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# Nanothermometry of gold nanoparticles

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## Background and Motivation

**Metallic nanoparticles (NPs)** are uniquely strong absorbers and re-emitters of light, especially when illuminated near their resonance wavelength. The position of this resonance depends on factors including NP shape and size [1].

***Impact*** - Understanding how NPs heat up under illumination unlocks **potential applications** [2,3] in:

**targeted cancer treatment** | **reaction catalysis**

Recent literature [4] has used the spectrum of re-emitted light to **extract the NP temperature:** this is known as **photoluminescence nanothermometry**.

## Research Objectives

***R.O. 1*** Develop novel methods of nanothermometry; test
(i) **accuracy** of each method
(ii) **consistency** between methods

***R.O. 2*** Use these methods to investigate relationship between NP size and its temperature increase when illuminated

## Theory

1. NP is illuminated. Some NP carriers absorb incident photons and are excited.
2. Excited carriers interact with other carriers/phonons, losing or gaining energy. These interactions depend on the NP temperature.
3. Excited carrier pairs recombine, emitting a photon as **photoluminescence.**

The ratio between two photoluminescence spectra from the same NP under different illumination powers [4], e.g. between a spectrum of interest and a reference spectrum, is:

**Equation (1)**

$$\frac{I}{I_{ref}} = \frac{P}{P_{ref}} \frac{e^{\frac{hc}{kT_{ref}}\left(\frac{1}{\lambda}-\frac{1}{\lambda_{laser}}\right)}-1}{e^{\frac{hc}{kT}\left(\frac{1}{\lambda}-\frac{1}{\lambda_{laser}}\right)}-1}$$

I: spectral emission P: power T: temperature λ: wavelength

We can use (1) to develop **4 novel analytical methods of photoluminescence nanothermometry**.

