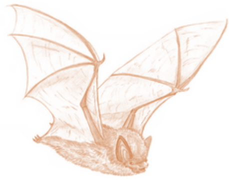
V1.1/NOVEMBER/2021

BICRHOMATIC REFLECTOMETRIC PYROMETER

500-1500ºC

Preliminary English Version

SUMMARY



NON-CONTACT TEMPERATURE MEASUREMENT

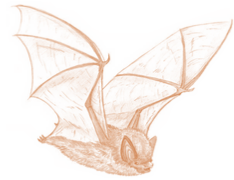
The fundamental equation

To measure the temperature without contact, an optical pyrometer is used which captures the light emitted by any hot body. This emitted light is governed by **Planck's law**:

$$L_{\Omega,\lambda}(\lambda, T, \epsilon) = \epsilon \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$$

The luminance of the object depends on its temperature, wavelength and hemispherical emissivity. The emissivity of a black body is equal to 1.

Since there is no such thing as a perfectly black body, **it is necessary to know the emissivity** of a body for the optical pyrometer to indicate the true temperature.



THERMOREF

The ultimate solution

Phonoptics has developed in partnership with a research laboratory a new kind of sensor:

Reflectometric bichromatic pyrometer
fiber optic

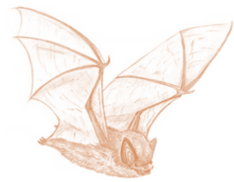
Thanks to the use of light sources, and by performing complex calculations to solve the right equations, our device is able to measure the emissivity of the target in real time and thus correct any change in surface, and therefore in emissivity.

So the ThermoRef ™ always indicates the TRUE temperature.

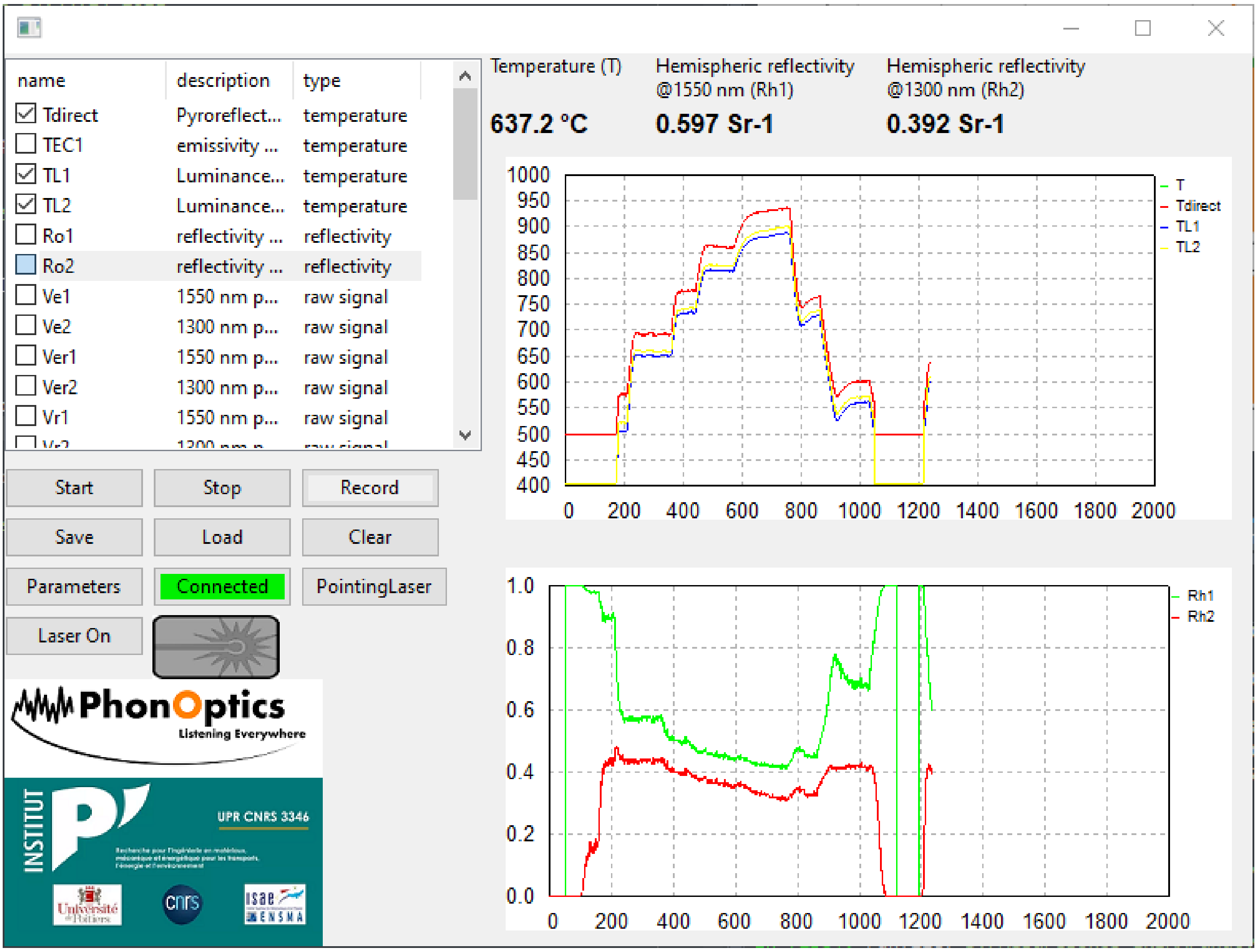
The control unit with touchscreen operation

