**supplementary information:**

# $LaMoBO_6$: $Tb^{3+}$, $Eu^{3+}$/ $Sm^{3+}$, $Bi^{3+}$ yellow phosphor with exceptionally high quantum yield that can be excited by blue light

Shuai Yang,[a,b#] Bin Jiang,[a#] Jiahao Wu,[a] Chungang Duan,[a,c] Yongkui Shan,[b] Qingbiao Zhao[a*]

[a] Key Laboratory of Polar Materials and Devices (MOE), Department of Electronic Science, East China Normal University, Shanghai, 200241 China

[b] School of Chemistry and Molecular Engineering, East China Normal University, Shanghai, 200241 China

[c] Collaborative Innovation Center of Extreme Optics, Shanxi University, Shanxi 030006, China

[#] These authors contributed equally

To whom correspondence should be addressed:

Dr. Qingbiao Zhao

Email: qbzhao@ee.ecnu.edu.cn

Tel: +86-021-33503200

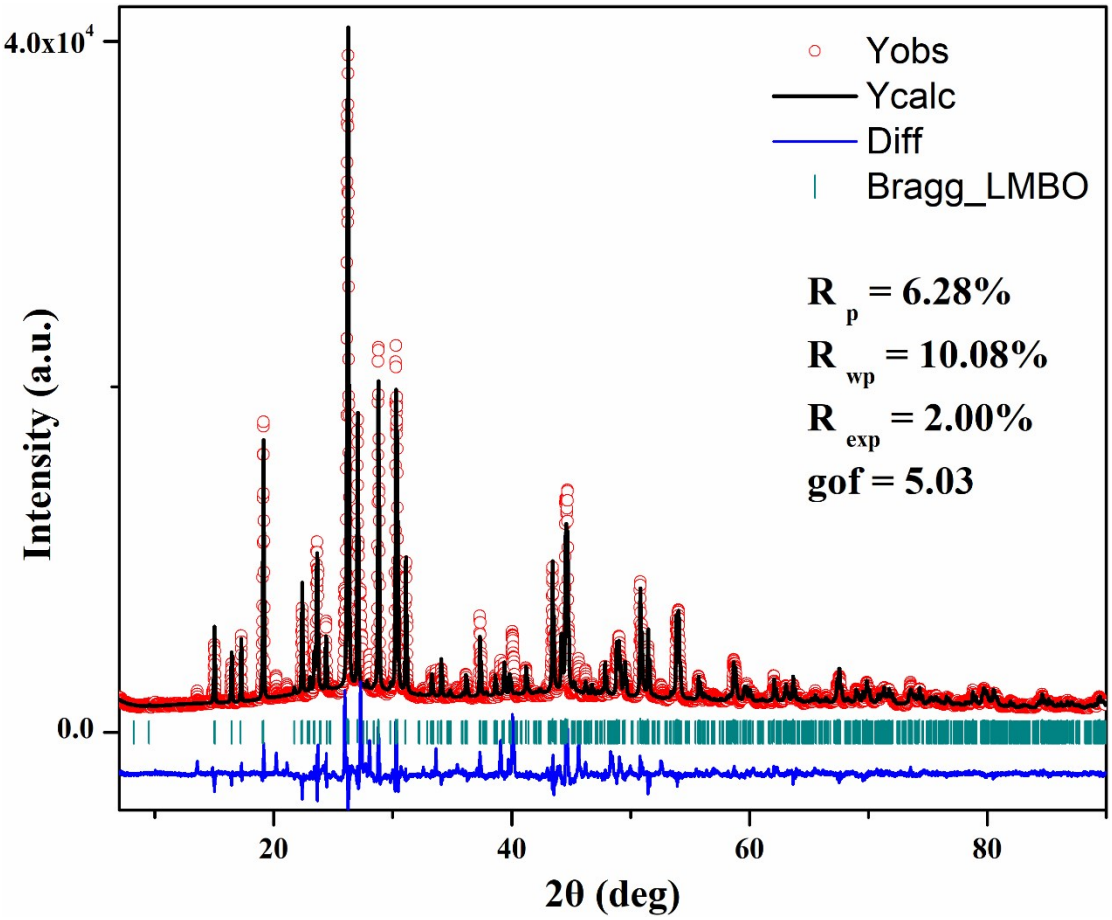



**Figure S1**. The XRD Rietveld refinement of $LaMoBO_6$ (LMBO) host lattice.

**Table S1**. The Rietveld refinement parameters and unit cell parameters of LMBO host lattice and LMBO: 0.1$Tb^{3+}$ phosphor

| Parameters | LMBO host lattice | LMBO: 0.1$Tb^{3+}$ phosphor |
|---|---|---|
| Space group | $P2_1/c$ | $P2_1/c$ |
| a (Å) | 10.29549 | 10.25266 |
| b (Å) | 4.16388 | 4.15637 |
| c (Å) | 23.84481 | 23.72538 |
| α | 90° | 90° |
| β | 115.38073° | 115.16018° |
| γ | 90° | 90° |
| V ($Å^3$) | 923.5440 | 915.1051 |
| $R_p$ | 6.28% | 5.86% |
| $R_{wp}$ | 10.08% | 9.68% |
| $R_{exp}$ | 2.00% | 1.98% |
| $R_{bragg}$ | 3.82% | 3.28% |
| gof | 5.03 | 4.89 |

