Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

SUPPORTING INFORMATION

Synthesis of monoclinic Ho, Tm:$KLu(WO_4)_2$ microrods with high photothermal conversion efficiency *via* a thermal decomposition-assisted method

Albenc Nexha, Joan J. Carvajal,* Maria Cinta Pujol, Francesc Díaz and Magdalena Aguiló
Universitat Rovira i Virgili, Departament Química Física i Inorgànica, Física i Cristal·lografia de Materials i Nanomaterials (FiCMA-FiCNA)-EMaS, Campus Sescelades, E-43007, Tarragona, Spain
*joanjosep.carvajal@urv.cat

Table S1. ICP-OES analysis of the dopant concentration of Ho^{3+},Tm^{3+} in $KLu(WO_4)_2$ rods synthesized by the thermal decomposition-assisted methodology.

Material $KLu_{1-x-y}Ho_xTm_y(WO_4)_2$	Ho^{3+} (w/w %) x (%)	Tm^{3+} (w/w %) y (%)	Lu^{3+} (w/w %) 1-x-y (%)
x=0.03, y=0.05	2.2	3.57	94.22
x=0.01, y=0.1	0.98	9.8	89.22

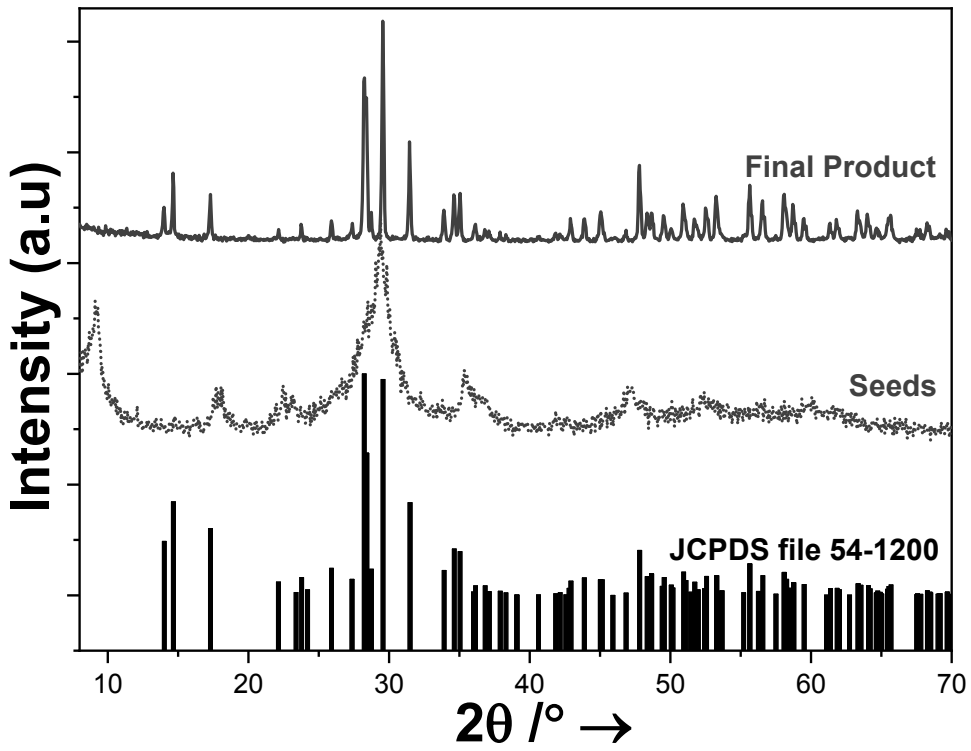

Fig. S1 XRPD patterns of the seeds and the final products (calcined at 1023 K for 2 h as an example) obtained in the synthesis of undoped KLuW particles *via* the thermal decomposition-assisted method. The KLuW reference pattern (JCPDS file 54-1200) was included for comparison.

