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Supporting Information

Excitation-power mediated optical hysteresis behavior in a one-demensional single upconverting microcrystal

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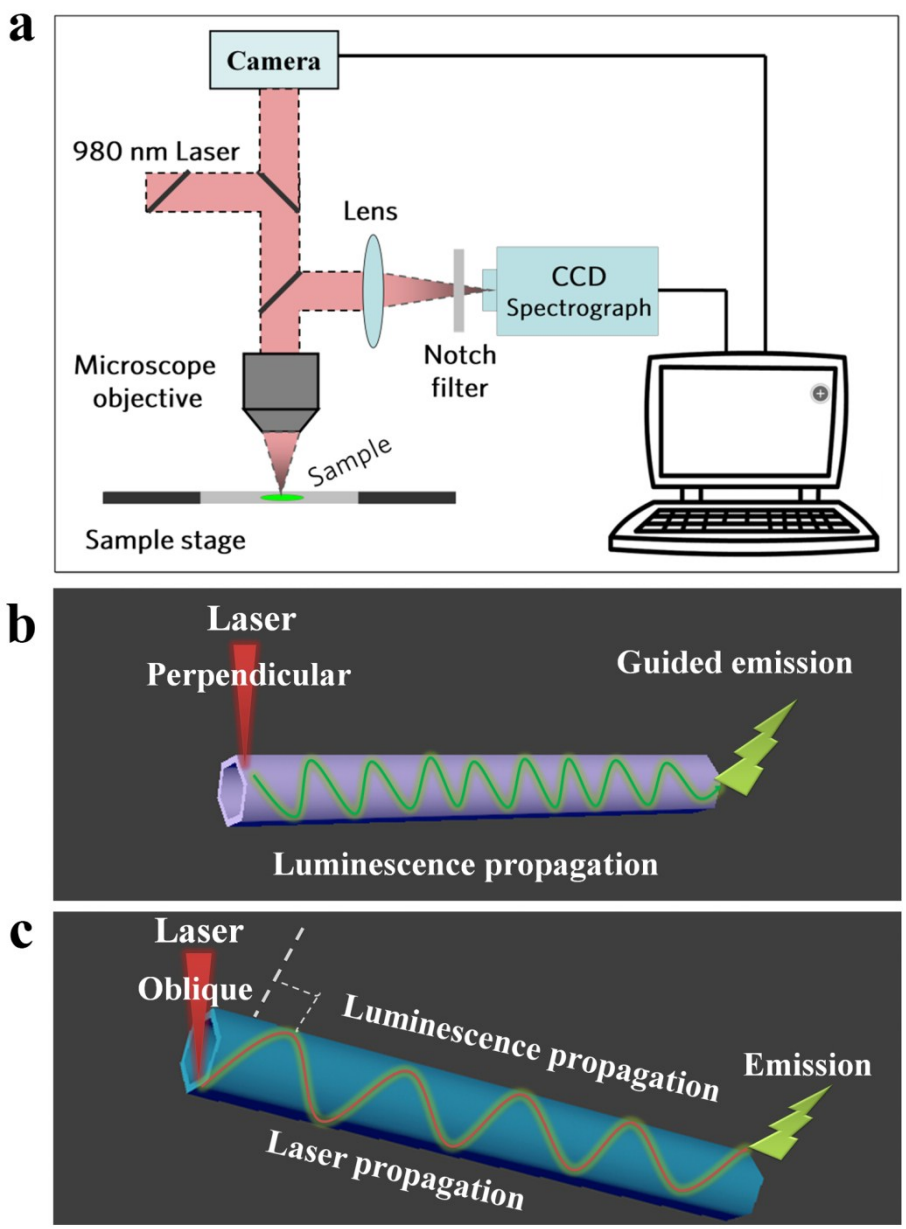

Figure S1 Specific single-particle confocal experimental devices (a), schematic of excitation approach for the spot-excitation approach (b) and the waveguiding-excitation approach (c). Note that waveguiding-excitation mode with an incident angle that is greater than the critical angle of 56° can efficiently couple the excited light ray into a single microtube. The spot-excitation approach can not efficiently trap high density laser photon.