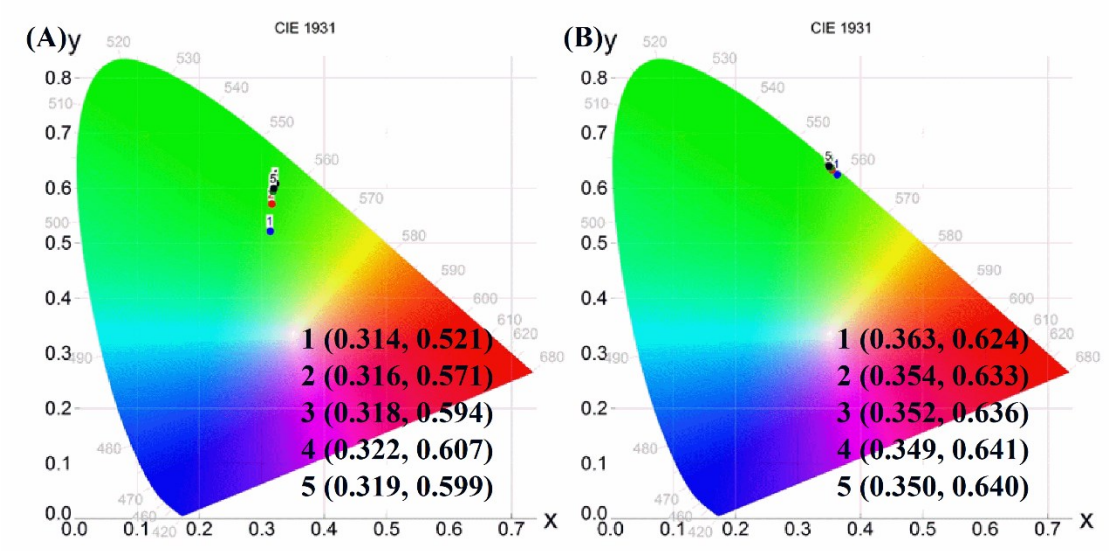



**Figure S2. (A & B)** The color coordinate diagrams of LMBO: $xTb^{3+}$ green phosphors under the excitation of 378 nm and 487 nm.

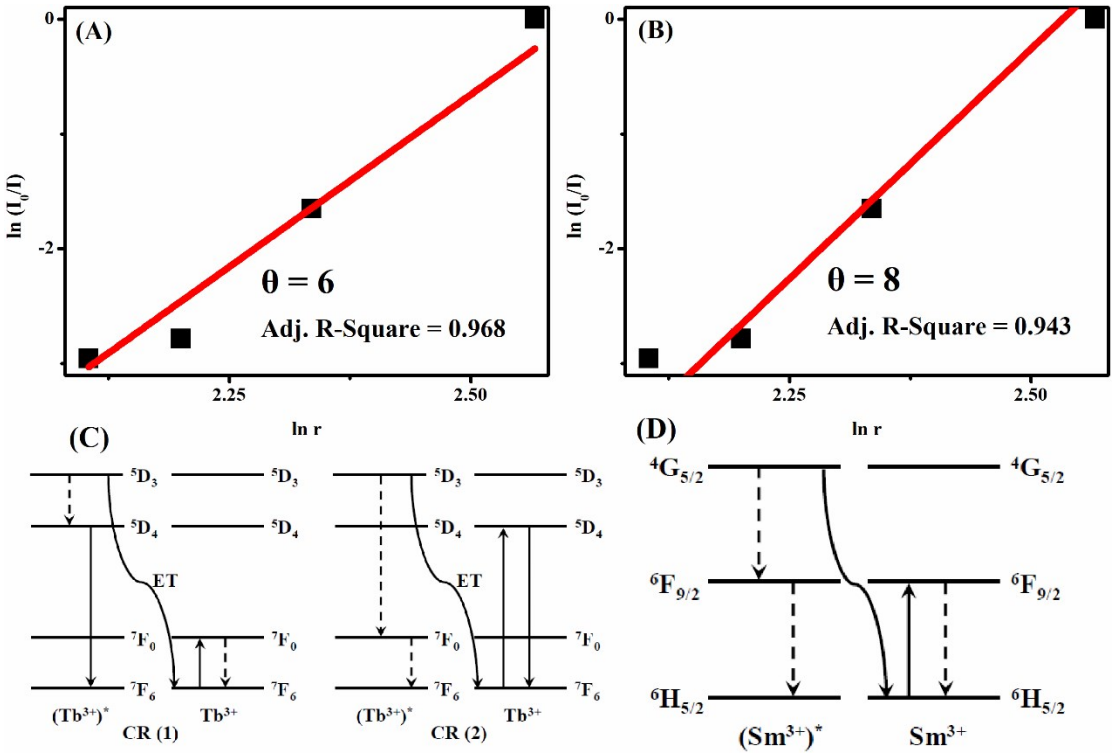



**Figure S3. (A & B)** The fitting of ln ($I_0$/I) against ln r for LMBO: x$Tb^{3+}$ green phosphors with the value of θ being 6 and 8, respectively; **(C & D)** The schematic diagram for the cross-relaxation of $Tb^{3+}$ and $Sm^{3+}$.

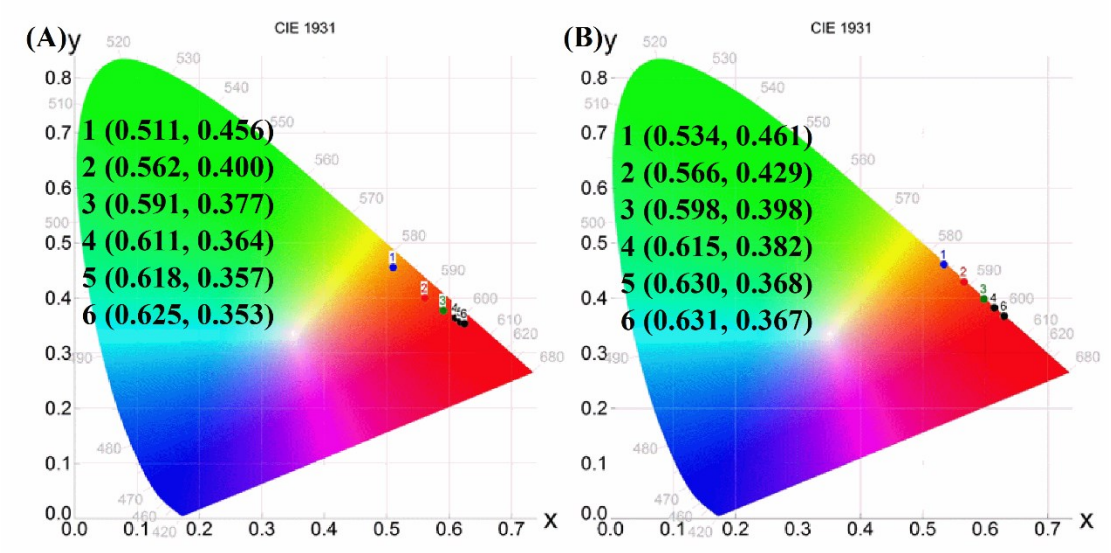



**Figure S4. (A & B)** The color coordinate diagram of LMBO: $0.04Tb^{3+}$, $yEu^{3+}$ yellow phosphors under the excitation of 378 nm and 487 nm.

