nanoTBtech webinars

Aiming at reliable luminescence thermal sensing: basic strategies to overcome the problem of light attenuation in tissues

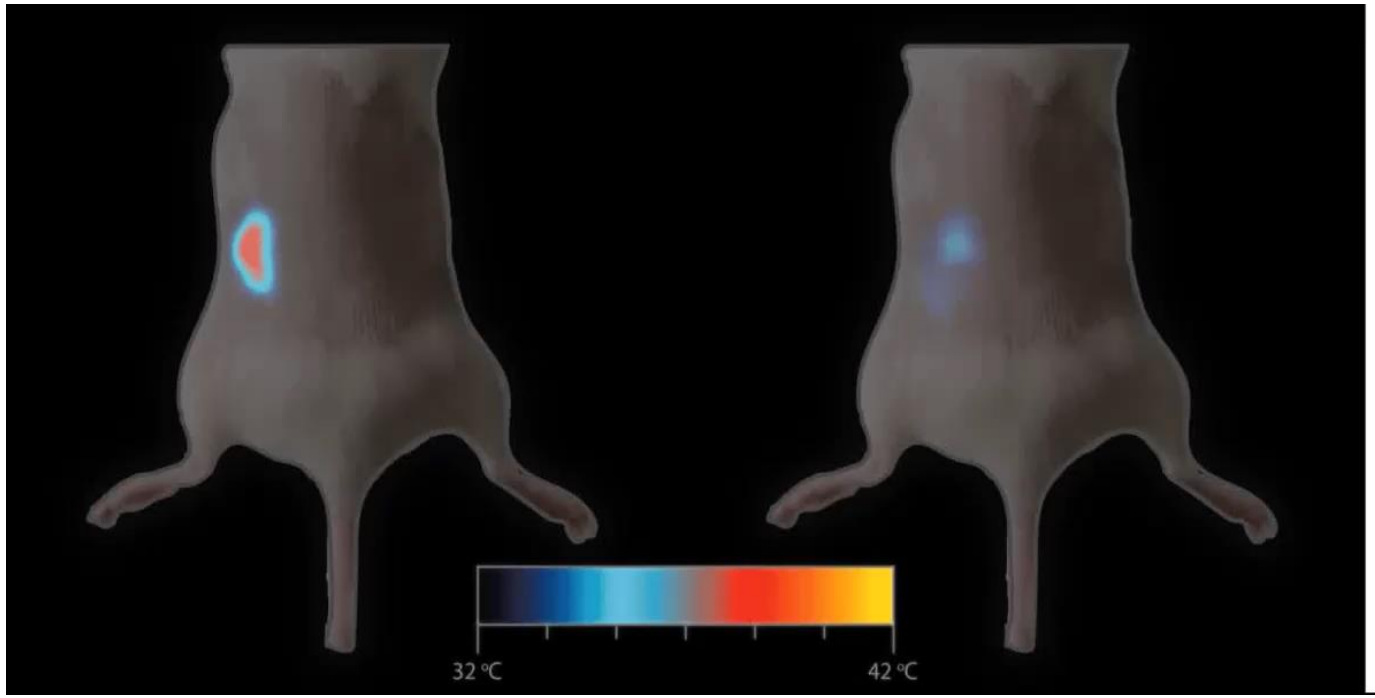
Speaker: E. Ximendes

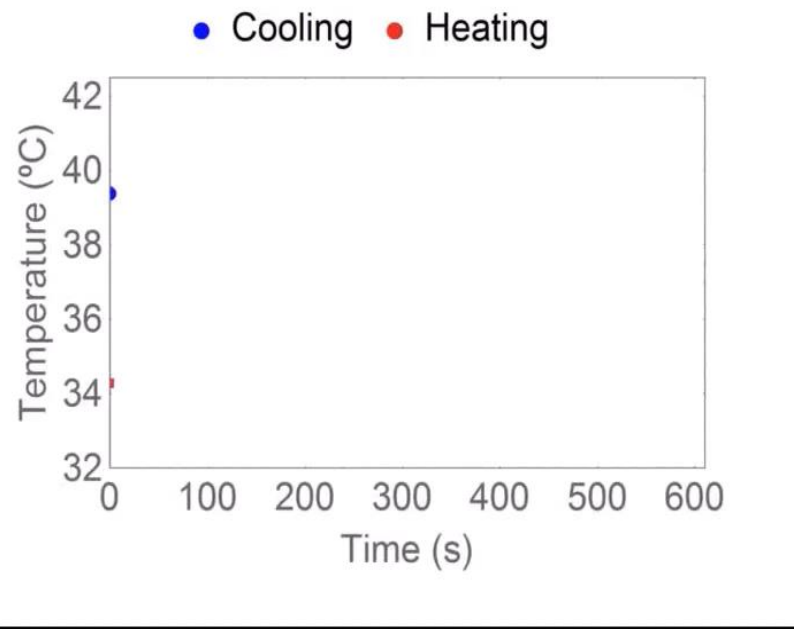
Introduction

- Luminescence thermometry is becoming quite popular!

Introduction

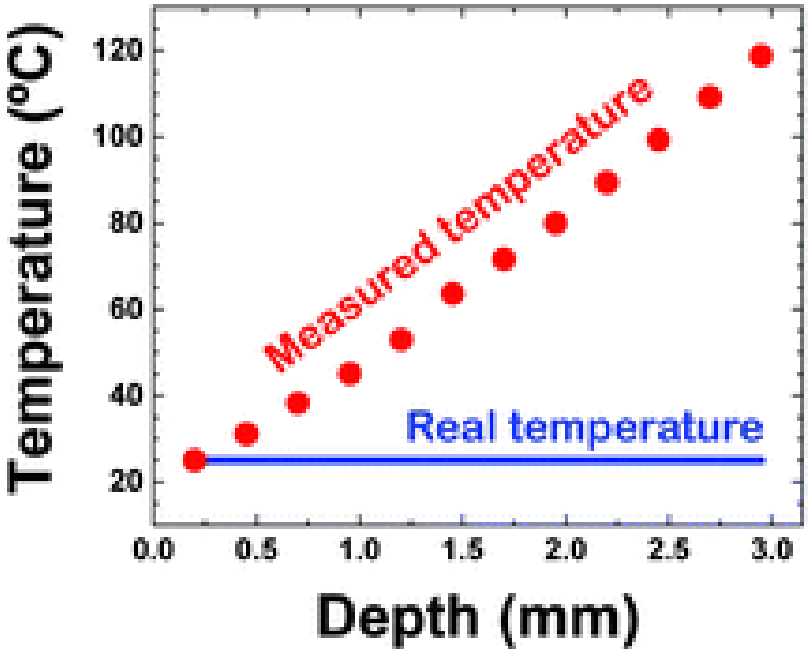
- This interest pushed forward some significant advancements in their *in vivo* applications.

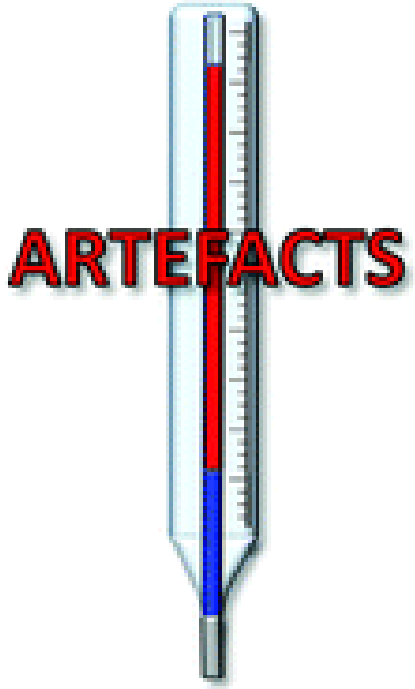




Ximendes et al., *Advanced Functional Materials*, **2017**, 27 (38), 1702249

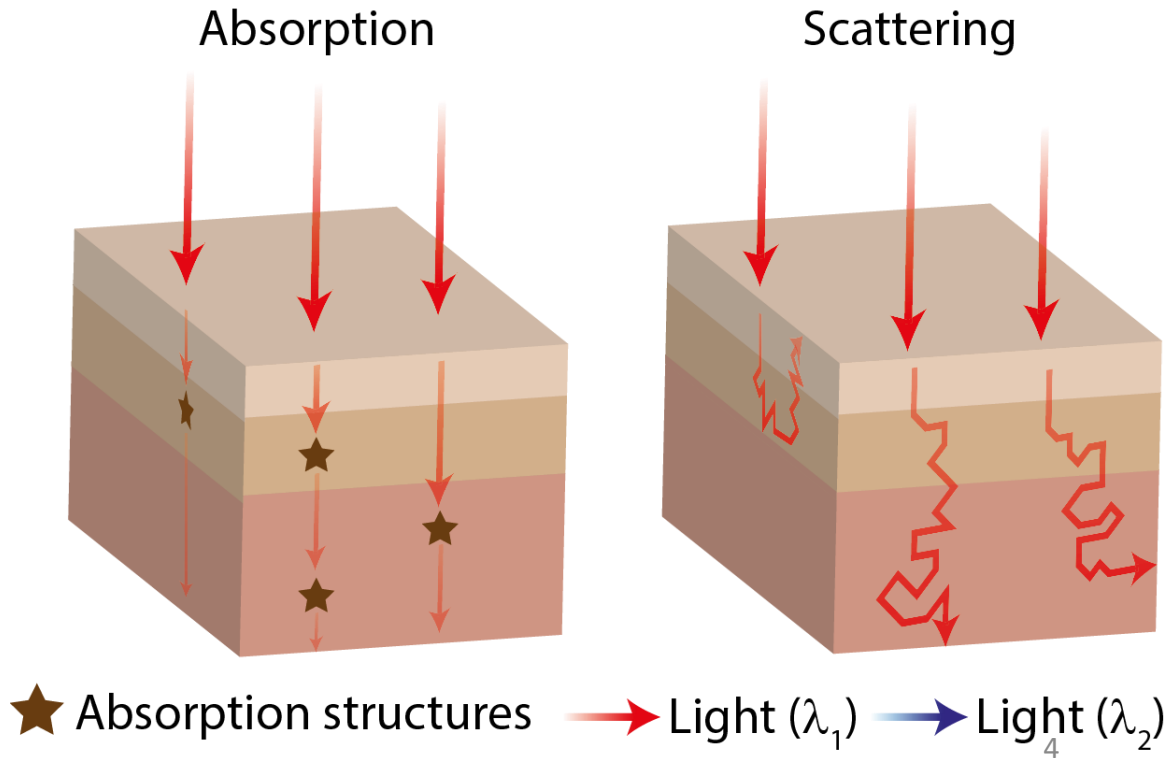
- Its reliability, however, is now being put to a thorough test.



