Supplemental Information
Down-/Up-Conversion Emission Enhancement by Li Addition: Improved Crystallization or Local Structure Distortion?

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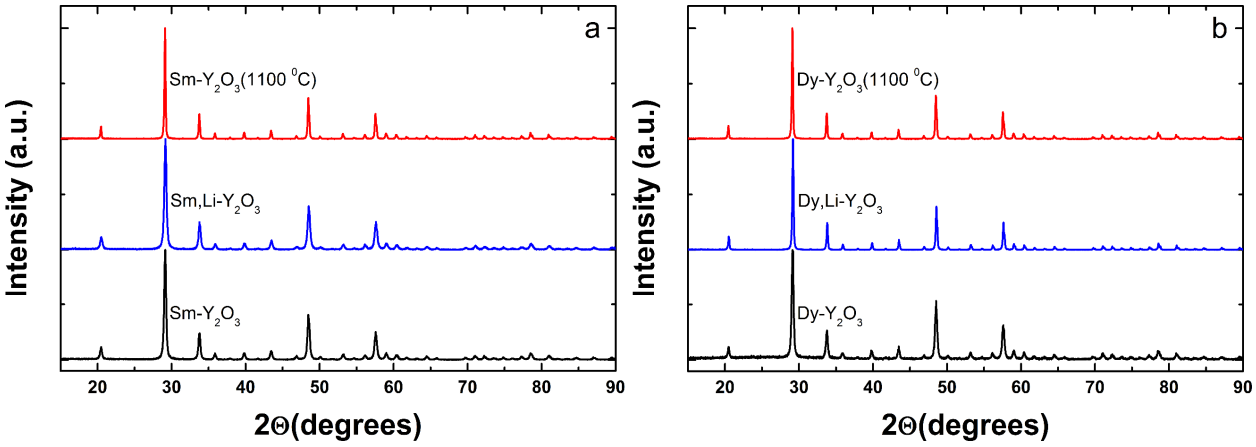

Figure S1. The effect of Li addition and calcination temperature on XRD patterns of Sm-Y_2O_3 and Dy-Y_2O_3.

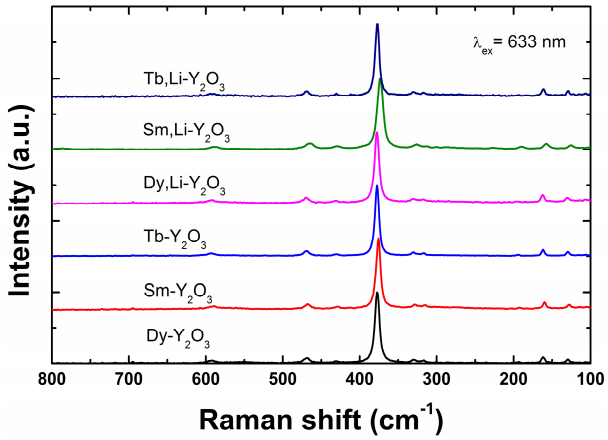

Figure S2. The effect of Li addition and calcination temperature on Raman spectra of Tb-Y_2O_3, Sm - Y_2O_3 and Dy - Y_2O_3.

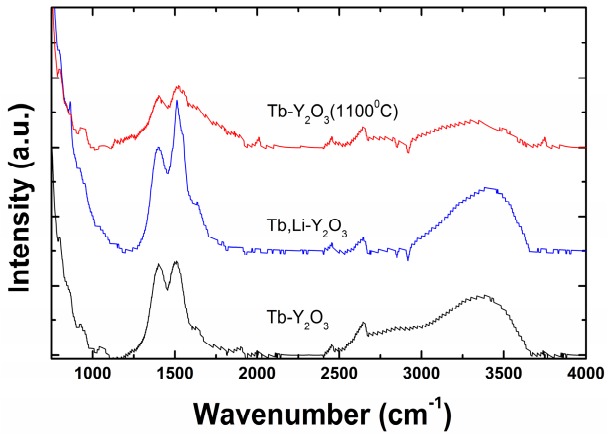

Figure S3. The effect of Li addition and calcination temperature on FTIR spectra of Tb-Y_2O_3.