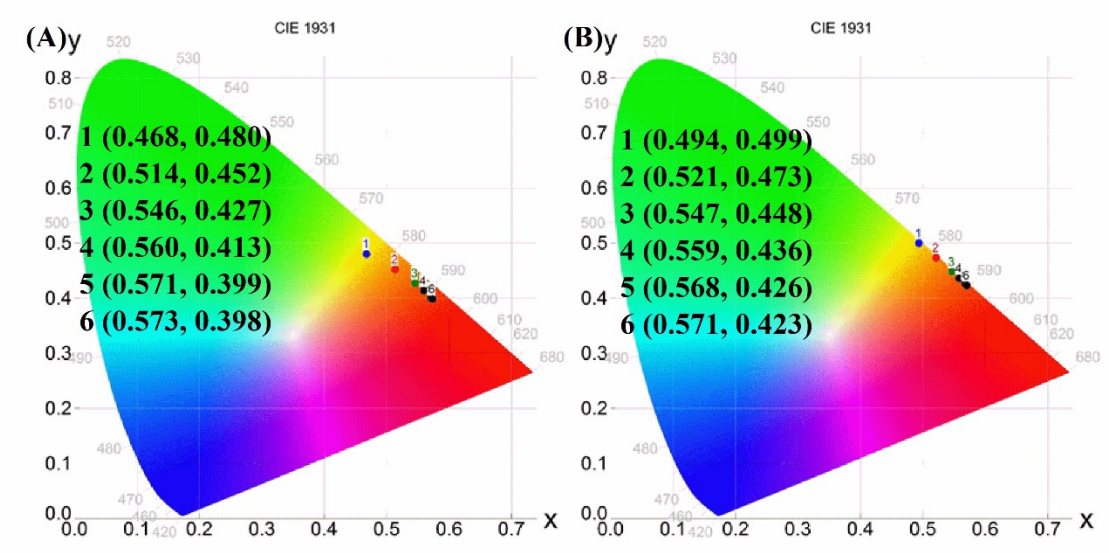


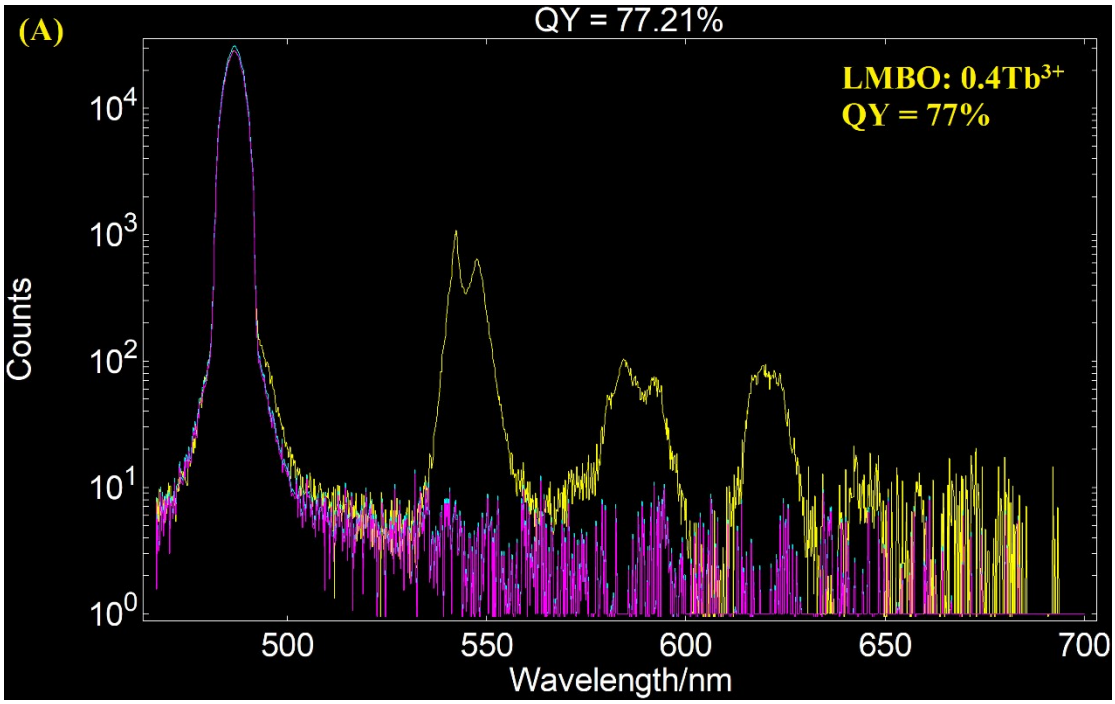

**Figure S5. (A & B)** The color coordinate diagram of LMBO: $0.04Tb^{3+}$, y'$Sm^{3+}$ yellow phosphors under the excitation of 378 nm and 487 nm.