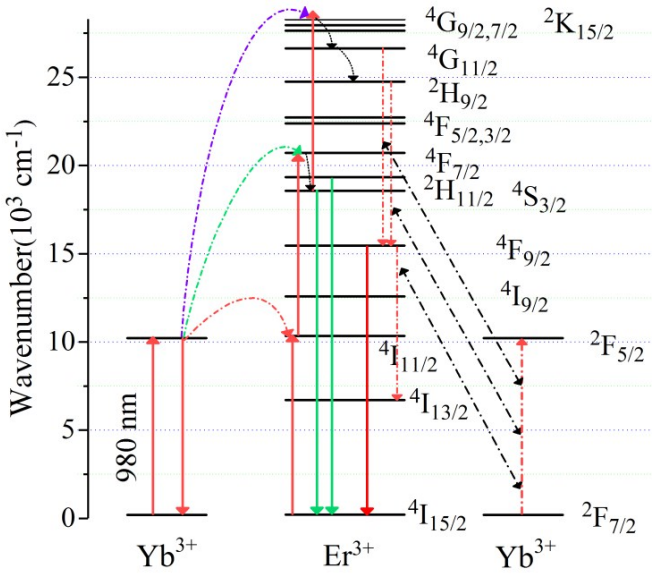

Figure S2 Simplified energy level diagram exhibiting proposed upconversion processes in single $NaYbF_4$: 2.0% Er microtubes.

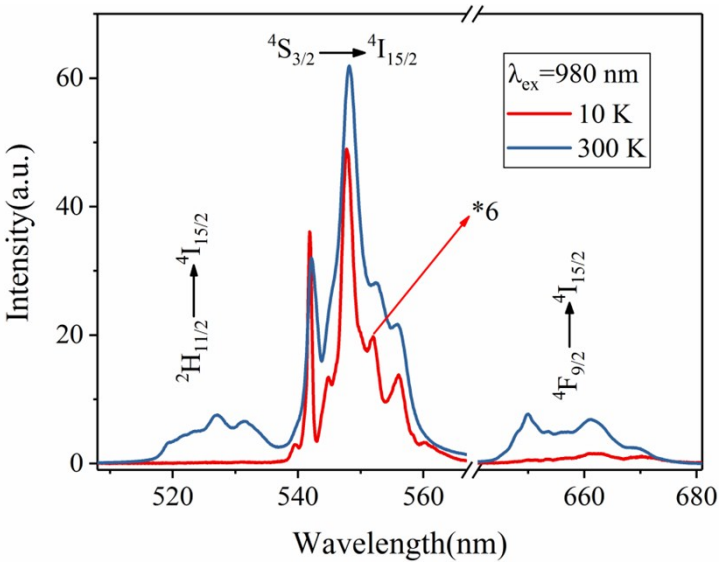

Figure S3 Visible UC spectra of single $NaYF_4$: Yb/Er (5/2 mol%) microtubes obtained at 10 K and 300 K, respectively, under 980 nm laser excitation.