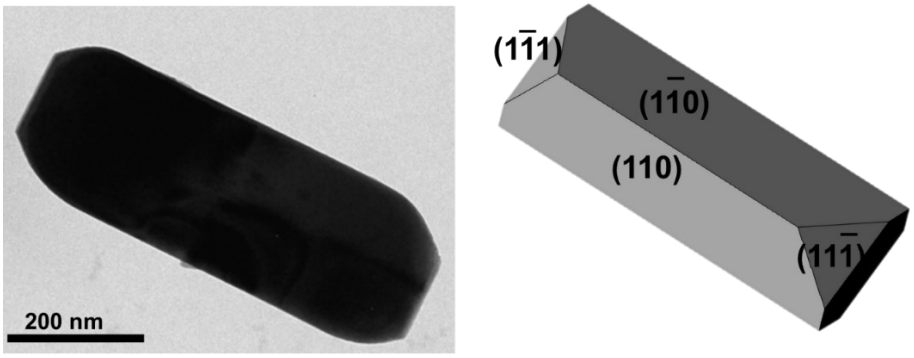

Fig. S2 Crystalline habit of the undoped KLuW rods, transmission electron microscopic image and morphology predicted by the SHAPE software.

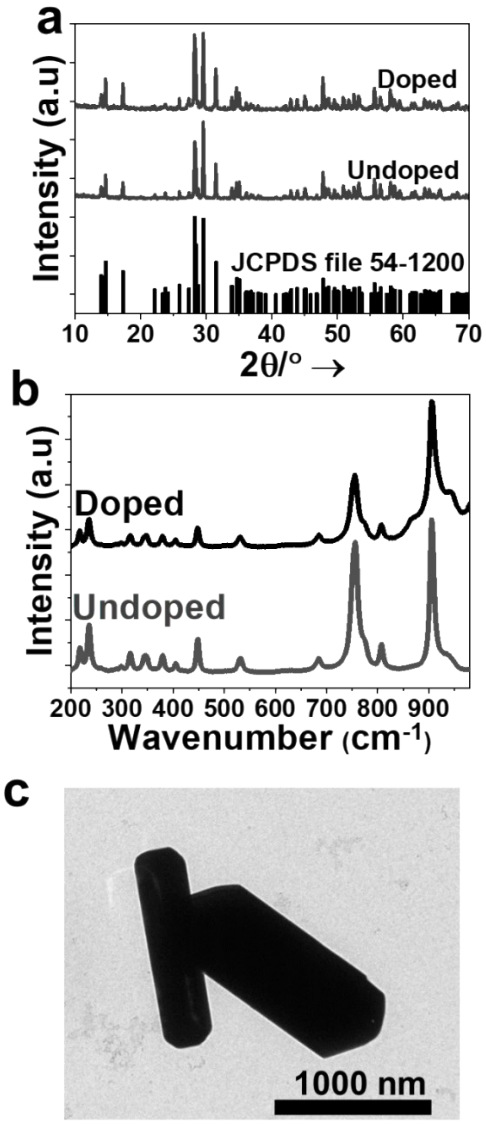

Fig. S3 (a) XRPD pattern of undoped KLuW and doped Ho, Tm:KLuW microrods. (b) Raman spectroscopy of undoped KLuW and doped Ho, Tm:KLuW microrods. (c) TEM image of doped Ho, Tm:KLuW microrods.