The wide band around 3360 cm^{-1} are due to OH stretching in the physiosorbed water molecules that are roughly similar for Tb- Y_2O_3 and Tb, Li- Y_2O_3. The bands at 1350 and 1510 cm^{-1} could correspond to NO_3^- and CO_3^{2-} (hydroxycarbonate like) species absorbed from the preparation procedure. The annealing at 1100°C suppressed significantly the presence of physiosorbed water molecules as well as the NO_3^- and CO_3^{2-} species. The effect of Li addition on the intensity of OH band remained inconclusive.

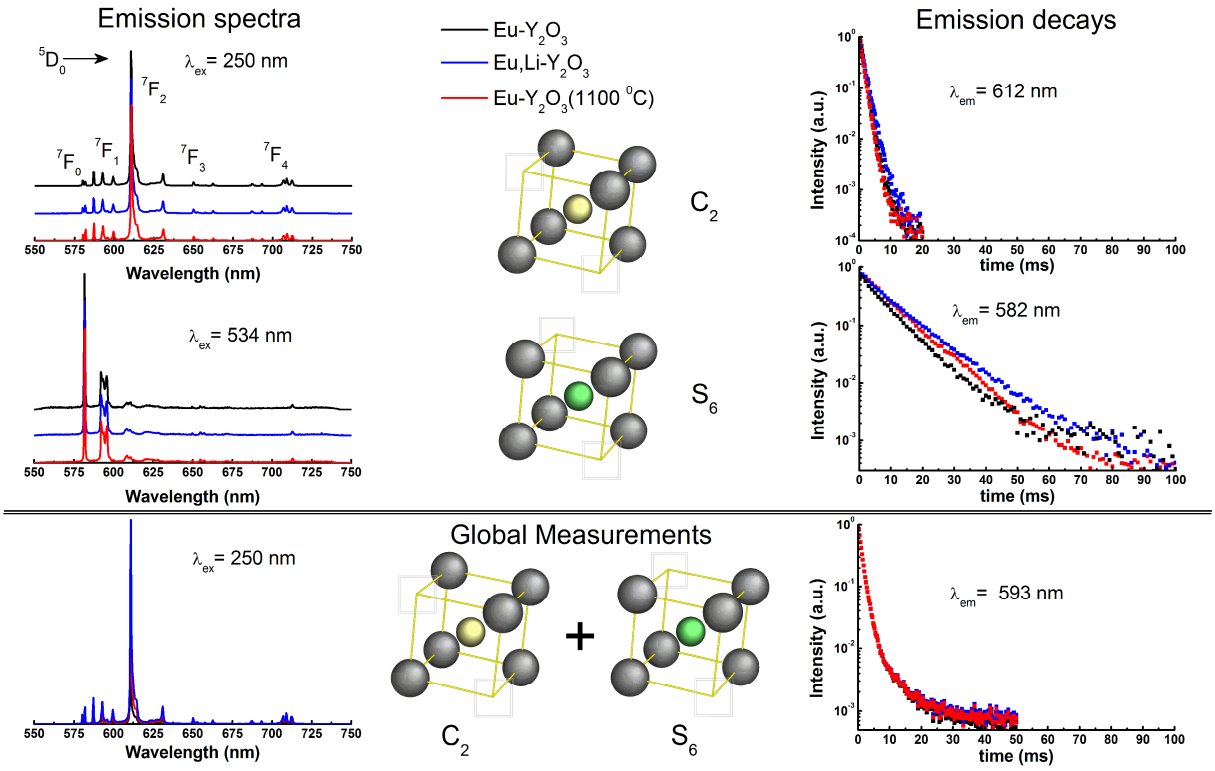

Figure S4. Effects of Li addition and increase of the calcination temperature from 800 to 1100 °C on the emission spectra and decays of C_2 and S_6 Eu centers as well as the global measurements. All the emission spectra were normalized to maximum peak intensity. The excitation and emission wavelengths ensured the best spectral separation of the distinct Eu centers. The schematic representations of C_2 and S_6 sites in cubic Y_2O_3 is also illustrated.

