TECHNICAL NOTE

ABSOLUTE QUANTUM YIELD OF UV-TO-NIR EMITTING SAMPLES

EDINBURGH INSTRUMENTS

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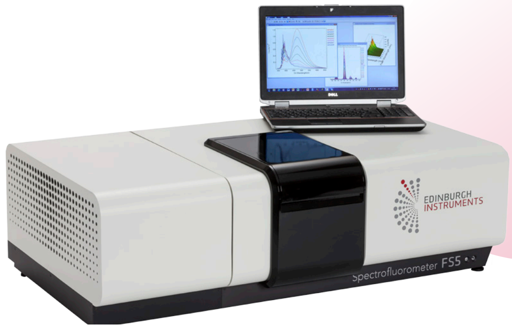
INTRODUCTION

The photoluminescence quantum yield (QY) or quantum efficiency η is one of the core parameters in the characterisation of luminescent materials[1,2]. The absolute QY, defined as the ratio of the photons emitted by the material over the absorbed photons, has widely replaced the relative QY method, requiring a fluorescent standard of known QY. It also constitutes a simpler method relying on minimum alignment and calibration compared to thermal lens/beam deflection and photoacoustic methods[3]. Instead, a fluorescence spectrometer equipped with an integrating sphere is employed in the absolute method.



FS5 Spectroflurometer

METHODS AND MATERIALS

Liquid and solid materials were measured spanning excitation and emission wavelengths from the UV to the NIR. LED phosphor powders and thin films doped with lanthanides such as Cerium (Ce^{3+}), Terbium (Tb^{3+}) and Europium (Eu^{2+}) were measured in standard PTFE trays. In the NIR range, semiconductor nanocrystal lead sulfide (PbS) quantum dots (QD-NIR-1V, Ocean Optics) in toluene were dispensed into 10 mm path-length quartz cuvettes.

Excitation and emission spectra were measured in a fluorescence spectrometer FS5-NIR equipped with an integrating sphere module (SC-30) and a single photon PMT detector (Hamamatsu, R2658P) extending the emission detection range to 1010 nm. For liquid samples a measurement over the scattering L_{sam} and emission E_{sam} of the sample, followed by a measurement of the solvent, also called reference or blank, L_{ref} and E_{ref}, as:

$$QY = \frac{E_{sam} - E_{ref}}{L_{ref} - L_{sam}}$$

For solid powder and thin film samples three measurements were performed for the calculation of the quantum yield: i) A measurement of the scattering without the sample, L_{ref}, ii) a measurement of the emission of the sample under direct excitation, E_{samdir}, and iii) a measurement of the scattering with the sample under indirect excitation, E_{samind}, as[4]:

$$QY = E_{samdir} - \frac{1-\left(1-\frac{L_{samdir}}{L_{samind}}\right) E_{samind}}{L_{ref}\left(1-\frac{L_{samdir}}{L_{samind}}\right)}$$

The calculation of the QY was performed in the wizard of the instrument's operating software, Fluoracle.

RESULTS - DISCUSSION

Figures 1 and 2 display the scattering and emission spectra of Ce^{3+} and Ce^{3+}/Tb^{3+}-doped phosphor, respectively.

In addition to the intense green emission, the QY increases from 85.1% for the Ce^{3+}-doped phosphor to 92% for Ce^{3+}/Tb^{3+}-doped phosphor[5,6].

Scattering, direct and indirect excitation emission spectra of a Eu^{2+}-doped thin film and PbS quantum dots can be seen in Figure 3 and 4, respectively. Note the considerable emission measured under indirect excitation of the thin film in the integrating sphere.

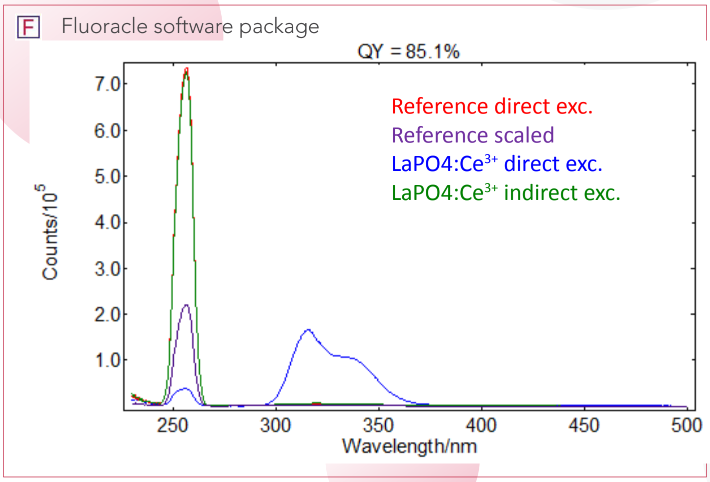


Figure 1: Scattering and emission spectra of $LaPO_4$:Ce^{3+} phosphor. The measurement conditions were: $\Delta\lambda_{exc}$=10 nm, $\Delta\lambda_{em}$=1 nm, step=0.5 nm, dwell=0.2s.

