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Supplementary information

Efficient White Light Emission by Upconversion in Yb^{3+}-, Er^{3+}- and Tm^{3+}-doped Y_2BaZnO_5

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Host [ref]	Dopants	Excitation conditions	CIE colour coord.	η_{UC} (%)
Transparent oxyfluoride glass ceramic embedded with YF_3 nanocrystals[6]	Yb^{3+} Er^{3+} Tm^{3+}	976 nm pulsed laser (2 ps, 15 nJ, 2W/mm^2)	x = 0.310 y = 0.359	0.1%
Y_2O_3 nanocrystals[7]	Yb^{3+} Er^{3+} Tm^{3+}	976 nm cw laser (down to 100 mW/mm^2)	x = 0.320 y = 0.340	
$Lu_3Ga_5O_{12}$ nanocrystals[8]	Yb^{3+} Er^{3+} Tm^{3+}	980 nm cw laser (down to 34 mW/mm^2)	x = 0.270 y = 0.338	
Transparent oxyfluoride glass ceramic embedded with YF_3 nanocrystals[9]	Yb^{3+} Ho^{3+} Tm^{3+}	976 nm pulsed laser (2 ps, 15 nJ, 2W/mm^2)	x = 0.351 y = 0.306	0.2%
Fluorolead germanate glass[10]	Yb^{3+} Ho^{3+} Tm^{3+}	975 nm cw laser (16 W/mm^2)	x = 0.344 y = 0.364	
Tellurite glass[11]	Yb^{3+} Er^{3+} Pr^{3+}	980 nm cw laser (3.4x10^6 W/mm^2)	x = 0.310 y = 0.335	

Table S1. Compositions, excitation conditions, colour coordinates and upconversion efficiencies of white light emitting materials reported in the literature.

Upconversion efficiency definition:

$$\eta_{UC} = \frac{P_{em}}{P_{abs}^{IR}} = \frac{P_{em}}{P_{inc}^{IR} - P_{not\,abs}^{IR}} \qquad \text{(Eq. 1)}$$

Where P_{em} is the power of the upconversion light emitted in the 380-780 nm range, P_{inc}^{IR} is the incident power in the near-infrared (integrated over the 950-1000 nm range), P_{abs}^{IR} is the power of the fraction of incident light that has been absorbed by the sample, and $P_{not\,abs}^{IR}$ is the power of the fraction of incident light that has not been absorbed by the sample.

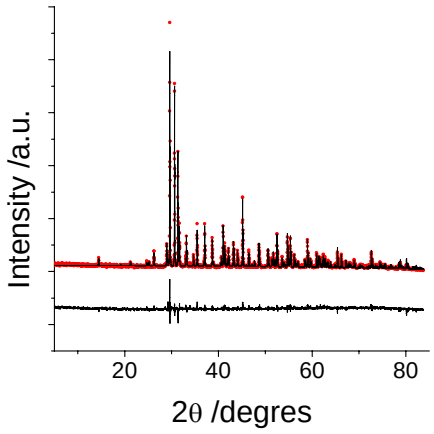

Fig. S1. Rietveld refinement based upon the X-ray powder diffraction pattern of Y_2BaZnO_5: Yb^{3+}(10%),Er^{3+}(0.3%),Tm^{3+}(1%). The cell parameters are: a = 12.3283(2) A, b = 5.7056(1) A and c = 7.0646(1) A (ICSD 87082). This X-Ray powder diffraction pattern was measured using a theta-theta diffractometer (Bruker D8), equipped with a Cu Kα source (generator: 40 kV and 40 mA), a scintillation detector with pulse height analysis, and a variable knife-edge collimator for high resolution X-ray diffractometry.

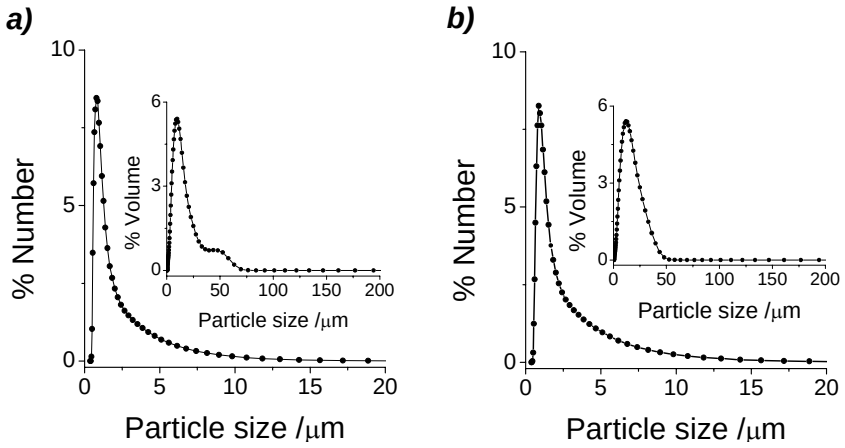

Fig. S2. Typical particle size distribution of white emitting *a)* Y_2BaZnO_5:Yb^{3+}(10%),Er^{3+}(0.3%),Tm^{3+}(1%), and *b)* Y_2BaZnO_5:Yb^{3+}(10%),Er^{3+}(0.4%) (4.8% w/w) + Y_2BaZnO_5:Yb^{3+}(10%),Tm^{3+}(0.25%) (95.2% w/w). Both the number mean and volume mean sizes are presented. The measurements were performed using a *Coulter LS 230* particle size analyser, under recirculating conditions in an isopropanol suspension.

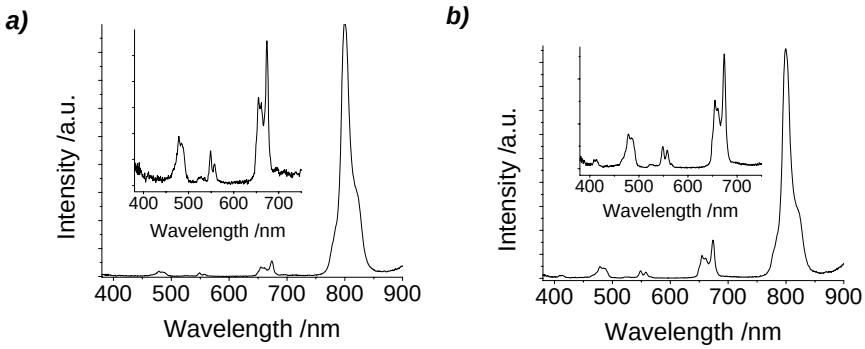

Fig. S3. Typical emission spectra of white emitting *a)* Y_2BaZnO_5:Yb^{3+}(10%),Er^{3+}(0.3%),Tm^{3+}(1%), and *b)* Y_2BaZnO_5:Yb^{3+}(10%),Er^{3+}(0.4%) (4.8% w/w) + Y_2BaZnO_5:Yb^{3+}(10%),Tm^{3+}(0.25%) (95.2% w/w) under 977 nm excitation (~90 mW/mm^2). The colour coordinates corresponding to these white emitting samples are *a)* x = 0.299, y = 0.298 and *b)* x = 0.306, y = 0.313.