Rear face with all I/O connectors

The optical head connected to the box via its shielded cable with polyurethane coating



Computer software, in addition to the touchscreen, for remote operations



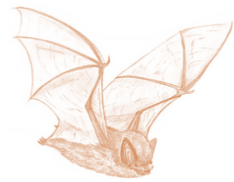
It is possible to fully control the electronic unit remotely via the ethernet connection.

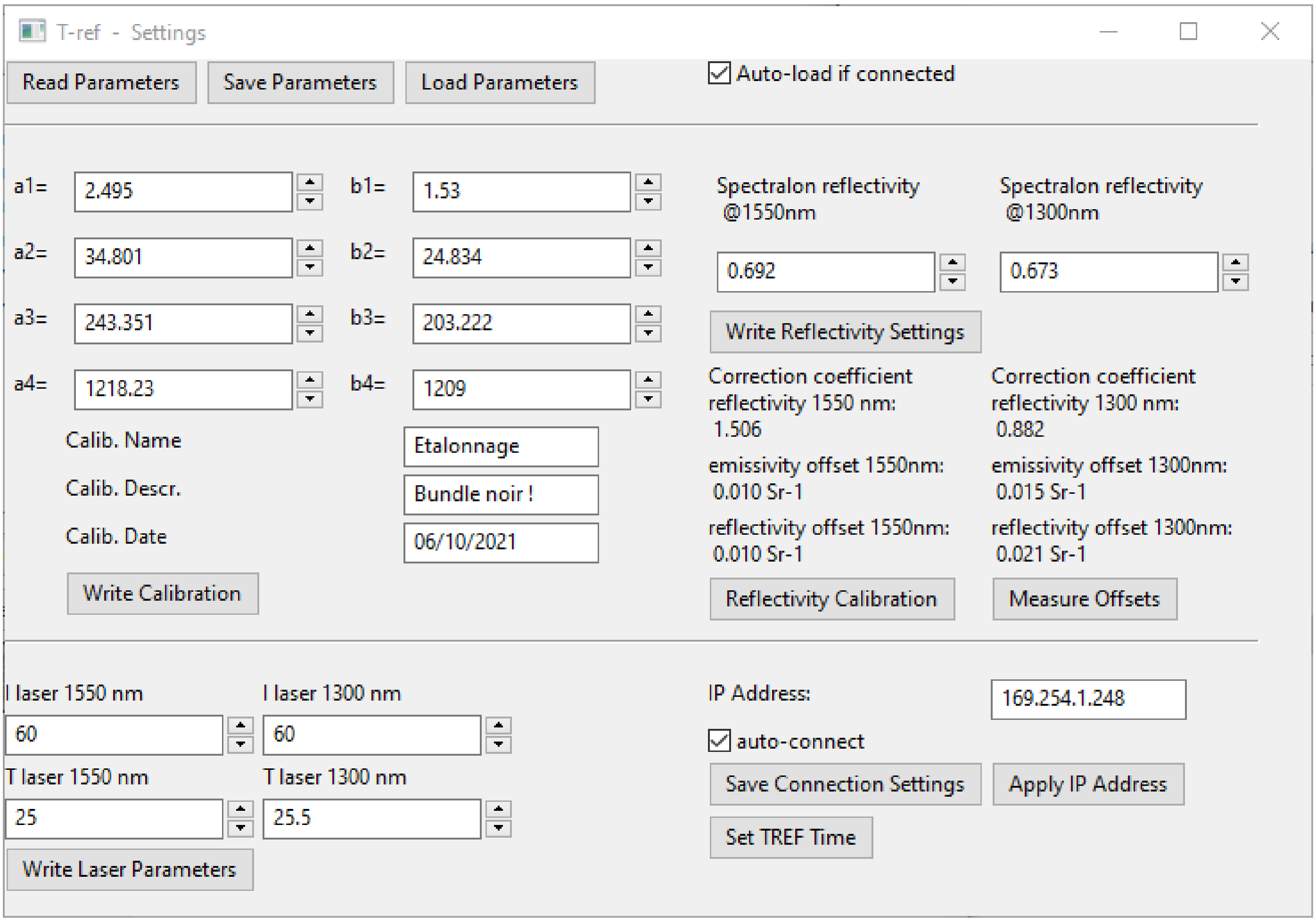
All measured and calculated data is viewable and recordable: Luminance temperature, reflectivities, bichromatic temperature, emissivity corrected temperature, reflectometric bichromatic temperature and more.

One can visualize the different values over time with a self-adjusting scale.

The reflectivity values are likewise visualized.

Lasers can be turned on and off as a safety measure, as well as the red aiming laser.

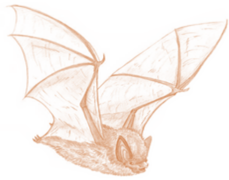




The software allows you to check the calibration file in order to perform or load new pyrometric and reflectometric calibrations.

It is the precision of these calibrations which will determine the precision of the measurements.