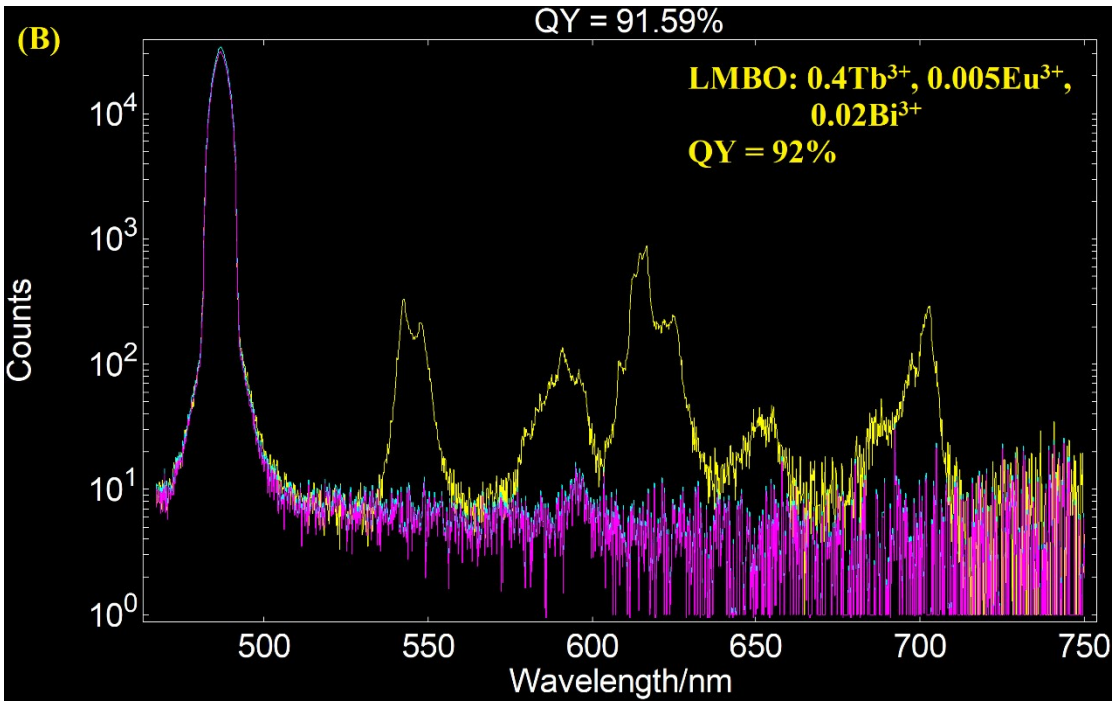
**Table S2.** The quantum yields of the LMBO: $0.4Tb^{3+}$ and LMBO: $0.4Tb^{3+}$, $xEu^{3+}$/ $Sm^{3+}$ phosphors.

| Doping ions and ratios | 378 nm | 487 nm |
|---|---|---|
| $0.4Tb^{3+}$ | 8% | **77%** |
| $0.4Tb^{3+}$, $0.005Eu^{3+}$ | 24% | **82%** |
| $0.4Tb^{3+}$, $0.01Eu^{3+}$ | 22% | 58% |
| $0.4Tb^{3+}$, $0.02Eu^{3+}$ | 29% | 23% |
| $0.4Tb^{3+}$, $0.03Eu^{3+}$ | 31% | 33% |
| $0.4Tb^{3+}$, $0.04Eu^{3+}$ | 58% | 41% |
| $0.4Tb^{3+}$, $0.05Eu^{3+}$ | 37% | 28% |
| $0.4Tb^{3+}$, $0.005Sm^{3+}$ | 12% | 56% |
| $0.4Tb^{3+}$, $0.01Sm^{3+}$ | 19% | 19% |
| $0.4Tb^{3+}$, $0.02Sm^{3+}$ | 23% | 17% |
| $0.4Tb^{3+}$, $0.03Sm^{3+}$ | 19% | 13% |
| $0.4Tb^{3+}$, $0.04Sm^{3+}$ | 13% | 10% |
| $0.4Tb^{3+}$, $0.05Sm^{3+}$ | 14% | 9% |

**Table S3.** The quantum yields of the LMBO: $0.4Tb^{3+}$, $zBi^{3+}$and LMBO: $0.4Tb^{3+}$, $0.005Eu^{3+}$/ $Sm^{3+}$, $zBi^{3+}$phosphors.

| Doping ions and ratios | 378 nm | 487 nm |
|---|---|---|
| $0.4Tb^{3+}$, $0.0005Bi^{3+}$ | 23% | 57% |
| $0.4Tb^{3+}$, $0.001Bi^{3+}$ | 25% | 70% |
| $0.4Tb^{3+}$, $0.005Bi^{3+}$ | 22% | 60% |
| $0.4Tb^{3+}$, $0.01Bi^{3+}$ | 13% | 46% |
| $0.4Tb^{3+}$, $0.01Eu^{3+}$, $0.001Bi^{3+}$ | 27% | 86% |
| $0.4Tb^{3+}$, $0.005Eu^{3+}$, $0.005Bi^{3+}$ | 24% | 81% |
| $0.4Tb^{3+}$, $0.005Eu^{3+}$, $0.01Bi^{3+}$ | 21% | 88% |
| $0.4Tb^{3+}$, $0.005Eu^{3+}$, $0.02Bi^{3+}$ | 14% | **92%** |
| $0.4Tb^{3+}$, $0.005Eu^{3+}$, $0.03Bi^{3+}$ | 5% | 78% |
| $0.4Tb^{3+}$, $0.005Sm^{3+}$, $0.001Bi^{3+}$ | 12% | 68% |
| $0.4Tb^{3+}$, $0.005Sm^{3+}$, $0.005Bi^{3+}$ | 11% | 46% |
| $0.4Tb^{3+}$, $0.005Sm^{3+}$, $0.01Bi^{3+}$ | 9% | 56% |
| $0.4Tb^{3+}$, $0.005Sm^{3+}$, $0.02Bi^{3+}$ | 4% | 53% |
| $0.4Tb^{3+}$, $0.005Sm^{3+}$, $0.03Bi^{3+}$ | 9% | 51% |


(A)
QY = 77.21%
LMBO: 0.4Tb3+
QY = 77%
Counts
10^4
10^3
10^2
10^1
10^0
500
550
600
650
700
Wavelength/nm


(B)
QY = 91.59%
LMBO: 0.4Tb3+, 0.005Eu3+,
0.02Bi3+
QY = 92%
Counts
10^4
10^3
10^2
10^1
10^0
500
550
600
650
700
750
Wavelength/nm

