Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics.

Supporting Information.

Figure S1. One-photon luminescence of continuous wave (cw) and nanosecond (ns) pulse laser excitations.

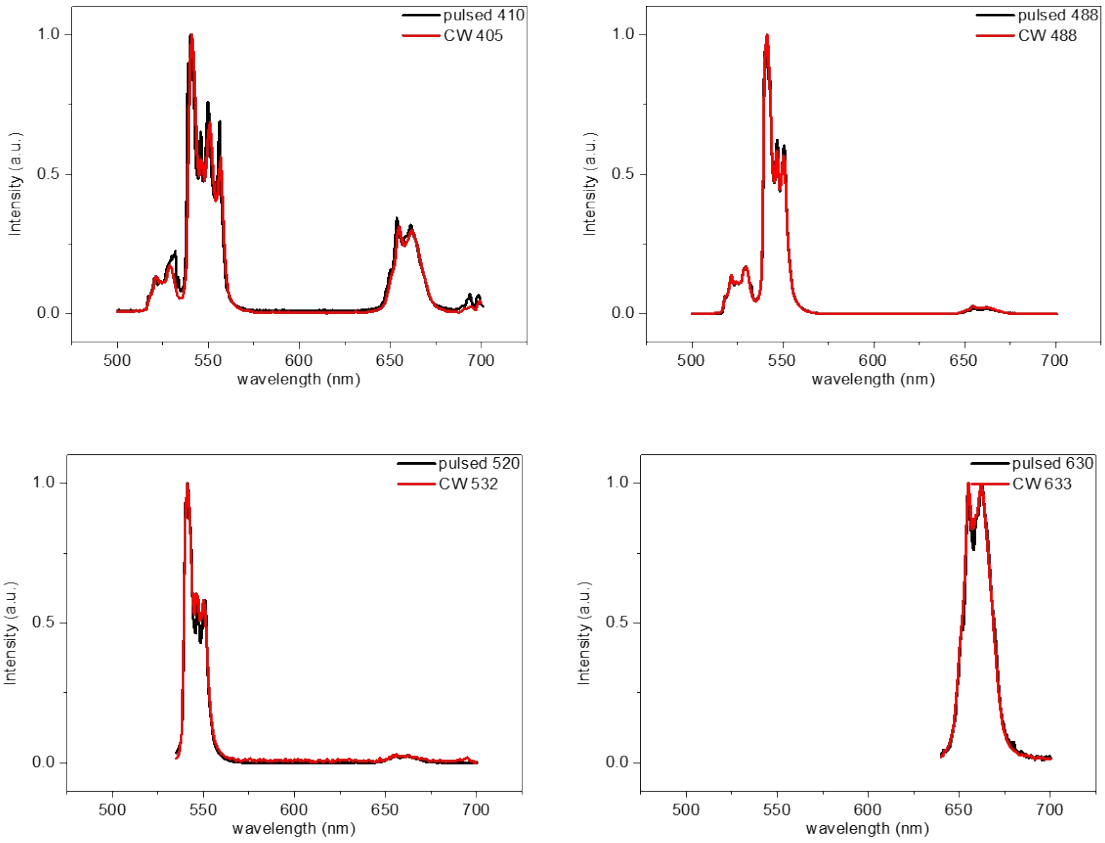


Figure S2. Time-resolved photoluminescence spectra of $NaYF_4$:Yb^{3+}, Er^{3+} phosphor with 660-nm detection. Note that the phosphor was excited with a nanosecond pulse laser at 640 nm to probe $^4F_{11/2} \rightarrow {}^4I_{15/2}$ (660 nm) transition.

