# Supporting information

## Highly efficient rare-earth-free deep red emitting phosphor $La_2Li_{1-y}Sb_{1-x}O_6$:$xMn^{4+}$,$yMg^{2+}$: Application in high-power warm w-LEDs

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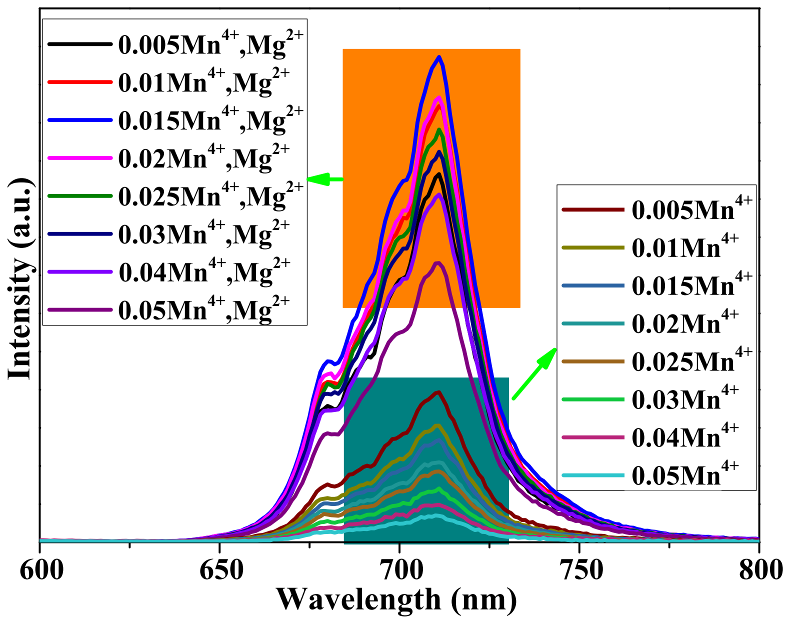


**Figure S1.** PL spectra of the $La_2LiSbO_6$: $Mn^{4+}$ with/without $Mg^{2+}$ ions at different $Mn^{4+}$ doping concentrations under 481nm excitation.

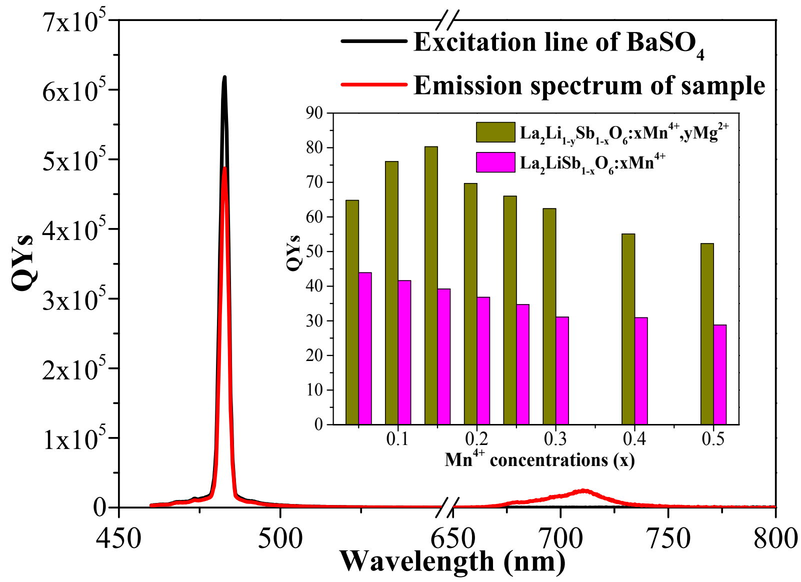


**Figure S2.** The excitation and emission spectra of the $La_2Li_{0.985}Sb_{0.985}O_6$:0.015$Mn^{4+}$,0.015$Mg^{2+}$ and reference sample. Inset is the QYs of the $La_2LiSbO_6$: $Mn^{4+}$ with/without $Mg^{2+}$ ions at different $Mn^{4+}$ doping concentrations.

