

Upconverting nanoparticles working as primary thermometers in different media

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Lanthanide-doped nanoparticles have recently emerged as very attractive multifunctional systems with potential for simultaneous thermal sensing and bio-imaging, due to near-infrared excitation and emission in the visible and near infrared spectral regions [1]. Non-invasive luminescent nanothermometry becomes popular in the last decade due to the limitations of traditional contact thermometers to operate at scales below 100 μm , as required by current technological demands in areas such as microelectronics, microoptics, photonics, microfluidics, and nanomedicine [2]. Generally, the usual calibration procedure of luminescent thermometers requires an independent measurement of the temperature to allow the corresponding conversion between the thermometry parameter (usually relative intensities) and temperature. A new calibration procedure is, then, necessary whenever the thermometer operates in a different medium, as other variables, such as the ionic strength, pH, pressure, or atmosphere composition impact the thermometric parameter. However, recording multiple calibrations in different medium is a time-consuming task and is not always possible (e.g., at the submicrometric scale). In general, a unique calibration relation is assumed to be valid, independently of the medium, which is a central bottleneck of secondary luminescent thermometers.

Here we show that the temperature calibration curve of upconverting luminescent thermometers can be predicted by the Boltzmann distribution, independently of the medium where the material operates. We illustrate this concept using SrF₂:Yb/Er upconverting nanoparticles in powder and in water suspensions that are primary Yb/Er co-doped luminescent nanothermometers. The maximum relative thermal sensitivity of the primary thermometer in the physiological temperature range (302–385 K) in two distinct mediums (powder and water suspension) is $1.159 \pm 0.004\%K^{-1}$.

[1] Bettinelli, M., Carlos, L.D., & Liu X. (2015). *Phys. Today* 68, 38-44.

[2] Brites, C.D., Xie, X., Debasu, M.L., Qin, X., Chen, R., Huang, W., Rocha, J., Liu, X., & Carlos, L.D. (2016). *Nat. Nanotechn.* 11, 851-856.

Keywords: [SrF₂:Yb/Er upconverting nanoparticles, nanothermometry, primary thermometers](#)