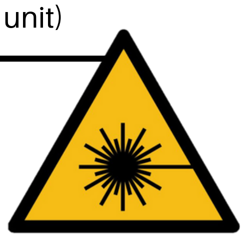
A calibration is provided as standard with the delivery. This calibration can be done again later.

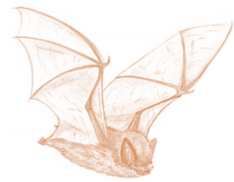


TECHNICAL SPECIFICATIONS

ThermoRef

Temperature range	500 to 1500°C (930 to 2730°F) (other on request)
Fiber optic and optical collimation measurement	standard length 2 meters (other on request)
Working distance	400mm typ. (other on request)
Spot size	5mm @400mm typ. (other on request)
Resolution	1°C (2°F)
Uncertainty	±10°C (±18°F) typ. @ 1500°C
Sampling frequency	10Hz (100Hz on request)
Wavelength range	1310nm & 1550nm. Laser class 3B (IIIB)
Power supply	AC adapter 80-260V to 24V
Alignment	Pointing laser class 2 (II)
Input/Output	4-20mA, 0-10V & Ethernet
Recording	SD Card (32gb max) & through software
User interface	7in tactile screen & computer software
Dimensions	21x14x25 cm (8.3x5.5x9.8 in) (fiber excl.)
Weigth	2.5 kg (5.5 lbs)
Environment	15 to 30°C (59 to 86°F) (electronic unit)





TO GO FURTHER...

