Supporting Information

An Orange-Yellow-Emitting $Lu_{2-x}Mg_2Al_{2-y}Ga_ySi_2O_{12}$: xCe^{3+} Phosphor-in-Glass Film for Laser-Driven White Light

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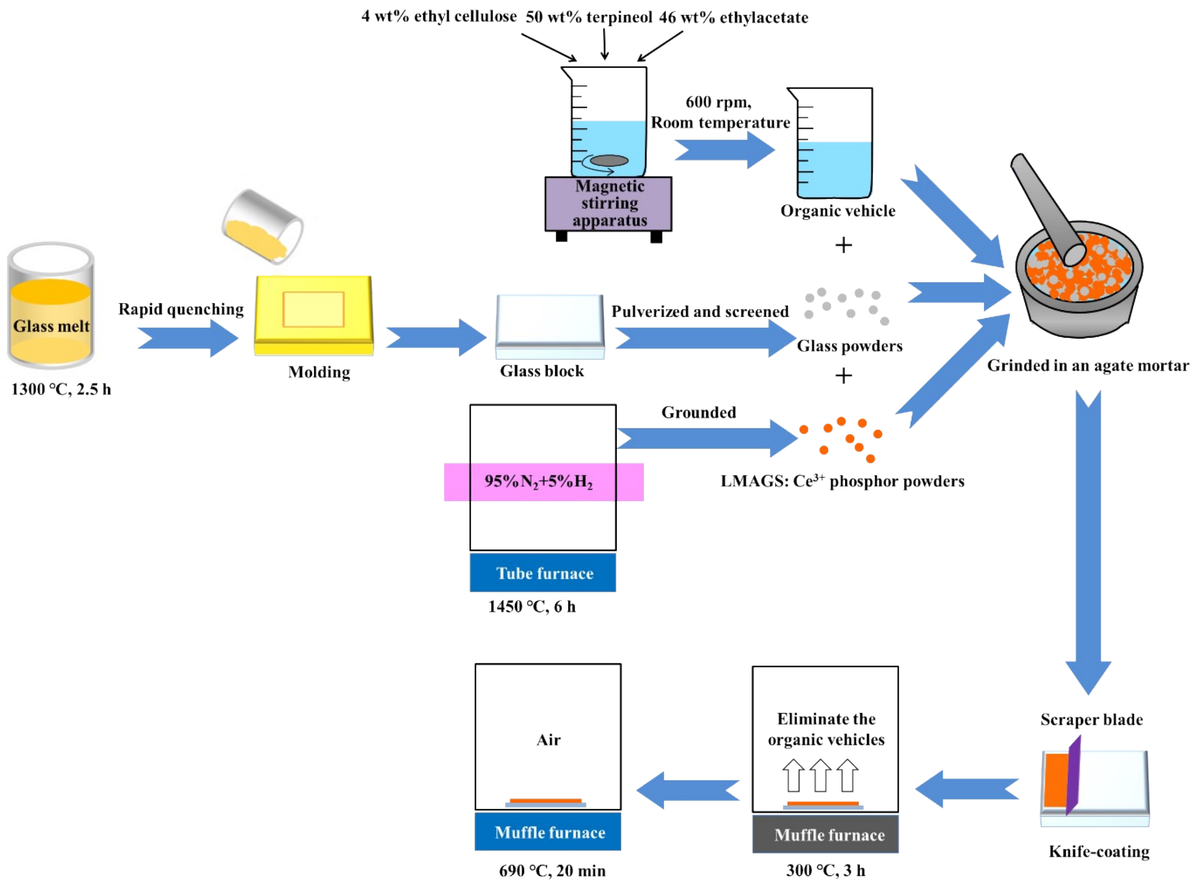

Figure S1. Schematical illustration of preparation procedure of the LMAGS: Ce^{3+} PiG film-on-SP.

