Application Note
FP-0014

Quantum Yield Measurement of the Up-Conversion Phosphors

Introduction

Up-conversion is a multi-step excitation process that results in fluorescence at shorter wavelengths than the excitation light (Figure 1). Molecules can be excited at longer wavelengths where light scattering and absorption do not occur. This is particularly useful for evaluating labels used for biological imaging, materials in infrared solar cells and development of inks for anti-counterfeiting.

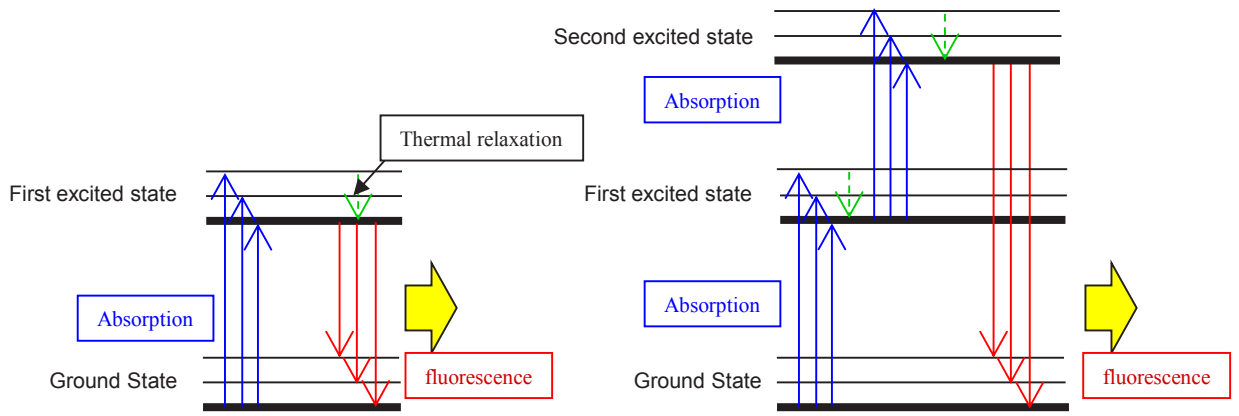

Figure 1. Energy diagram of conventional fluorescence (left) and up-conversion fluorescence (right).

Up-conversion fluorescence intensity is proportional to the *n*-th power of the excitation intensity, where n is the number of excitation photons. When using up-conversion to analyze the excitation processes of materials it is also of interest to determine the up-conversion quantum yield.

Since the quantum yield of up-conversion materials is very low, a measurement system with a high sensitivity is required. JASCO has developed an up-conversion quantum yield measurement system that can detect very small fluorescence intensities through the use of a laser for excitation.

This application note reports the up-conversion quantum yield measurement of phosphors with heavy rare earth elements.

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Figure 2. FP-8700 Up-conversion system.

Keywords

FP-8700, Fluorescence, Up-conversion, Quantum yield, Near-infrared

Experimental

Measurement Conditions			
Emission Bandwidth	5 nm	Data Acquisition Interval	0.2 nm
Response Time	0.2 sec	Scan Speed	1000 nm/min
Laser Wavelength	980 nm	Laser Output	150 mW

Solutions of tryptophan (0.0175 mg/L), humic acid (0.5 mg/L) and folic acid (1mg/L) were prepared in the following mixture ratios (tryptophan: humic acid: folic acid): 6:2:2, 5:5:0, 5:0:5, 4:4:2, 4:2:4, 2:6:2, 2:4:4, 2:2:6, 0:5:5.

Results

The excitation and fluorescence spectra of 6 samples were measured (YTa_7O_{19}: Er_{10}, Yb_{40}, YTa_7O_{19}: Ho_4, Yb_{60}, YTa_7O_{19}: Tm_3, Yb_{80}, $RETa_7O_{19}$: Er_{90}, Tm_{10}, $GdTa_7O_{19}$: Er_{10}, Yb_{40}, and Gd_2O_3: Er_5, Yb_{10}). Each sample was measured three times to evaluate the measurement reproducibility. The three measurements are overlaid and shown in different colors in Figures 3-8. Tables 1- 6 show the quantum yield measurement results.