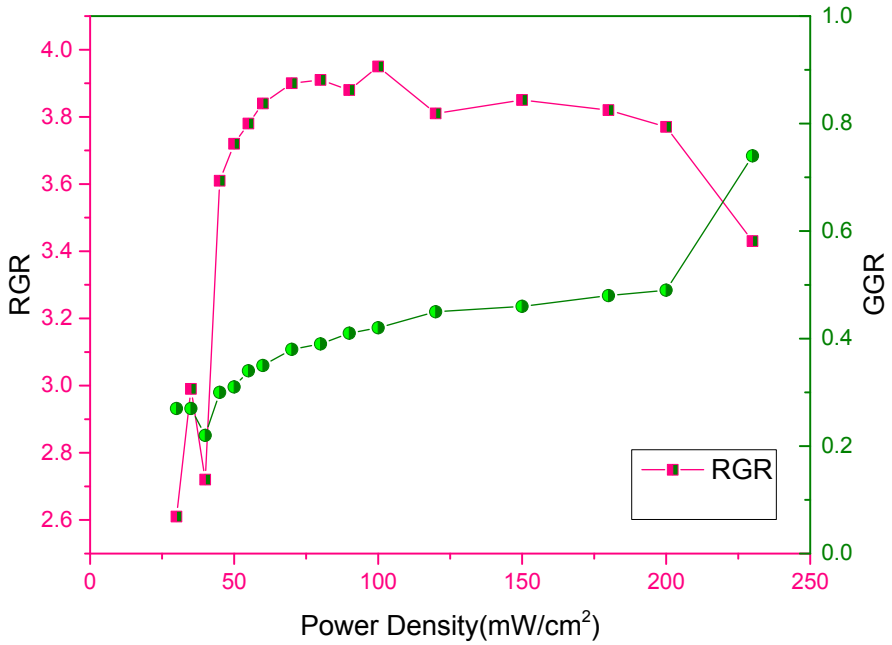

Figure S4 The dependence of GGR and RGR on excitation power density, respectively, from a single $NaYbF_4$: 2.0% Er^{3+} microtube in the cycles of power dropping. G1 is luminscence intensity from $^2H_{11/2}\rightarrow{}^4I_{15/2}$ transition and G2 stands for emission intensity from $^4S_{3/2}\rightarrow{}^4I_{15/2}$ transition. Noting that GGR and RGR denote luminscence intensity ratios of G1 to G2 and red to green, respectively. The dots are the experimental data and the lines are drawn to guide the eye.

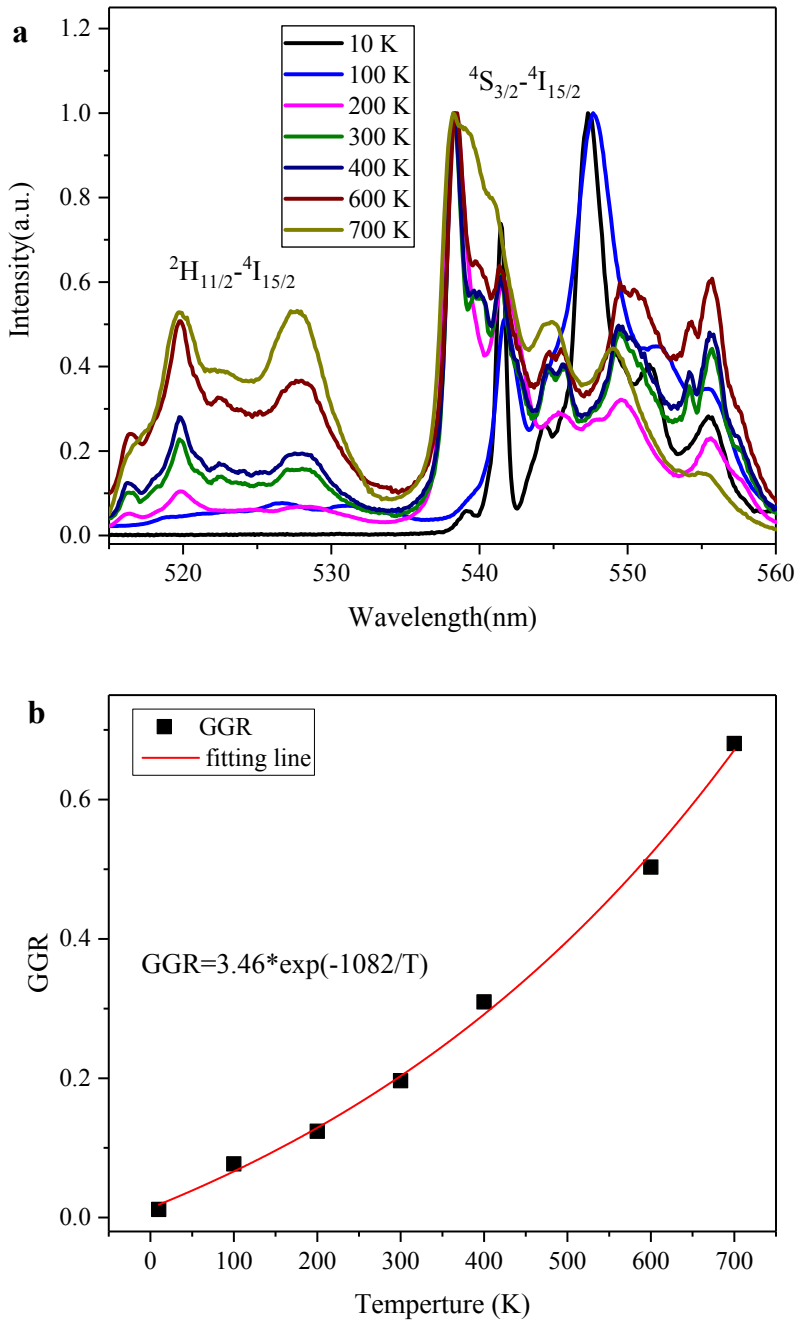

Figure S5 (a) Temperature dependence of the green UC luminescence spectra of $NaYbF_4$: 2% Er^{3+} under 980 nm excitation. The spectra are normalized to the most intense emission peak at 539.6 nm. (b) GGR data versus absolute temperature for $NaYbF_4$: 2%Er^{3+} sample.