## Methods

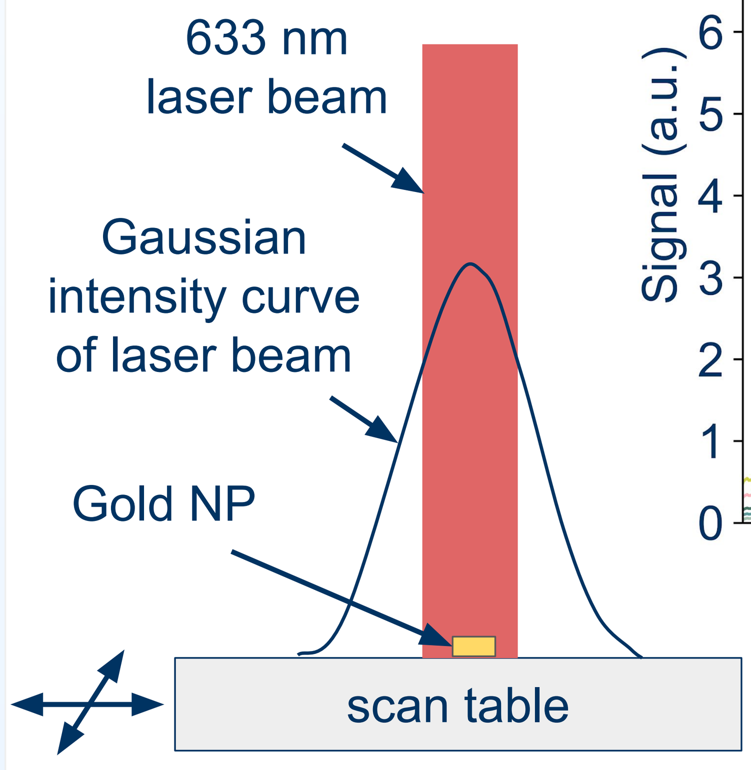


**Fig. 1** Schematic of set-up to measure photoluminescence spectrum of NP at different laser powers

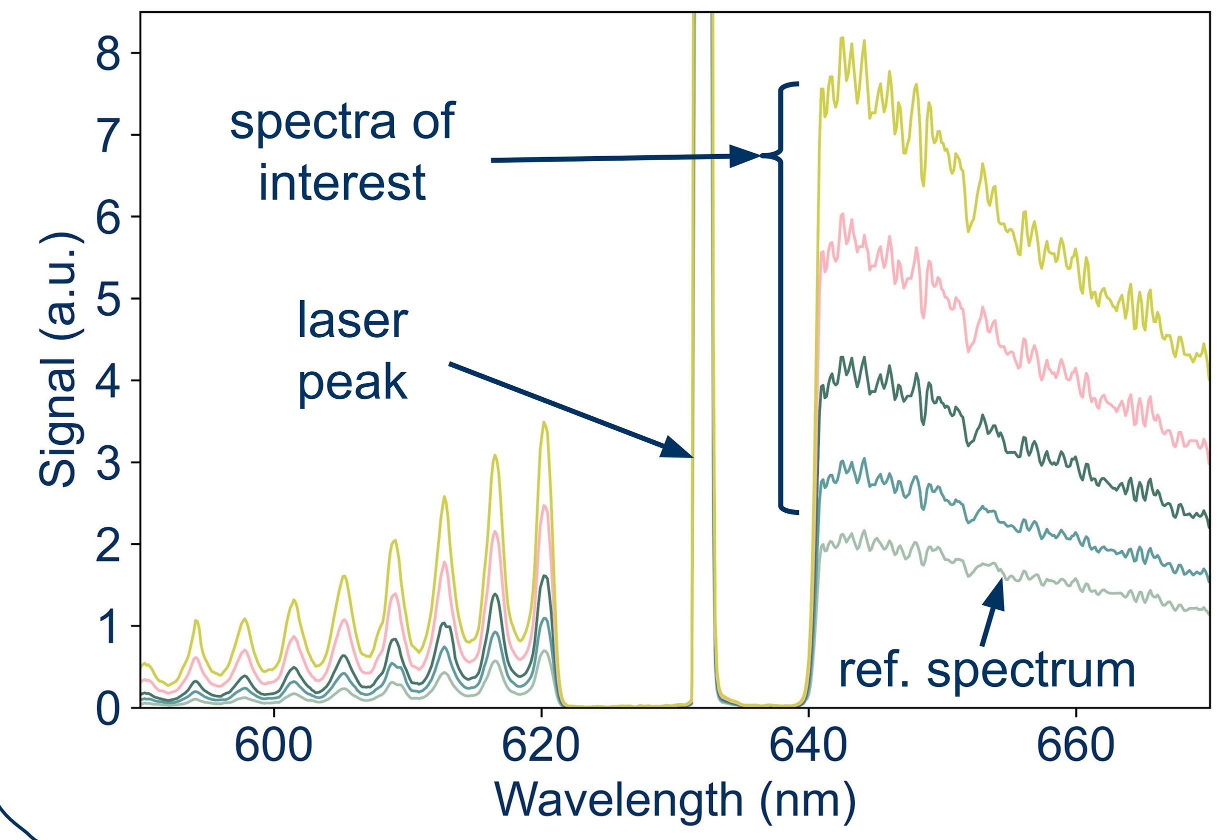


**Fig. 2** 5 photoluminescence spectra for the same 70nm particle, at different laser powers

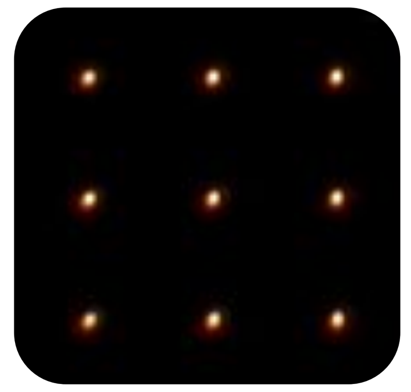

**Fig. 3** NPs illuminated by dark field lamp

1. Measure NP photoluminescence spectra at range of laser powers by moving NP within laser beam
2. Apply equation (1): use each of our 4 analytical methods to extract NP temperature at each laser power
3. Determine and compare temperature-power relationship between the 4 analytical methods
4. Repeat 1-3 for NPs over range of sizes

