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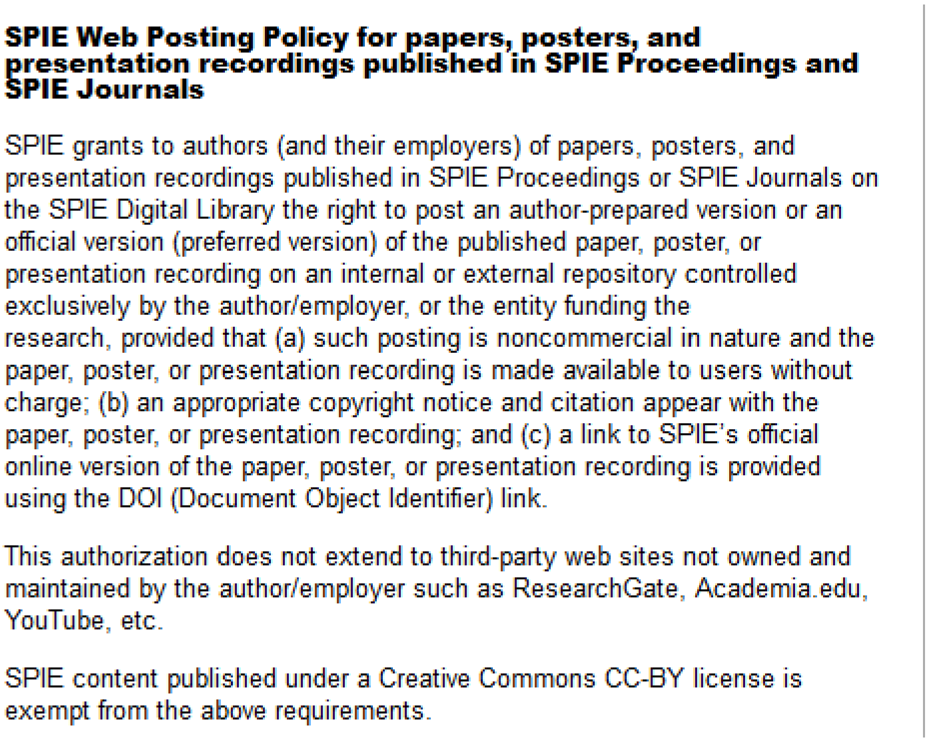

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ABSTRACT

Nanoscale thermometry of biological systems offers new insights into cell metabolism at a sub-cellular scale. Currently, there is no way in which we can achieve high resolution temperature sensing on these systems without the use of foreign materials such as biological markers. Using rare-earth doped tellurite glass as a platform for thermometry, we report micron scale scale temperature sensing via confocal scanning microscopy. We demonstrate this technique by monitoring the cooling from a water droplet and report a net temperature change of 7.04K with a sensitivity of 0.12K. These results pave the way for "marker free" micron scale temperature sensing in biological systems.

1. INTRODUCTION

Temperature sensing with optical probes has been studied extensively due to advantages such as physical stability and high sensitivity. One recent development through optical analysis involves the use of lanthanide doped glasses to sense changes in temperature,[1,2] as these glasses show excellent prospects for accurate temperature measurement due to their high sensitivity and fast response rates. Many optical temperature probes that utilize these glasses involve coatings in order to resolve small areas, however to obtain spatial information the probe must be moved, thus limiting the ability to acquire measurements at multiple locations within a short time period. We solve this problem by using Er^{3+}:Yb^{3+} doped tellurite (hereafter referred to as Er:Yb:tellurite) as a platform for sensing small temperature changes.

2. METHOD

The thermometry process that we use is governed by the two-photon upconversion photo-emission of different population states, these correspond to three main emission bands Fig.1a. In our thermometry modality, we focus on the emission ratio of the $\mathrm{H}_{11/2}$ and $\mathrm{S}_{3/2}$ states. The change in these two bands has been well documented to correspond to variations of temperature.[1,3] In order to achieve high spatial resolution we adopt scanning confocal microscopy (SCM) Fig.1b, where a focussed beam is used to scan a small area of our Er:Yb:tellurite substrate. Using this technique we are able to measure a fluorescence intensity map of a 0.5μL droplet on the surface of our substrate as shown in Fig.1c.

