Supplementary Information

Control of photoluminescence in $Ba_{0.97}Y_2Si_3O_{10}:Eu^{2+}$ phosphors *via* intensification effect of the second luminescence center

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Table S1 Structure parameters of BYSO:Eu, xLu^{3+} (x = 0.00-2.00) and BYSO:Eu, yGd^{3+} (y = 0.00-2.00) obtained by Rietveld refinement of the XRD data.[a]

Concentration (mol)	a (Å)	b (Å)	c (Å)	β (°)	V (Å^3)	Rwp (%)	Rp (%)	χ^2 (%)
x/y = 0.00	5.38941(13)	12.18531(30)	6.84419(15)	106.39811(142)	431.186(18)	7.18	5.39	5.47
x = 0.20	5.38942(13)	12.18531(30)	6.84419(15)	106.39809(140)	431.187(18)	7.14	5.34	5.42
x = 0.40	5.38437(16)	12.17705(34)	6.83658(18)	106.41795(122)	429.969(21)	6.84	5.27	5.16
x = 0.60	5.37985(15)	12.17085(35)	6.83006(19)	106.43977(175)	428.931(21)	8.15	6.22	7.76
x = 0.80	5.37773(12)	12.16570(28)	6.82542(15)	106.46254(146)	428.239(17)	7.96	6.15	7.55
x = 1.00	5.37362(16)	12.16141(36)	6.82030(19)	106.47823(176)	427.406(21)	8.57	6.67	9.14
x = 1.20	5.36875(18)	12.15524(40)	6.81263(22)	106.51219(204)	426.246(24)	8.48	6.47	8.72
x = 1.40	5.36640(12)	12.14487(26)	6.80621(14)	106.52750(135)	425.262(16)	7.88	6.15	8.08
x = 1.60	5.36134(17)	12.13978(37)	6.80000(21)	106.55408(189)	424.237(22)	8.80	6.59	10.50
x = 1.80	5.35754(17)	12.13042(38)	6.79295(22)	106.57686(196)	423.120(23)	8.69	6.33	10.20
x = 2.00	5.35454(13)	12.12361(29)	6.78654(17)	106.59412(169)	422.209(18)	8.71	6.45	9.48
y = 0.20	5.39744(16)	12.19615(37)	6.85961(19)	106.35909(173)	433.273(22)	6.58	5.44	7.42
y = 0.40	5.40005(15)	12.20254(35)	6.86741(18)	106.34378(157)	434.237(21)	6.08	4.54	4.60
y = 0.60	5.40267(20)	12.21044(48)	6.87579(25)	106.33934(206)	435.27(28)	3.24	4.28	5.76
y = 0.80	5.40572(17)	12.21460(39)	6.88337(20)	106.31702(204)	436.193(23)	2.00	3.67	4.73
y = 1.00	5.40988(16)	12.22088(37)	6.89162(20)	106.29896(166)	437.318(22)	2.85	3.44	4.48
y = 1.20	5.41345(23)	12.23102(54)	6.90039(28)	106.28969(253)	438.548(32)	2.21	3.34	4.36
y = 1.40	5.4155(22)	12.23095(50)	6.90656(27)	106.27875(220)	439.128(30)	2.88	3.2	4.43
y = 1.60	5.42027(19)	12.23268(45)	6.91352(24)	106.26128(208)	440.059(27)	2.93	3.07	4.32
y = 1.80	5.42511(22)	12.236(50)	6.92185(28)	106.25181(234)	441.124(31)	2.96	3.14	4.34
y = 2.00	5.42955(23)	12.24176(54)	6.93003(29)	106.23469(259)	442.253(34)	3.55	3.68	5.15

[a]Space group: $P2_1/c$, $\alpha = \gamma = 90^o$.

Table S2 Bond distances of Y/Lu-O and Y/Gd-O in BYSO:Eu, xLu^{3+} (x = 0.00-2.00) and BYSO:Eu, yGd^{3+} (y = 0.00-2.00) obtained by Rietveld refinement of the XRD data.