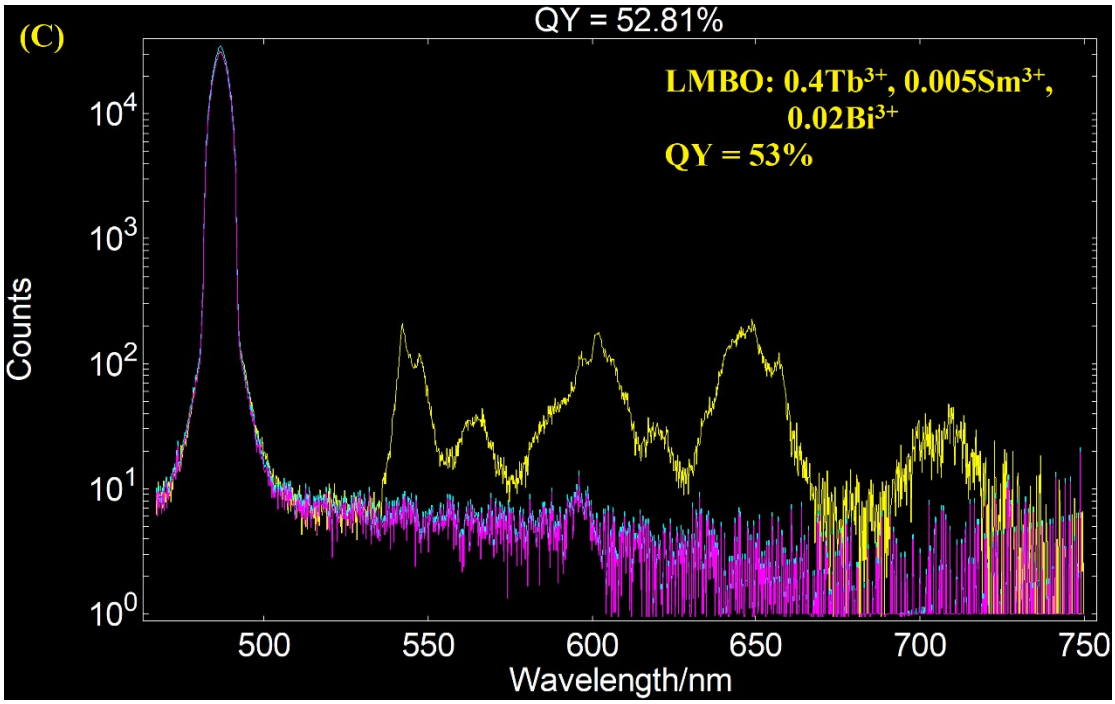



**Figure S6**. The quantum yield test charts of (A) LMBO: 0.4$Tb^{3+}$, (B) LMBO: 0.4$Tb^{3+}$, 0.005$Eu^{3+}$, 0.02$Bi^{3+}$ and (C) LMBO: 0.4$Tb^{3+}$, 0.005$Sm^{3+}$, 0.02$Bi^{3+}$ phosphors.

The quantum yield was tested using an integrating sphere and calculated according to equation:

$$QY = \frac{P_c}{L_a - L_c}$$

where QY is the quantum yield, $P_c$ is the count of emitted photons of the sample in the integrating sphere, $L_a$ is the count of reflected photons of the excitation light in the integrating sphere with a blank background, and $L_c$ is the count of reflected photons of the excitation light in the integrating sphere of the sample.

