Microlens Array Enhanced Upconversion Luminescence at Low Excitation Irradiance

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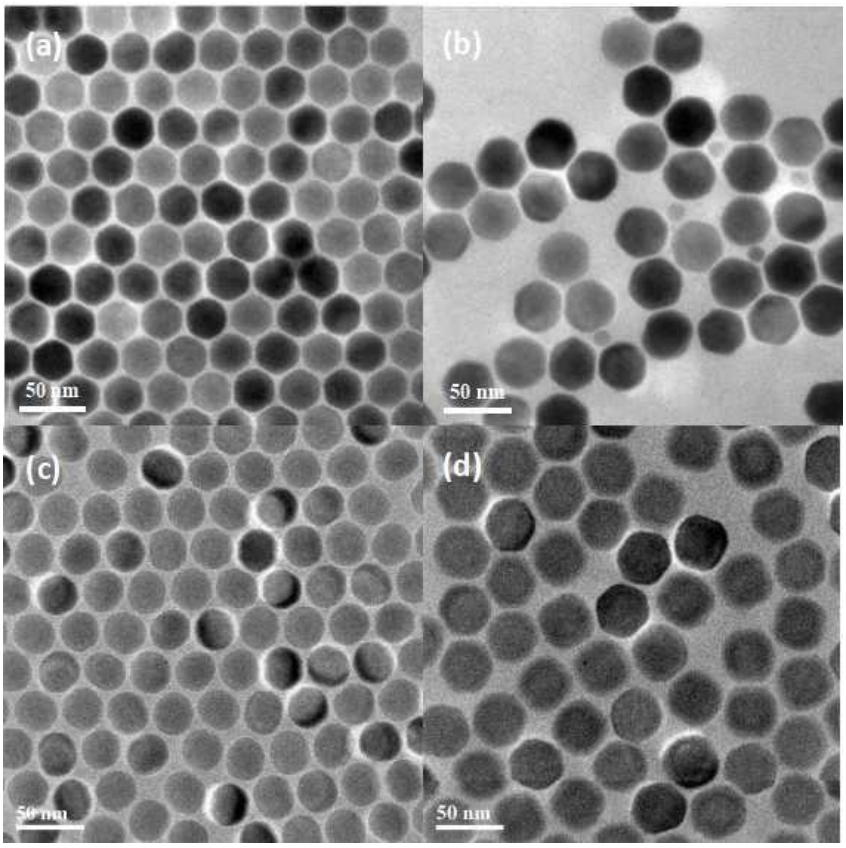

Figure S1 TEM images of (a) core $NaYF_4$:20%Yb^{3+},2%Er^{3+}, (b) core-shell $NaYF_4$:20%Yb^{3+}, 2%Er^{3+}@20%Yb^{3+},30%Nd^{3+}, (c) core $NaYF_4$:20%Yb^{3+},0.5%Tm^{3+}, (d) core-shell $NaYF_4$:20%Yb^{3+}, 0.5%Tm^{3+}@20%Yb^{3+},30%Nd^{3+} nanoparticles. Scale bars: 50 nm.

