Supplementary Material (ESI) for the Journal of Materials Chemistry Supplementary Information:



25

Fig. S1 TEM images of BaGdF₅:20%Yb³⁺/2% Er^{3+} nanocrystals prepared at different reaction time: a) 1 h, b) 2 h, c) 3 h. 30



Fig. S2 XRD pattern and TEM images of β -NaYF₄: 20 mol% Yb³⁺/ 2 mol% Er³⁺NPs prepared in OA and ODE.



Fig. S3 The UC excitation spectra monitored within the green Er^{3+} emission lines ($\lambda_{em} = 541 \text{ nm}$) and the diffuse reflection spectra of BaGdF₅:Yb/Er, BaGdF₅:Yb/Er@BaGdF₅:Yb/Er@BaGdF₅: 20%Yb NPs, respectively.



Fig. S4 The energy level diagrams of Er^{3+} , Yb^{3+} dopant ions and upconversion mechanism following 980 nm laser diode excitation. The full, colorized dashed, dotted and curly arrows represent excitation, emission, multiphonon relaxation and energy transfer processes, respectively.