	BYSOE	x/y = 0.20	x/y = 0.40	x/y = 0.60	x/y = 0.80	x/y = 1.00	x/y = 1.20	x/y = 1.40	x/y = 1.60	x/y = 1.80	x/y = 2.00
Y/Lu-O1	2.2916	2.2916	2.2898	2.2885	2.2876	2.2880	2.2340	2.3370	2.1350	2.2350	2.1380
Y/Lu-O2	2.3486	2.3486	2.3468	2.3452	2.3441	2.3380	2.3870	2.2740	2.4440	2.3480	2.4480
Y/Lu-O4	2.2054	2.2054	2.2031	2.2010	2.1998	2.2100	2.0860	2.1090	2.0460	2.1140	2.1730
Y/Lu-O5	2.1912	2.1912	2.1887	2.1866	2.1852	2.2000	2.1490	2.1720	2.1370	2.1130	2.1740
Y/Lu-O6	2.2856	2.2856	2.2830	2.2808	2.2791	2.2600	2.4250	2.3490	2.3590	2.3610	2.2740
Y/Lu-O6	2.2761	2.2761	2.2743	2.2728	2.2718	2.2630	2.2940	2.2730	2.3450	2.4040	2.3600
Y/Gd-O1	2.2916	2.1960	2.1990	2.2260	2.2700	2.2280	2.1630	2.2910	2.2900	2.1750	2.0940
Y/Gd-O2	2.3486	2.3920	2.3700	2.3820	2.3940	2.3544	2.3720	2.3820	2.4050	2.3700	2.4950
Y/Gd-O4	2.2054	2.0550	2.0650	2.1060	2.0990	2.1060	2.2030	2.31000	2.3230	2.5540	2.8080
Y/Gd-O5	2.1912	2.1500	2.1290	2.1630	2.2000	2.1500	2.3290	2.3020	2.3300	2.4940	2.5530
Y/Gd-O6	2.2856	2.2620	2.2480	2.1410	2.2420	2.2030	2.2900	2.2550	2.3310	2.2560	2.1310

Y/Gd-O6	2.2761	2.2940	2.3360	2.2390	2.3230	2.4070	2.4810	2.4120	2.3480	2.3620	2.3460

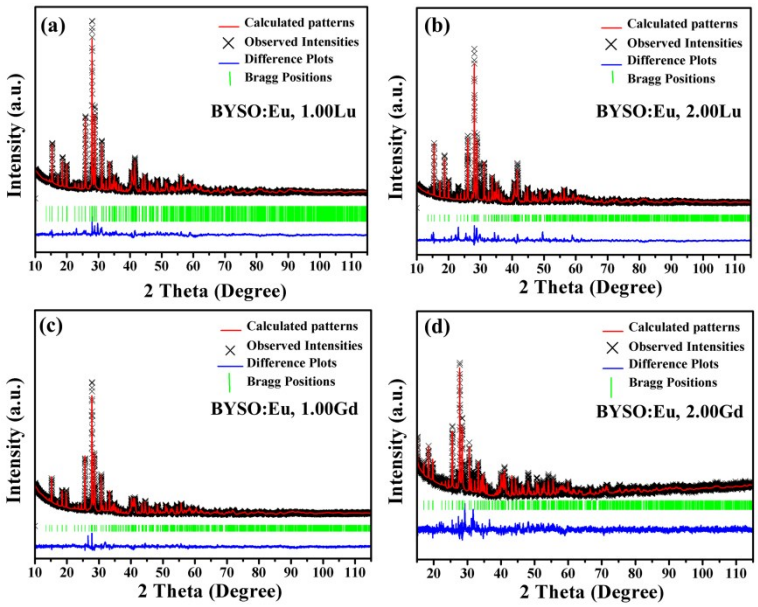

Figure **S**1. Rietveld refinements results for representative BYSO:Eu, 1.00Lu (a), BLSO:Eu (b), BYSO:Eu, 1.00Gd (c) and BGSO:Eu (d) using FullProf. Program.