## Results

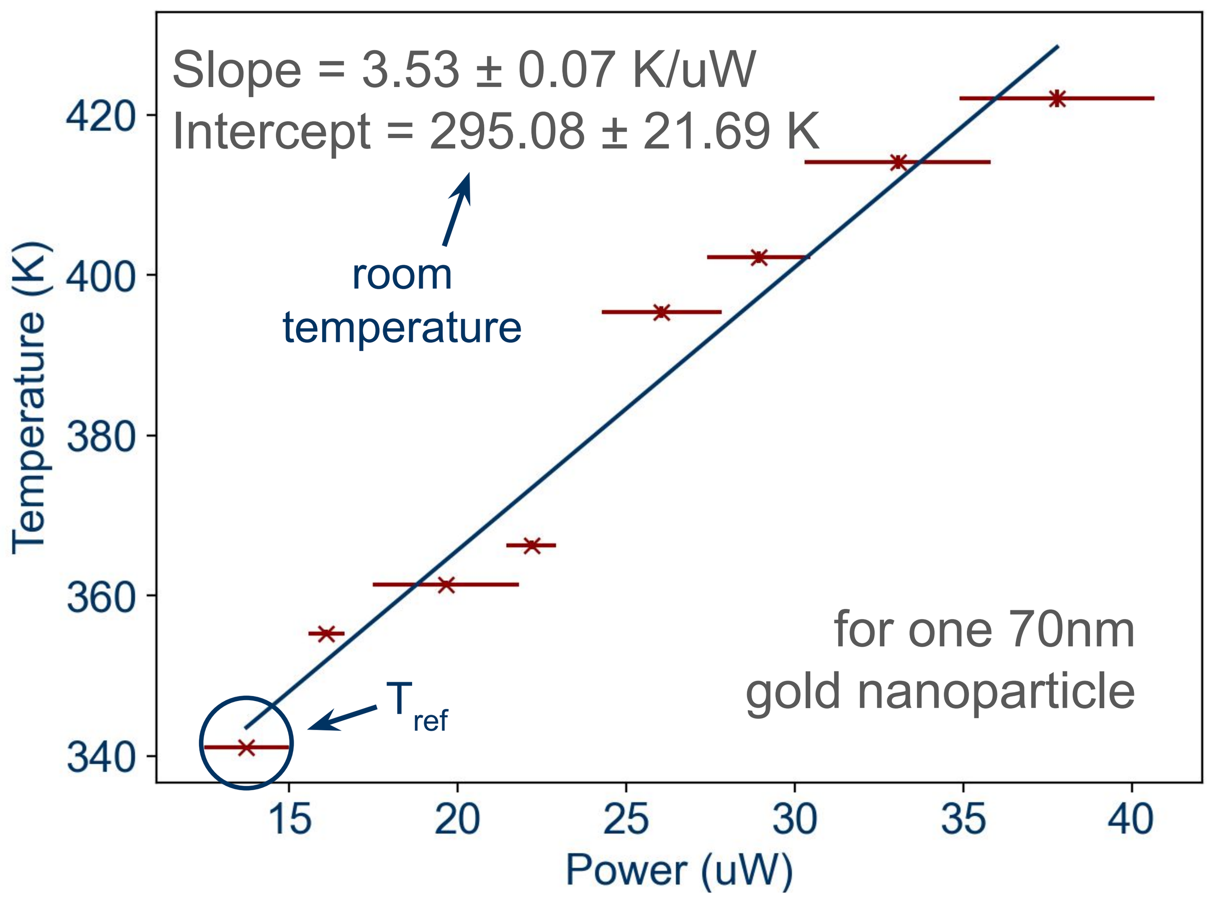


**Fig. 4** For 1 NP, using one of 4 analytical methods: extracted NP temperature against illumination power. $T_{ref}$ from equation (1) is calculated iteratively until intercept lies at room temperature as shown.