For the curious

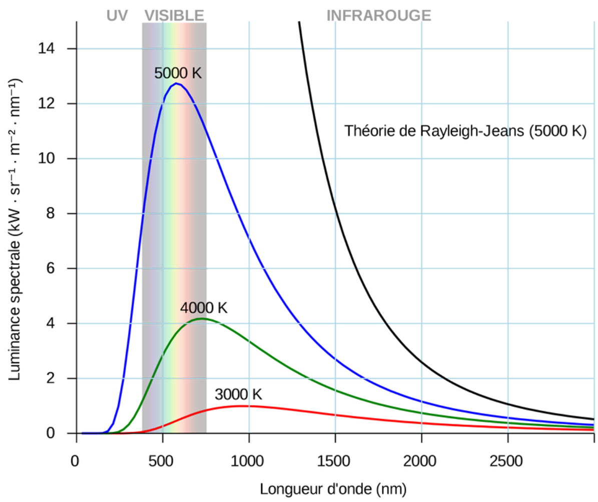
In order to measure the temperature of an object without contact, it is possible to use an optical pyrometer. An optical pyrometer is generally composed of a photodiode capturing the light emitted by the target, and transforming it into a current. This current is proportional to the amount of light collected.

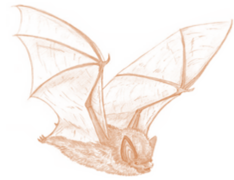
To go back to the temperature of the object, one must use the generalized Planck's law which describes how much and how light is emitted by the surface of a body.

$$L_{\Omega,\lambda}(\lambda,T,\epsilon) = \epsilon \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$$

The luminance of the object depends on its temperature, wavelength and emissivity.

it is therefore necessary to know the emissivity of a body for the optical pyrometer to indicate the correct temperature. In general, it is possible to manually change, during a calibration, the emissivity factor of an optical pyrometer, by making one or more measurement points at known temperatures of the object.





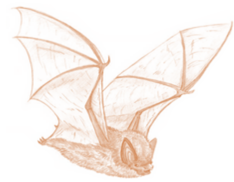
However, the temperature of the thermocouple is never equal to the surface temperature, and for moving parts, it is not necessarily possible to use this method. In addition, the emissivity can change over time and as a function of temperature, which will result in falsifying the calibration.
The challenge is therefore to be able to correct the emissivity in real time.

In other words, when the surface of the object changes, this means that its emissivity changes, and therefore the calculation of the temperature by the pyrometer becomes false: **the given temperature is no longer the right one**. The deviations can go up to 100% in theory, and in practice up to 50%.

Bichromatic Pyrometer

To overcome this problem, bicrhomatic pyrometers have been developed.
They are composed of 2 monochromatic pyrometers, at 2 different wavelengths.
By making the ratio of the two, we obtain a new temperature value, called bichromatic. This value is correct only if the emissivity varies in the same way for both wavelengths. This is true for a gray body.

It seems like a very good solution. However, if the assumption is not correct, and the body is not gray, the result drifts, and the uncertainty explodes.



This is why another type of pyrometer has been developed.

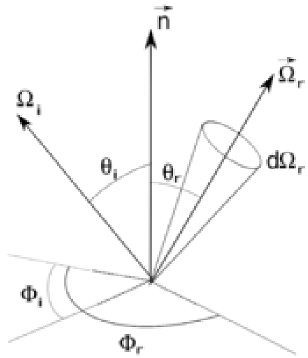
Emissivity corrected Pyrometer

Most of the measurement uncertainty arises from the variation in emissivity. What if it was possible to **measure the emissivity** of the target in order to automatically correct the value in the pyrometer?

In order to do this, pyrometers with emissivity correction have been developed. The pyrometer includes a light source, whose light will be sent to the target and whose reflection will be analyzed in return, in order to **evaluate the changes in reflectivity** over time, and thus to deduce the change in emissivity.