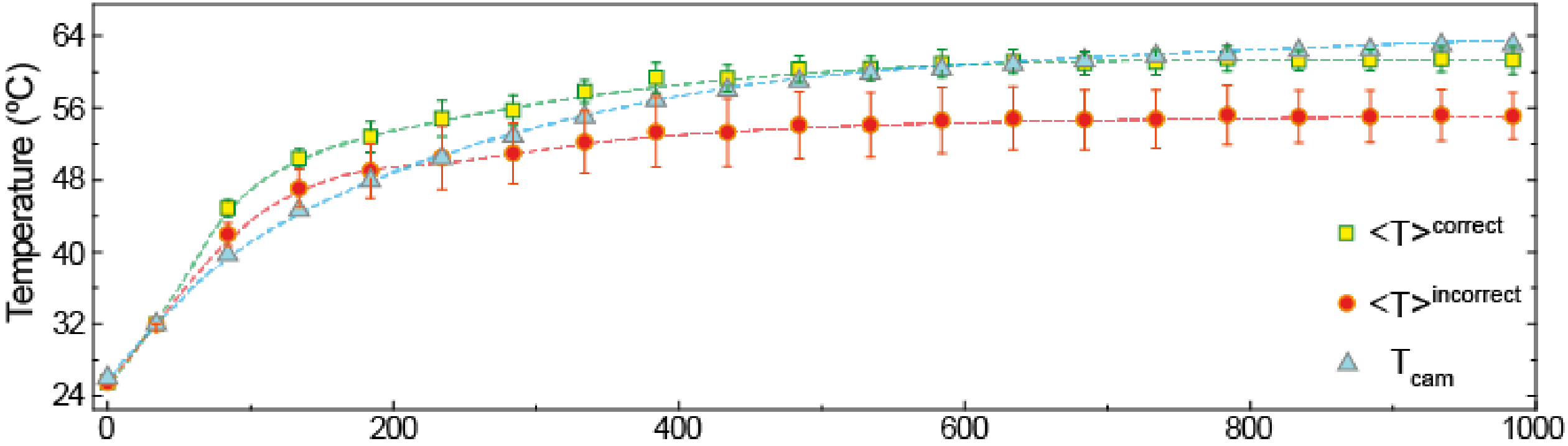


Error induced by luminescence thermometry in NPs doped with lanthanides.

L. Labrador-Paéz et al. *Nanoscale* **2018**, *10,* 22319

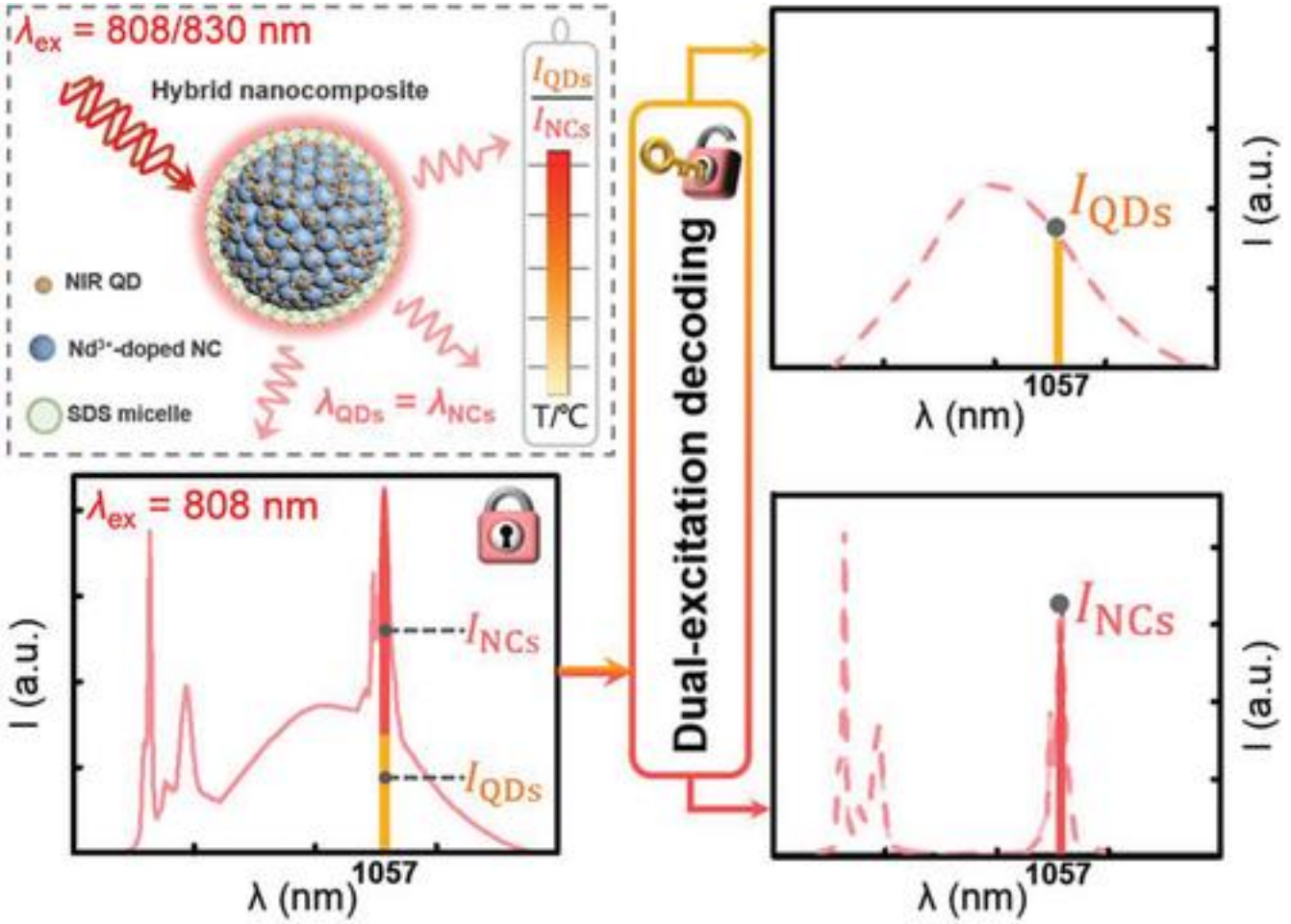


- Biological tissues could completely distort the thermal readout provided by LNThs.



Shen et al, ACS Nano, **2020**, 14, 4122

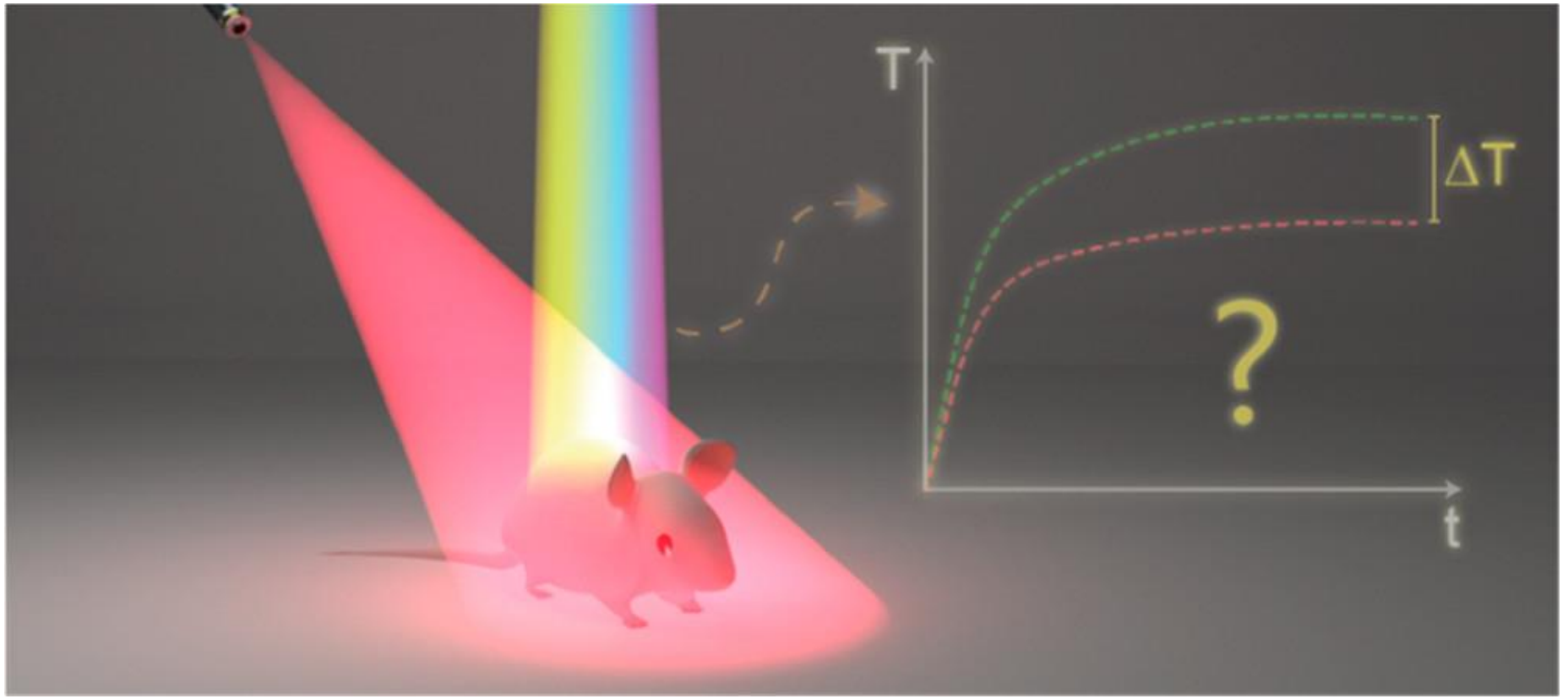
- As a result, new strategies are already being proposed to overcome such a problem.