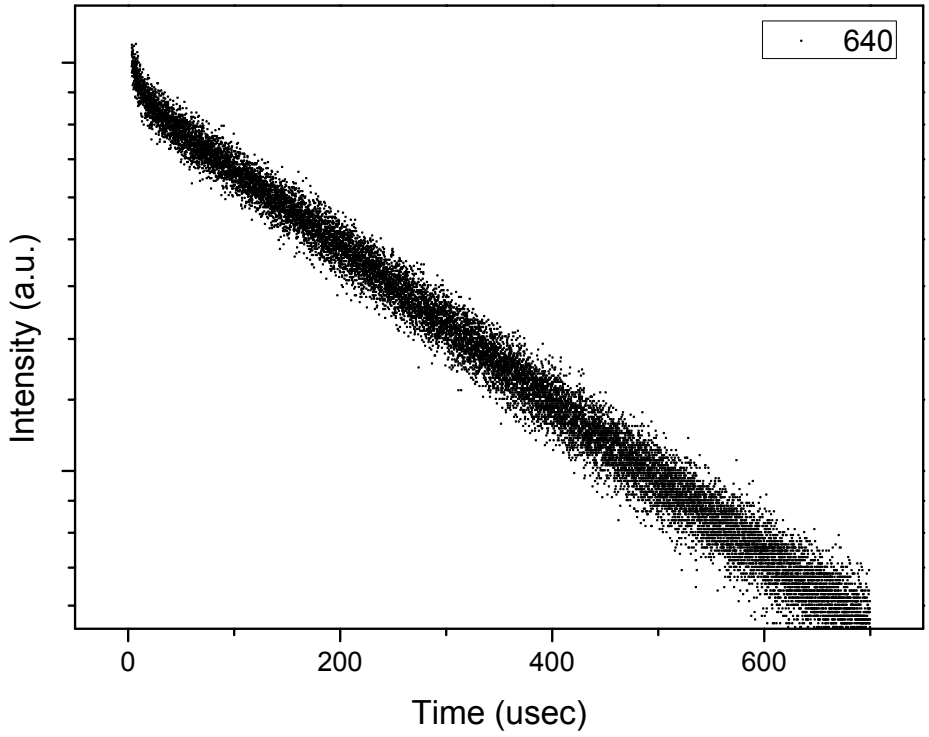


Figure S3. Comparison of red emission intensity at 405, 488, 532, and 632.8 nm excitations at 3 mW power.

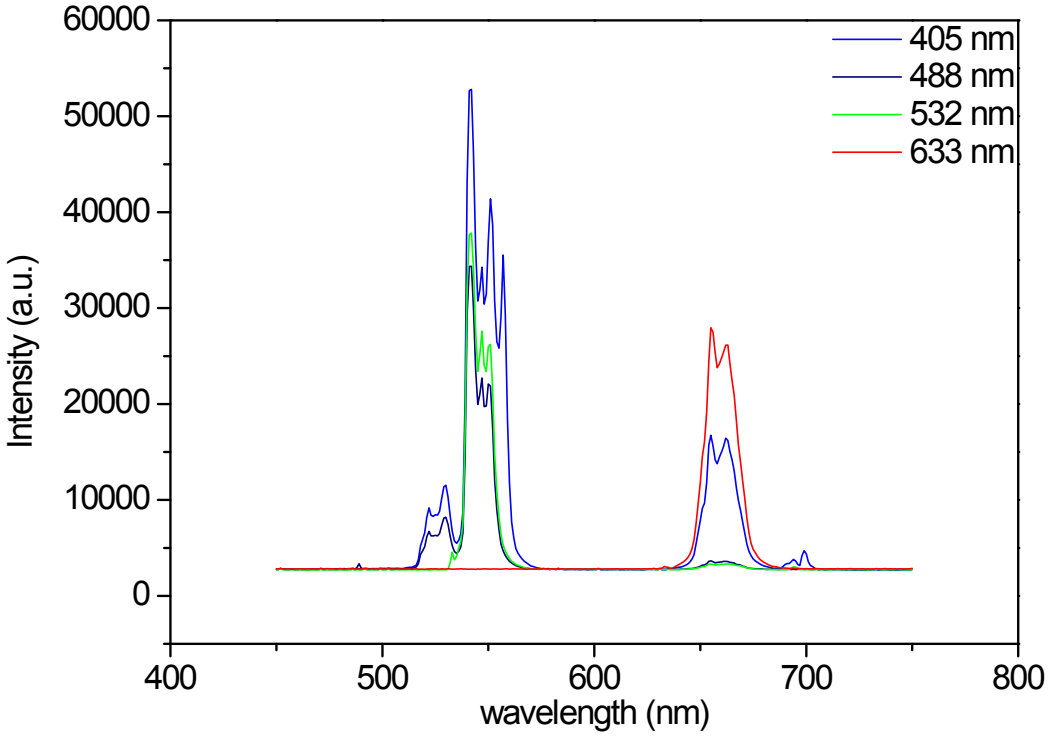
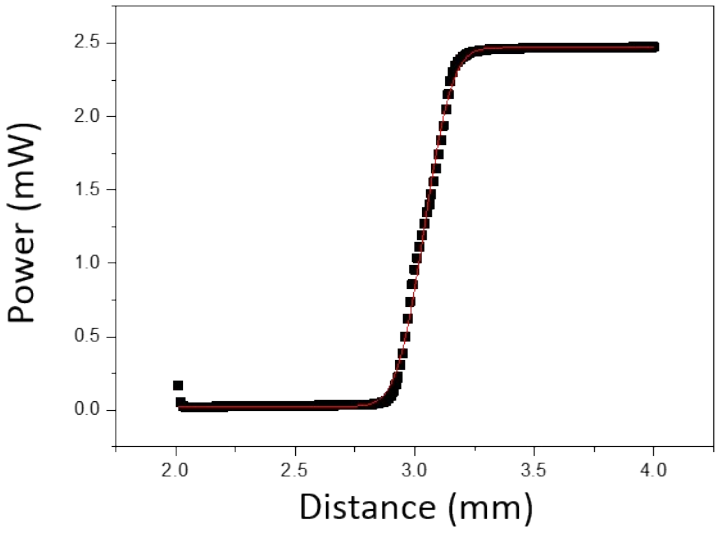