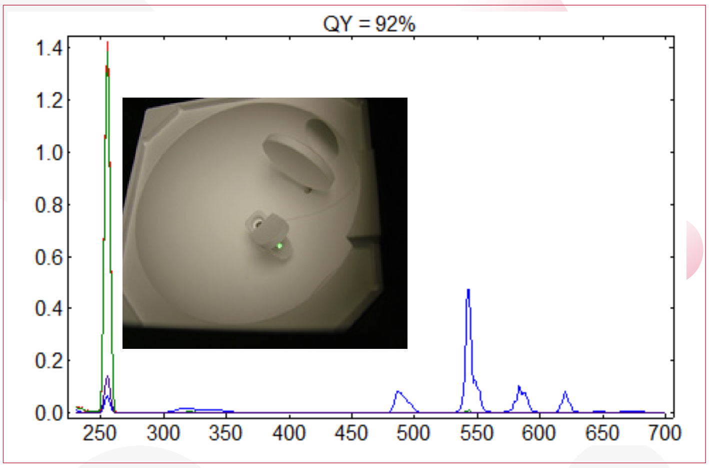


Figure 2: Scattering and emission spectra of Ce^{3+}/Tb^{3+}-doped phosphor. The measurement conditions were: $\Delta\lambda_{exc}$=10 nm, $\Delta\lambda_{em}$=0.5 nm, step=0.25 nm, dwell=0.1s.

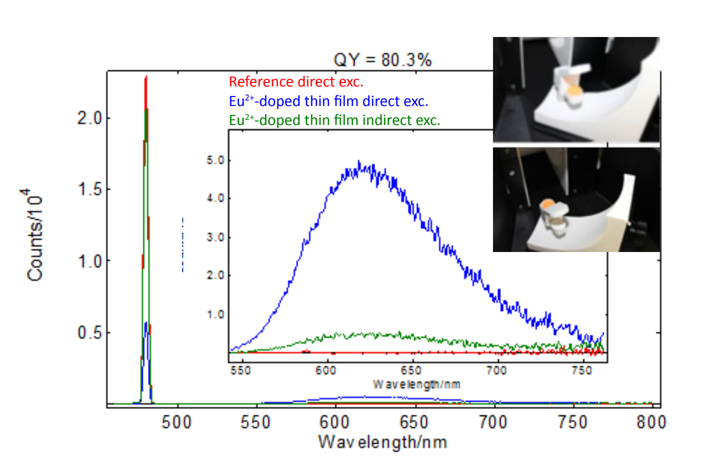


Figure 3: *Eu²⁺-doped thin film under (a) direct and (b) indirect excitation. The samples were excited at 480 nm with excitation and emission bandwidths $\Delta\lambda_{exc}$=3 nm and $\Delta\lambda_{em}$=0.2 nm, respectively, with a step of 0.25 nm and integration time of 0.1s.*

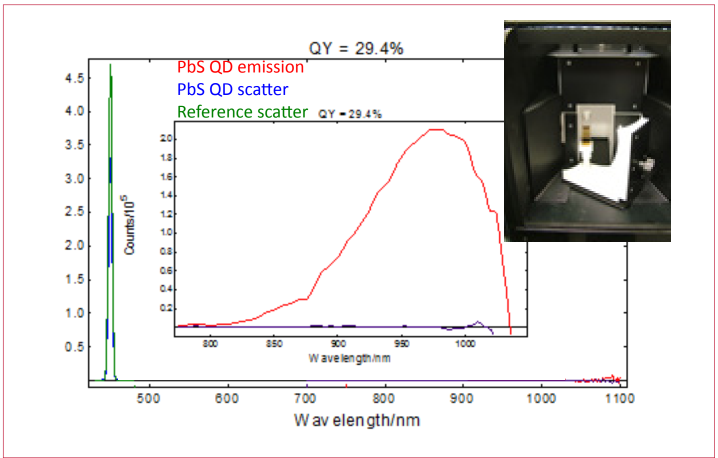


Figure 4: *Scattering and emission spectra of PbS quantum dots. Conditions were: $\Delta\lambda_{exc}$=5 nm, $\Delta\lambda_{em}$=2 nm, step=1 nm, dwell=0.5s.*

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