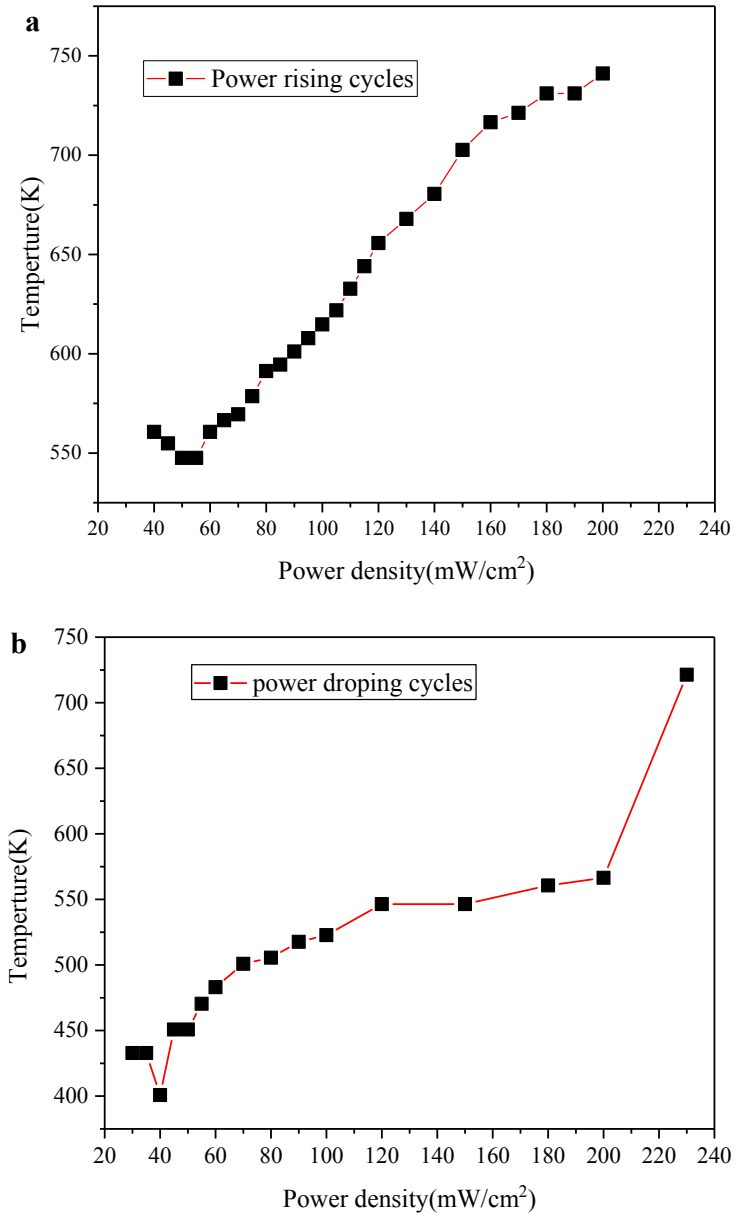

Figure S6 The relationship between the actual temperature of the sample and the exciting power at room temperatures for $NaYbF_4$: 2%Er^{3+} under 980 nm focused laser excitation.