The characteristic emissions of C_2 and S_6 Eu centers were obtained by excitation into Eu^{3+} - O^{2-} charge transfer band and f-f absorption of Eu around 534 nm (corresponding to $^7F_0$-$^5D_1$ transition), respectively. The C_2 type emission of Eu-Y_2O_3 is dominated by ED (electric dipole) $^5D_0 - {}^7F_2$ transition around 612 nm.[1,2] Conversely, the S_6 type emission of Eu-Y_2O_3,is dominated by the MD (magnetic dipole) $^5D_0 - {}^7F_1$ transition peaked around 585 nm.[1] The average emission lifetime of S_6 Eu is estimated to be around ~7 ms, which is five times greater than the value of C_2 Eu (~1.4 ms). Slightly different decays measured for S_6 Eu in the three samples are likely related to incomplete spectral separation of S_6 and C_2 centeres.

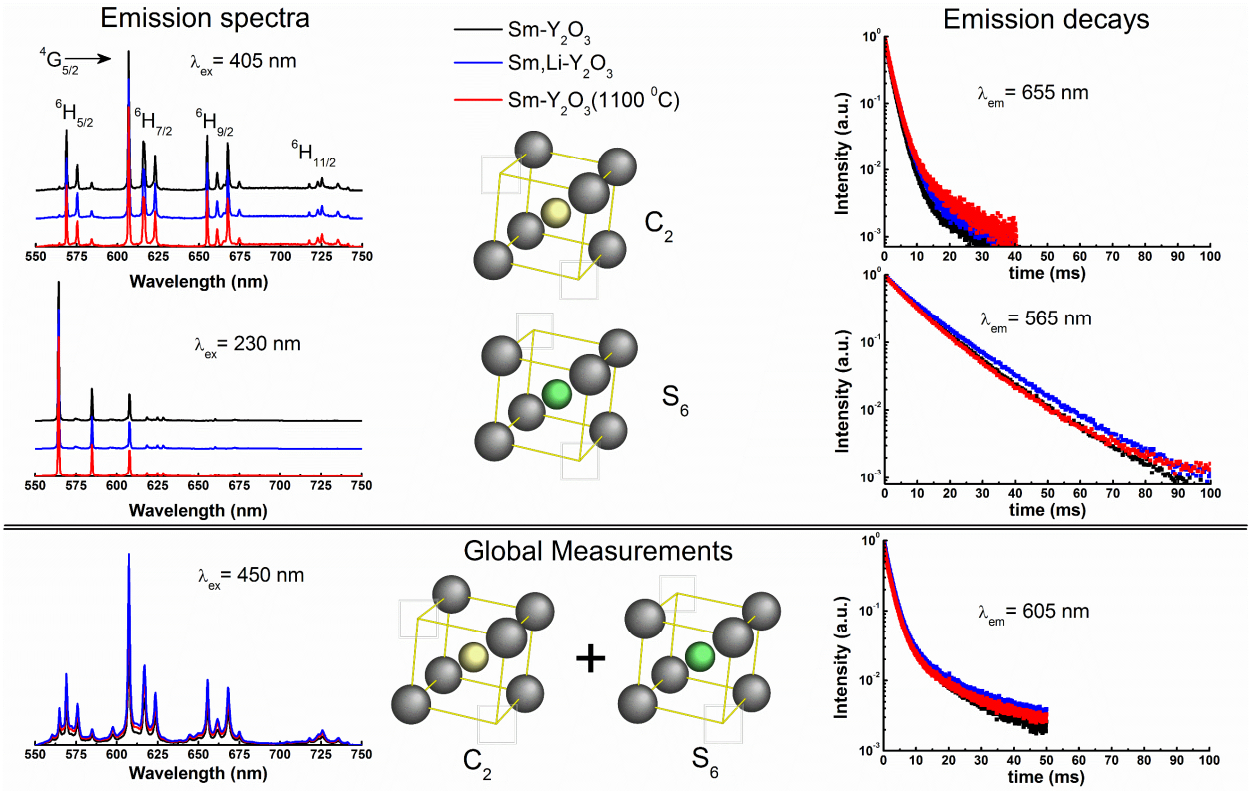

Figure S5. Effects of Li addition and increase of the calcination temperature from 800 to 1100 °C on the emission spectra and decays of C_2 and S_6 Sm centers as well as the global measurements. All the emission