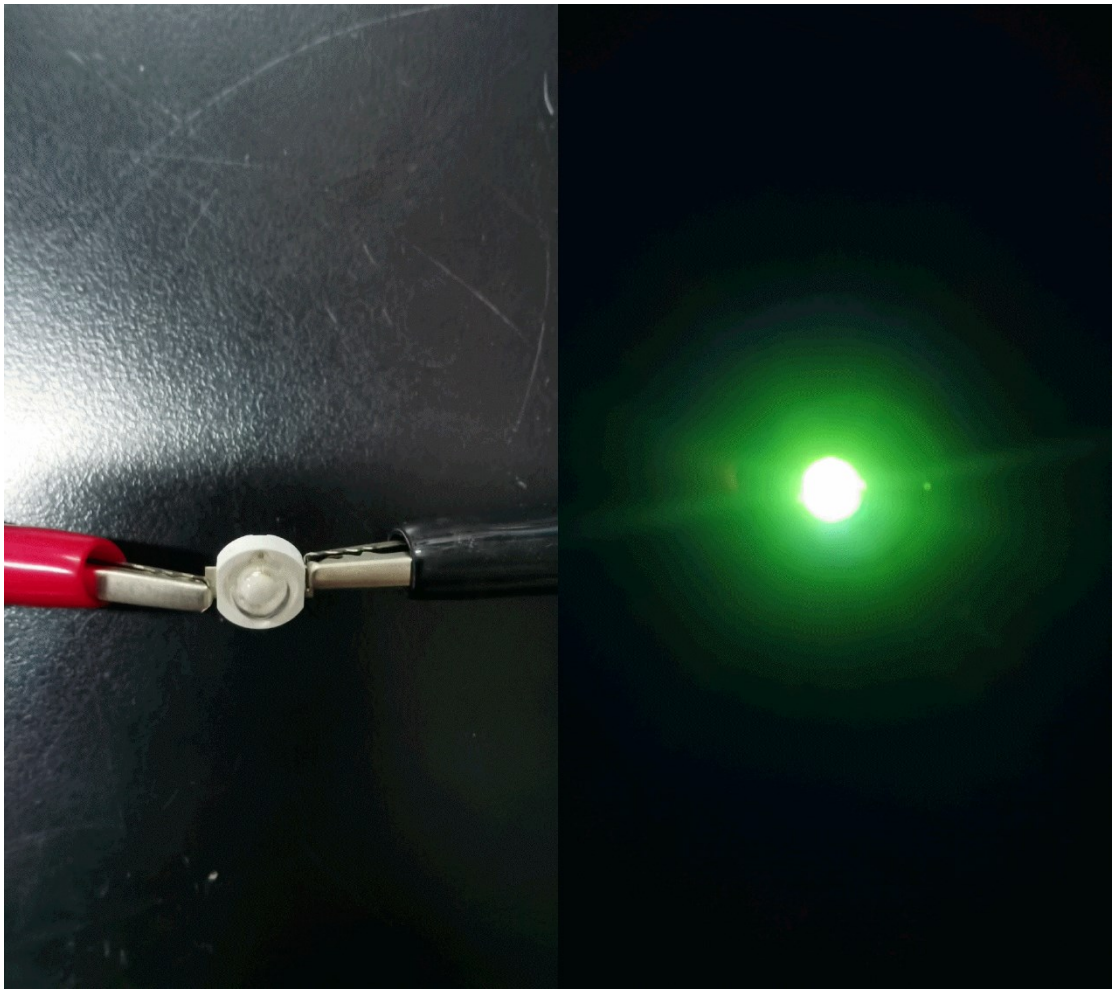


**Figure S7.** The photograph of green LED with 375~380 nm UV-LED and LMBO: $0.4Tb^{3+}$ green phosphor combined.

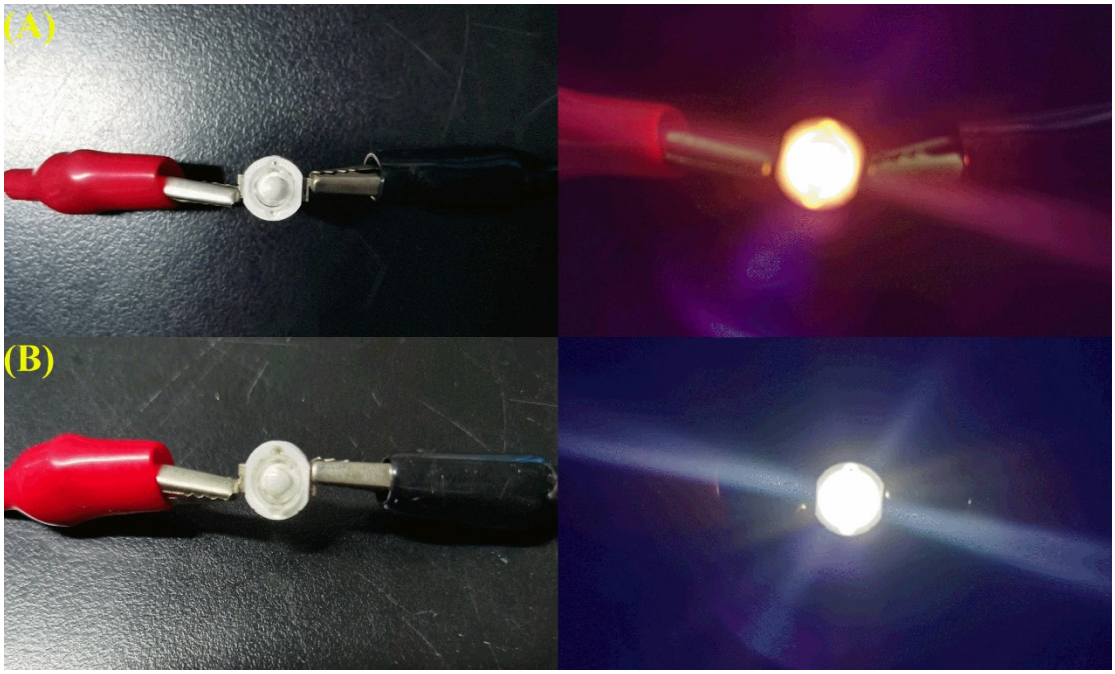



**Figure S8.** (A) The photograph of yellow LED with 375~380 nm UV-LED and LMBO: $0.4Tb^{3+}$, $0.005Eu^{3+}$ yellow phosphor combined; (B) The photograph of white LED with 375~380 nm UV-LED, LMBO: $0.4Tb^{3+}$, $0.005Eu^{3+}$ yellow phosphor and blue phosphor (BAM: $Eu^{2+}$) combined.