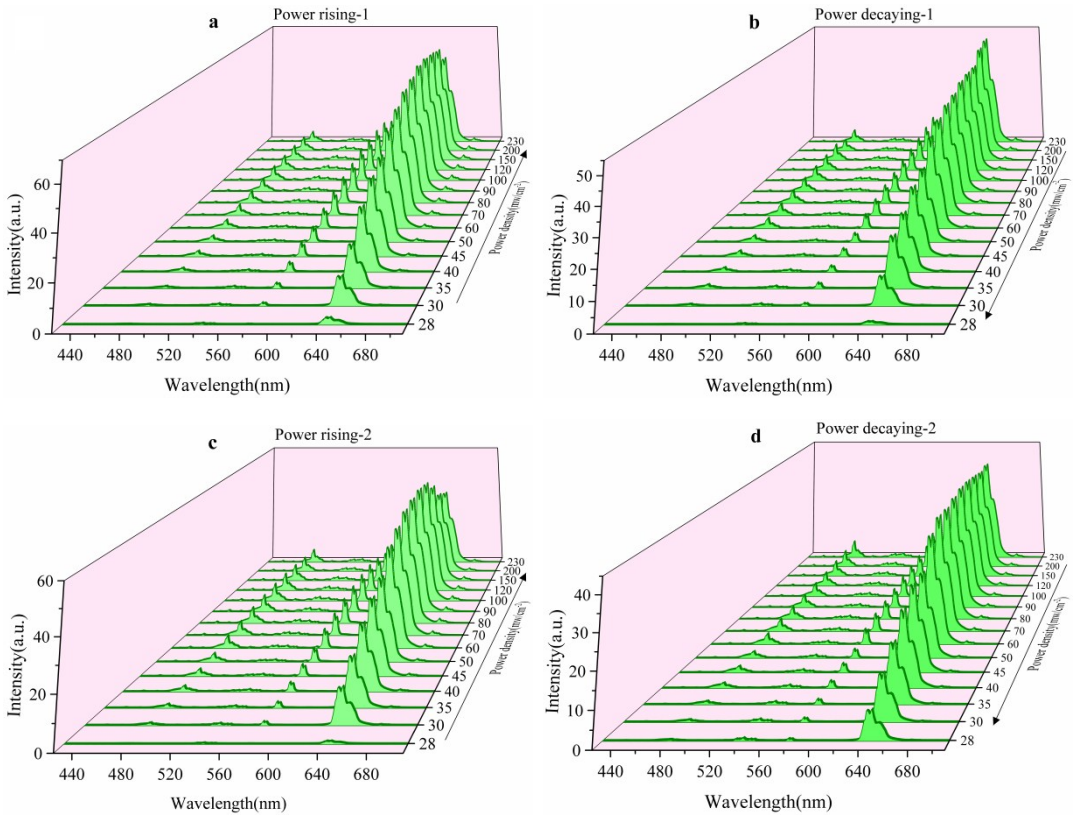

Figure S7 Power dependence UC luminescence spectra of a single $NaYbF_4$: 1.0% Ho^{3+} microrod under 980-nm laser excitation.