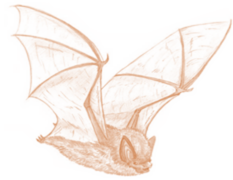
Because there is indeed a direct link between **emissivity and reflectivity**:

$$\boldsymbol{\varepsilon = 1 - R\sigma}$$



where
ε is the emissivity
R is the bidirectional reflectivity factor
σ is the scattering factor

An emissivity-corrected pyrometer requires setting the diffusion factor at the start of the measurement and assumes that it does not vary over time.



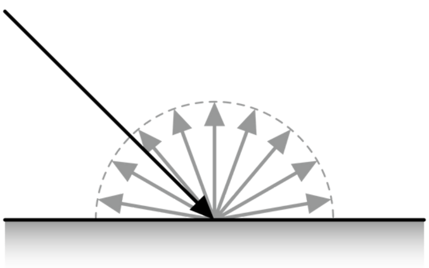
A perfect black body absorbs all radiation and therefore reflects nothing. The absorbed radiation increases the body temperature, which it will re-emit according to Planck's law.
A perfectly reflective body will not absorb any light because it will be fully reflected.

By taking this measurement at regular intervals, it is then possible to correct the emissivity factor and thus keep a correct temperature reading.

However...

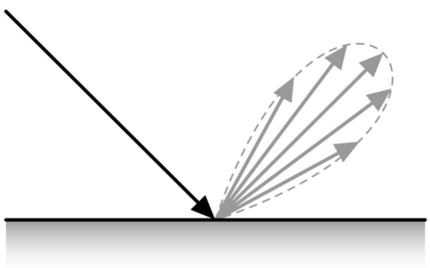
Unfortunately, this does not make it possible to get rid of all the situations of surface condition modifications.
Indeed, the light reflected and collected in return by the pyrometer can vary while the emissivity of the target has not changed: another criterion than the black / white character is the **scattering factor** (noted σ in the equation previous) of the surface: a body can be **matt or shiny**. If the diffusion factor changes, this measurement is no longer valid. This especially happens when a body oxidizes.

This limitation has led us to develop a new product with a whole new technology ...



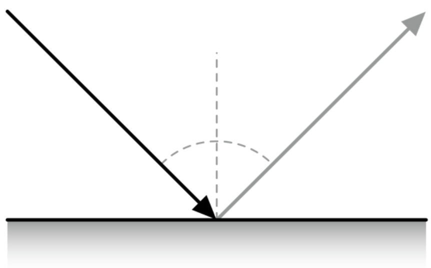
Lambertian surface

$\sigma=1$



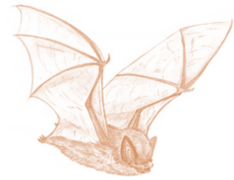
any surface

$0<\sigma<1$



Specular surface

$\sigma=0$

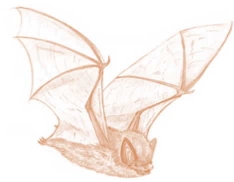


In order to be completely free from all variations of the surface state of the object, we have developed a bichromatic reflectrometric pyrometer called "pyroreflectometric".

- Bichromatic because using two photodiodes at two different wavelengths measuring 2 luminance temperatures
- Reflectometric because using the light sources to perform the reflectivity measurement. They are the same number as that of the photodiodes, i.e. 2 (but a solution of 3 or more could be considered for even more specific cases)

This PyRef is able to perform all the measurements like the previous solutions, but adds the missing element which makes it possible to avoid any change in the surface state of the target: a double reflectivity measurement.

To top it off, this is not just 2 separate measurements as it might be with a dual wavelength emissivity corrected pyrometer as this would not allow the scattering factor to be measured, it is a complex calculation combining the two measurements in order to **calculate the scattering factor leading to be independent of the measurement angle**



The developed product performs internally, thanks to a new generation high performance microcontroller, all the calculations necessary to obtain a unique temperature value: the pyro-reflectometric temperature. This is the **truest** temperature value that can be obtained at the present time.

