Electronic Supporting Information (ESI)

Control of Green and Red Upconversion in $NaYF_4:Yb^{3+},Er^{3+}$ Nanoparticles by Excitation Modulation

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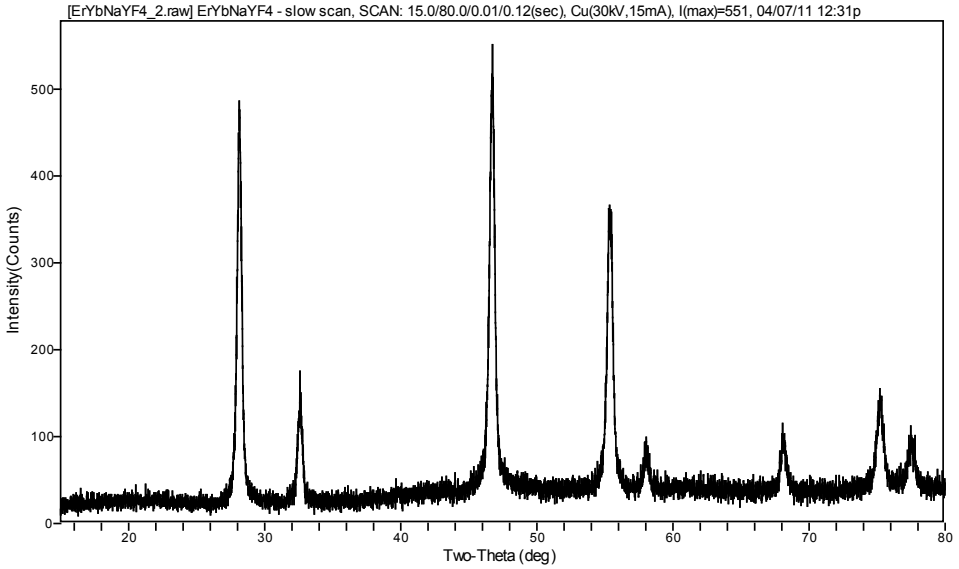

Fig. S1. X-ray powder diffraction (XRD) pattern of $NaYF_4:Er^{3+},Yb^{3+}$ nanoparticles.

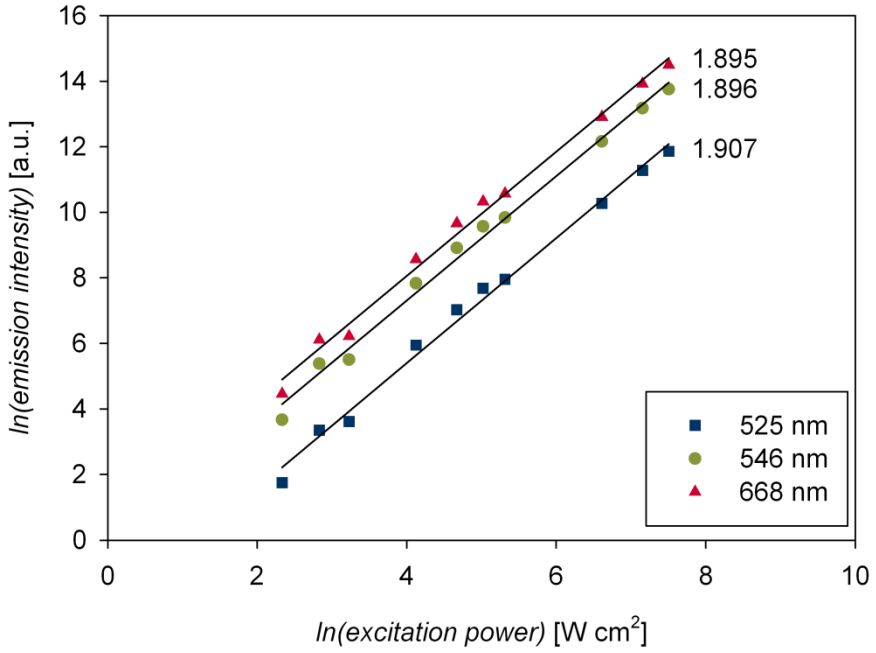

Fig. S2. Power density dependence of three emission peaks in $NaYF_4$: Yb^{3+},Er^{3+} nanoparticles. Data for visible peaks are well matched to linear fits with slopes of approximately 2, indicating 2-photon processes. Excitation was by 980 nm laser diode pulsed at 500 Hz with a 100 μs pulse width.