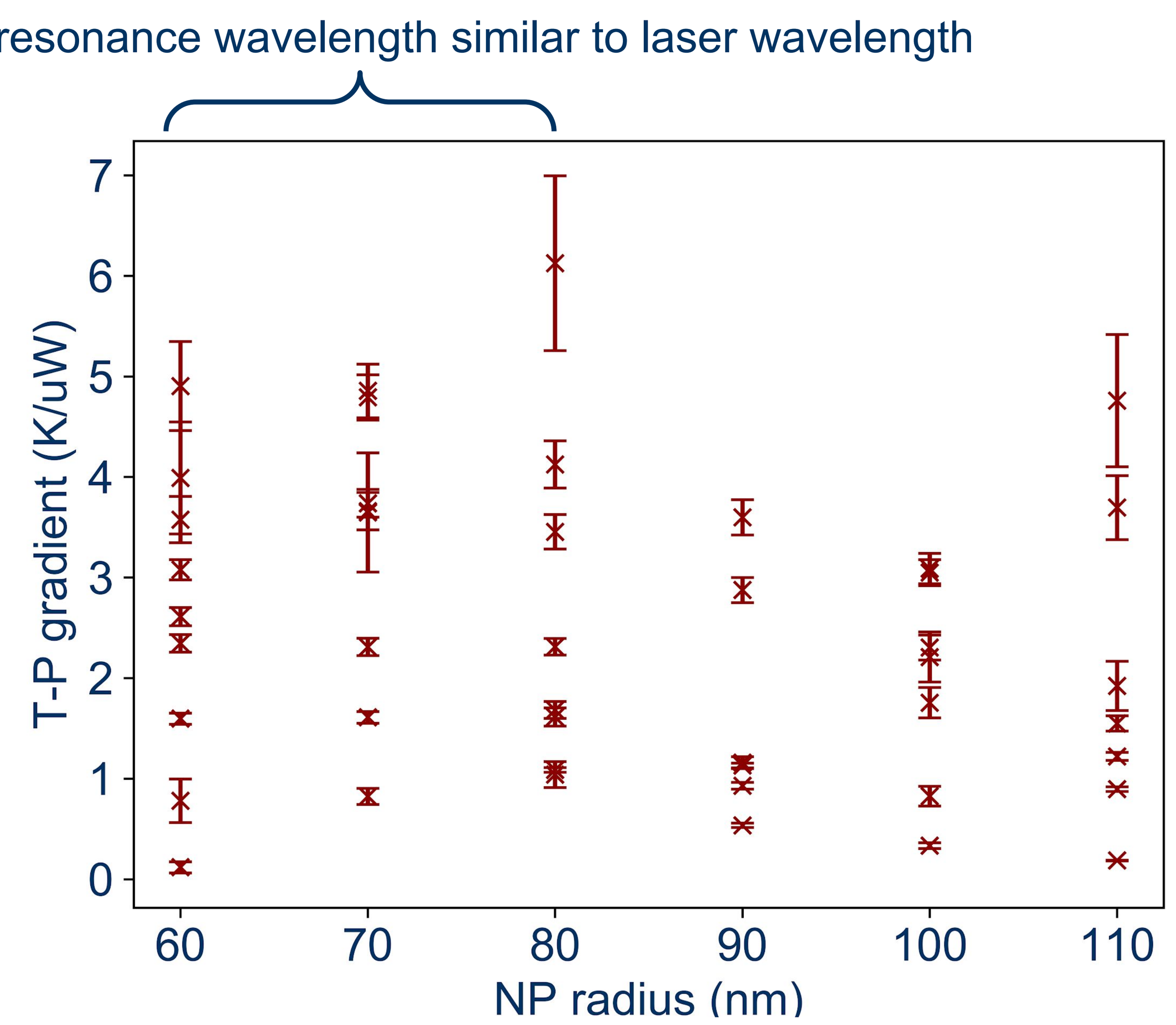


**Fig. 5** Gradient of temperature-power graph against NP radius. Each data point represents a different NP. Error bar shows range of gradients returned by 4 analytical methods.

- ***R.O. 1* (ii)**: 4 methods of photoluminescence nanothermometry developed return **consistent** results for each NP
- ***R.O. 2***: NPs near 70nm (which have NP resonance nearest laser resonance) may have greater heating efficacies, but spread far too large to conclude this at present

The NP temperature-power gradient (e.g. as in Fig. 4) describes the **efficacy of the NP heating process**

## Next steps

- Address ***R. O. 1 (i)*** Compare NP temperatures extracted using 4 nanothermometry methods to temperature extracted using established Raman thermometry method
- Investigate why NPs of same size show wide range of heating behaviour (see Fig. 5)

## References

[1] El-Brolossy, T. A., et al. "Shape and size dependence of the surface plasmon resonance of gold nanoparticles studied by Photoacoustic technique." *Eur Phys J Spec Top* 153.1 (2008): 361-364
[2] Hainfeld, James F., Daniel N. Slatkin, and Henry M. Smilowitz. "The use of gold nanoparticles to enhance radiotherapy in mice." *Phys. Med. Biol.* 49.18 (2004): N309
[3] Thompson, David T. "Using gold nanoparticles for catalysis." *Nano Today* 2.4 (2007): 40-43
[4] Carattino, Aquiles, Martín Caldarola, and Michel Orrit. "Gold nanoparticles as absolute nano-thermometers." *Nano Lett.*18.2 (2018): 874-880