Bias-free multiparametric luminescence sensing by a single upconverting particle

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Abstract: Very recently, it has been demonstrated how single laser beams can not only trap but also induce rotation of birefringent upconverting particles. [5] The rotation dynamics of these microparticles has been found to be strongly dependent on the rotating mass and environmental conditions (e.g., viscosity, temperature, etc.) so that they have been introduced to the scientific community as a potential high-sensitivity sensors. [6, 7]

In this work, we have taken advantage of the sensing properties of NaYF₄:Er,Yb micron-sized particles to develop a contactless temperature and viscosity sensor, by analyzing its emission spectrum.

1 Introduction

Sensing at the micro/nano scale is one of the most challenging topics that the scientific community is nowadays facing and are becoming increasingly important for applications spanning biomedical diagnosis, biosensing, environmental monitoring or nanostructure assembly. It should be ideally done in a contactless way for a twofold reason: a) to reduce or avoid the risk of cross-contamination; and b) to keep the external perturbation over the sample at minimum values.

In this context, biophotonics has emerged as a possible alternative to traditional methods. A variety of optical methods has been developed based on spectroscopy and microscopy approaches that exploit the light–matter interaction. Different types of inorganic micro/nanoparticles have raised great expectations over the traditional organic fluorophores because of their attractive optical and chemical features. Among the different particles used in biophotonics, upconverting particles have attracted great attention due to their capability of infrared-to-visible optical conversion through sequential multistep absorption of infrared photons. This makes possible the acquisition of high resolution and low background bioimages. One of the most commonly used upconverting particle for thermal sensing is NaYF₄ doped with Er³⁺ ions. The ratio of the relative intensities, from the radiative de-excitation of its thermally coupled states, is temperature-dependent on excitation since the emitted intensities are proportional to the population of the corresponding excited states. [1, 2]

Optical trapping has emerged as a reliable technique to achieve precise translation and rotational control over micro/nanostructures. It is a contactless technique that has been already used for long-term studies of single cells and bacteria. [3, 4] Very recently, it has been

2 Methods

The NaYF₄:Er,Yb microparticles were synthesized by hydrothermal method and dispersed in D₂O at a very low concentration to avoid multiple particle trapping. [5] The solution was introduced into a 120 µm height microchamber. A linearly polarized 808 nm, single-mode, fiber coupled diode laser was used as the optical excitation source. A quarter-wave plate placed afterwards converted the laser beam into circularly polarized light. Optical excitation at 808 nm was selected as it keeps at minimum the laser-induced thermal loading of the microspinner and surrounding medium. The NaYF₄:Er,Yb microparticles used here show an intense visible emission when optically excited by 808 nm radiation thanks to a multiphoton excitation process already described elsewhere. [8] The visible emission spectra generated by our NaYF₄:Er,Yb microparticles is collected by a spectrometer.

3 Result and discussion

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Figure 1(a). Emission spectra of an optically trapped single microparticle when excited at 808 nm. The two spectra correspond to different detection angle (0º and 90º).

(b) Temperature-dependent ratio between the two green bands.

(c) Viscosity dependence as a function of the angular velocity, extracted from the red emission band.

Finally, we want to demonstrate the capacity of the NaYF<sub>4</sub>:Yb<sup>3+</sup>, Er<sup>3+</sup> upconverting microparticle for local and remote sensing at the microscale by luminescence signal analysis. With that purpose, the dispersion was introduced in a microchannel and a single microparticle was trapped (Figure 2(a)). After that, a viscous solution was also introduced. The luminescent signal was monitored in real time, and the temperature and viscosity were obtained.

Under our experimental conditions, the temperature remains constant during mixing (Figure 2(b)), and the medium viscosity has increased (Figure 2(c)) up to 5 mPa·s.

4 Conclusions

This work has been partially supported by the Ministerio de Ciencia e Innovación de España (PID2019-105195RA-I00, CNS2022-135495, and TED2021-129937B-I00). E.O.R gratefully acknowledges the financial support provided by the Spanish Ministerio de Universidades, through the FPU program (FPU19/04803).

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