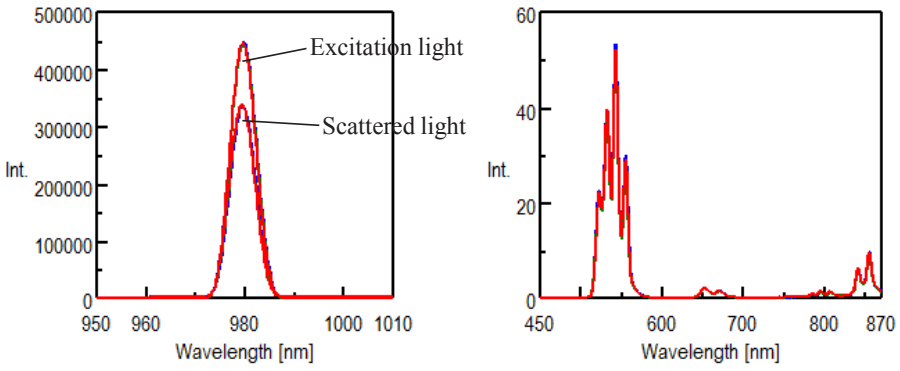

Figure 3. Excitation and scattered light (left) spectra and the fluorescence spectrum (right) of YTa_7O_{19}: Er_{10}, Yb_{40}.

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Table 1. Internal quantum yield measurement results of YTa_7O_{19}: Er_{10}, Yb_{40}.

Measurement	Area of Excitation Light	Area of Scattered Light	Area of Absorption	Area of Fluorescence	Sample Absorbance (%)	Internal Quantum Yield (%)
1	$2.8 \cdot 10^6$	$2.14 \cdot 10^6$	663270	1453.86	23.69	0.22
2	$2.73 \cdot 10^6$	$2.14 \cdot 10^6$	587840	1378.84	21.57	0.23
3	$2.83 \cdot 10^6$	$2.14 \cdot 10^6$	687620	1433.8	24.28	0.21

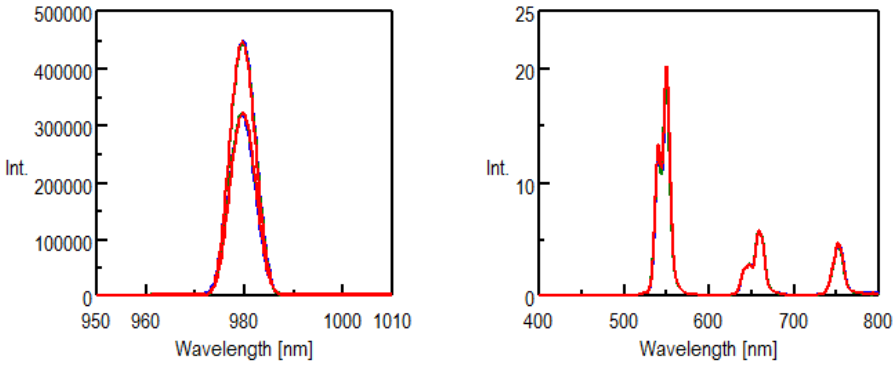

Figure 4. Excitation and scattered light (left) spectra and the fluorescence spectrum (right) of YTa_7O_{19}: Ho_4, Yb_{60}.

Table 2. Internal quantum yield measurement results of YTa_7O_{19}: Ho_4, Yb_{60}.