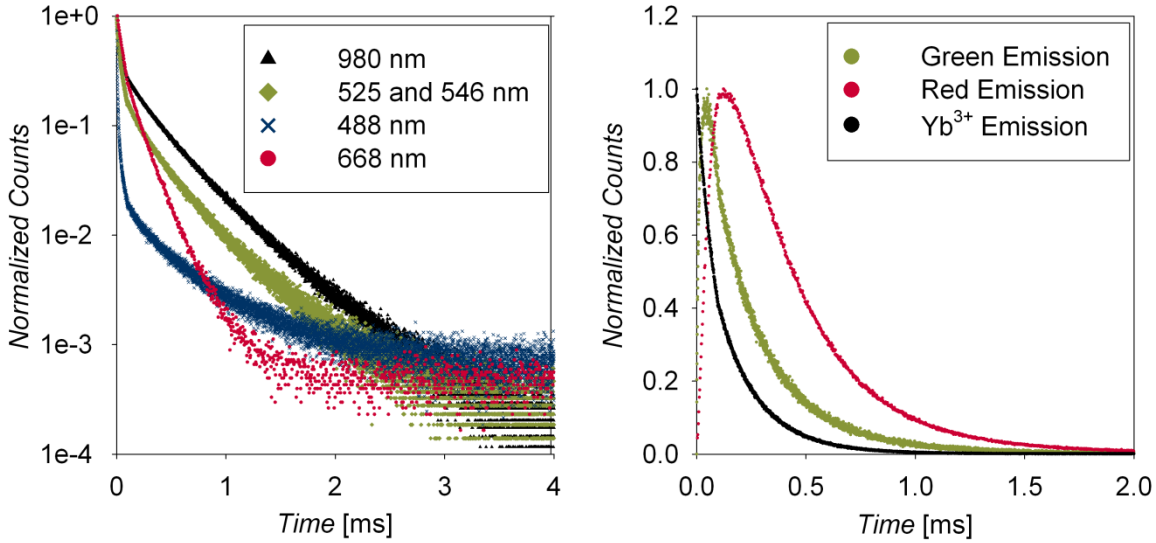

Fig. S3. Left: Luminescence decay of $NaYF_4$:Er^{3+},Yb^{3+} nanoparticles at several wavelengths following direct excitation of the associated transitions. Excitation and measurement matched the wavelengths listed in the legend. Right: Luminescence decay of transitions resulting in green and red emission in upconverting nanoparticles as well as the luminescence decay of $NaYF_4$:Yb^{3+} nanoparticles at 980 nm. Excitation for all three was 980 nm. Excitation was by an OPO tuned NdYAG laser pulsed at 20 Hz with 3 ns pulse width for all measurements.