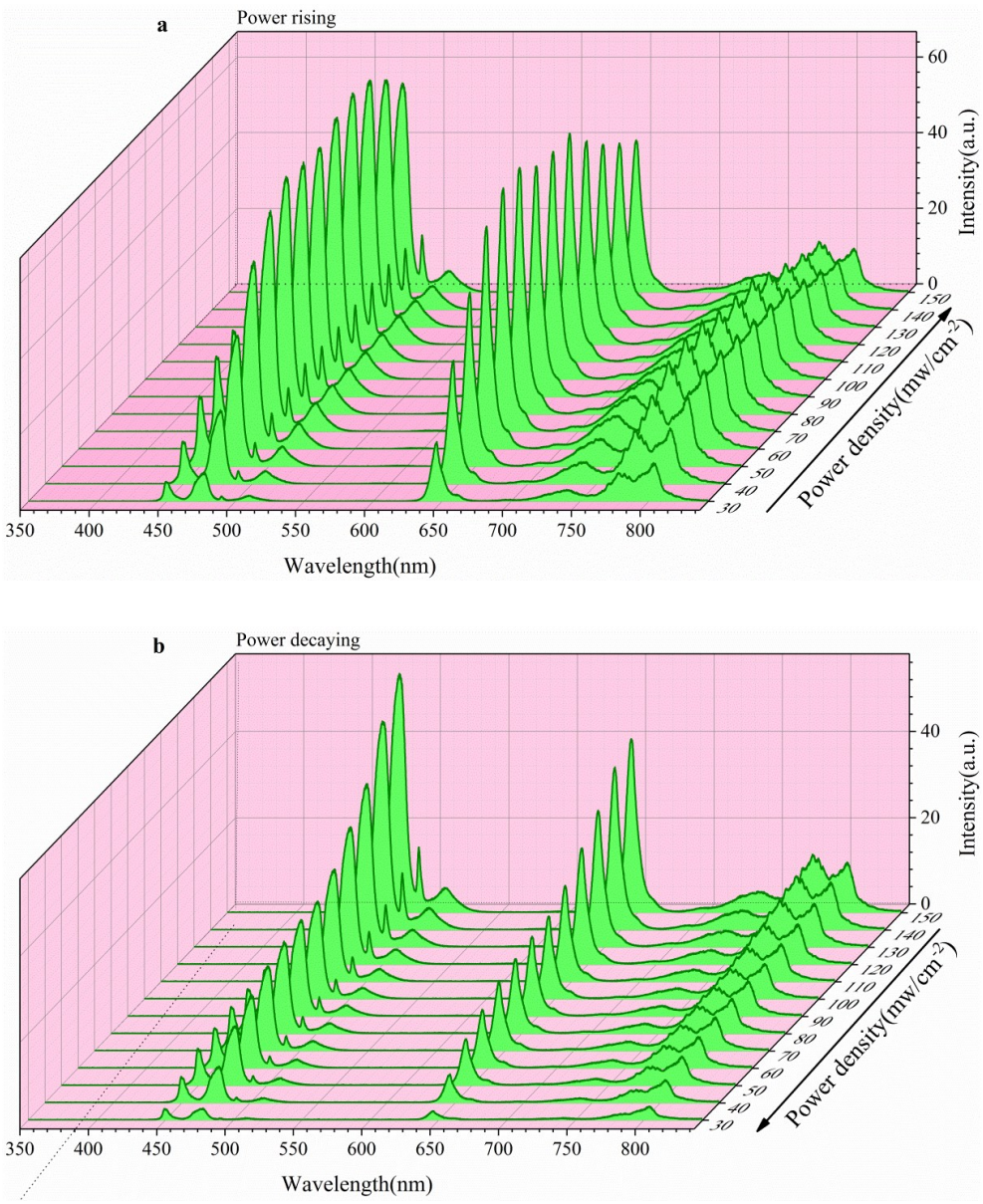

Figure S8 UC luminescence spectra of a single $NaYbF_4$: 0.5% Tm^{3+} microrod under 980 nm excitation of varying power.