spectra were normalized to maximum peak intensity. The excitation and emission wavelengths ensured the best spectral separation of the distinct Sm centers. The schematic representations of C_2 and S_6 sites in cubic Y_2O_3 is also illustrated.

The characteristic emissions of C_2 and S_6 Sm centers were obtained by excitation into Sm^{3+} - O^{2-} charge transfer band and f-f absorption of Sm at 230 and 405 nm, respectively.[3] The C_2 type emission of Sm-Y_2O_3 is dominated by mixed MD (magnetic dipole) + ED (electric dipole) $^4G_{5/2}$ - $^6H_{7/2}$ (~608 nm) followed by the MD $^4G_{5/2}$ - $^6H_{5/2}$ (~569 nm) and ED $^4G_{5/2}$ - $^6H_{9/2}$ (~655 nm) emission transitions. Conversely, the S_6 type emission of Sm-Y_2O_3 is dominated by the MD $^4G_{5/2}$ - $^6H_{5/2}$ transition (~565 nm) followed by mixed MD + ED $^4G_{5/2}$ - $^6H_{7/2}$ (~608 nm) transition.[3,4] The average emission lifetime of S_6 Sm is estimated to be around ~10 ms, which is roughly 6 times greater than the value of C_2 Sm (~1.8 ms).