Figure S4. Power density conversion table and knife edge methods

Power (mW)	Power density (W/cm^2)
0.05	0.995223
0.1	1.990446
0.15	2.985669
0.2	3.980892
0.25	4.976115
0.3	5.971338
0.4	7.961783
0.6	11.94268
0.8	15.92357
1.0	19.90446
2	39.80892

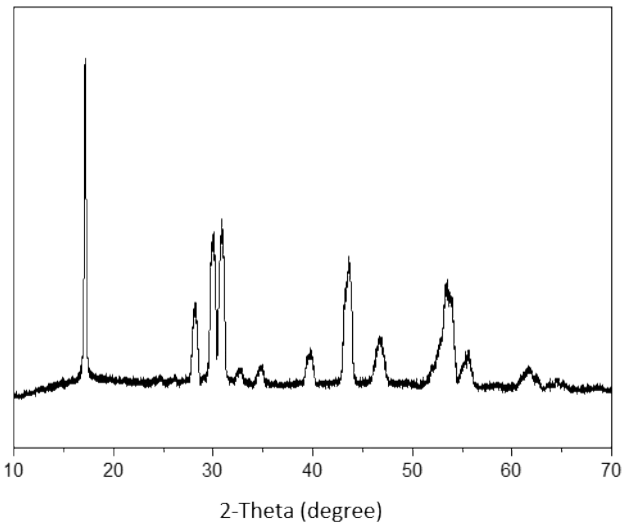
We measured beam spot size though the knife edge method that record the total power in the beam as a knife edge is translated through the beam using a calibrated translation stage. The beam spot is assumed Gaussian profile and fitted as follow equation.

$$y = A * pi/4 * w * w * (1 + erf(sqrt(2) * (x - x0)/w)) + y0;$$



The measured beam size is 8 micrometers.

Figure S5. XRD data of UC powder.



X-ray diffraction (XRD) results of the $NaY_xYb_yEr_zF_4$ (x=0.77 y=0.20 z=0.03) green phosphors. The peak positions of these upconversion materials agree with hexagonal $NaYF_4$:Yb^{3+},Er^{3+} crystal (the line patterns are matched Joint Committee on Powder Diffraction Standards file number PDF 16-0334). Also there was a small portion of XRD cubic phase peak patterns (the line patterns are matched Joint Committee on Powder Diffraction Standards file number PDF 77-2042).

Figure S6. Compare UC decay curves to the routine PL decay ones.