3. RESULTS

A confocal scanning map of the edge of a water droplet is shown in Fig.1c, where each pixel has a width of 1μm. The spatial resolution of this map is limited to the spot size of the confocal beam we use to interrogate our substrate. With this we are able to determine the spectral components of the two green emission bands at 524 and 547nm at each individual pixel. The spectral response to temperature is pre-calibrated, to allow for us to estimate the effective temperature of unknown quantities placed on the substrate. Monitoring the ratio between these two bands resulted in a net decrease in temperature over 180 seconds as shown in Fig.1d. Here we report a total temperature change of 7.04K ±0.12K as a result of the droplet cooling the Er^{3+}:Yb^{3+} tellurite glass. The uncertainty in our measurements is derived from the average variations in room temperature from our external

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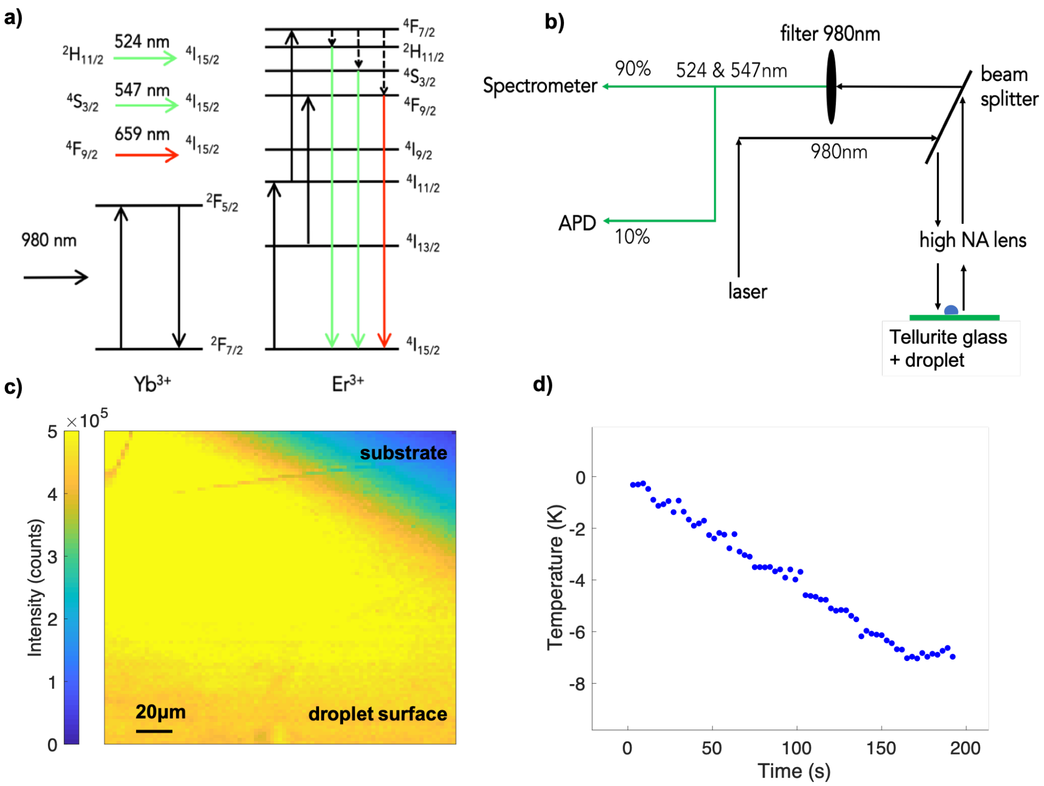

Figure 1. a) The energy band diagrams for Er^{3+} and Yb^{3+}, where Yb^{3+} acts as a sensitiser increasing the probability for photoemission. b) A schematic of the SCM method, we use this to obtain a signal from the two emission bands of 524 and 547nm. c) A confocal fluorescence intensity map of a water droplet on our Er:Yb:tellurite substrate. d) When focused on the droplet we observe a temperature change due to the cooling effect of the droplet on the substrate.

sensor (408-6109, RS Components, UK) over 300 seconds. This result is also mirrored by a similar change in our measured emission band ratio over the same acquisition time, showing that we are able to achieve micron scale resolution temperature sensing.

In summary we are able to show a micrometer resolution confocal map of a water droplet using Er:Yb:tellurite glass. Over a time period of 180 seconds we report a temperature change of 7.04K due to the cooling effect of a water droplet. This proof of concept experiment paves the way for measuring small changes in temperature with micron scale resolution for biological and chemical systems.

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