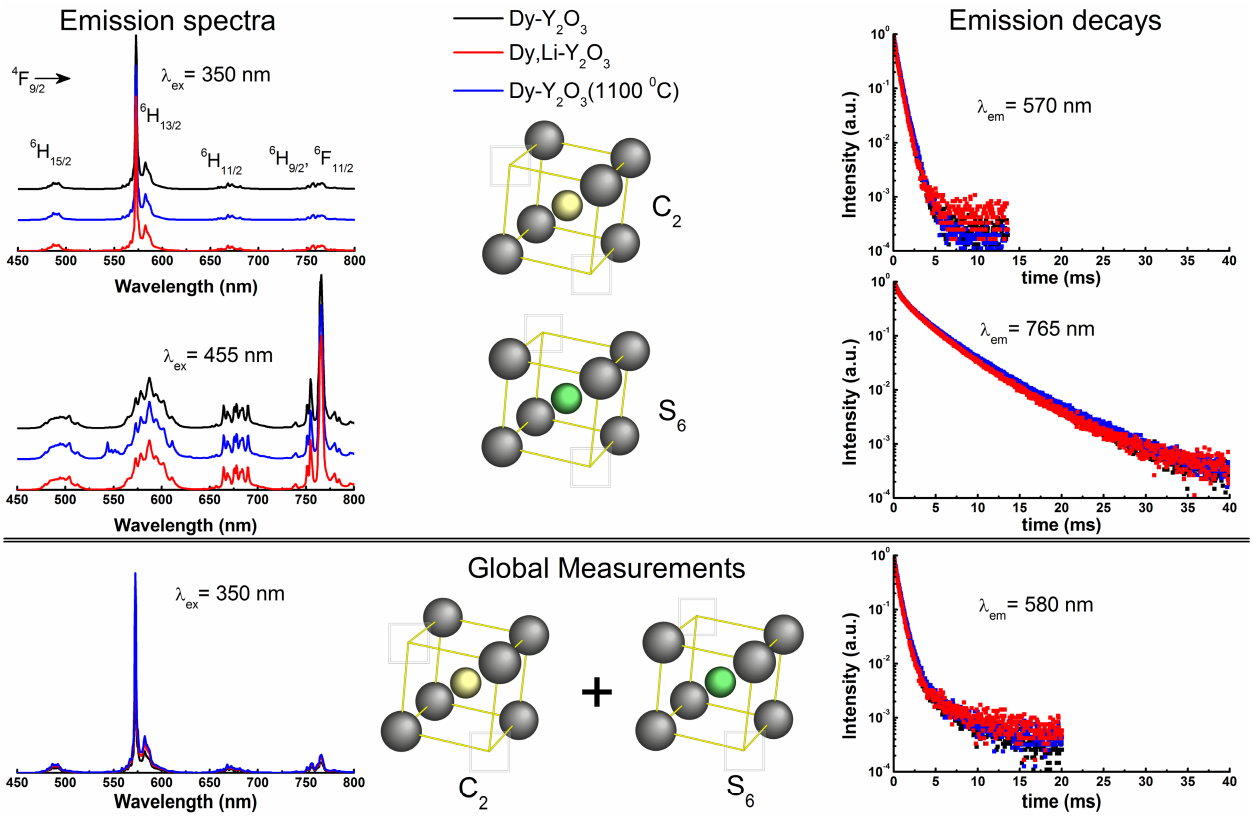

Figure S6. Effects of Li addition and increase of the calcination temperature from 800 to 1100 °C on the emission spectra and decays of C_2 and S_6 Sm centers as well as the global measurements. All the emission spectra were normalized to maximum peak intensity. The excitation and emission wavelengths ensured the best spectral separation of the distinct Sm centers. The schematic representations of C_2 and S_6 sites in cubic Y_2O_3 is also illustrated.

The characteristic emissions of C_2 and S_6 Dy centers were obtained by excitation into f-f absorptions of Dy at 350 and 455 nm, respectively.[5] The emission of C_2 Dy is dominated by the $^4F_{9/2}$ - $^6H_{13/2}$ yellow transition at 570 nm. The fingerprint emission of S_6 Dy is striking different to that of C_2 Dy with a relatively intense NIR emission corresponding to the MD $^4F_{9/2}$ - $^6H_{9/2}$/$^6F_{11/2}$ transitions around 765 nm.[4] The average emission lifetime of S_6 Dy is estimated to be around 4.8 ms, which is one order of magnitude greater than the value of C_2 Dy (0.43 ms).

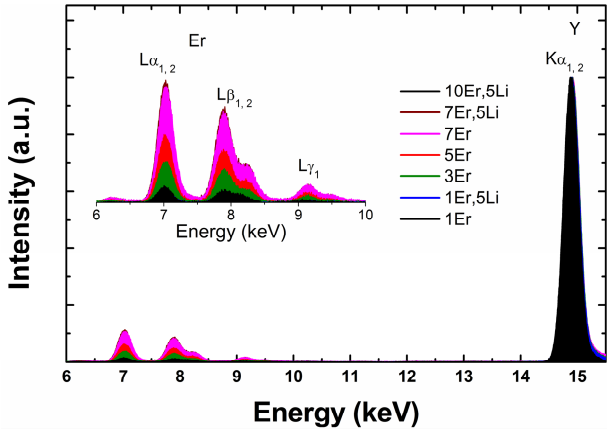

Figure S7. Elemental analysis of Er- Y_2O_3 by use of X-ray induced fluorescence. The energy of Er and Y X-ray emission lines were attributed from http://xdb.lbl.gov/Section1/Table_1-2.pdf [5].

