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Controllable and tuneable growth of NaYbF₄:Tm (0.5%) Fe (5%) @ Na(Yb/Y)F₄ - core @ shell and the effect of their geometry on upconversion luminescence..

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Figure S1. Size histograms of core and core shell structures using different Yb³⁺ concentration during the shell growth: a) NaYbF₄: Tm (0.5%) Fe (5%) core and (b-f) NaYbF₄: Tm (0.5%) Fe (5%) @ NaYF₄: Yb (x%) core shell nanoparticles synthesized with x= 0%, 20%, 40%, 60%, 80%, and 100%. Black bars from the histograms indicate the size of core length meanwhile the red colour corresponds to the diameter.



Figure S2 FTIR spectra of NaYbF₄: Tm (0.5%) Fe (5%) core and NaYbF₄: Tm (0.5%) Fe (5%) @ NaYF₄:Yb(x%) - core @ shell structures synthesized where x = 0%, 20%, 40%, 60%, 80%, and 100%.



Figure S3 XRD spectra of NaYbF₄: Tm (0.5%) Fe (5%) core and NaYbF₄: Tm (0.5%) Fe (5%) @ NaYF₄:Yb(x%) - core @ shell structures synthesized where x = 0%, 20%, 40%, 60%, 80%, and 100%. Measurements were acquired using a Cu K- α source (with λ = 1.54059 Å). Hexagonal β -NaYbF₄ (PDF card No.: 00-027-1427) and cubic α -NaYbF₄ (PDF card No.: 00-077-2042.



Figure S4. Enlargement of (a)(101) and (b)(201) diffraction peaks of the XRD pattern obtained for core and core @ shell nanoparticles. Measurements were acquired using a Cu K- α source (with λ = 1.54059 Å).



Figure S5. a) UC emission spectra of NaYbF₄: Tm (0.5%) Fe (5%) core and NaYbF₄: Tm (0.5%) Fe (5%) @ NaYF₄: Yb (x%) - core @ shell where x = 0, 20, 40, 60, 80 and 100%. For the measurements, nanoparticles were dispersed in hexane and measured with a 980 nm CW laser excitation.



Figure S6. Integrated intensity in the range of a) 438-490 nm and b) 270-380 nm. For the measurements, nanoparticles were dispersed in hexane and measured with a 980 nm CW laser excitation.



Figure S7. Dependence of the integrated intensity in the range of 330 - 353 nm (red line), 353 - 370 nm (blue line), 438 - 462 nm (green line), and 462- 490 nm (purple line) on pump power from (a) core, (b) core @ shell with 0% Yb³⁺, and (c) core @ shell with 100% Yb³⁺concentration. The excitation wavelength was fixed to 980 nm, and the PL spectra was recorded using different pump powers.



Figure S8. Lifetime measurement of the UCL emission at 362 nm (a-c) and 450 (d-f) obtained from (a,d) NaYbF₄: Tm (0.5%) Fe (5%) core, (b,e) NaYbF₄: Tm (0.5%) Fe (5%) @ NaYF₄ core – shell, and (c,f) NaYbF₄: Tm (0.5%) Fe (5%) @ NaYbF₄ core – shell structures.