THERMOGRAPHY

Non-contact sensing can provide the ability to evaluate the internal properties of objects without damage or disturbance by observing its shape, color, size, material or appearance. Non-contact measurements generate no process interruptions and thus result in time and cost savings. Continuous innovations in sensing technologies give the possibility to get ever more richer information, surpassing by far the common human sensing capabilities.

The industrial sector is of course the most demanding sector for this application in order to monitor processes and increase production quality with high accuracy and high speed. Potential defects can be detected and erroneous operations can be stopped rapidly thanks to inspection. To make these controls and inspections efficient, the set of parameters to be monitored should be selected carefully according to the specificity of each process.

Temperature is a common key parameter for many industries as thermal behavior is often a relevant process indicator. It is possible to turn a whole process field into a temperature map, then temperature can be controlled and monitored at any specific points in order to ensure that a planed process is correctly carried out. For example, production of glass relies on the ability to maintain the material at a specific temperature, according to its state and step of the process. This guarantees at the end high-quality glass-based products.

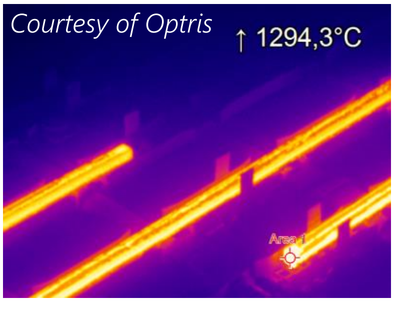


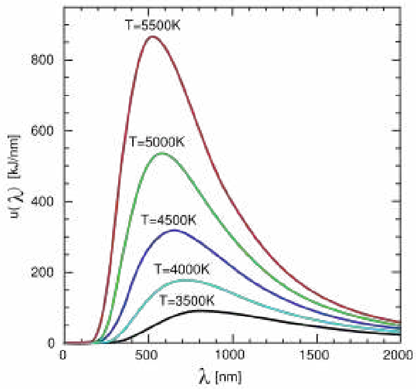
Fig1 : Thermographic image of steel slabs captured with PI1M

This 2D temperature mapping is defined as thermography, which consists in measuring the temperature of an object by using the object's own electromagnetic radiation, so it can be done without any contact. This technique is based on the detection of the radiated energy, which is emitted by all materials above 0 Kelvin temperatures. The intensity and spectral distribution of the emitted radiation are function of the temperature and the surface emissivity of the hot body.

Indeed, the internal thermo-generated radiation of an object will be emitted to free space by its surface, so the surface state will influence the emission quantity. An object with the most efficient emission is called a black-body. All surfaces have an emissivity between 0 and 1, representing the ratio compared to the emission efficiency of a black-body.

$$\varepsilon = \frac{E_{body}}{E_{blackbody}} \qquad 0 \leq \varepsilon \leq 1$$

Emissivity depends on intrinsic parameters (material, surface quality), but also on extrinsic parameters such as wavelength and measuring conditions.



A blackbody is an ideal emitter: its intensity and spectral distribution are defined by Planck's law. Higher is the temperature, shorter is the wavelength corresponding to the peak energy.

Knowing the surface emissivity, the temperature of a hot body can be obtained by measuring the intensity, with potentially the spectral distribution of its radiation. The detected radiation by a sensor is also modulated according to its optical aperture. A larger aperture generates more radiation on the sensing surface of the sensor.

Energy emitted : $\boldsymbol{E} \propto \frac{\mathbf{1}}{\boldsymbol{N}^{\mathbf{2}}}$

The aperture of a sensor is often defined by its f-number N. The larger the aperture, the smaller the f-number.

To succeed in providing reliable products at the end of the production line, the temperature has to be monitored all along the process, leading often to a large temperature span. In several industries such as steel, glass, ceramic or cement industries, that involves temperatures between 300°C and 1500°C.

