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Measuring PL Upconversion Spectra and Lifetimes of Lanthanide-Doped Nanoparticles

FL-40

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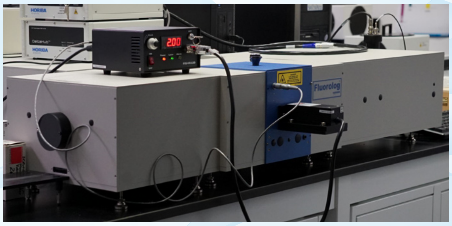
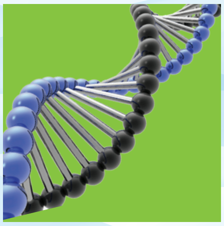




Fluorescence Upconversion Laser Accessories: FL-LAS-980 and QM-LAS-980

Introduction

Upconverting lanthanide-based nanomaterials exhibit a unique fluorescence anti-Stokes shift, which enables them to convert NIR wavelength excitation into visible shorter wavelength emissions (NIR to UV-Vis). Applications utilizing these light energy upconverters have been growing rapidly and include bioimaging, biosensing, solid-state lasers, photo-controlled delivery, photodynamic therapy, to name a few. Among various rare earth ions, trivalent erbium seems to be one of the most attractive choices due to its rich energy level structure which provides several potential emission channels in the short-wavelength part of the spectrum, including the most demanded green and blue regions.

Experiment and Results[1]

The Er^{3+} doped nanoparticles in hexane were excited using a cw DPSS laser with 980 nm output set at 1W (user adjustable). The laser was mounted to the front of a plug-in sample drawer assembly for the Fluorolog-3 spectrofluorometer with an electronic laser safety interlock, replacing the standard Fluorolog-3 sample compartment.

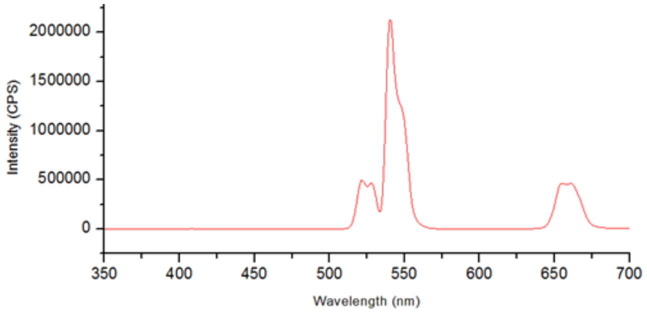


Figure 1: Steady state upconversion emission spectrum of Er3+ doped nanoparticles exhibiting 3 prominent peaks at 522, 540 and 661 nm.

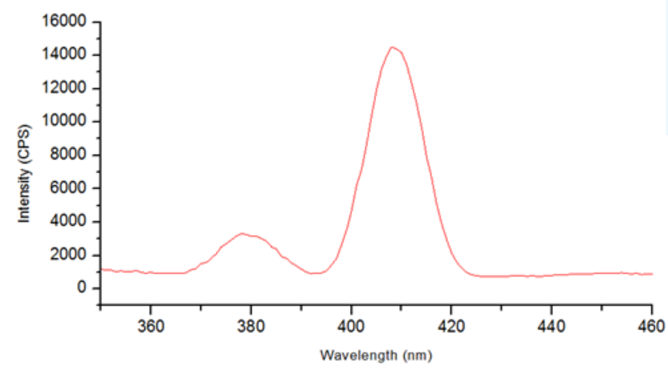


Figure 2: Shows two weak PL upconversion peaks of Er3+ doped nanoparticles in hexane with maxima at 378 and 408 nm recorded in the weak UV-blue spectral region measured with 10 nm slits.

The same DPSS laser can be conveniently used to measure PL unconversion lifetimes. By using a TTL trigger from the DeltaHub TCSPC electronic module, operating in the MCS mode, the laser can be set to a pulsed operation with the pulse position, duration and repetition rate under software control.

Figures 3, 4 and 5 show upconversion decays measured with the use of the DeltaTime kit for the 980 nm laser at three upconversion bands . The decays at 522 and 540 nm were fitted with a 3-exponential function resulting in one risetime and two lifetimes, while the decay at 657 nm was fitted with a 2-exponential function yielding one risetime and one lifetime (Table 1). The presence of the risetimes indicates that the emitting states are not directly populated by the excitation pulse, but are reached by a non-radiative relaxation from a higher excited state.

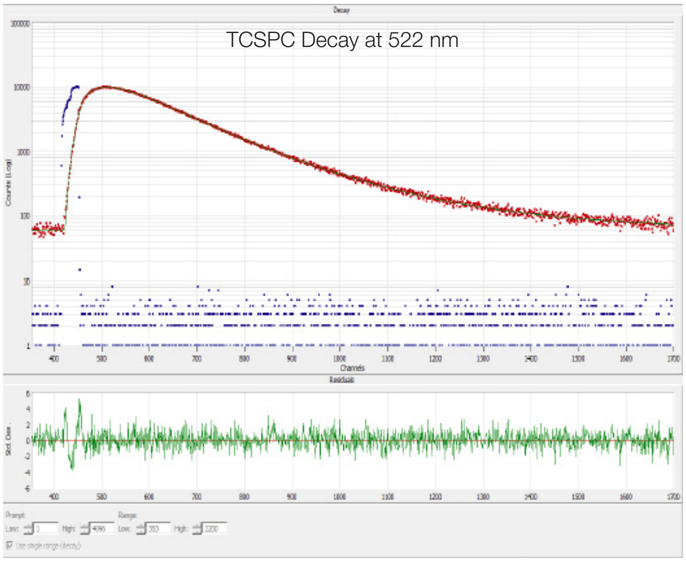


Figure 3: Upconversion PL decay at em = 522 nm excited with the 980nm laser operating in the pulse mode. The decay analysis required a 3-exponential fitting function resulting in 2 lifetimes and 1 risetime (see Table 1 below). The negative pre-exponential factor represents the risetime.