In addition to this, the PyRef is able to indicate the temperatures that other types of pyrometer would give in order to compare and adapt the measurement to the best and obtain the best uncertainty.
The user of PyRef knows **in real time the evolution of his object of study**, at the same time as its temperature. This makes it possible, for example, to know the state of degradation of a mold or of a part subjected to high stresses.

In brief

As soon as the surface condition of an object changes, pyrometers can give poor temperature readings.

The most reliable solution to deal with all surface state modifications is our pyro-reflectometry solution.

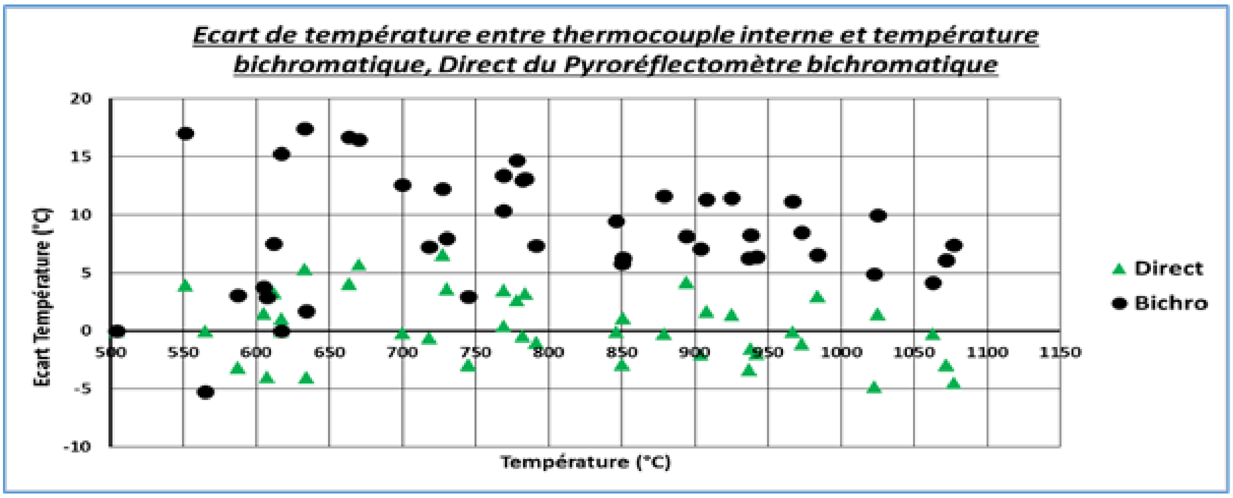
This solution responds in particular to the problem of measurement on metal surfaces which are subject to oxidation; but also to new complex multi-material objects and for any application where standard pyrometers drift over time.

The ThermoRef gives the most exact temperature that it is possible to obtain, and also makes it possible to have an active look at the evolution of the object of study

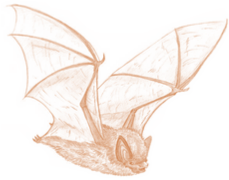
USE CASE

ThermoRef

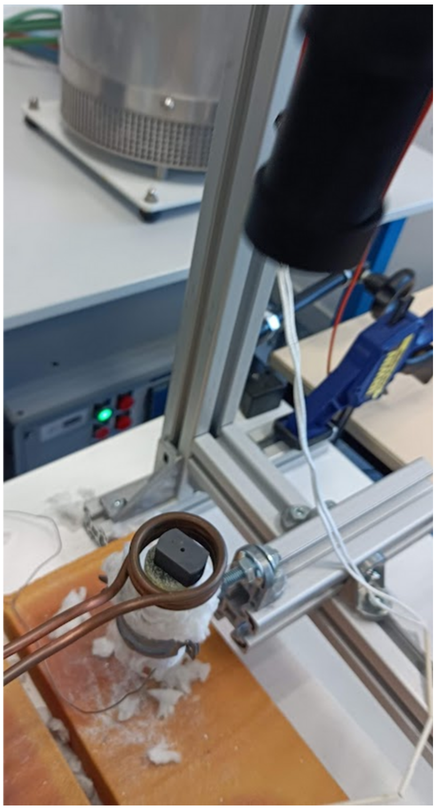
- Visible or expected change in surface state (not visible to the naked eye)
Example: oxidation of metals
Perfect for the study of materials heated by induction (no electromagnetic disturbance EMI/RFI)
- Need the best possible uncertainty
- New materials study
The reflectivity measurement can provide information about oxidation and though aging of metal (copper mould for instance)