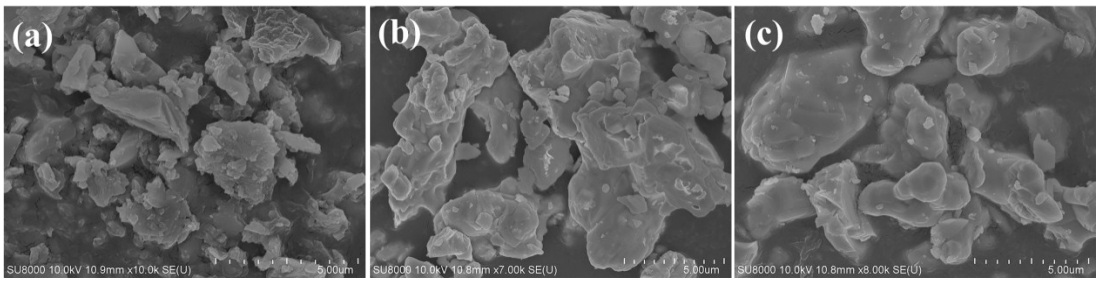

Figure S2. The typical SEM image of BYSO:Eu sample (a), BYSO:Eu, 1.00Lu sample (b) and BGSO:Eu (c).

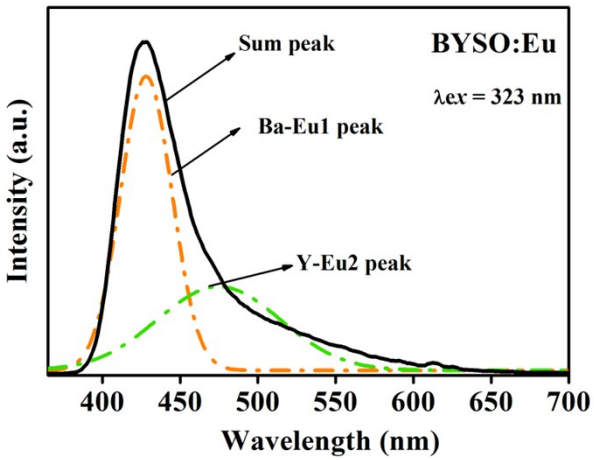

Figure **S**3. The Gaussian peaks fitting of BYSO:Eu at Ba-Eu1 site and Y-Eu2 site (λ_{ex} = 323 nm).

It has been suggested that the relationship between energetic position of the Eu^{2+} emission and local structure in various compounds obeyed Van Uitert's equation empirically as following[1]:

$$E\,(cm^{-1}) = Q^{*}\left[1-\left(\frac{V}{4}\right)^{\frac{1}{V}}\times 10^{-\frac{CN\cdot r\cdot E_a}{80}}\right]$$

here E is the position for the Eu^{2+} ion emission peak, Q* is the energy position of the lower d-band edge for the free ions and equals to 34,000 cm^{-1} for Eu^{2+}, V is the valence of the Eu^{2+} ion (V = 2), CN is the coordination number of the Eu^{2+} ion (CN = 8 for Ba site; CN = 6 for Y site), E_a is the electron affinity of the atoms (eV), and r is the radius of the host cation replaced by the Eu^{2+} ion (Å). Among them, E_a, V and Q* are constant in BYSO:Eu matrix, the value of E is directly proportional to the product of CN and r. Thus, we could conclude that the peaks 429 and 475 nm originate from Ba and Y sites, respectively.

References:

(1) Uitert L.G.V.; An empirical relation fitting the position in energy of the lower d-band edge for Eu^{2+} or Ce^{3+} in various compounds; J. Lumin. 1984, 29, 1-9.