Shaohua Yu et al., Advanced Science, **2020**, 21, 2001589

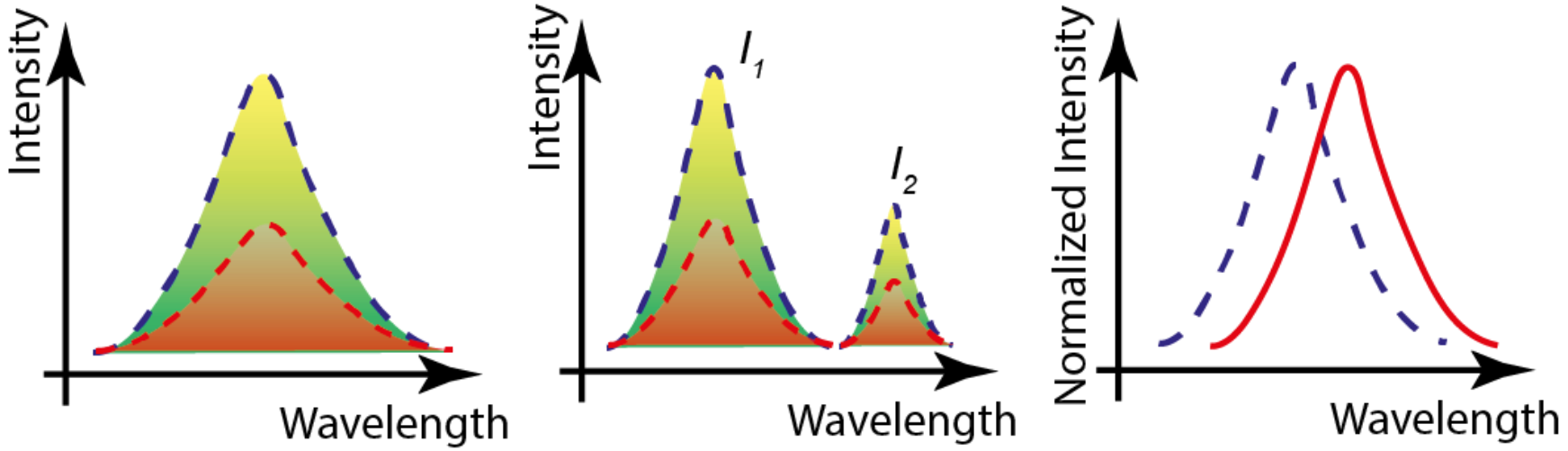
Introduction

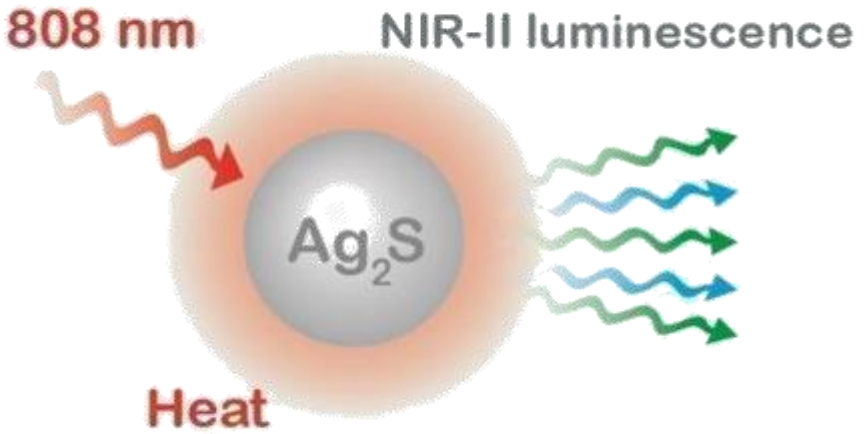
- We need to think of ways of reducing this problem.

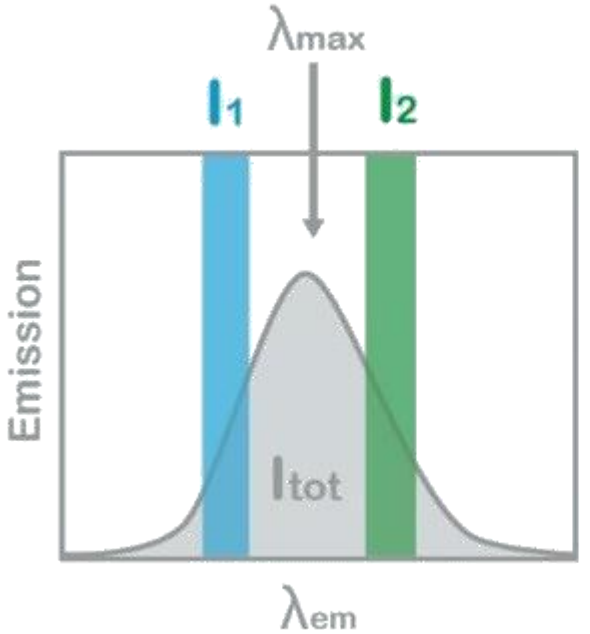


Multiparametric thermal sensing:

One probe, multiple ways of measuring temperature







Calibration

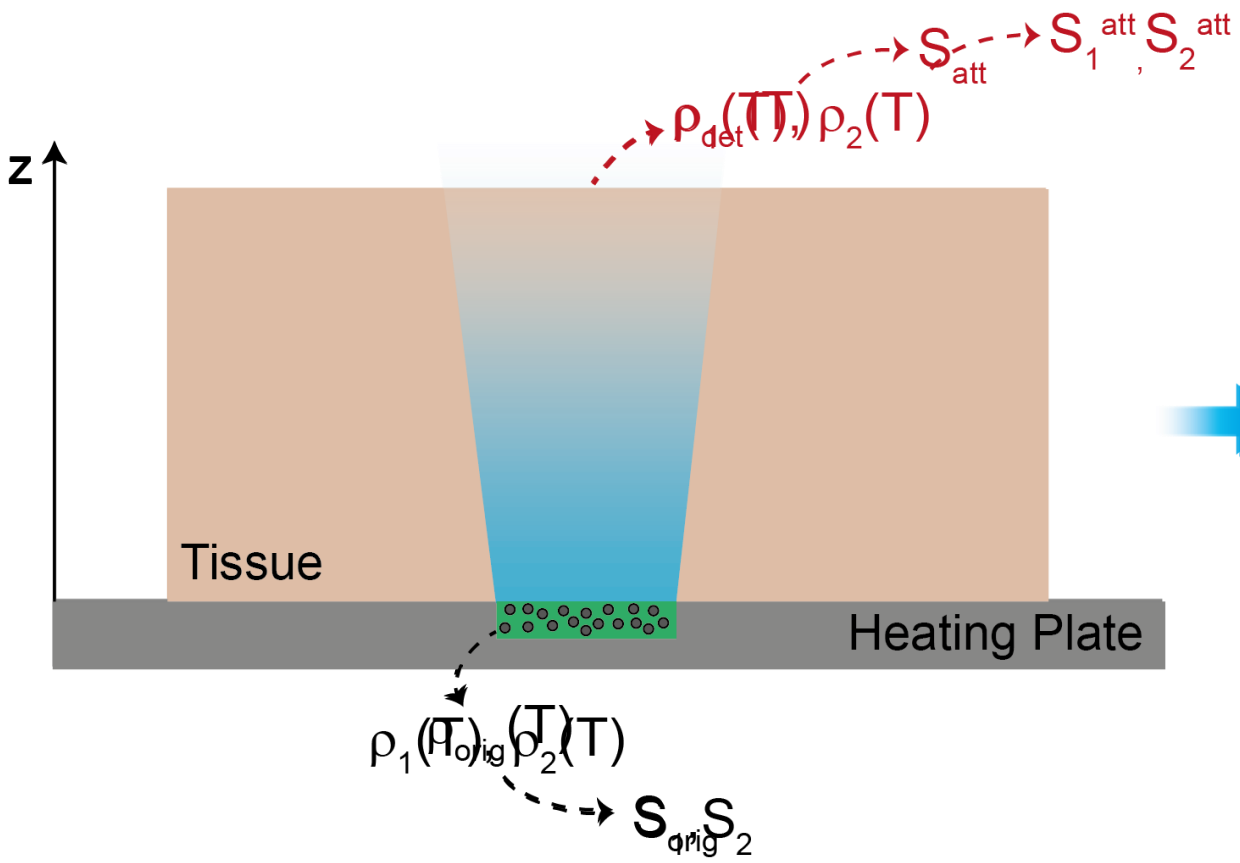
$T_R = f(R); R = I_2/I_1$

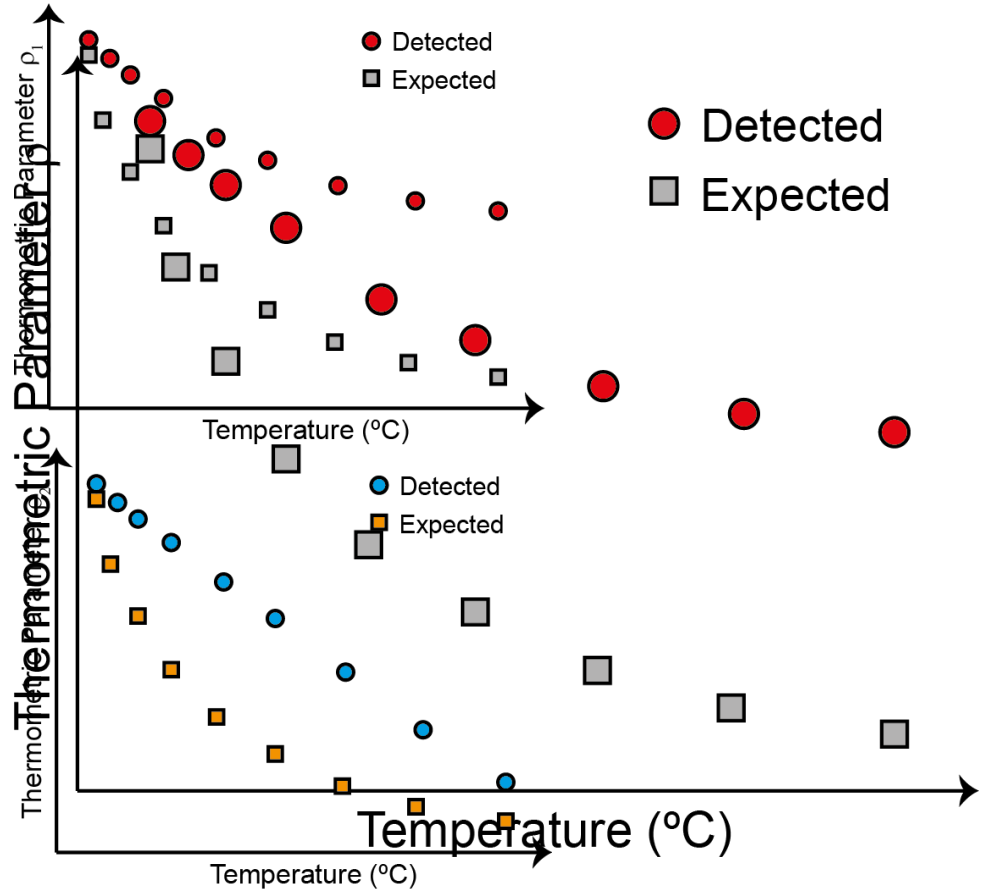
$T\lambda = g(\lambda_{max})$

$T_I = h(I_{tot})$

Concept

The attenuation of light could still affect many parameters. So what's the advantage?





Concept

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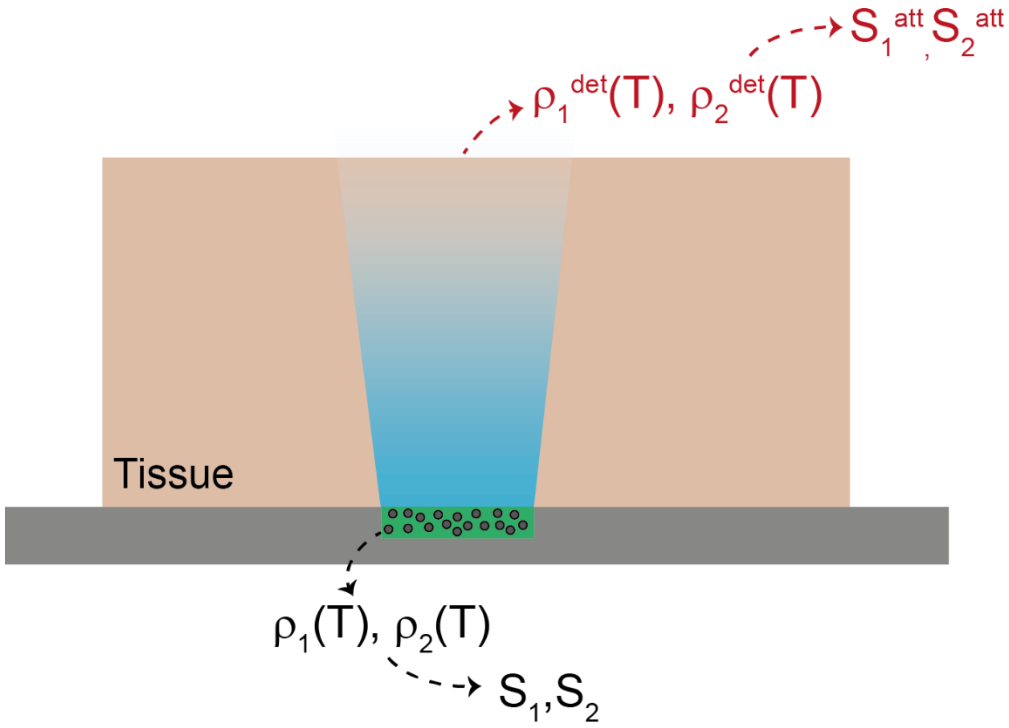


$$S_1^{att} = S_{\rho_1} + \Delta S_{\rho_1} = \frac{1}{\rho_1^{det}} \left| \frac{d\rho_1^{det}}{dT} \right| \Leftrightarrow |dT| = \frac{1}{S_{\rho_1} + \Delta S_{\rho_1}} \frac{|d\rho_1^{det}|}{\rho_1^{det}}$$

$$S_2^{att} = S_{\rho_2} + \Delta S_{\rho_2} = \frac{1}{\rho_2^{det}} \left| \frac{d\rho_2^{det}}{dT} \right| \Leftrightarrow |dT| = \frac{1}{S_{\rho_2} + \Delta S_{\rho_2}} \frac{|d\rho_2^{det}|}{\rho_2^{det}}$$

$$\frac{1}{S_{\rho_1} + \Delta S_{\rho_1}} \frac{|d\rho_1^{det}|}{\rho_1^{det}} = \frac{1}{S_{\rho_2} + \Delta S_{\rho_2}} \frac{|d\rho_2^{det}|}{\rho_2^{det}}$$

Multiparametric thermal readouts will only converge if you take the proper calibration into account.

But what if you found thermometric parameters whose **sub-tissue** thermal readouts agree by considering only the intrinsic calibration?

$$\frac{1}{S_{\rho_1}} \frac{|d\rho_1^{det}|}{\rho_1^{det}} = \frac{1}{S_{\rho_2}} \frac{|d\rho_2^{det}|}{\rho_2^{det}} \Rightarrow \Delta S_{\rho_2} \frac{|d\rho_1|}{\rho_1} = \Delta S_{\rho_1} \frac{|d\rho_2|}{\rho_2}$$

$$\Delta S_{\rho_1} = \Delta S_{\rho_2} = 0$$

$$\frac{1}{\Delta S_{\rho_1}} \frac{|d\rho_1|}{\rho_1} = \frac{1}{\Delta S_{\rho_2}} \frac{|d\rho_2|}{\rho_2}$$

Concept - Analogy

Do you think that this man is dangerous?