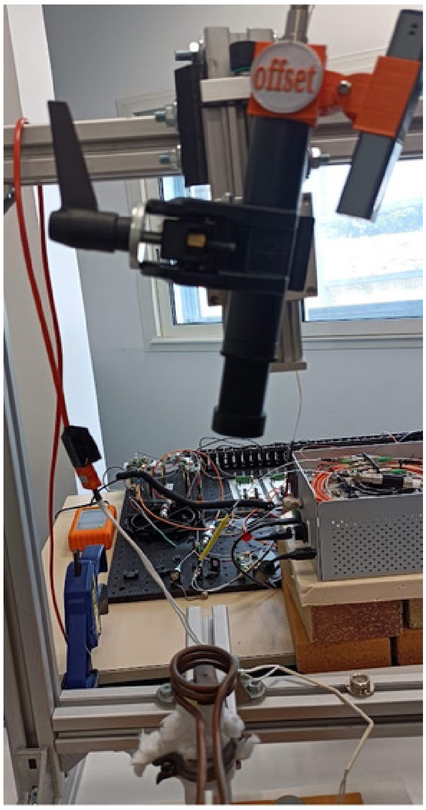
standard deviation of temperature measurement for the ThermoRef (Green) and Bichromatic pyrometer (**Black**)



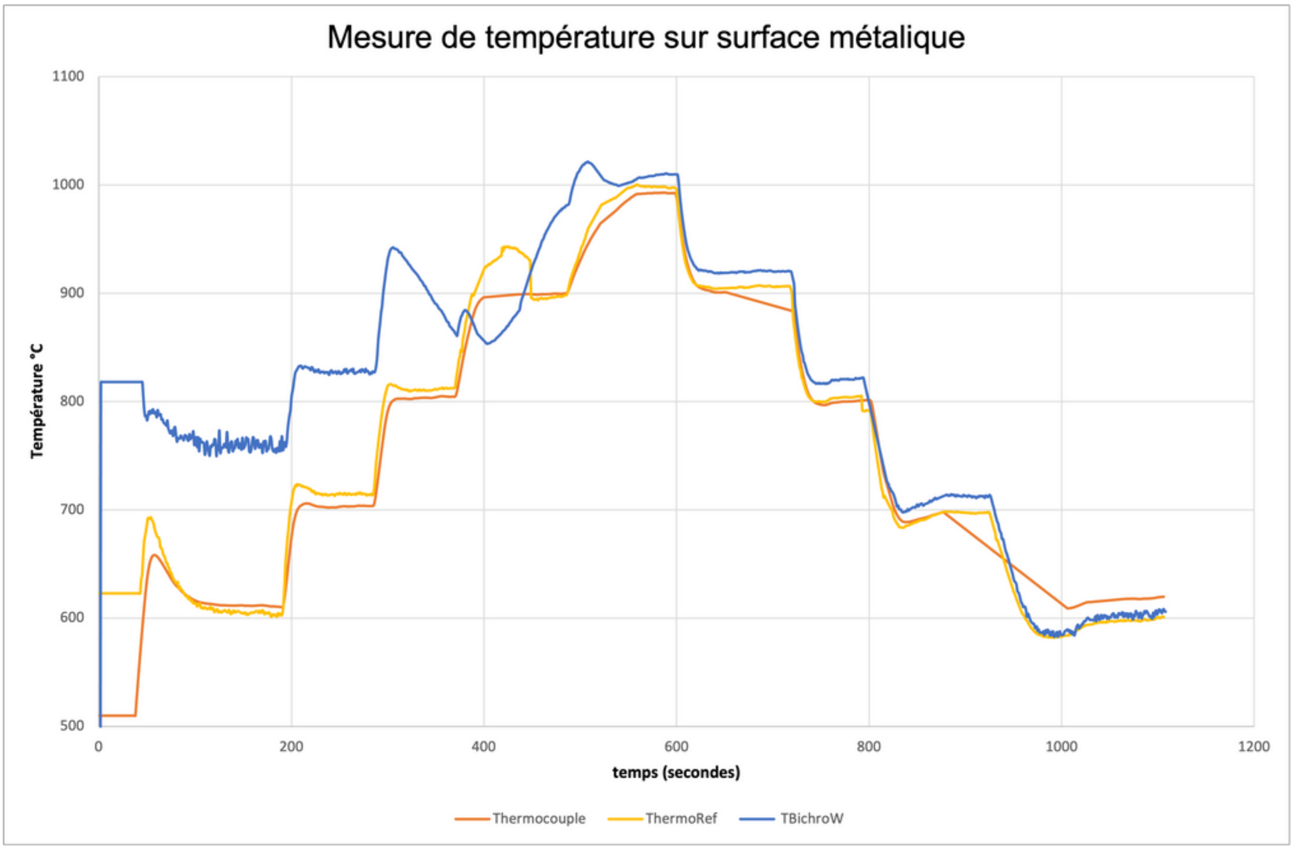
Before heating



After heating



Optical head



The temperature measured by the Thermoref (in yellow) is