Measurement	Area of Excitation Light	Area of Scattered Light	Area of Absorption	Area of Fluorescence	Sample Absorbance (%)	Internal Quantum Yield (%)
1	$2.75 \cdot 10^6$	$2.07 \cdot 10^6$	685000	501.572	24.88	0.073
2	$2.80 \cdot 10^6$	$2.09 \cdot 10^6$	708860	498.81	25.32	0.070
3	$2.87 \cdot 10^6$	$2.05 \cdot 10^6$	821920	515.899	28.59	0.063

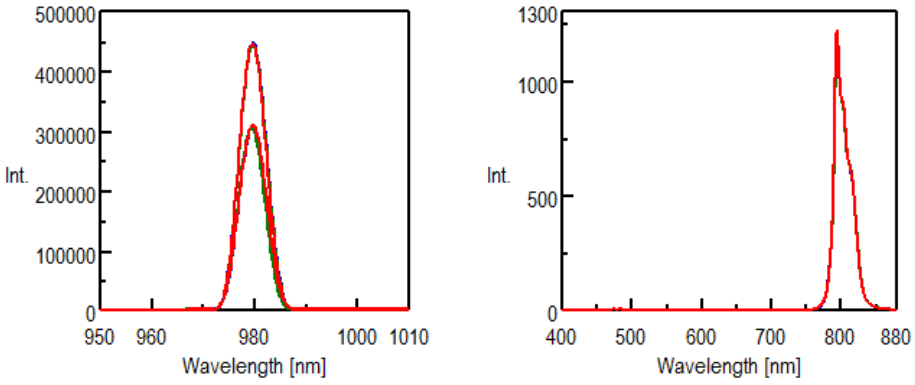

Figure 5. Excitation and scattered light (left) spectra and the fluorescence spectrum (right) of YTa_7O_{19}: Tm_3, Yb_{80}.

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Table 3. Internal quantum yield measurement results of YTa_7O_{19}: Tm_3, Yb_{80}.

Measurement	Area of Excitation Light	Area of Scattered Light	Area of Absorption	Area of Fluorescence	Sample Absorbance (%)	Internal Quantum Yield (%)
1	$2.75 \cdot 10^6$	$1.92 \cdot 10^6$	833340	31500.1	30.32	3.78
2	$2.75 \cdot 10^6$	$1.91 \cdot 10^6$	845170	32176.7	30.73	3.81
3	$2.77 \cdot 10^6$	$1.95 \cdot 10^6$	819330	31277.2	29.55	3.82

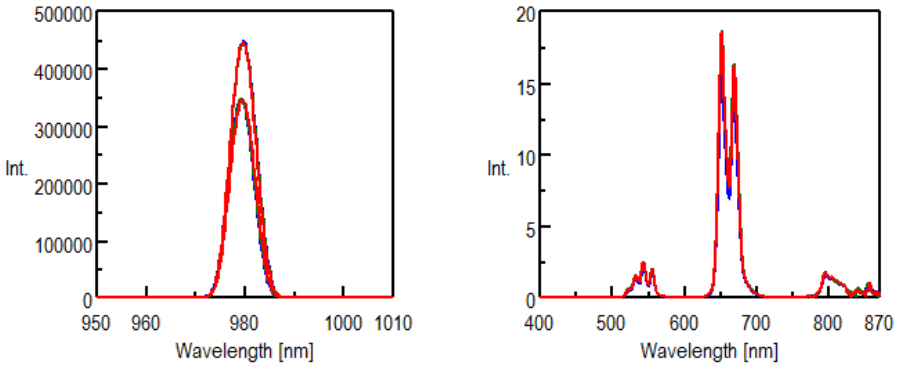

Figure 6. Excitation and scattered light (left) spectra and the fluorescence spectrum (right) of $RETa_7O_{19}$: Er_{90}, Tm_{10}.

Table 4. Internal quantum yield measurement results of $RETa_7O_{19}$: Er_{90}, Tm_{10}.

Measurement	Area of Excitation Light	Area of Scattered Light	Area of Absorption	Area of Fluorescence	Sample Absorbance (%)	Internal Quantum Yield (%)
1	$2.74 \cdot 10^6$	$2.14 \cdot 10^6$	594410	501.341	21.71	0.084
2	$2.86 \cdot 10^6$	$2.16 \cdot 10^6$	698340	446.071	24.44	0.064
3	$2.76 \cdot 10^6$	$2.14 \cdot 10^6$	620210	566.941	22.45	0.091