Jesse– ρ_1

Narrative – thermal readout

Hank– ρ_6

Narrative – thermal readout

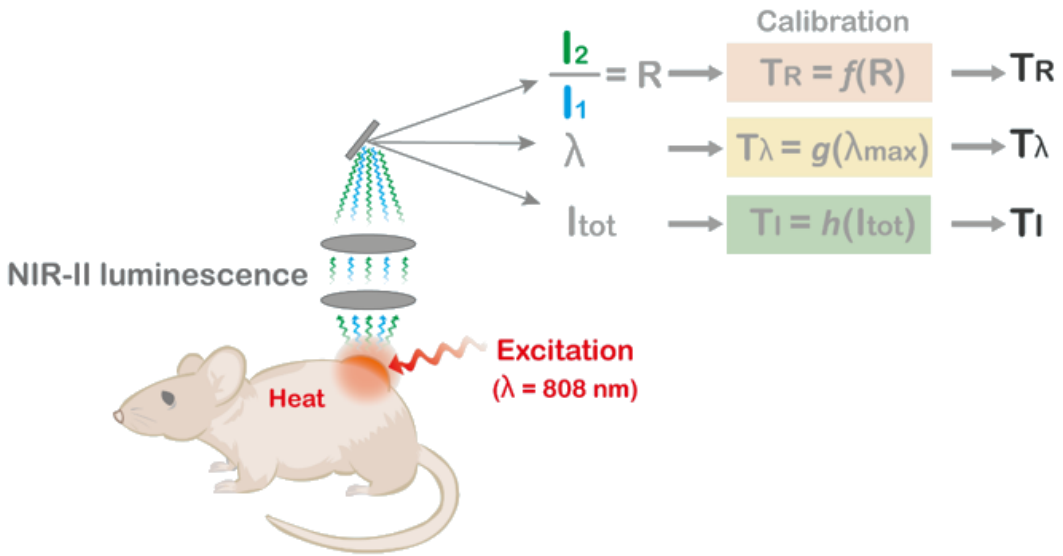
Tuco – ρ_2

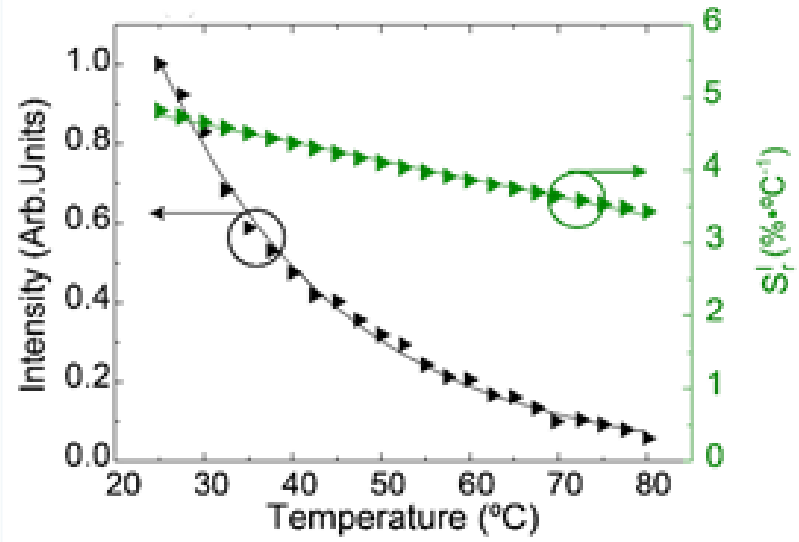
Skyler– ρ_3

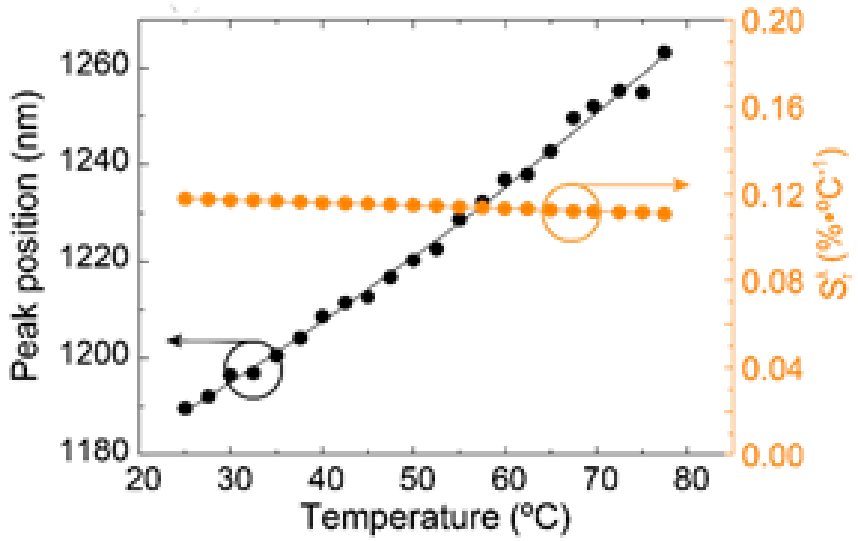
Marie– ρ_4

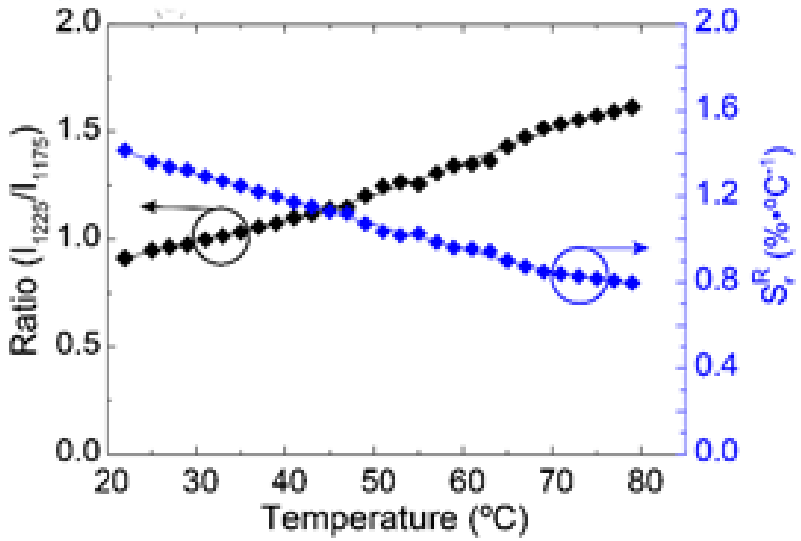
Saul– ρ_5

Depiction of the experiment

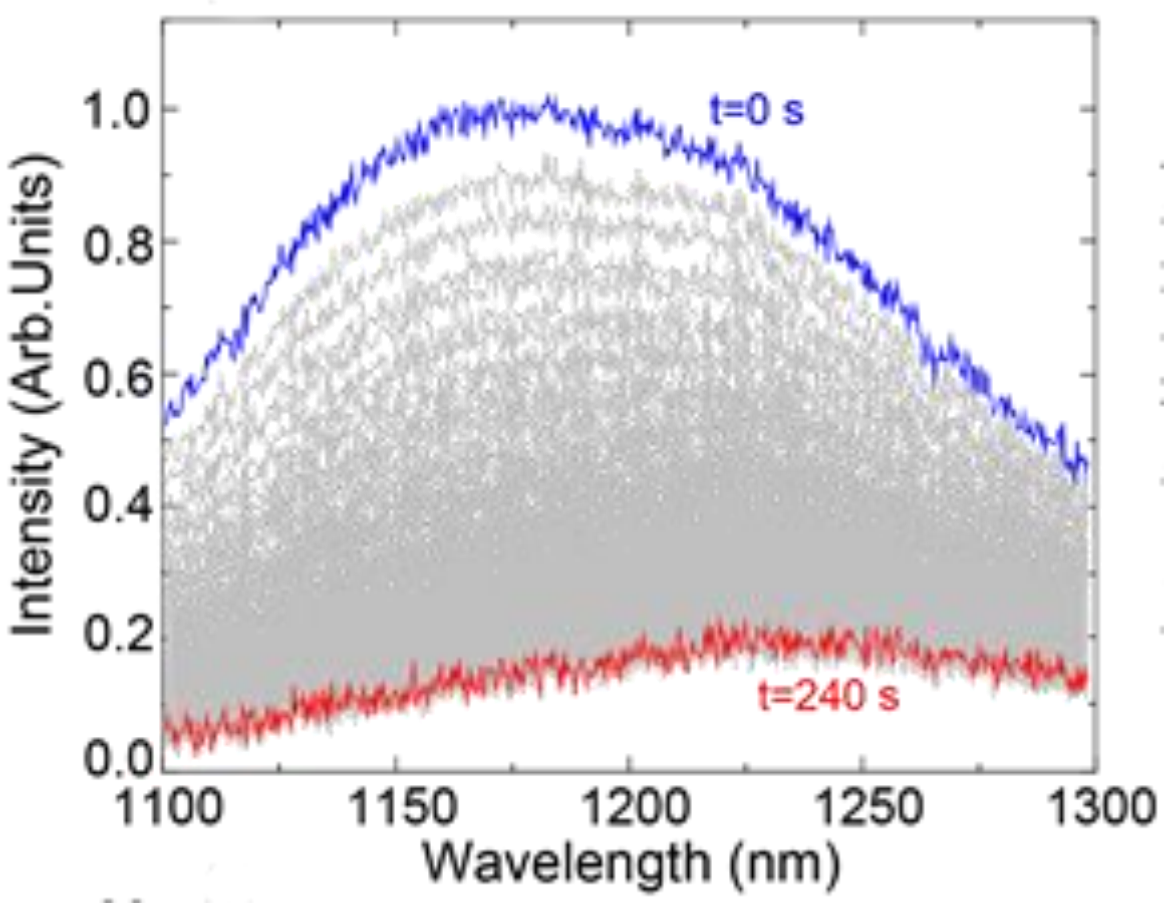