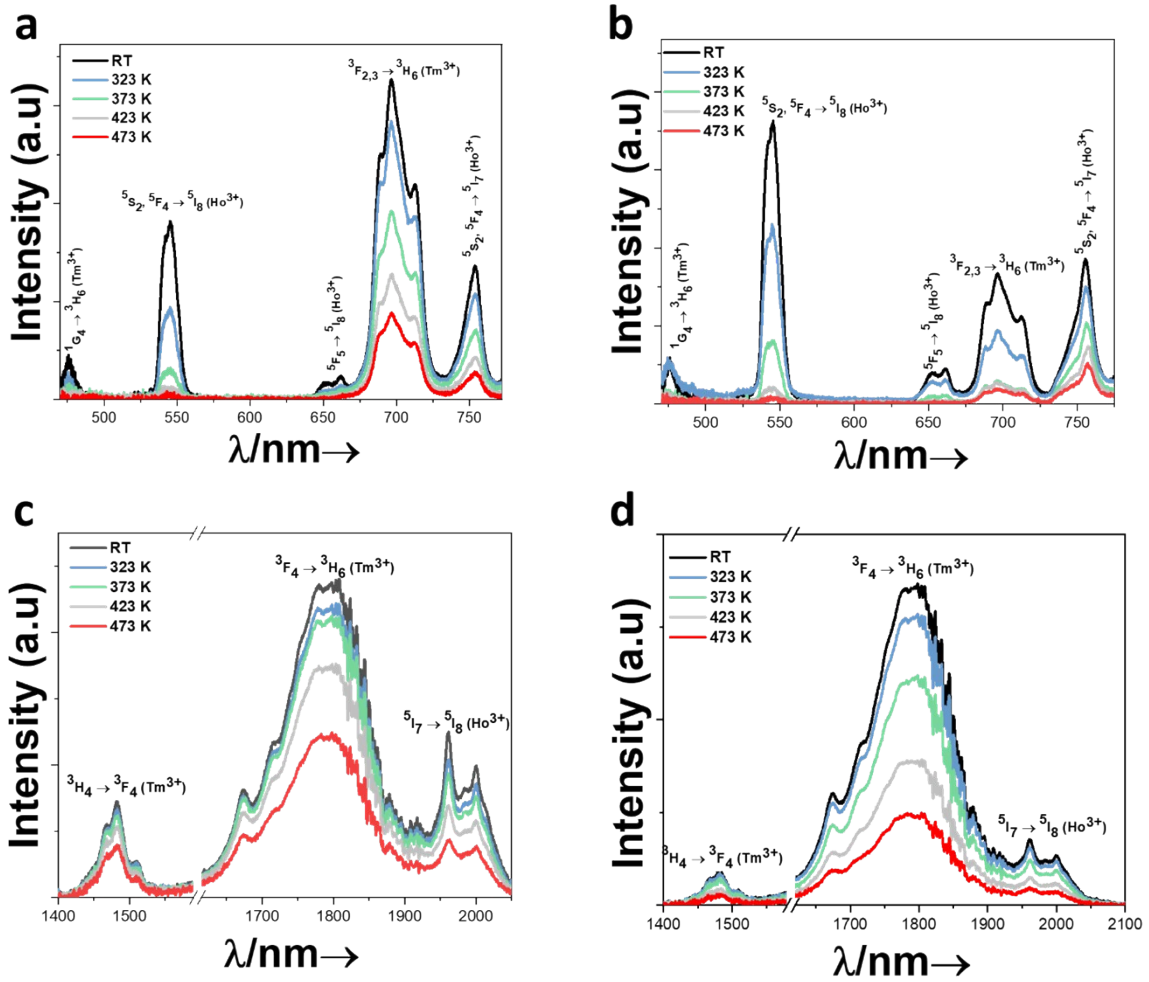

Fig. S4 Evolution with temperature of the intensity of the emission bands in the visible of Ho, Tm doped KLuW microrods containing: (a) 3 mol% Ho^{3+}, 5 mol% Tm^{3+}, and (b) 1 mol% Ho^{3+}, 10 mol% Tm^{3+}. Evolution with temperature of the intensity of the emission bands in the NIR of Ho, Tm:KLuW rods containing: (c) 3 mol% Ho^{3+}, 5 mol% Tm^{3+} and (d) 1 mol% Ho^{3+}, 10 mol% Tm^{3+}.