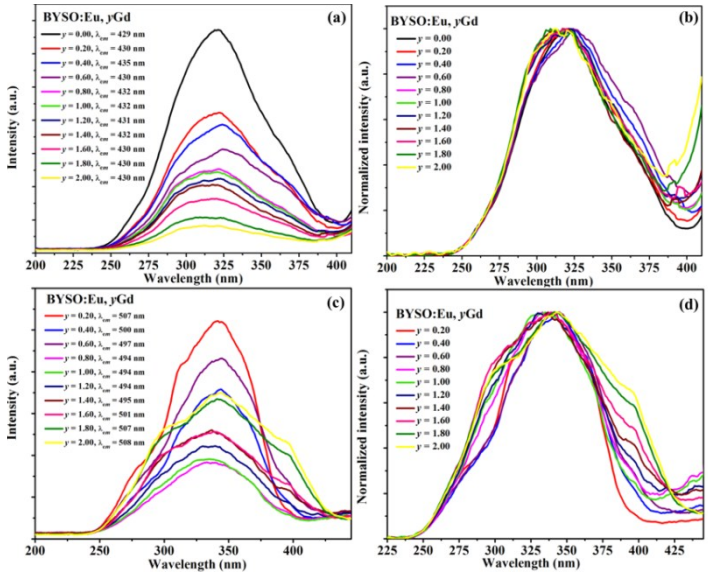

Figure S4. The PLE spectra and normalized PLE spectra with varying Gd^{3+} concentrations using a variety of monitoring wavelengths including λ_{em}= 429-435 nm (a and b) and λ_{em}= 494-508 nm (c and d) for BYSO:Eu, yGd.

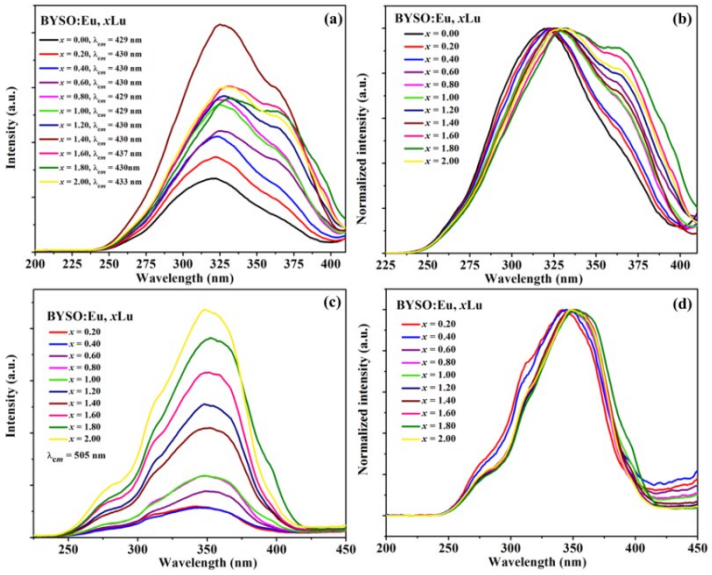

Figure S5. The PLE spectra and normalized PLE spectra with varying Lu^{3+} concentrations using a variety of emission wavelengths including λ_{em} = 429-437 nm (a and b) and λ_{em} ~ 505 nm (c and d) for BYSO:Eu, *x*Lu.