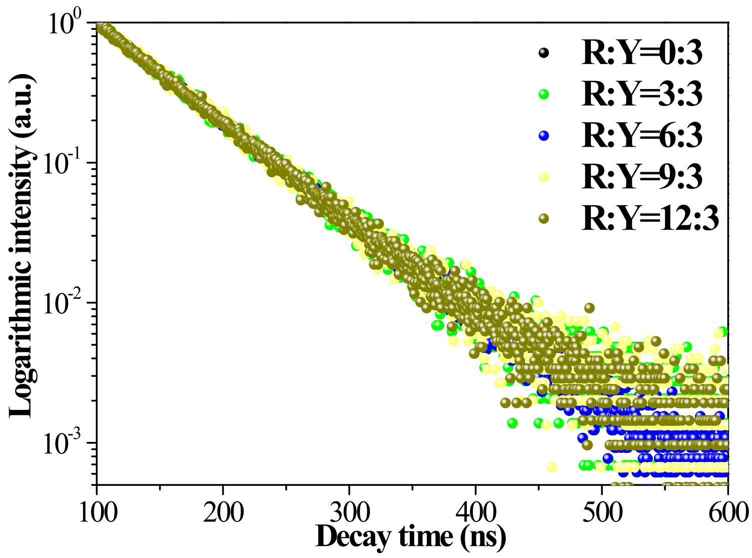


**Fig. S3** Decay curves of $Ce^{3+}$: 5d emitting-state with various ratios of R:Y in the PiG samples

**Table S1**. The crystal field strength ($D_q$), Racah parameters (B, C), Nephelauxetic ratio ($\beta_1$) and

$^2E$

energy level ($E(^2E)$) of $Mn^{4+}$ ion in various hosts

| Host | Dq($cm^{-1}$) | B($cm^{-1}$) | C($cm^{-1}$) | $\beta_1$ | $E(^2E)(cm^{-1})$ | Ref. |
|---|---|---|---|---|---|---|
| $Na_2SiF_6$ | 2174 | 775 | 3475 | 1.051 | 16210 | 1 |
| $Na_2SnF_6$ | 2101 | 589 | 3873 | 1.033 | 16171 | 2 |
| $K_2MnF_6$ | 2183 | 604 | 3821 | 1.029 | 16129 | 3 |
| $K_2TiF_6$ | 2137 | 582 | 3778 | 1.011 | 15835 | 4 |
| $K_2NaAlF_6$ | 2165 | 600 | 3815 | 1.027 | 16078 | 5 |
| $K_2LiAlF_6$ | 2160 | 650 | 3678 | 1.022 | 16000 | 5 |
| MMG* | 2380 | 700 | 3416 | 0.997 | 15576 | 6 |
| $CaAl_{12}O_{19}$ | 2132 | 807 | 3088 | 0.999 | 15244 | 7,8 |
| $SrMgAl_{10}O_{17}$ | 2237 | 791 | 3084 | 0.989 | 15152 | 9 |
| $BaMg_2Al_{16}O_{27}$ | 2136 | 828 | 3013 | 0.98 | 15152 | 10 |
| $Sr_4Al_{14}O_{25}$ | 2222 | 680 | 3397 | 0.983 | 15361 | 11-13 |
| $Lu_3Al_5O_{12}$ | 2137 | 789 | 2990 | 0.97 | 14925 | 14 |
| $Mg_2TiO_4$ | 2096 | 700 | 3348 | 0.985 | 15267 | 15 |
| $Mg_2Al_4Si_5O_{18}$ | 2141 | 927 | 2560 | 0.996 | 14409 | 16 |
| $Li_2MgTi_3O_8$ | 2061.8 | 765.4 | 3004 | 0.9606 | 14700 | 17 |
| $Ba_2GdNbO_6$ | 1931 | 855 | 2859 | 0.9923 | 14793 | 18 |
| $Ba_2LaNbO_6$ | 1780 | 670 | 3290 | 0.958 | 14679 | 19 |
| $Ca_2LaNbO_6$ | 1934 | 838 | 2827 | 0.976 | 14599 | 20 |

**Table S2**. Performances of the fabricated w-LEDs devices with various ratios of R:Y

| R:Y | Chromaticity coordinate | | LE (lm/W) | CCT (K) | Ra |
|---|---|---|---|---|---|
| | X | Y | | | |
| 0:3 | 0.3087 | 0.3495 | 107.8 | 6555 | 73.7 |
| 3:3 | 0.3279 | 0.3623 | 98.1 | 5799 | 77.8 |
| 6:3 | 0.3431 | 0.3701 | 89.7 | 5158 | 80.2 |
| 9:3 | 0.3608 | 0.3815 | 81.3 | 4646 | 83.5 |
| 12:3 | 0.3779 | 0.3926 | 74.8 | 4130 | 86.6 |

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