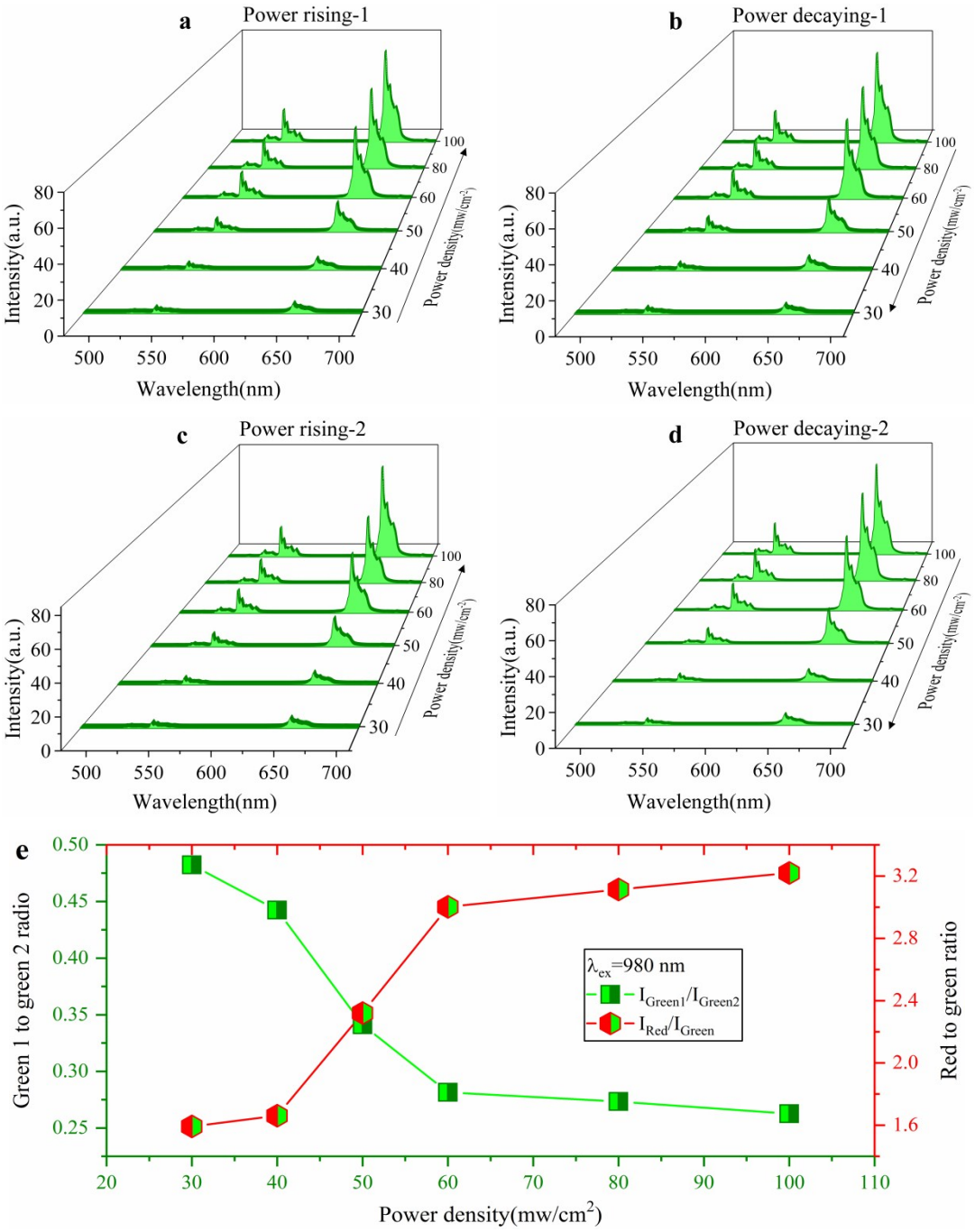

Figure S9 (a)-(d) Emission spectra from $NaYbF_4$: 2%Er microtube for the transitions of $^2H_{11/2}/^4S_{3/2}\rightarrow{}^4I_{15/2}$ and $^4F_{9/2}\rightarrow{}^4I_{15/2}$ of Er^{3+} for two cycles of varying power fs laser scan. (e) RGR and GGR with local excitation at the central part of the $NaYbF_4$: 2% Er microtube. PR and PD denote power raising and power decaying, respectively. The dots are experimental data and the lines are drawn to guide the eye.