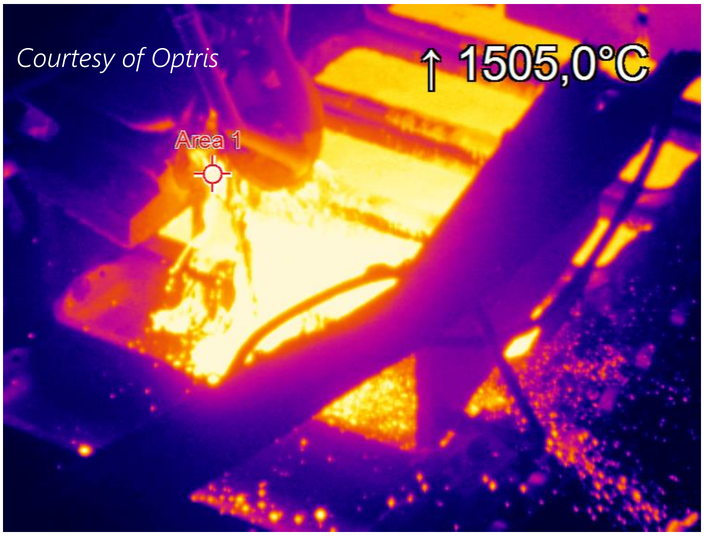
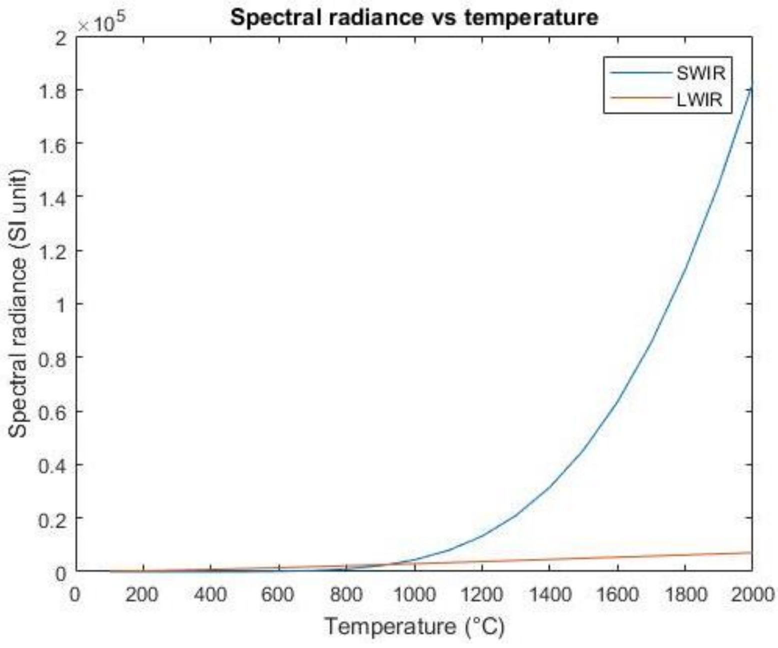


Fig2 : Non-contact measurement of casting temperature with PI1M

For each body's temperature range, the adequate wavelength band should be selected. The Short-Wavelength Infrared (SWIR) band – from 0,9 to 1,7 µm - is, in this way, perfectly adapted to fit these high temperatures. Visible wavelengths can also be suitable for the highest temperature ranges, from 600°C to 2000°C. Sensors made of Indium Gallium Arsenide (InGaAs) are very efficient quantic detectors in SWIR band at room temperature.

Operating in Short-Wavelength Infrared (SWIR) band enables to tolerate more inaccuracies on emissivity, as measured values are the highest, compared to Medium-Wavelength Infrared (MWIR) or Long-Wavelength Infrared (LWIR) bands. Slight variations will only have minor consequences on the resulting temperatures.



However, due to near-exponential relationship between temperature and radiation in Planck's law, such large temperature ranges imply huge variations of the electromagnetic radiation. To succeed in monitoring throughout the whole temperature range, the dynamic range of sensors is critical.

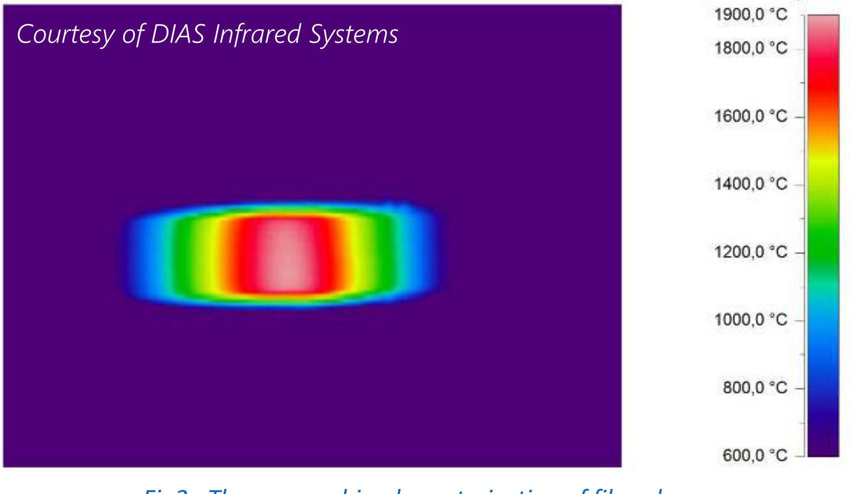
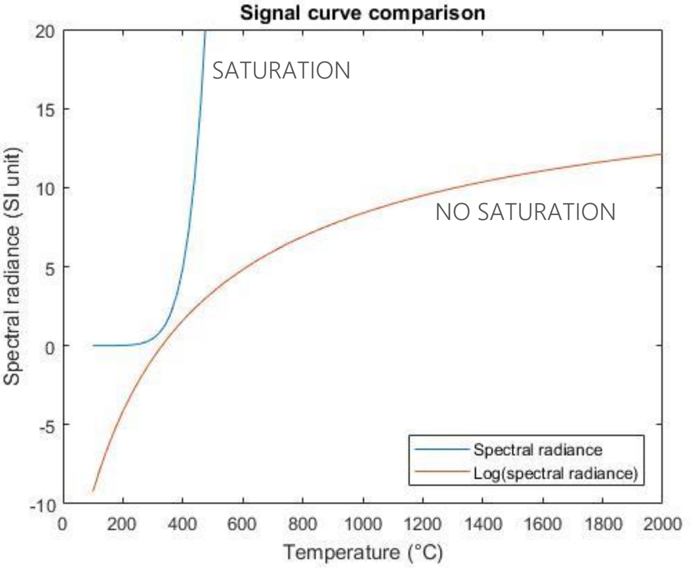