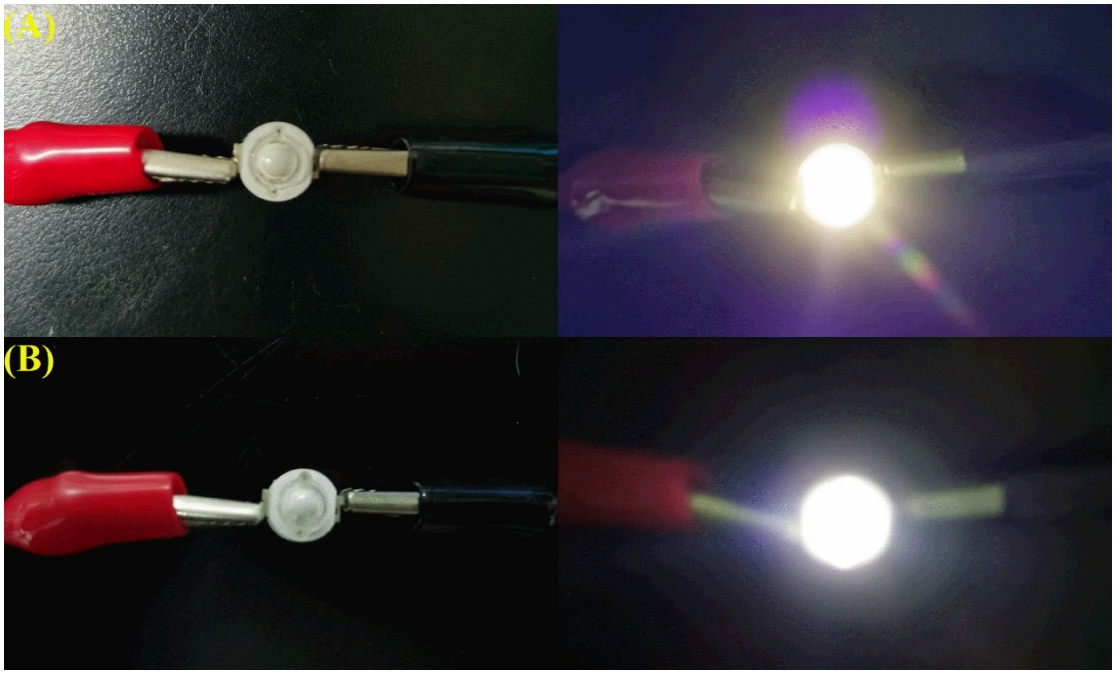



**Figure S9.** (A) The photograph of yellow LED with 375~380 nm UV-LED and LMBO: $0.4Tb^{3+}$, $0.005Sm^{3+}$ yellow phosphor combined; (B) The photograph of white LED with 375~380 nm UV-LED and LMBO: $0.4Tb^{3+}$, $0.005Sm^{3+}$ yellow phosphor and blue phosphor (BAM: $Eu^{2+}$) combined.

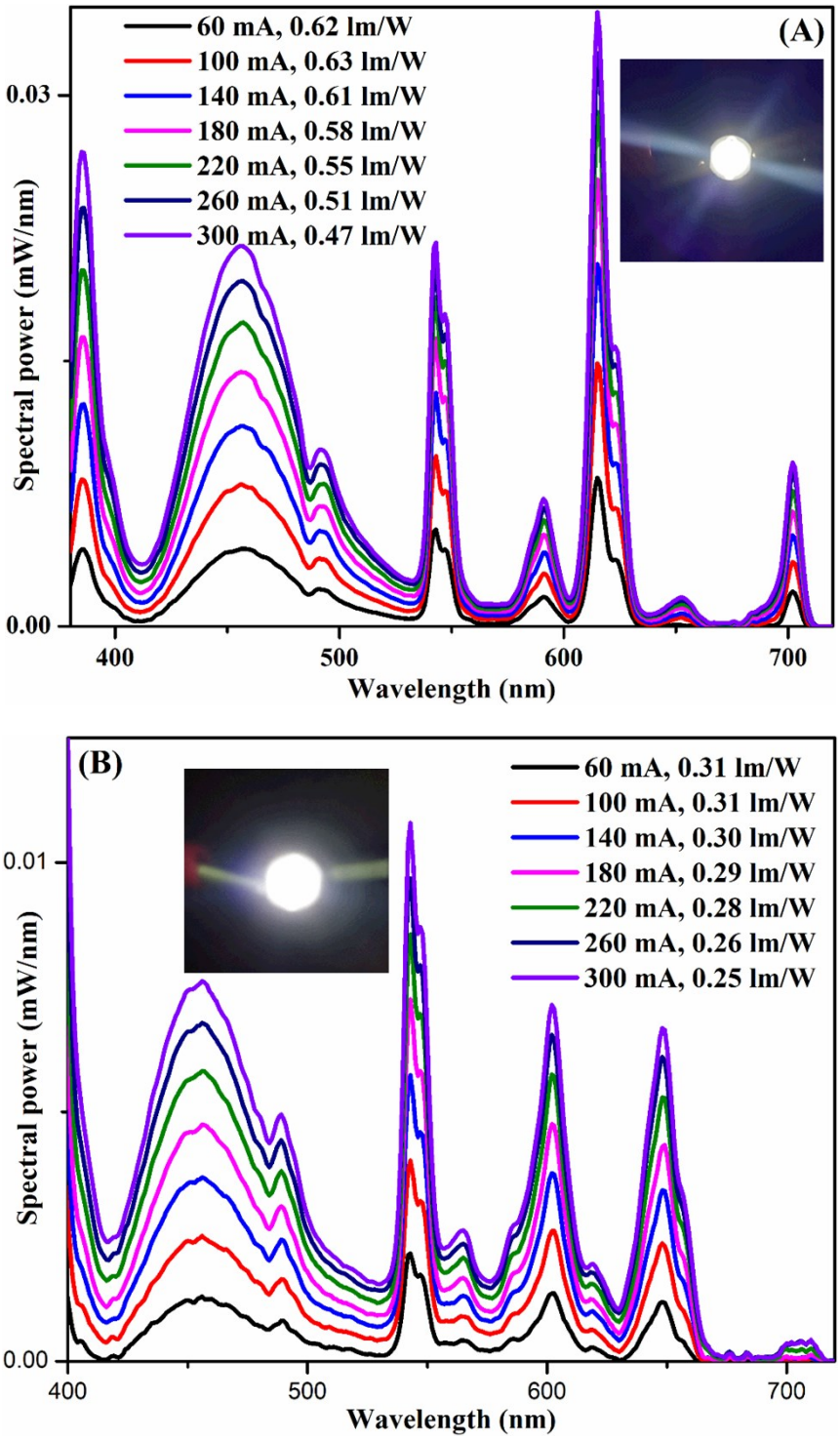



**Figure S10.** (A) The spectral power distribution of the white light LED combined with LMBO: 0.4$Tb^{3+}$, 0.005$Eu^{3+}$ yellow phosphor, BAM: $Eu^{2+}$ blue phosphor and 375~380 nm UV-LED; (B) The spectral power distribution of the white light LED combined with LMBO: 0.4$Tb^{3+}$, 0.005$Sm^{3+}$ yellow phosphor, BAM: $Eu^{2+}$ blue phosphor and 375~380 nm UV-LED.