the one that most closely matches that of the thermocouple (in orange), unlike the bichromatic temperature value (in blue)

WANT TO KNOW MORE ? CONTACT US!

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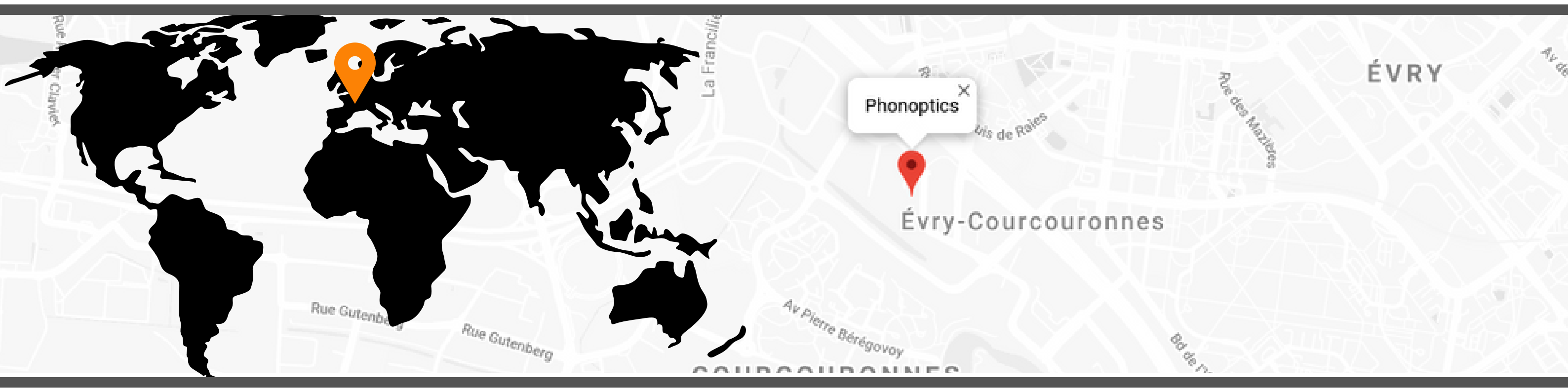

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