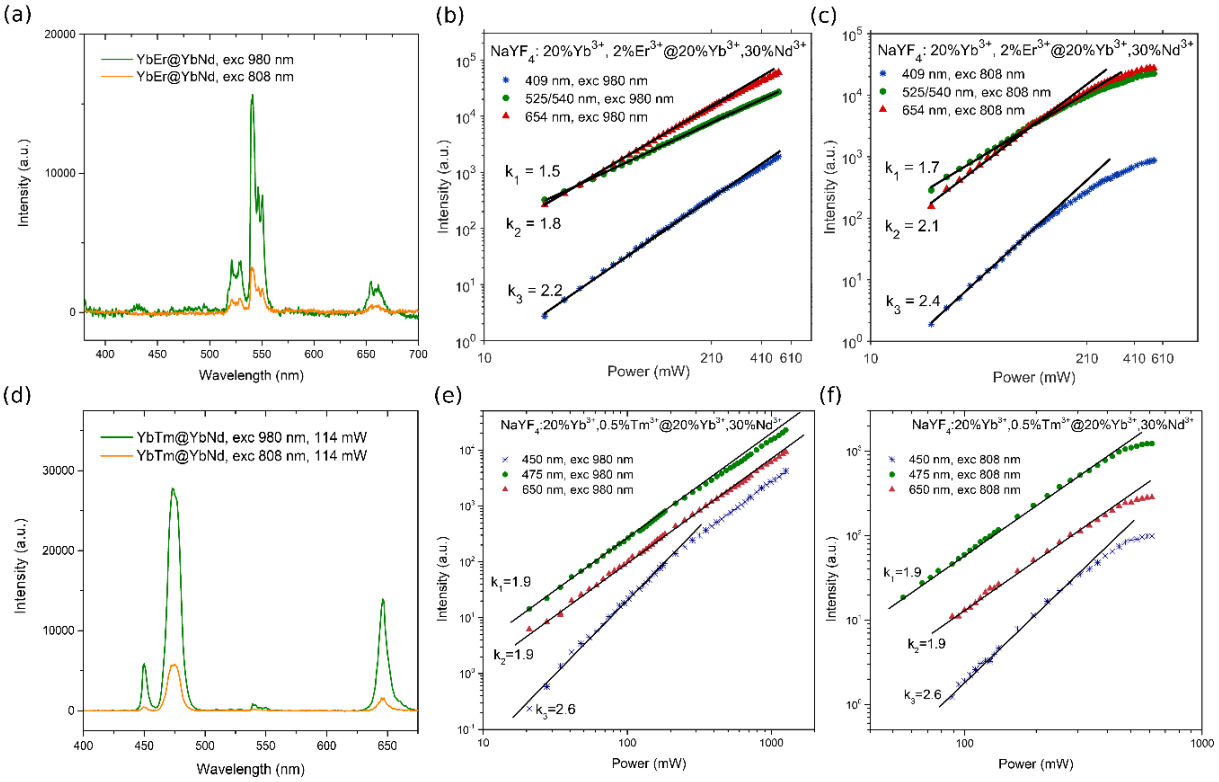

Figure S2 (a) Upconversion emission spectra of $NaYF_4$:20%Yb^{3+}, 2%Er^{3+}@20%Yb^{3+},30%Nd^{3+} nanoparticles under CW 980 nm and 808 nm excitation. Excitation power density for both lasers was 1.3 W/cm^2. Excitation power-density response of $NaYF_4$:20%Yb^{3+}, 2%Er^{3+}@20%Yb^{3+},30%Nd^{3+} under (b) CW 980 nm excitation and (c) CW 808 nm excitation. (d) Upconversion emission spectra of $NaYF_4$:20%Yb^{3+}, 0.5%Tm^{3+}@20%Yb^{3+},30%Nd^{3+} nanoparticles under CW 980 nm and 808 nm excitation. Excitation power density for both lasers was 14.5 W/cm^2. Excitation power-density response of $NaYF_4$:20%Yb^{3+}, 0.5%Tm^{3+}@20%Yb^{3+},30%Nd^{3+} under (e) CW 980 nm excitation and (f) CW 808 nm excitation. Laser beam diameter for both lasers: ~1.0 mm.

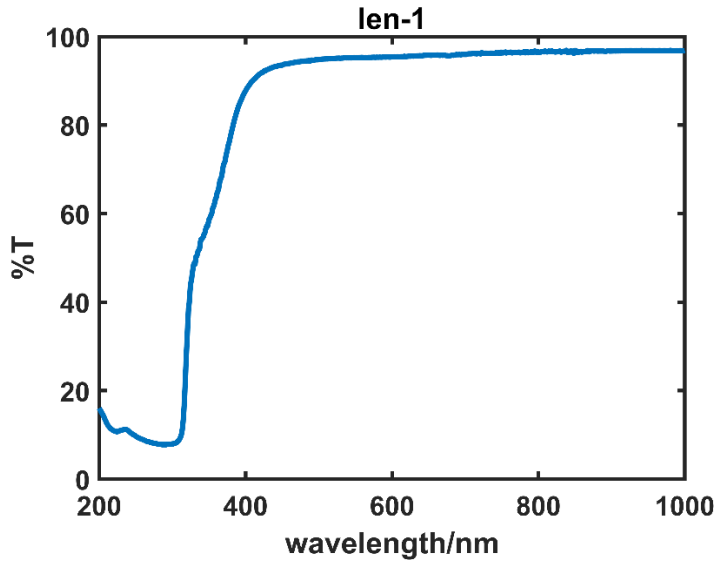

Figure S3 Transmission spectrum of the microlens array

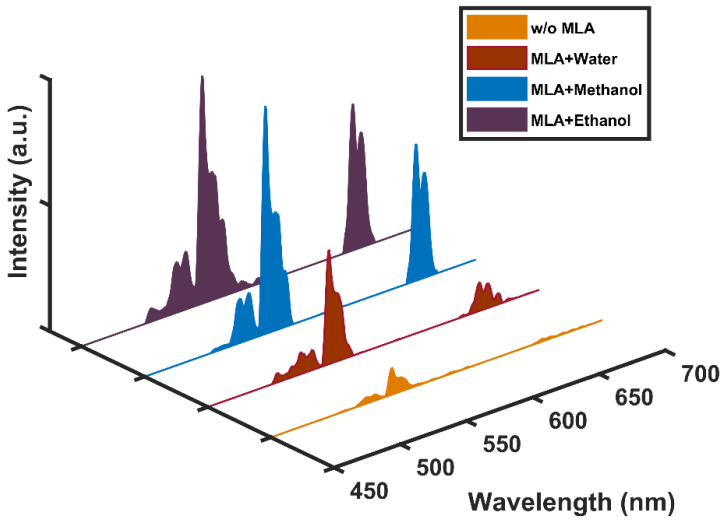

Figure S4 Upconversion luminescence spectra of $NaYF_4$:20%Yb^{3+},2%Er^{3+}@20%Yb^{3+},30%Nd^{3+} nanoparticles under 980 nm CW excitation (Average excitation intensity: 3.9 W/cm^2) without and with the addition of microlens array (MLA), using different solvents as the interface medium (ethanol, water, methanol).