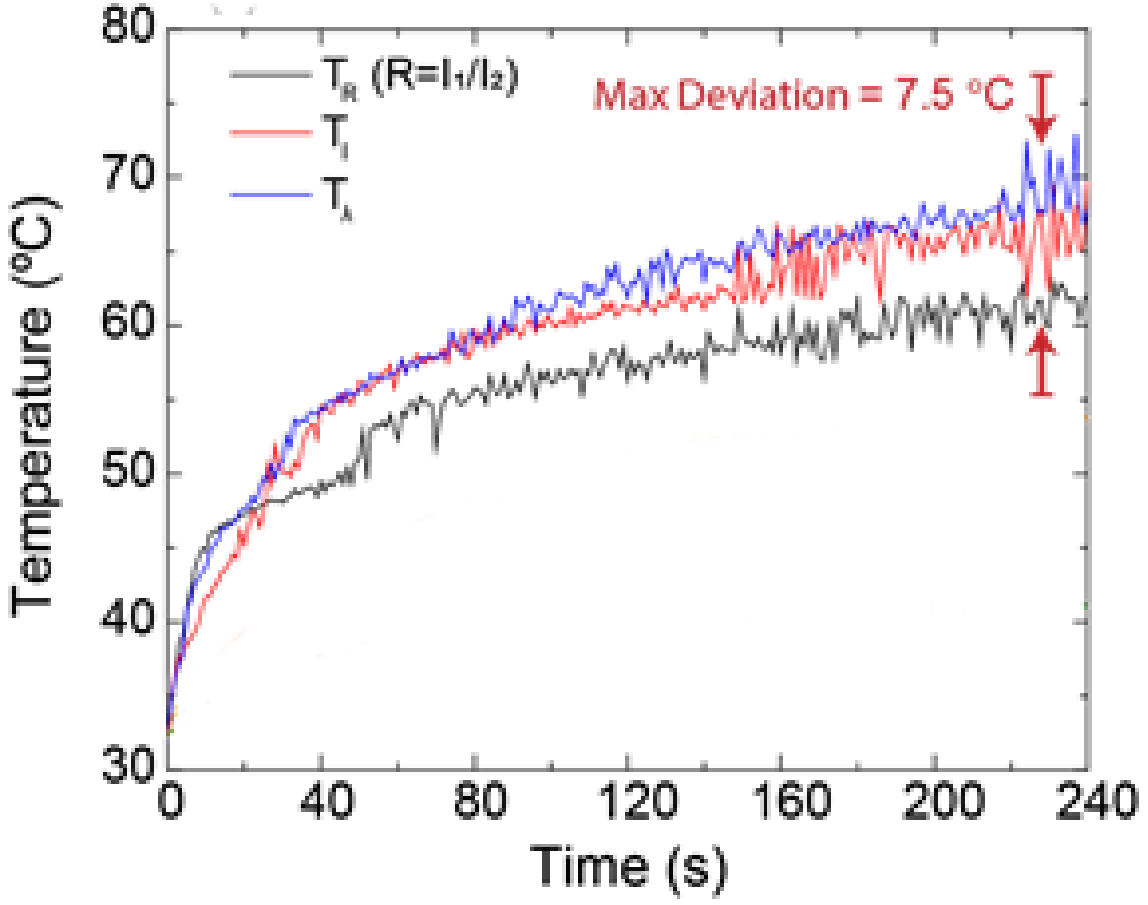




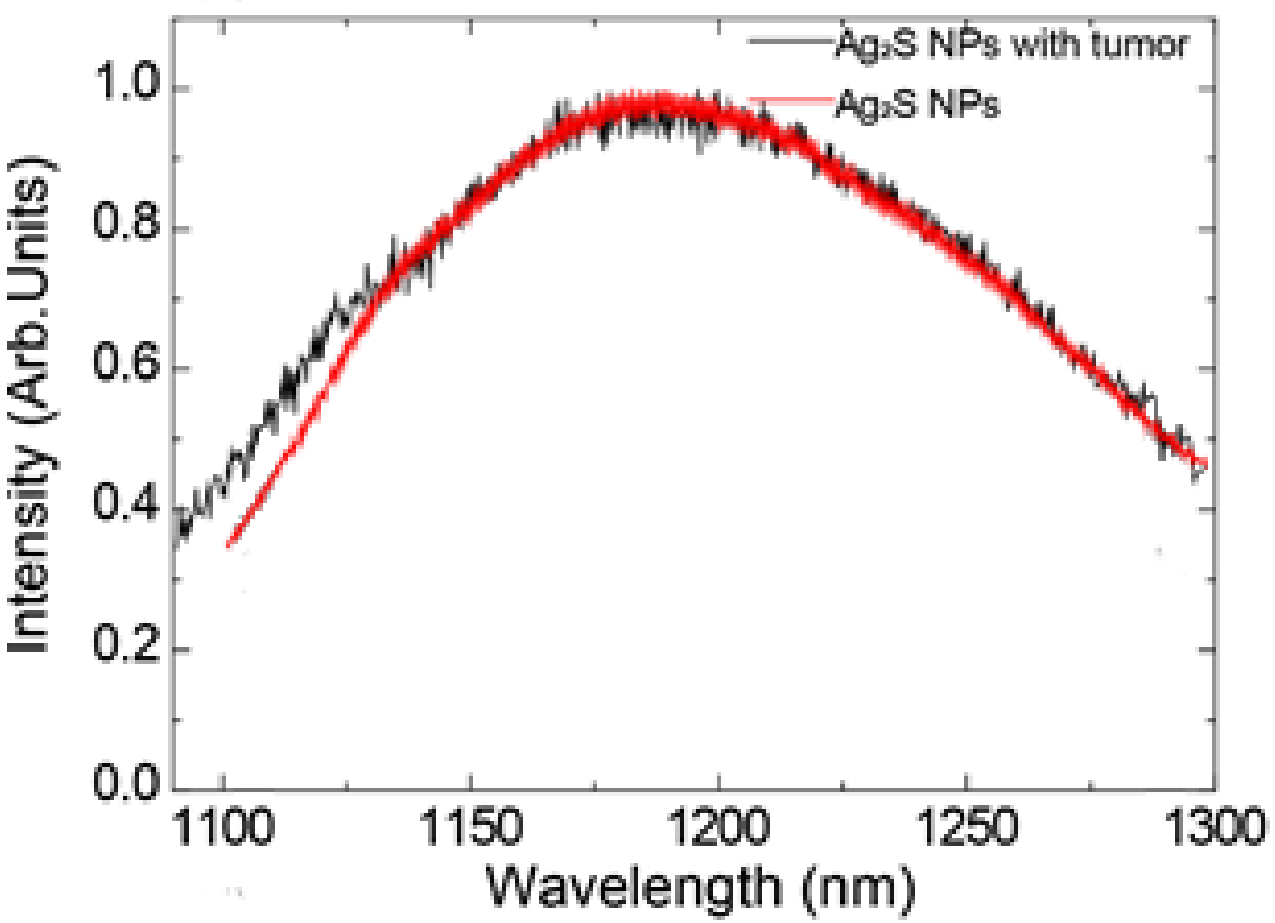


An arbitrary selection of the thermometric parameters will provide conflicting termal readouts.

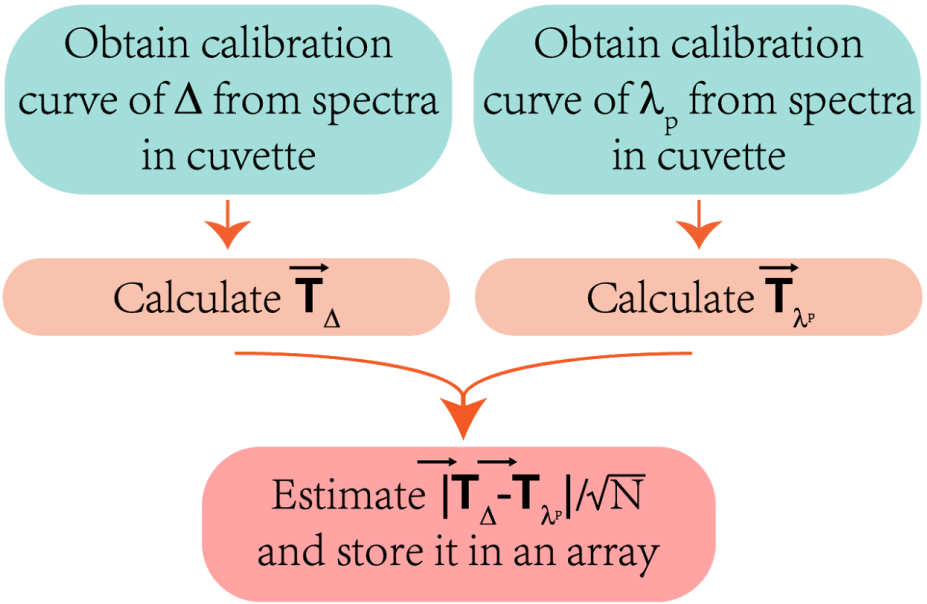




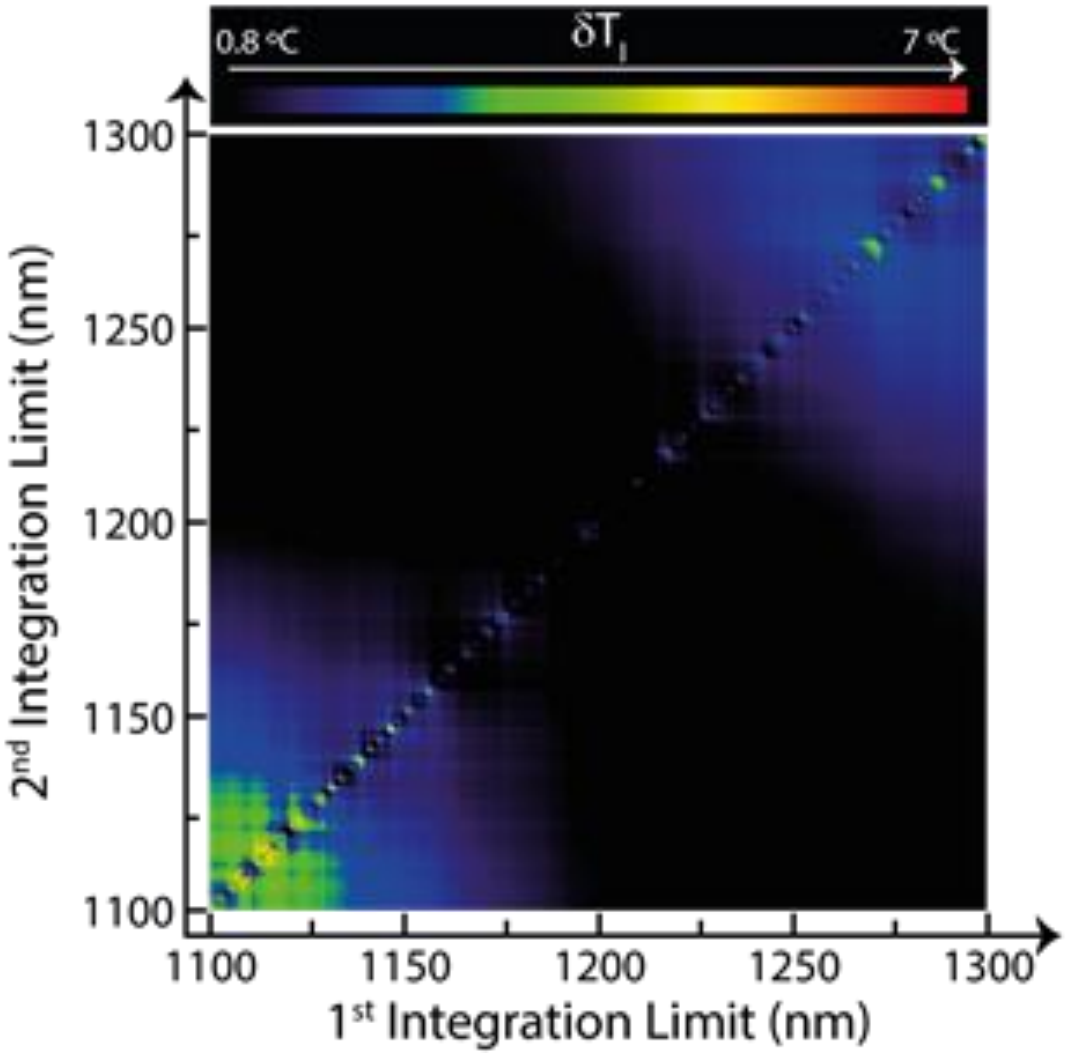
What seems to be the most reliable witness in our case?



The peak position!