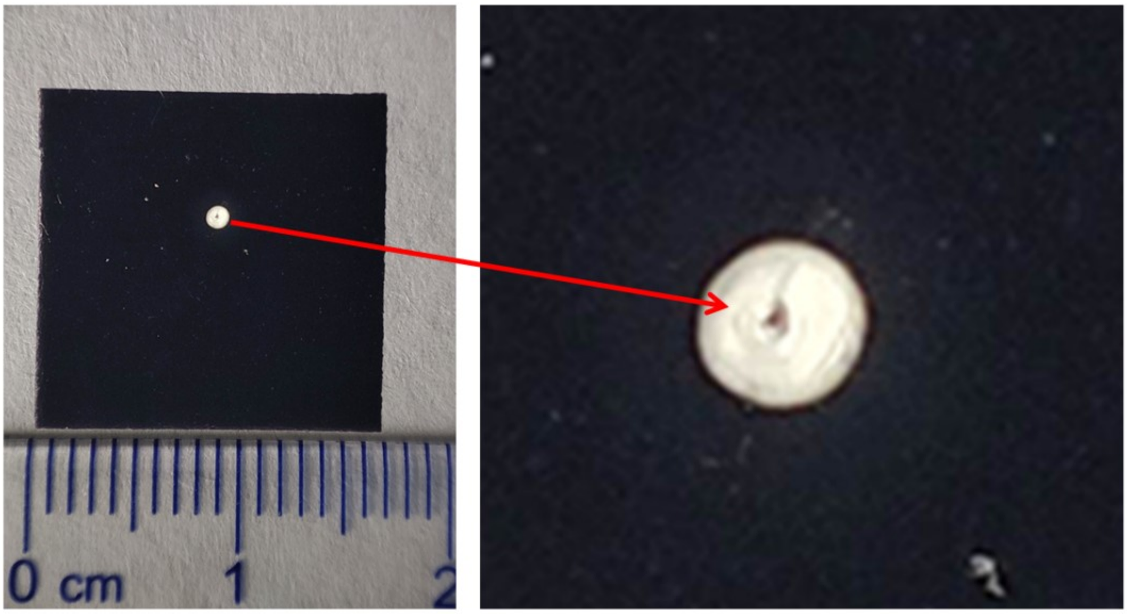

Figure S2. Photograph of the photo-sensitive paper upon blue laser irradiation

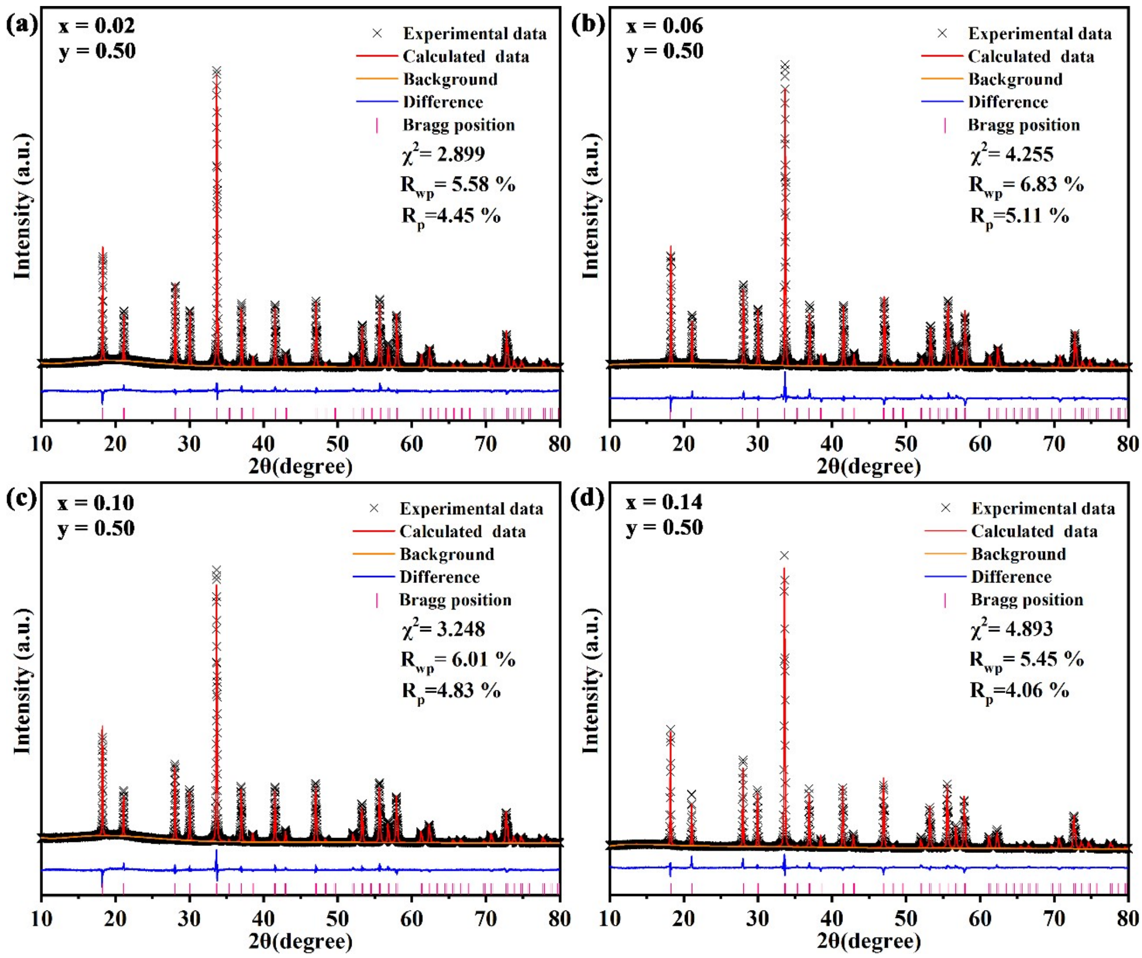

Figure S3. Rietveld refinement on $Lu_{2.0-x}Mg_2Al_{1.5}Ga_{0.5}Si_2O_{12}$: xCe^{3+} phosphor, showing the observed (black crosses) and calculated (red line) XRD profiles, and the difference between them (blue line).