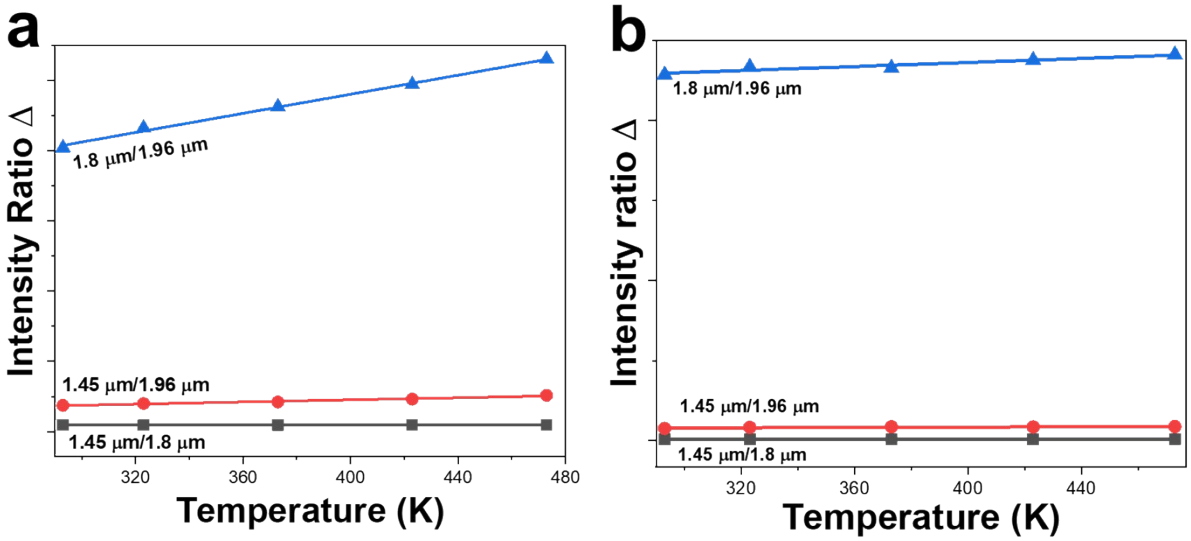

Fig. S5 Temperature dependence of the three possible intensity ratios in the NIR of Ho, Tm doped KLuW microrods containing: (a) 3 mol% Ho^{3+}, 5 mol% Tm^{3+} and (b) 1 mol% Ho^{3+}, 10 mol% Tm^{3+}.