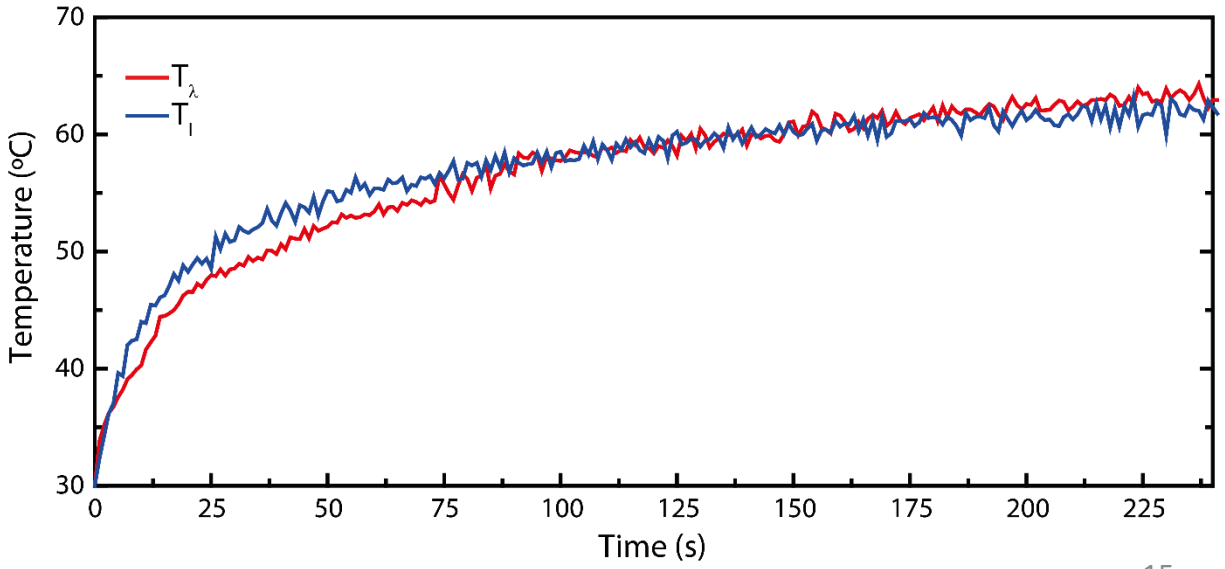


We found other parameters that agree with the trusted one.



After an iterative search, the best wavelength range to integrate the intensity was found to be:

$$\int_{1175\ nm}^{1260\ nm} I(\lambda)d\lambda$$



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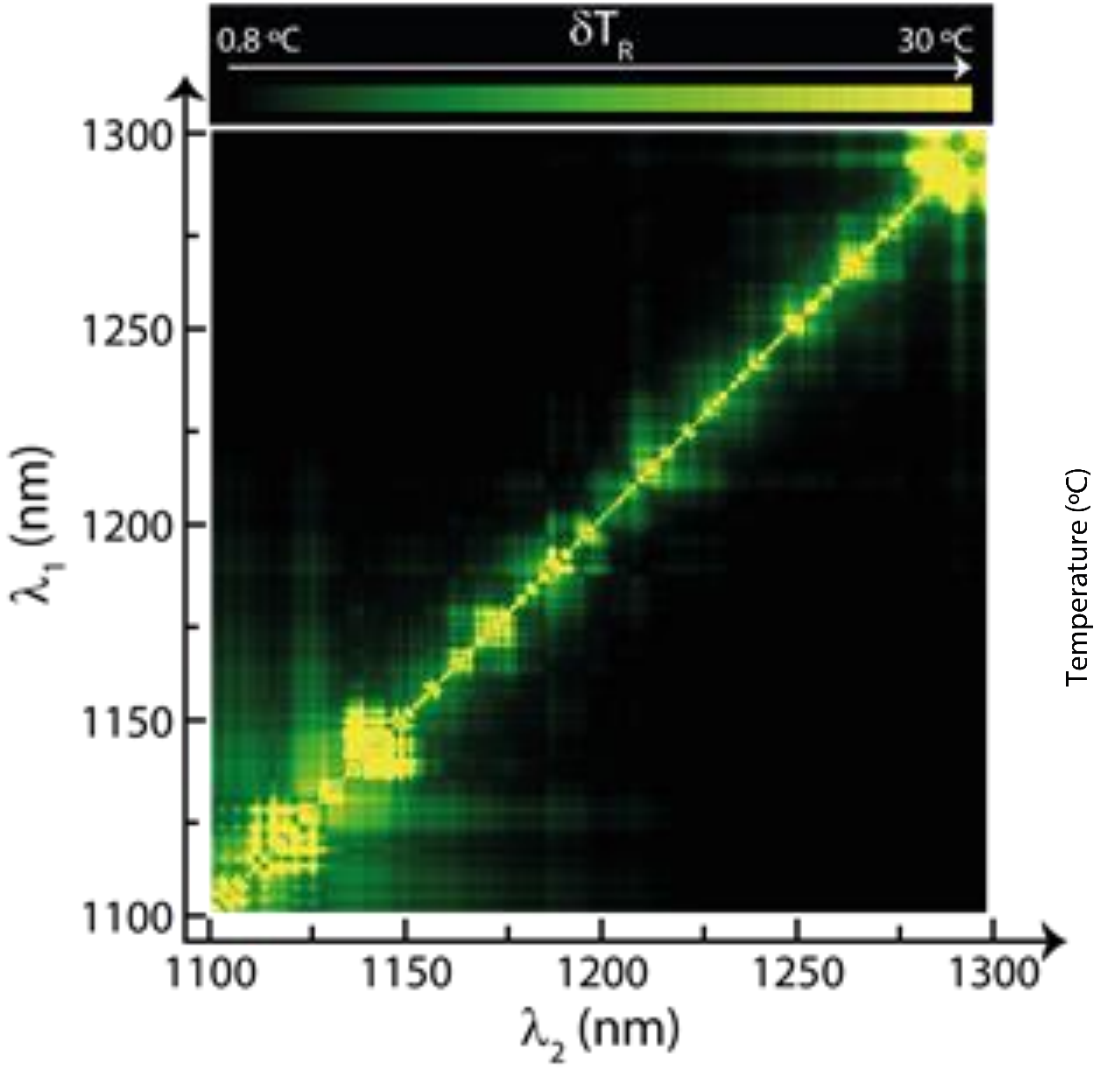
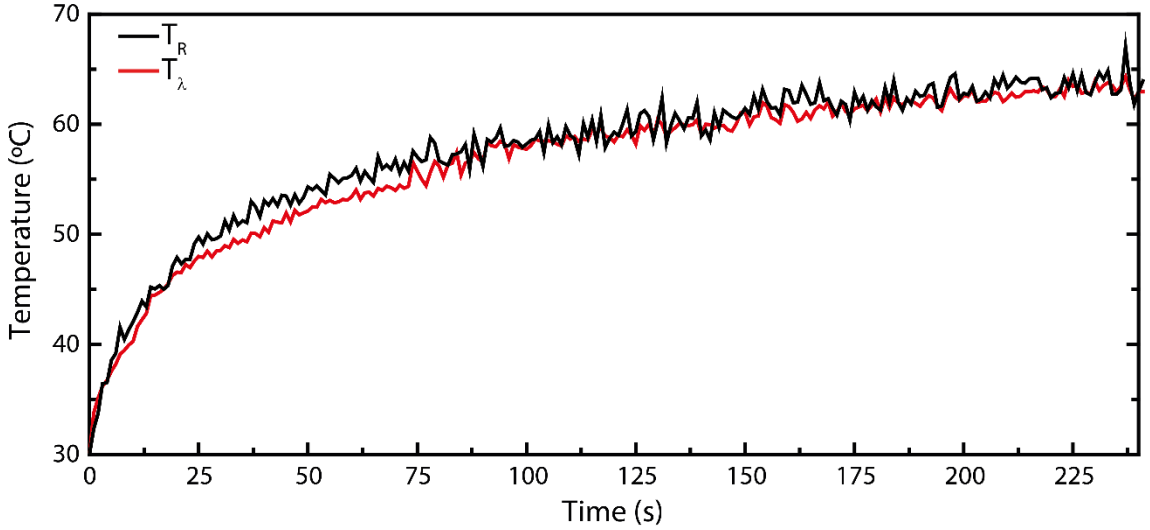
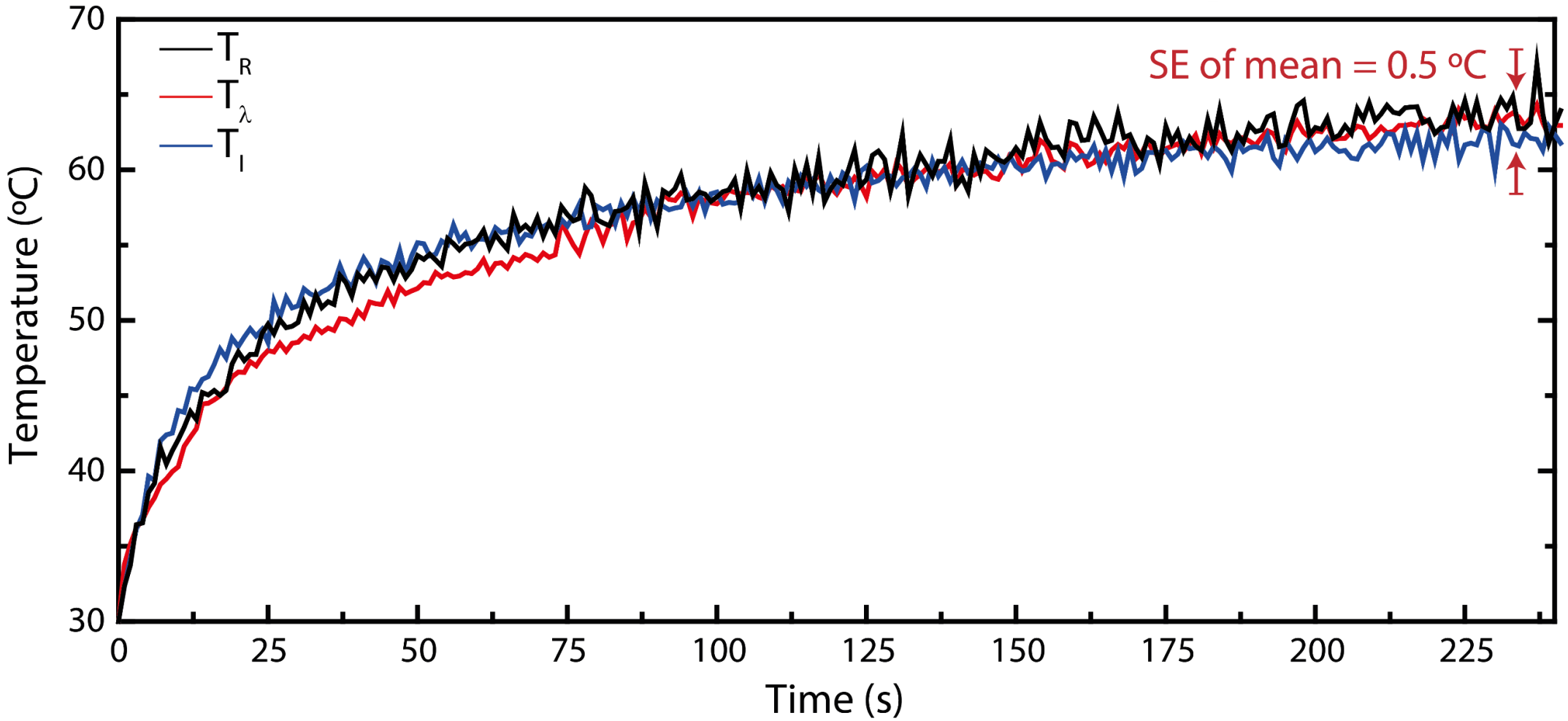