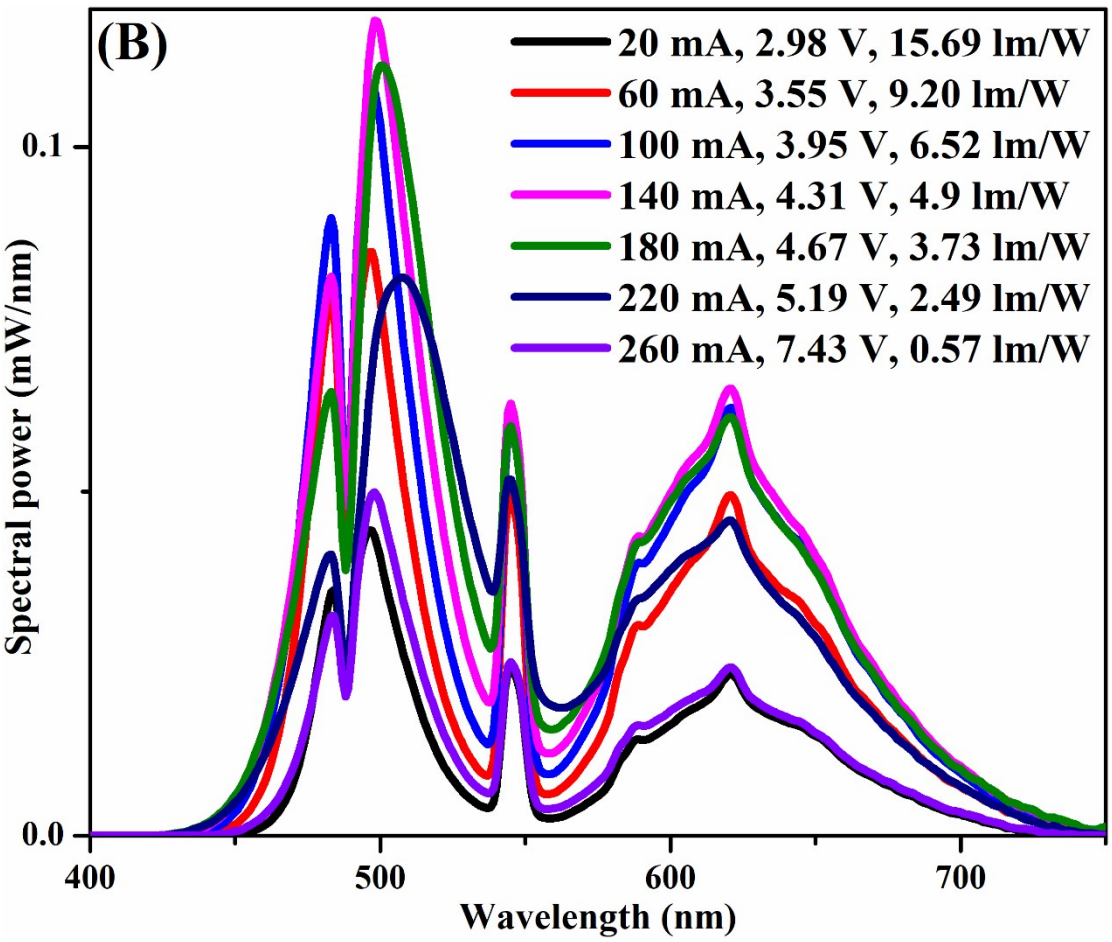



**Figure S11.** The spectral power distribution of the white LED combined with LMBO: $Tb^{3+}$ green phosphor, red phosphor ($CaAlSiN_3$: $Eu^{2+}$) and blue LED (Both voltage and current increase).

**Table S4**. The performance of white LED assembled by LMBO: $0.4Tb^{3+}$, $0.005Eu^{3+}$ yellow phosphor, BAM: $Eu^{2+}$ blue phosphor and UV-LED.

| Voltage (V) | Current (mA) | CRI | CCT (K) | luminescence efficiency (lm/W) |
|---|---|---|---|---|
| 3.14 | 60 | 44.4 | 25079 | 0.53 |
| 3.19 | 100 | 48.5 | 23233 | 0.55 |
| 3.23 | 140 | 49.5 | 26272 | 0.54 |
| 3.26 | 180 | 49.8 | 30336 | 0.52 |
| 3.3 | 220 | 50 | 38164 | 0.49 |
| 3.33 | 260 | 50.2 | 54940 | 0.47 |
| 3.36 | 300 | 50.2 | 94138 | 0.44 |

**Table S5.** The performance of white LED assembled by LMBO: $0.4Tb^{3+}$, $0.005Sm^{3+}$ yellow phosphor, BAM: $Eu^{2+}$ blue phosphor and UV-LED.

| Voltage (V) | Current (mA) | CRI | CCT (K) | luminescence efficiency (lm/W) |
|---|---|---|---|---|
| 3.18 | 60 | 88.6 | 9438 | 0.31 |
| 3.24 | 100 | 89.5 | 8960 | 0.31 |
| 3.29 | 140 | 88.7 | 9411 | 0.3 |
| 3.33 | 180 | 88.1 | 9773 | 0.29 |
| 3.37 | 220 | 87.3 | 10114 | 0.28 |
| 3.41 | 260 | 86.6 | 10469 | 0.26 |
| 3.45 | 300 | 86.3 | 10933 | 0.25 |

**Table S6.** The performance of white LED assembled by LMBO: $0.4Tb^{3+}$ green phosphor, $CaAlSiN_3$: $Eu^{2+}$ red phosphor and blue-LED.

| Voltage (V) | Current (mA) | CRI | CCT (K) | luminescence efficiency (lm/W) |
|---|---|---|---|---|
| constant voltage mode | | | | |
| 5.65 | 60 | 33.9 | 4676 | 0.23 |
| 5.65 | 140 | 34.5 | 4642 | 0.1 |
| 5.65 | 220 | 35.8 | 4571 | 0.06 |
| 5.65 | 300 | 34.6 | 4601 | 0.05 |
| variable voltage mode | | | | |
| 2.98 | 20 | 46.4 | 4203 | 15.69 |
| 3.55 | 60 | 47.5 | 4186 | 9.2 |
| 3.95 | 100 | 50.5 | 4300 | 6.52 |
| 4.31 | 140 | 55.9 | 4491 | 4.9 |
| 4.67 | 180 | 63 | 4704 | 3.73 |
| 5.19 | 220 | 72 | 4905 | 2.49 |
| 7.43 | 260 | 52.1 | 4527 | 0.57 |