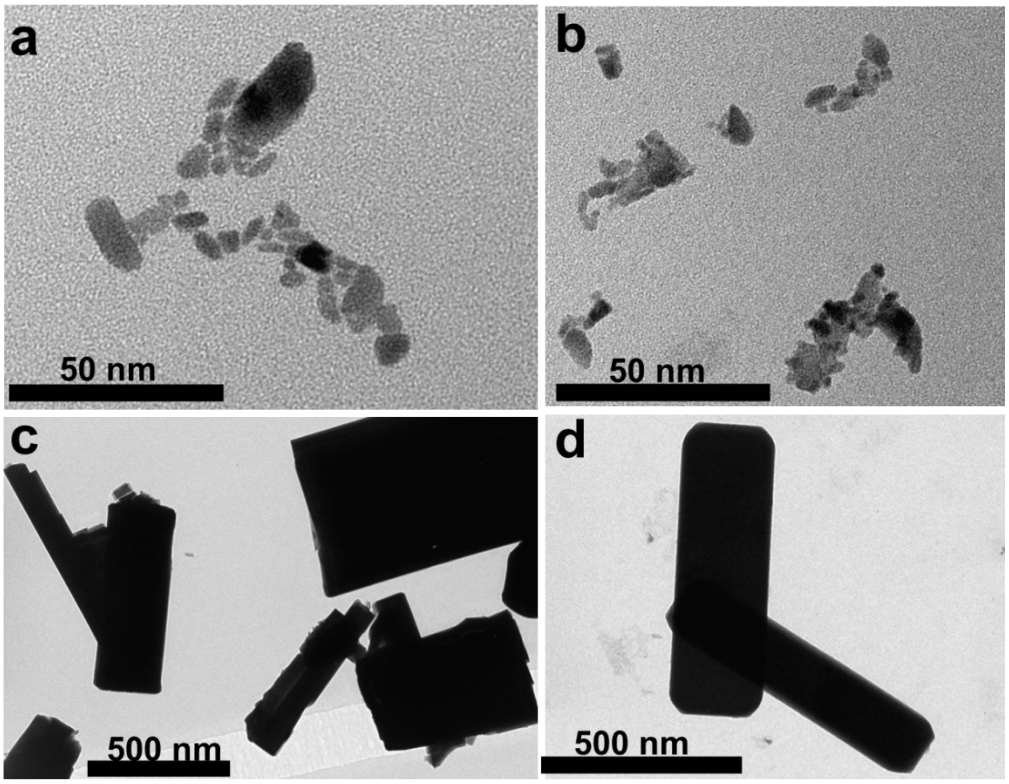

Fig. S6 TEM images of Ho, Tm doped KLuW particles synthesized via four different synthetic methodologies: (a) MW=microwave-assisted solvothermal method, (b) CA=conventional autoclave solvothermal method, (c) P=modified sol-gel Pechini method, and (d) TD=thermal decomposition-assisted method.

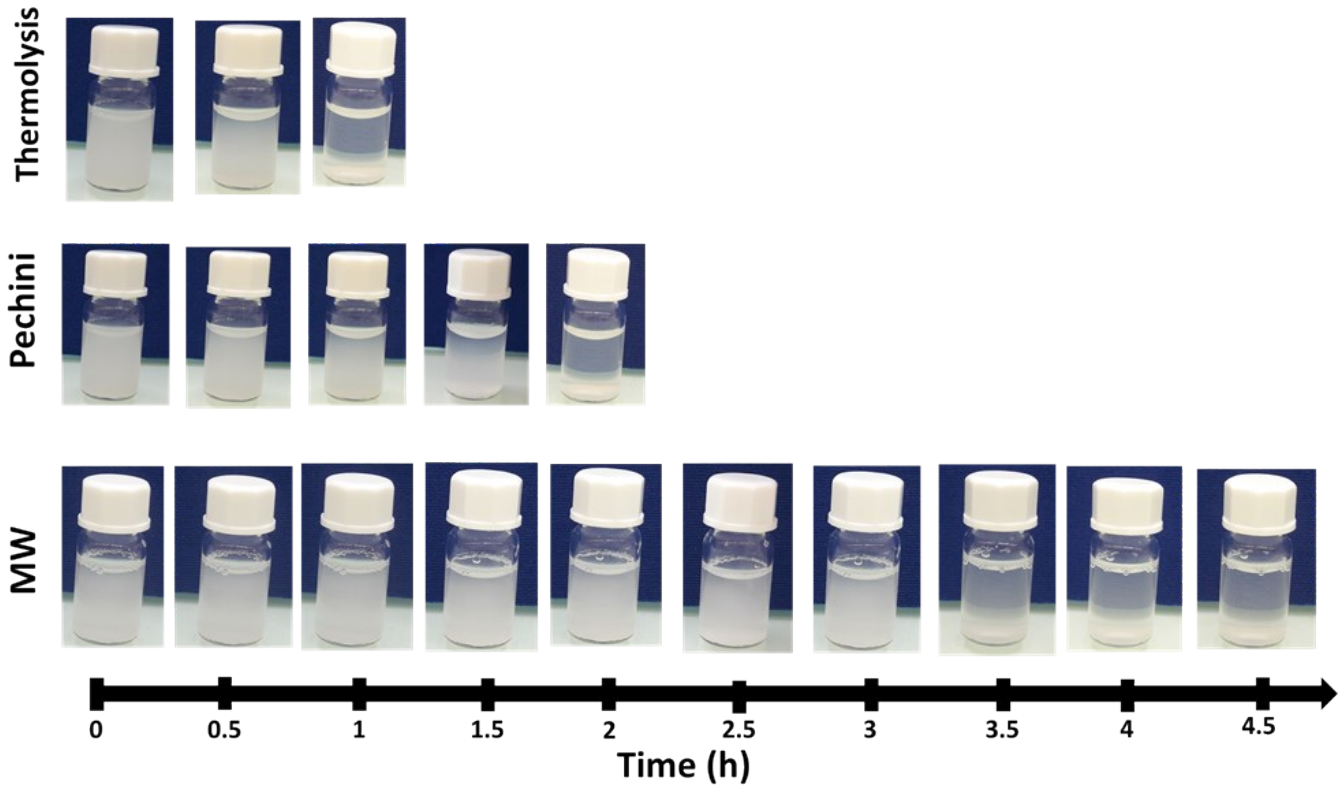

Fig. S7 Sedimentation test of Ho, Tm doped $KLu(WO_4)_2$ nanocrystals synthesized from the modified sol-gel Pechini, solvothermal (MW as an example) and thermolysis methodologies.