After an iterative search, the best intensity ratio was found to be:

$$I_{1170\pm5nm}/I_{1256\pm5nm}$$



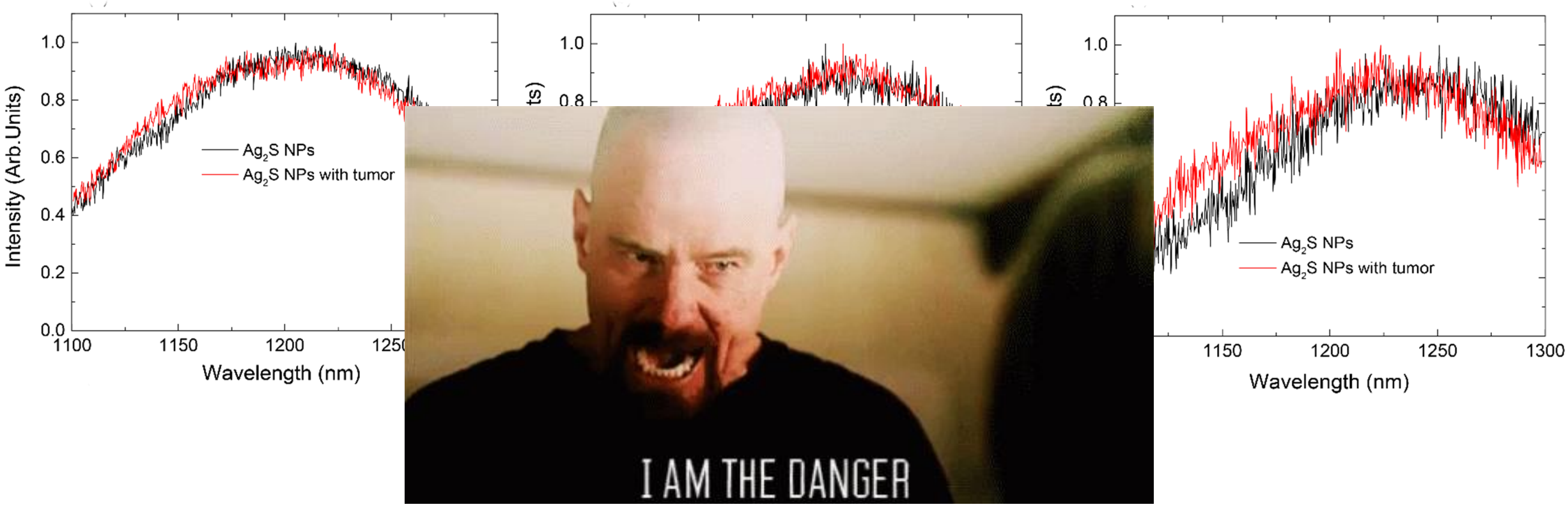
We can find three thermometric parameters, computed in three different ways, whose termal readouts differ in only 0.5 ºC.



Shen et al, Advanced Functional Materials, **2020**, DOI: 10.1002/adfm.202002730

Results

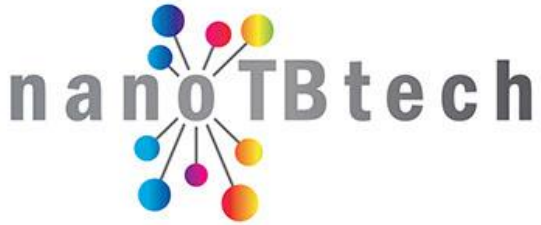
- Besides impressive agreement, what makes you trust that your witnesses are not in a plot?

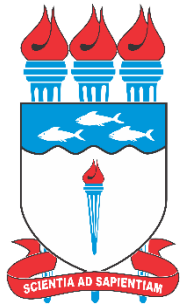


Conclusions/Perspectives

- The strategy of multiparametric thermal sensing can be reasonably applied to cases where there is at least a clue about the minimal interference of the tissue over a specific thermometric parameter.
- For the case of Ag2S NPs found in superficial tumors, this parameter seemed to be the peak position.
- Similar thermal readouts were iteratively found and, through ex vivo calibration, it was found that they were also minimally affected by the tissues.
- The approach, though not universal, could still be applied in many situations.

Acknowledgements





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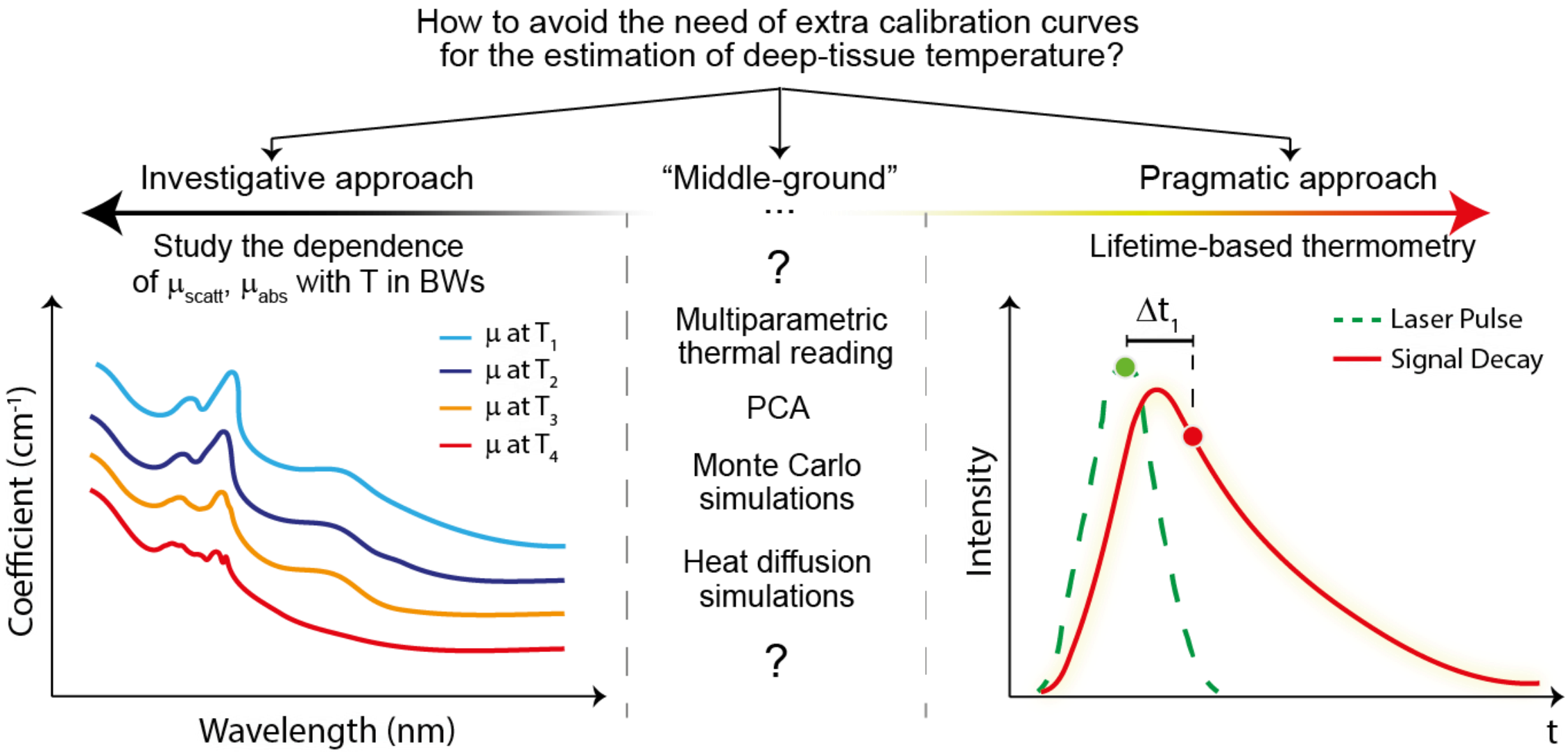
de aveiro

UAM

Appendix


How to avoid the need of extra calibration curves for the estimation of deep-tissue temperature?
Investigative approach
"Middle-ground"
Pragmatic approach
Study the dependence of μ_{scatt}, μ_{abs} with T in BWs
?
Multiparametric thermal reading
PCA
Monte Carlo simulations
Heat diffusion simulations
?
Lifetime-based thermometry
μ at T_1
μ at T_2
μ at T_3
μ at T_4
Coefficient (cm^{-1})
Wavelength (nm)
Δt_1
Laser Pulse
Signal Decay
Intensity
t