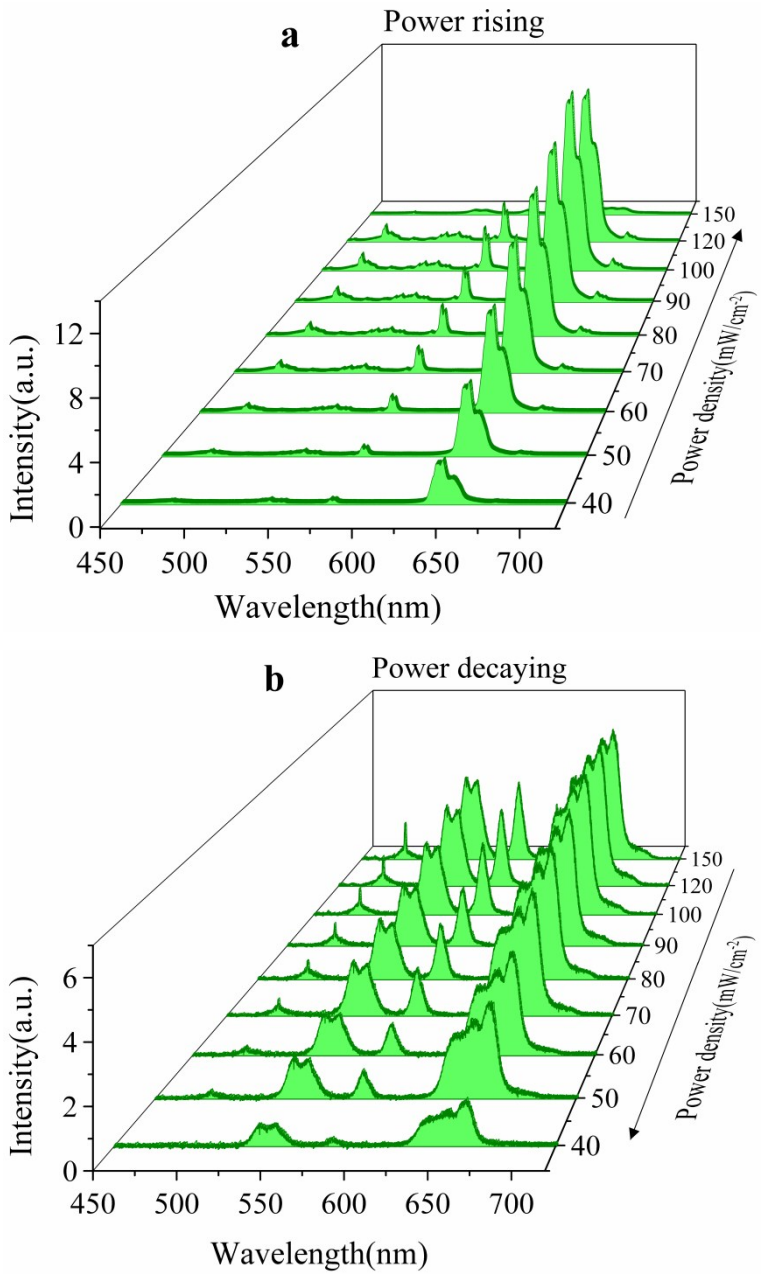

Figure S10 Power dependence UC luminescence spectra of a single $NaYbF_4$: 1.0% Ho^{3+} microtube under 980-nm laser excitation.

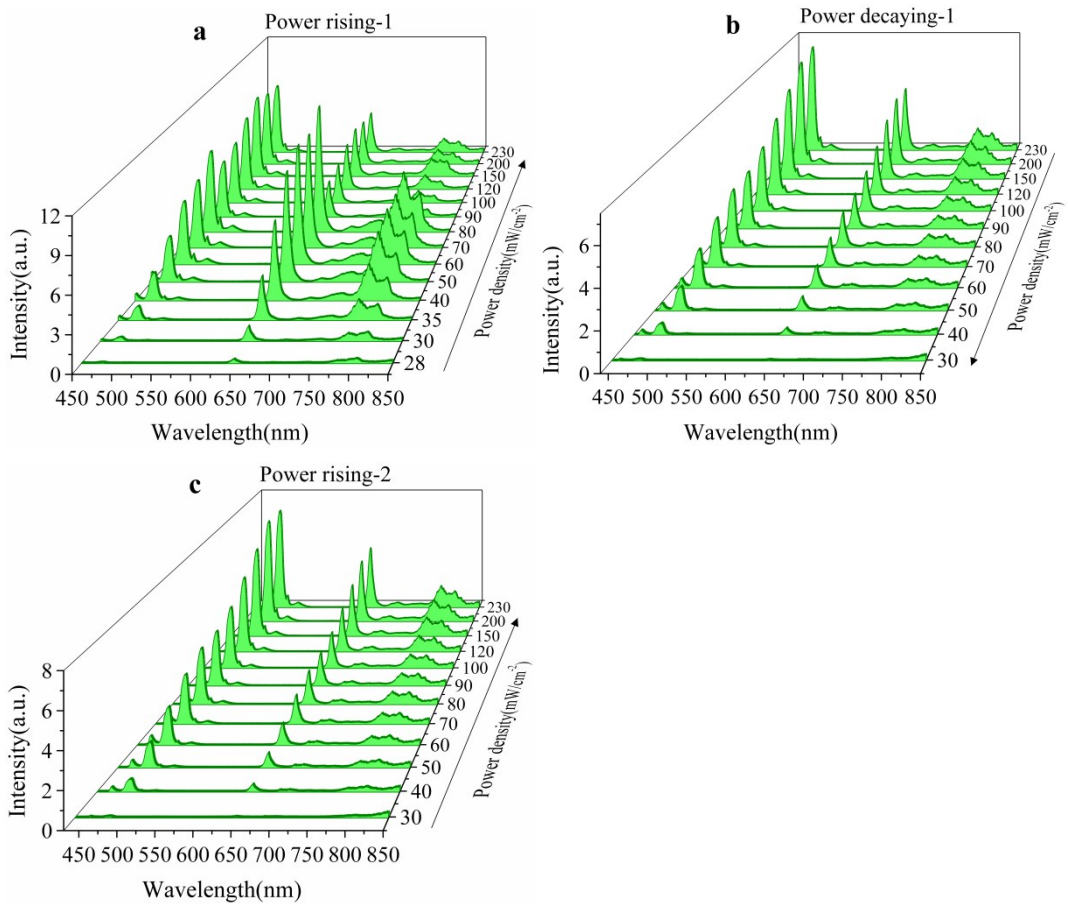

Figure S11 (a-c) Emission spectra from a $NaYbF_4$: 0.5% Tm microtube excited using a 980-nm laser for the varying of power rising and decaying scan cycles, recorded at room temperature.