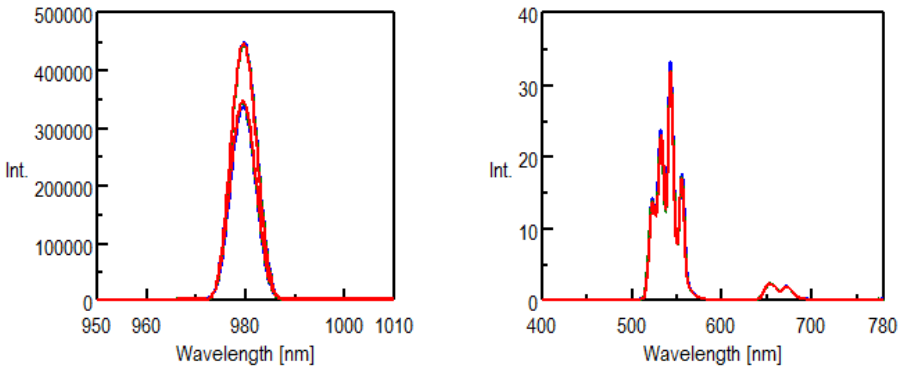

Figure 7. Excitation and scattered light (left) spectra and the fluorescence spectrum (right) of $GdTa_7O_{19}$: Er_{10}, Yb_{40}.

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Table 5. Internal quantum yield measurement results of $GdTa_7O_{19}$: Er_{10}, Yb_{40}.

Measurement	Area of Excitation Light	Area of Scattered Light	Area of Absorption	Area of Fluorescence	Sample Absorbance (%)	Internal Quantum Yield (%)
1	$2.74 \cdot 10^6$	$2.08 \cdot 10^6$	663190	908.777	24.22	0.14
2	$2.83 \cdot 10^6$	$2.16 \cdot 10^6$	664660	863.496	23.51	0.13
3	$2.85 \cdot 10^6$	$2.20 \cdot 10^6$	654600	843.468	22.97	0.13

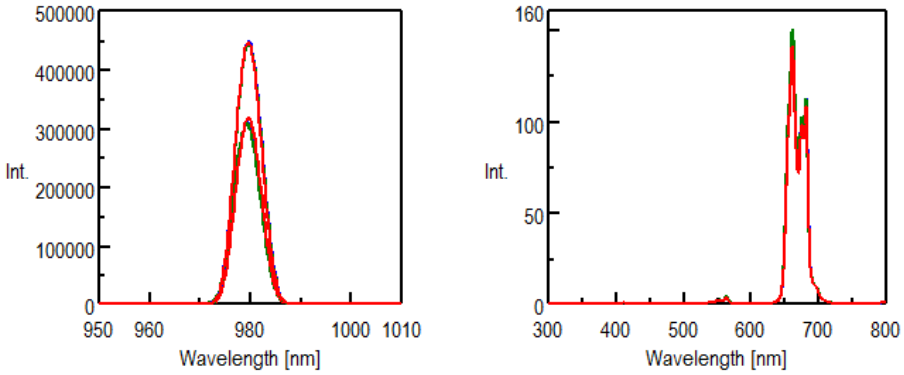

Figure 8. Excitation and scattered light (left) spectra and the fluorescence spectrum (right) of Gd_2O_3: Er_5, Yb_{10}.

Table 6. Internal quantum yield measurement results of Gd_2O_3: Er_5, Yb_{10}.

Measurement	Area of Excitation Light	Area of Scattered Light	Area of Absorption	Area of Fluorescence	Sample Absorbance (%)	Internal Quantum Yield (%)
1	$2.74 \cdot 10^6$	$2.08 \cdot 10^6$	663190	908.777	24.22	0.14
2	$2.83 \cdot 10^6$	$2.16 \cdot 10^6$	664660	863.496	23.51	0.13
3	$2.85 \cdot 10^6$	$2.20 \cdot 10^6$	654600	843.468	22.97	0.13

Conclusion

With the exception of the YTa_7O_{19}: Tm_3, Yb_{80} complex (Figure 6, Table 3), these results demonstrate that the up-conversion system can evaluate quantum yields at levels of less than 1%.

Data courtesy of Dr. Kouji Tomita, Department of Chemistry, School of Science, Tokai University

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