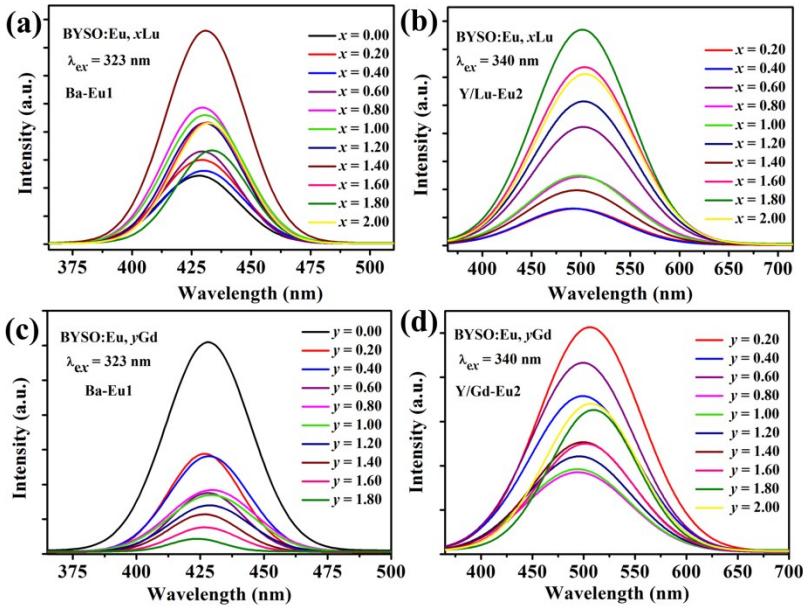

Figure S6. The Gaussian peaks fitting of BYSO:Eu, *x*Lu ($0 \le x \le 2.00$) at Ba-Eu1 site (λ_{ex} = 323 nm) (a) and Y/Lu-Eu2 site (λ_{ex} = 340 nm) (b)； the Gaussian peaks fitting of BYSO:Eu, *y*Gd ($0 \le y \le 2.00$) at Ba-Eu1 site (λ_{ex} = 323 nm) (c) and Y/Gd-Eu2 site (λ_{ex} = 340 nm) (d).

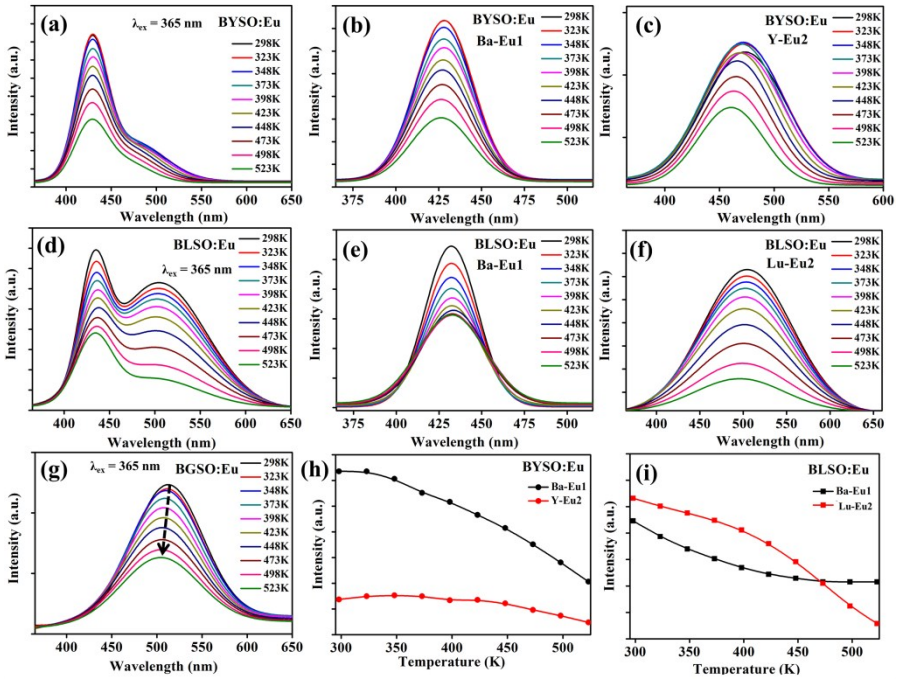

Figure **S**7. Temperature-dependent emission spectra of BYSO:Eu (a), BLSO:Eu (d) and BGSO:Eu (g) under different temperatures in the range of 298~523 K (λ_{ex} = 365 nm). (b) Temperature-dependent emission spectra of BYSO:Eu at Ba-Eu1 site (b) and Y-Eu2 site (c). Temperature-dependent emission spectra of BLSO:Eu at Ba-Eu1 site (e) and Lu-Eu2 site (f). The variations of the relative emission intensities at Ba-Eu1 and Y-Eu2 sites. (h). The variations of the relative emission intensities at Ba-Eu1 and Lu-Eu2 sites. (i).