Table S2 Fitting parameters and thermometric performance of Ho, Tm doped KLuW microrods synthesized via the thermal decomposition-assisted method, operating in different spectral regimes and on the temperature range 293 K-473 K.

Based on Equation 1

Doping	**Regime**	Δ_0	B	α	**R²**	S_{abs} **(K^{-1})**	S_{rel} **(% K^{-1})**	δT **(K)**
3 mol% Ho, 5 mol% Tm	VIS	3.95	0.0066	0.011	0.98	0.013	0.25	1.97
1 mol% Ho, 10 mol% Tm	VIS	0.55	10312	0.032	0.94	0.028	1.9	0.26

Based on Equation 5

Doping	**Regime**	B	C	$\Delta E_1 - \Delta E_2$ **(cm^{-1})**	**R²**	S_{abs} **(K^{-1})**	S_{rel} **(% K^{-1})**	δT **(K)**
3 mol% Ho, 5 mol% Tm	NIR	8.07	203.9	141.7	0.99	0.0096	0.24	2.1
1 mol% Ho, 10 mol% Tm	NIR	10.38	36.6	25.4	0.90	0.0039	0.04	11.7

Table S3 Fitting parameters, thermometric performance, and photothermal conversion efficiency of Ho, Tm doped KLuW particles synthesized via four different synthetic methodologies (P = modified sol-gel Pechini method; MW = microwave-assisted solvothermal method; CA = conventional autoclave solvothermal method; and TD = thermal decomposition-assisted method).

Doping	**Synthesis**	**Size (nm)**	**B**	C	$\Delta E_1 - \Delta E_2$ **(cm^{-1})**	**R²**	S_{abs} **(K^{-1})**	S_{rel} **(% K^{-1})**	δT **(K)**	η (%)	Ref.
1 mol% Ho, 10 mol% Tm	P	2000	155.6 ± 15.1	773.2 ± 30.7	537	0.99	0.097	0.90	0.55	40	1
1 mol% Ho, 10 mol% Tm	MW	12	8.5 ± 0.3	159.7 ± 9.9	111	0.98	0.0091	0.18	2.6	45	2
1 mol% Ho, 10 mol% Tm	CA	16	5.1 ± 0.7	172.7 ± 44.8	120	0.99	0.0056	0.20	2.4	43	2
1 mol% Ho, 10 mol% Tm	**TD**	**1480**	**12.1 ± 0.66**	**172.7 ± 17**	**60**	**0.92**	**0.009**	**0.1**	**5**	**41**	**This Work**
3 mol% Ho, 5 mol% Tm	P	2000	13.2 ± 1.2	318.2 ± 29.3	221	0.95	0.016	0.37	1.34	30	1
3 mol% Ho, 5 mol% Tm	MW	12	3.7 ± 0.1	198.9 ± 10.8	138	0.98	0.0044	0.23	2.1	33	2
3 mol% Ho, 5 mol% Tm	CA	16	4 ± 0.1	284.9 ± 10.1	198	0.99	0.0051	0.33	1.5	36	2
3 mol% Ho, 5 mol% Tm	**TD**	**1480**	**12.5 ± 0.2**	**354.6 ± 5.1**	**247**	**0.99**	**0.015**	**0.41**	**1.2**	**66**	**This Work**

References

1. A. Nexha, J. J. Carvajal, M. C. Pujol, F. Díaz and M. Aguiló, *J. Mater. Chem. C*, 2020, **8**, 180-191.
2. A. Nexha, M. C. Pujol, J. J. Carvajal, F. Díaz and M. Aguiló, *Submitted at Nanomaterials*