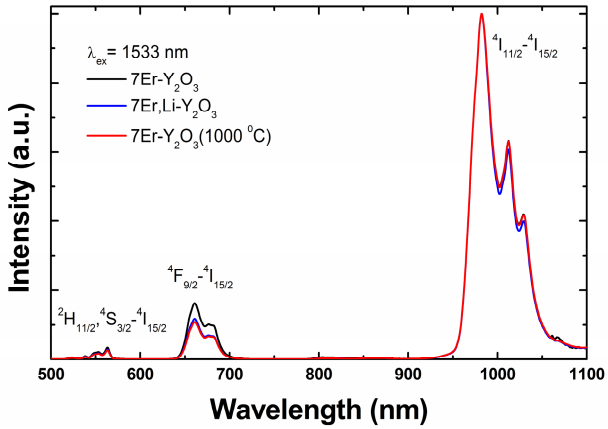

Figure S8. Effect of Li addition and extended calcination temperature on the UPC emission shapes of 7Er-Y_2O_3 under 1533 nm excitation. All spectra were normalized to 980 nm based peak.

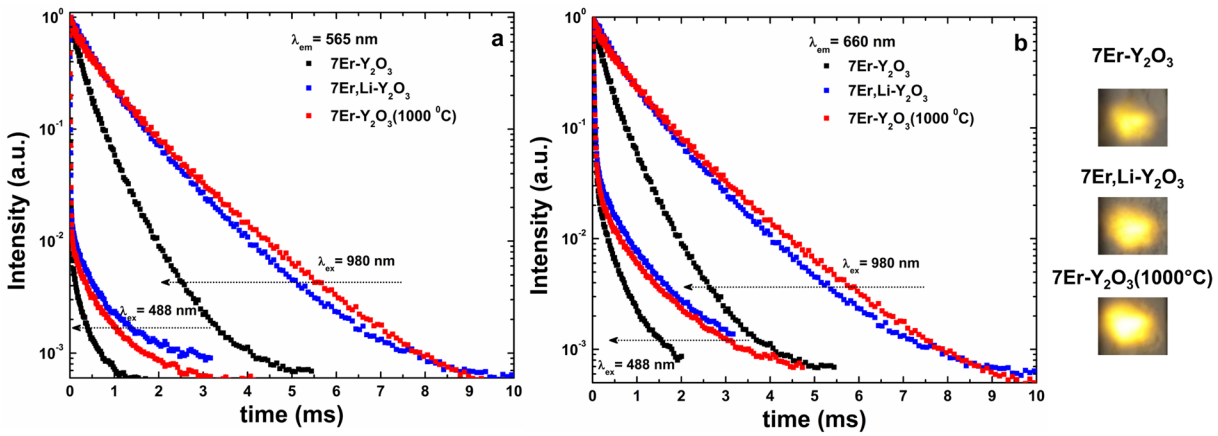

Figure S9. Effect of Li addition and extended calcination temperature on the UPC emission decays of 7Er-Y_2O_3 under excitation at 980 nm. The digital images of the nanopowders were obtained in the *ambient room light conditions* by use of Canon EOS 60D under exposure time of 1s with 400 ISO.

References:

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3. Lupei, A.; Tiseanu, C.; Gheorghe, C.; Voicu, F.; Optical spectroscopy of Sm^{3+} in C_2 and C_{3i} sites of Y_2O_3 ceramics. *Applied Physics B*, **2012**, *108*(4), 909-918.
4. Avram, D.; Cojocaru, B.; Florea, M.; Tiseanu, C.; Advances in luminescence of lanthanide doped Y_2O_3: case of S_6 sites. *Optical Materials Express*, **2016**, *6*(5), 1635-1643.
5. Thompson, A.; Attwood, D.T.; Gullikson, E.; Howells, M.; Kortright, J.; Robinson, A.; X-ray data booklet (2009). URL http://xdb. lbl. gov.