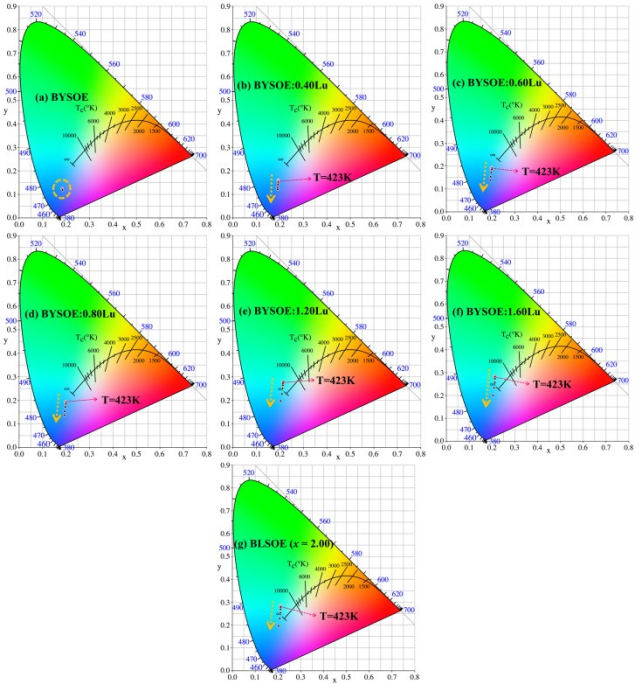

Figure **S**8. Temperature-dependent CIE chromaticity diagram of BYSO:Eu, *x*Lu (*x* = 0.00, 0.40, 0.60, 0.80, 1.20, 1.60, 2.00) phosphors under 365 nm; the yellow arrows stand for the variation with temperature increase and the pink arrows point out the color coordinates at 423K.

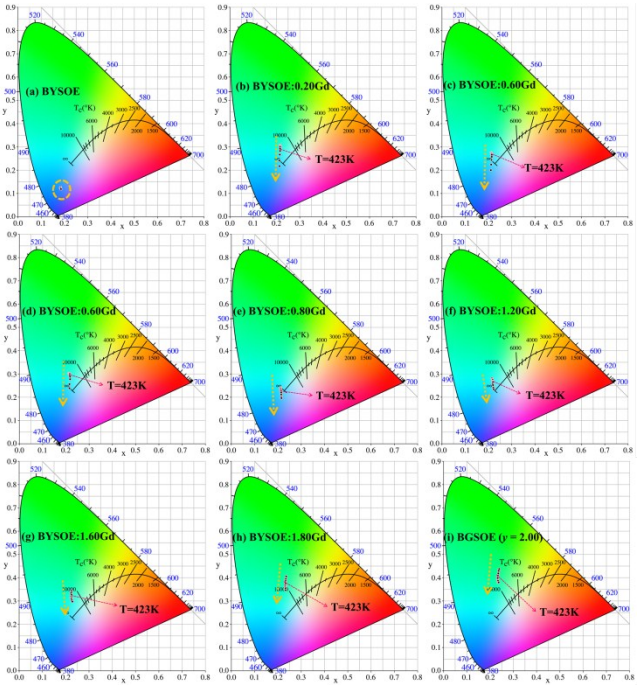

Figure **S**9. Temperature-dependent CIE chromaticity diagram of BYSO:Eu, *y*Gd (*y* = 0.00, 0.20, 0.60, 0.80, 1.20, 1.60, 1.80, 2.00) phosphors under 365 nm; the yellow arrows stand for the variation with temperature increase and the pink arrows point out the color coordinates at 423K.