Fig3 : Thermographic characterization of fiberglass

Just for glass industry, materials are heated from a temperature of more than 1000°C during the melting process, to about 600°C during the forming process and finally reach 50°C at the end of the cooling process.

New Imaging Technologies (NIT) has developed a complete portfolio of InGaAs sensors with ultra-high dynamic range thanks to its patented logarithmic pixel technologies. This InGaAs sensor and camera portfolio, under the name WiDy SWIR, offers different resolutions, output formats and operating frame rates. The logarithmic pixel structure providing High Dynamic Range exceeding 120dB is capable to map an entire scene with a temperature span from 300°C to 3000°C simultaneously. In the glass industry, one single camera enables to check continually molten glass drops at almost 1000°C and glass in containers maintained at nearly 300°C without any operation on the camera.

A traditional InGaAs sensor has a dynamic range limited to 60dB; this temperature range needs to be divided into several sub-ranges, resulting in not only local saturation but also complexity in the practical use.



Thanks to the logarithmic pixel structure, NIT's sensors consider the logarithm of signal, widening the temperature range to be measured.

Reliability of processes is only ensured if infrared cameras and thermometers are able to follow the operating speed. The reaction of the sensors is of critical importance here. Thanks to a frame rate of over 200 fps, NIT's sensors can measure the temperature of moving objects in a production line or in very fast processes.

In many industrial process, temperature is uniform and a difference of emissivity can be detected by a thermographic camera and used as a powerful tool of inspection. Especially in metal industry, it becomes easy to detect slag impurities on molten metal. Indeed, these two elements have their own physical properties, which implies a difference of emissivity and leads to different intensities of emitted radiation, even at same temperatures. Rather than waiting until the end of the process to sort the pieces of metal, the defective slabs can be removed during the process.

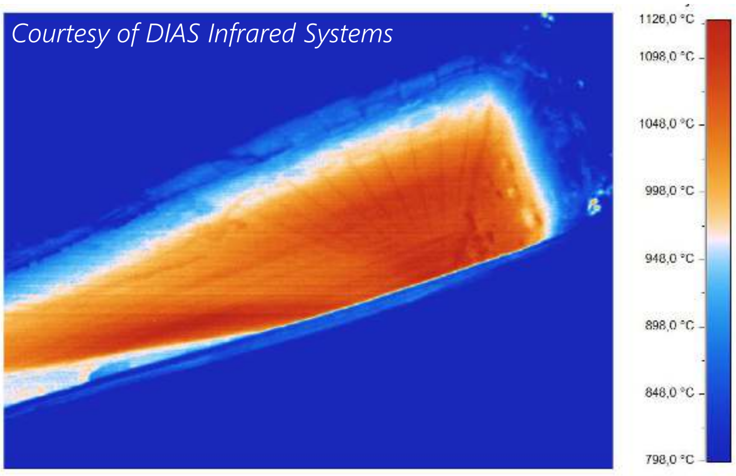


Fig4 : Non-contact temperature measurement in combustion chambers

Related industries operate in hard conditions, where equipment can be submitted to high temperatures, severe dust loads or even corrosive liquids.

Thus, best-suited technologies are integrated in resistant cameras, pyrometers and borescopes. One gives thermographic plans, the other temperature measurements and the latter is specially designed to be inserted inside furnaces.

A quality control is implemented in real time by using thermographic cameras without human presence in such hard conditions. Besides WiDy SWIR images can also be merged with NIT visible images, giving visible pictures of the scene and its temperature map at the same time.

NIT provides very flexible cameras and sensors to facilitate their integration and give them the capacity to encounter a very large range of conditions. Inside compact production machines, these modules can solve many challenges thanks to their optimization in terms of size, weight and power.

Thermography is nowadays a reliable tool to upgrade industry standards. Well managed in SWIR band, thanks to NIT's convenient camera modules, it guarantees a monitoring over large temperature ranges thanks to the Wide Dynamic Range. This contributes to decrease the number of defective final products as well as save resources, consequently impacting customer satisfaction and company profits.