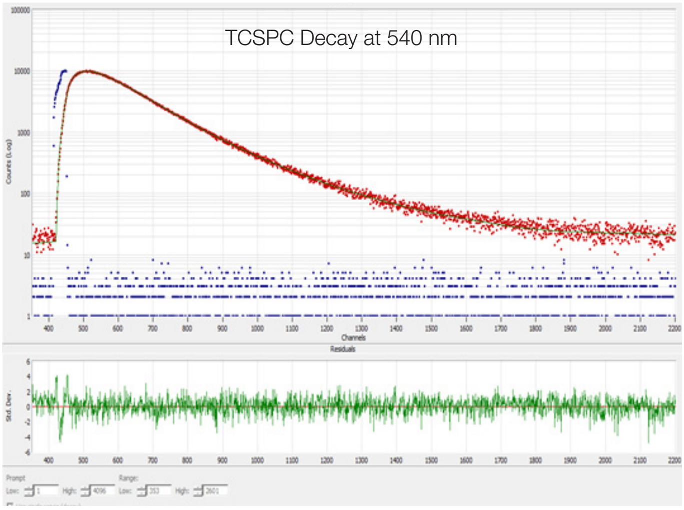
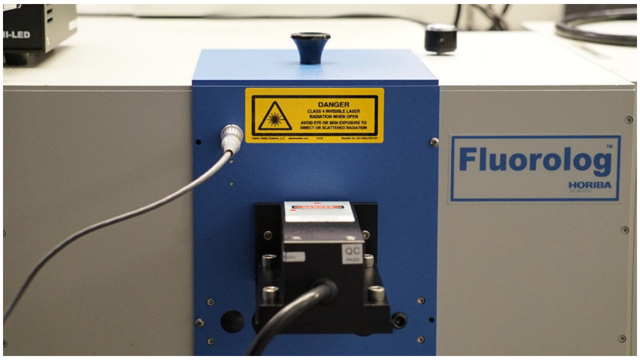


Figure 4: Upconversion PL decay at em = 540nm excited with the 980nm laser operating in the pulse mode. The decay analysis required a 3-exponential fitting function resulting in 2 lifetimes and 1 risetime (see Table 1). The negative pre-exponential factor represents the risetime.



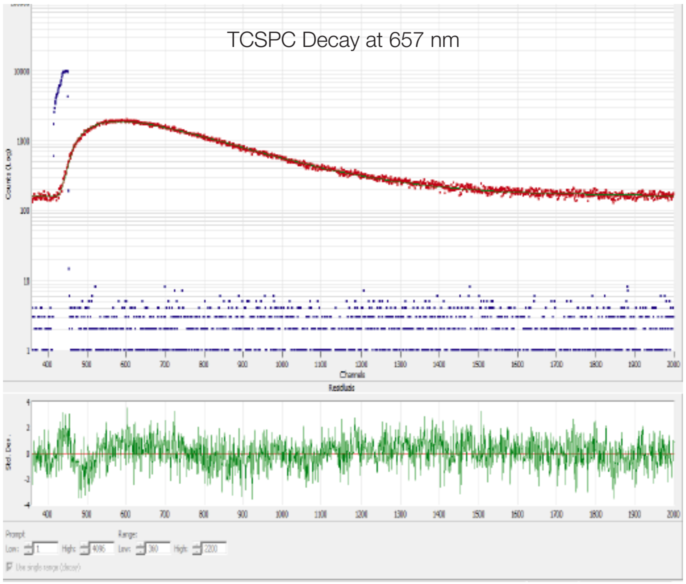


Figure 5: Upconversion PL decay at em = 657 nm excited with the 980nm laser operating in the pulse mode. The decay analysis required a 2-exponential fitting function resulting in 1 lifetime and 1 risetime (see Table 1 below). The negative pre-exponential factor represents the risetime.

Table 1: Lifetimes and pre-exponential factors

	λ_{em}/nm	T1/μs	T2/μs	T3/μs	B1	B2	B3	Chi-square
Figure 3	522	124.1	265.1	64.7	0.45	0.07	-0.48	1.21
Figure 4	540	130.3	283.7	64.00	0.46	0.06	-0.48	1.19
Figure 5	657	260.9	136.9	-	0.50	-0.50	-	1.20

Conclusion

The Fluorolog-3 equipped with the 980 nm DPSS laser upconversion accessory is a powerful and convenient tool to study photoluminescence of upconverting nanomaterials. It can provide complementary spectral and lifetime information which is critical to fully characterize the photophysical mechanism and efficiency of these materials.

Instrument: Fluorolog 3-22
Accessories: DT-980L-FL; DeltaTime kit for 980 nm laser
FL-LAS-980 – upconversion nm laser accessory
Experimental Conditions:
Ex = 980 nm
Em= 350–700 nm
Solvent: n-hexane
Experiment Type: Upconversion emission spectra
Upconversion lifetimes

[1]All Experimental data are courtesy of: Dr. Robeth Victoria Manurung, Research Center for Electronics and Telecommunication - Indonesian Institute of Sciences.

(These experiments can also be performed with the PTI QuantaMaster 8000 Series fluorometer equipped with the QM-LAS-980 upconversion accessory.)

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