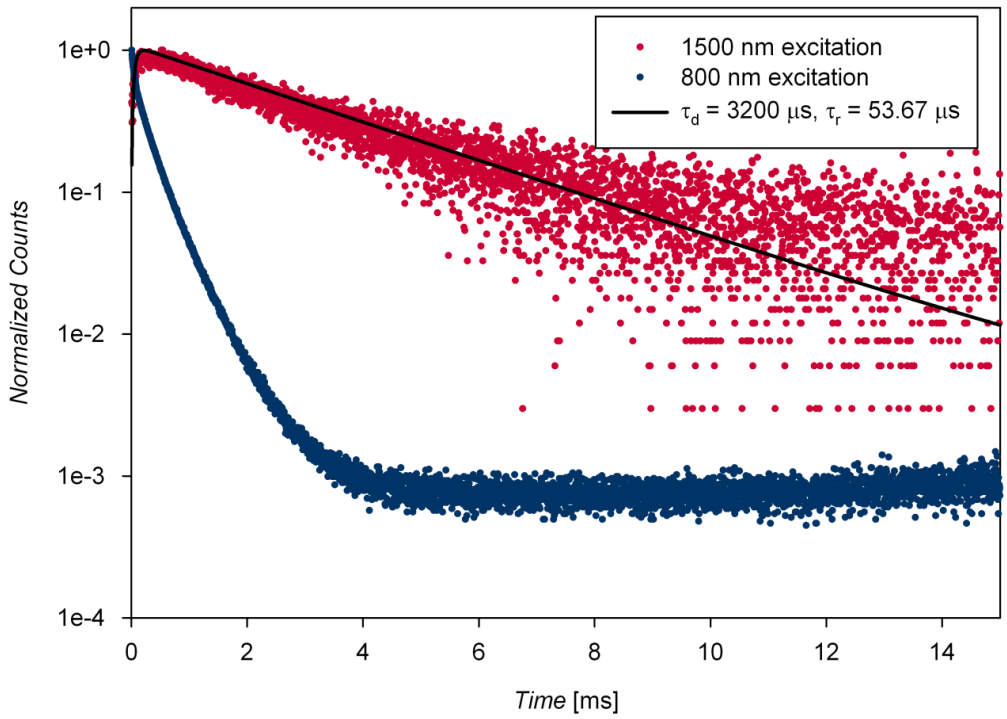

Fig. S4. Luminescence decay measured at 980 nm following excitation by 1500 nm (red) and 800 nm (blue).

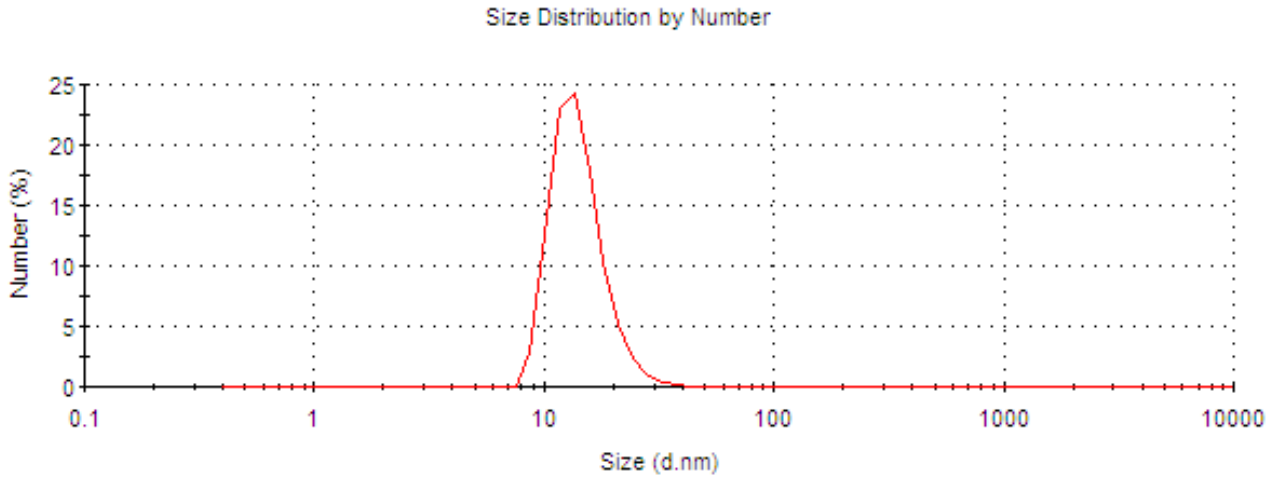

Fig. S5. Size distribution of $NaYF_4:Er^{3+},Yb^{3+}$ nanoparticles. The peak is at 14.3 nm.

Coefficients for rate equations presented in the main text:

$C_{22} = \frac{k_{02}N_0N_{S*}^0}{W_2-W_S}$ and $C_{21} = N_2^0 - \frac{k_{02}N_0N_{S*}^0}{W_2-W_S}$

$C_{42} = \frac{k_{24}N_{S*}^0N_2^0}{W_4-(W_S+W_2)} - \frac{k_{02}k_{24}N_0{N_{S*}^0}^2}{W_4(W_2-W_S)-(W_S^2+W_2^2)}$,

$C_{43} = \frac{k_{02}k_{24}N_0{N_{S*}^0}^2}{W_4(W_2-W_S)-2(W_2W_S-W_S^2)}$, and $C_{41} = -(C_{42}+C_{43})$

$C_{31} = -(C_{32}+C_{33}+C_{34}+C_{35})$,

$C_{32} = \frac{k_{13}N_{S*}^0C_{11}}{W_3-W_S-W_{10}}$, $C_{33} = \frac{\left(W_{43}C_{42}-\frac{k_{13}N_{S*}^0C_{21}}{W_2}\right)}{W_3-W_S-W_2}$

$C_{34} = \frac{\left(W_{43}C_{43}-\frac{k_{13}N_{S*}^0C_{22}}{W_S}\right)}{W_3-2W_S}$, and $C_{35} = \frac{W_{43}C_{41}}{W_3-W_4}$