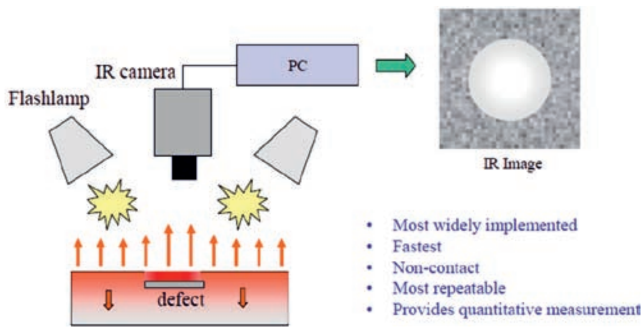

Fig. 3. Thermal Wave Imaging
Rys. 3. Obrazowanie fali cieplnej

The point is that infrared thermography is truly becoming a mainstream technology with wide applications in many industries. The expansion of the use of infrared has been driven by advances in our understanding of the behavior of heat and our ability to measure radiosity. We are on the cusp of a technological revolution in the application of infrared technology. Two years ago, Flir surprised the entire industry with the introduction of the Flir One: a very small 8-14 micron infrared camera designed to utilize the processing capabilities of our smart phones, turning any smart phone into a real infrared camera.The Flir One combines all the standard features of a smart phone and features a 160x120 pixel detector and thermal sensitivity of about 100mK. And in addition to its performance specifications, it has a price of only $249. About the same price as the doctor's stethoscope! I point out the technical specifications and the price because the combination of these factors determines the adaptability of the device to applications that were previously impractical due to size, performance and cost limitations.

This year we have seen two additional and similar advances. Seek Thermal introduced their SeekIR CompactPro: another small infrared camera that utilizes the processing capability of the smart phone, featuring a 320x240 pixel detector, 70mK thermal sensitivity, and at a price of $499. This camera takes another substantial step forward as it meets the benchmark for a serious higher performance infrared camera in an even smaller package. The SeekIR CompactPro is designed for a more serious user. It includes added capabilities such as selectable emissivity settings, an adjustable lens for sharp focus, and on-screen apparent temperature measurement indications. It also includes on-screen level and span adjustability and isotherms to aid in analyzing thermal patterns. This camera is the perfect companion for those who are serious about wanting professional results such as investigating energy efficiency in buildings, detecting water intrusion in building materials, locating electrical problems and much more.

The other product introduction this year is from i3systems, Inc: the Thermal Expert infrared camera. Similarly using the capability of the smart phone, and featuring a 384x288 pixel detector and 50mK thermal sensitivity, it is priced at $995. Like the SeekIR CompactPro, the Thermal Expert takes another substantial step forward. The Thermal Expert is designed for a more sophisticated and serious user. Where the CompactPro allows you to select emissivity settings of .3, .6, .8 and .95, the Thermal Expert allows any emissivity value from 0.01 to 1.00 which allows you to correct accurately for temperature measurements. The Thermal Expert features the option of 2 interchangeable and adjustable lenses to better match your needs.

While the other "smart phone infrared cameras" are tied to the phone (or tablet), the Thermal Expert goes beyond. Software is included for post processing saved infrared images and producing reports. And an MS Windows application is available for live interface directly to the Thermal Expert infrared camera.

3. The Future

The newest introduction to the smart phone product category is i3system's new VGA Thermal Expert, featuring a 640 x 480 pixel detector, 50mK thermal sensitivity, and 4 interchangeable and focusable lenses. The introduction is planned for October 2016. This newest camera, with an introductory price of $3,500 rivals high-end cameras costing $10,000 and more.

Infrared technology will continue to become more powerful, smaller and even lower in cost. And as the price/performance curve advances, the applications for the technology are expected to advance at an increasing rate. The point of including the price of these instruments is that the single greatest attribute of nondestructive testing and condition monitoring is value. With the tremendous reductions in cost of this highly sophisticated instrumentation, and its practical convenience, infrared cameras will become as common to the NDT and Condition Monitoring professionals as the stethoscope is to a doctor or a digital multi-meter is to an electrician.