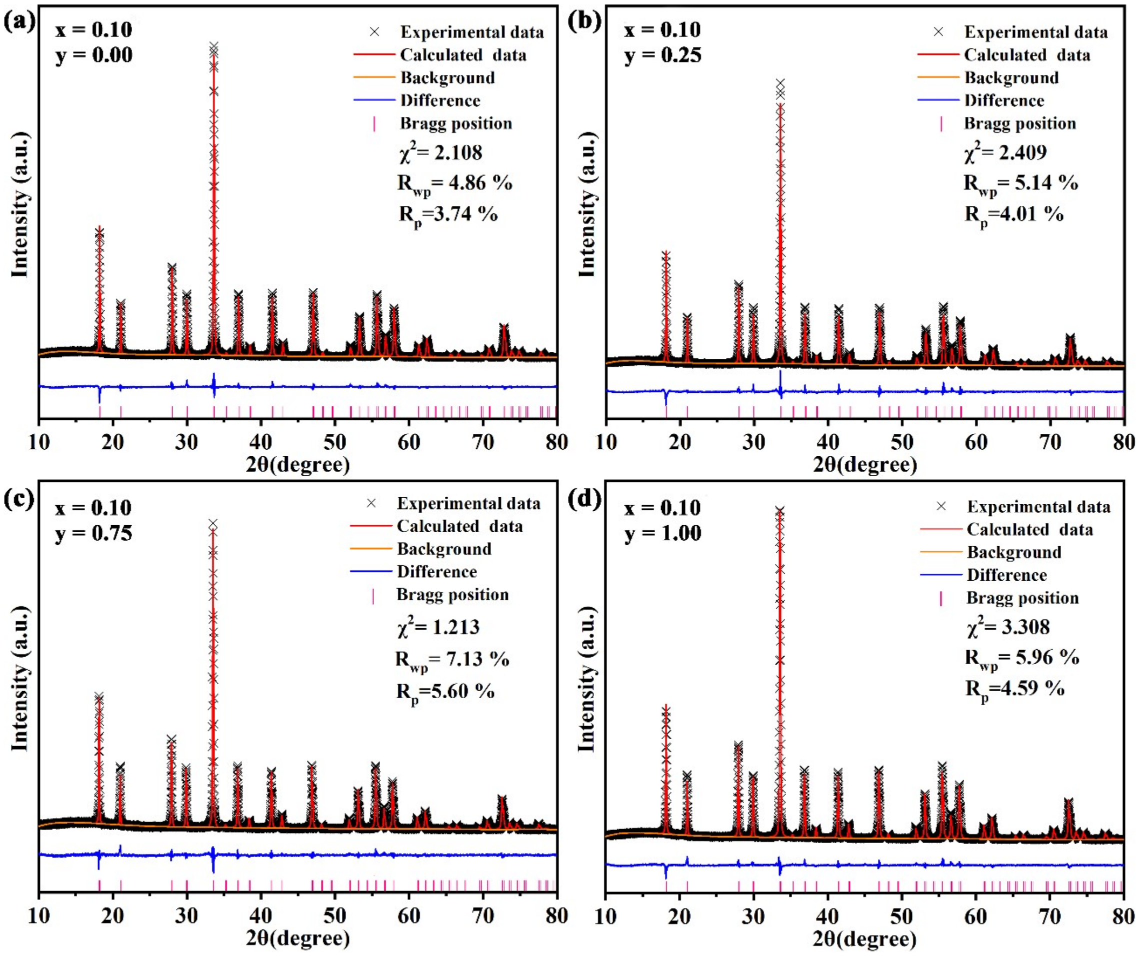

Figure S4. Rietveld refinement on $Lu_{1.9}Mg_2Al_{2.0-y}Ga_ySi_2O_{12}$: $0.1Ce^{3+}$ phosphor, showing the observed (black crosses) and calculated (red line) XRD profiles, and the difference between them (blue line).

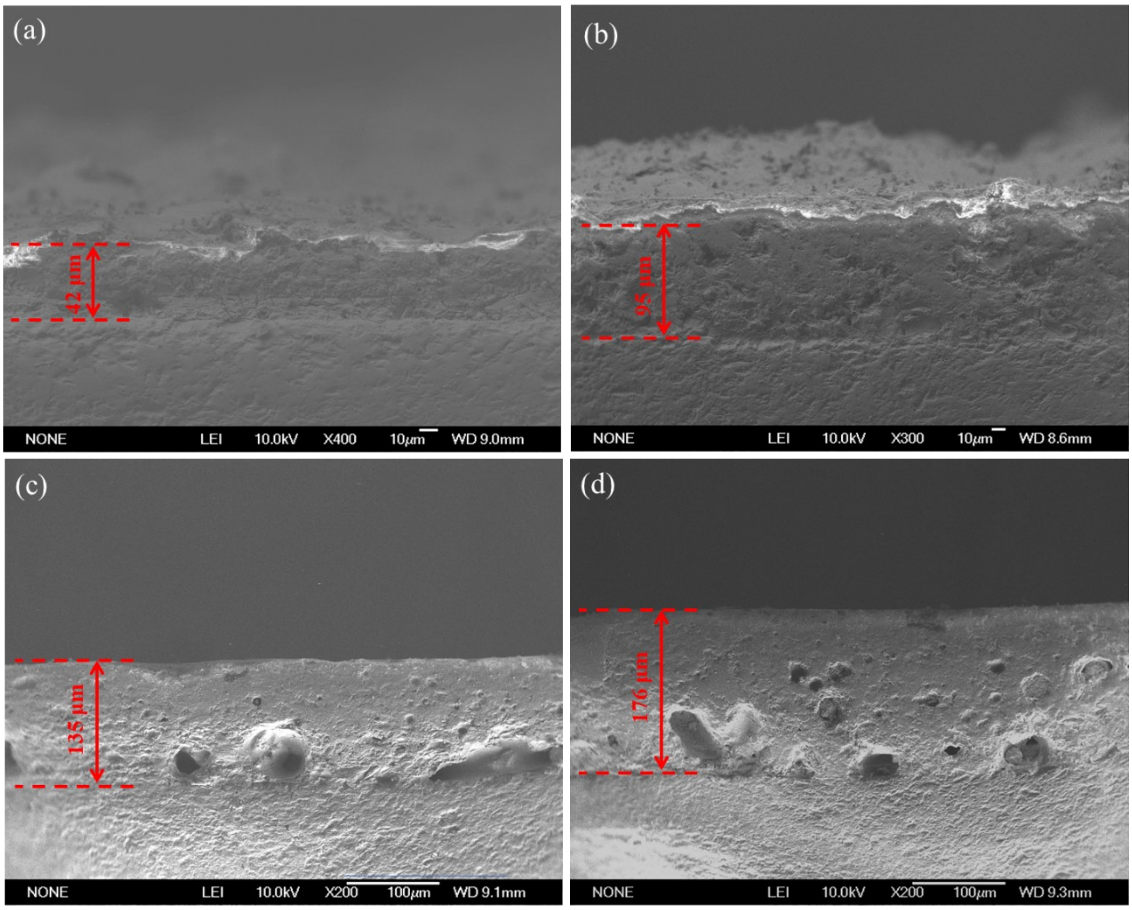

Figure S5. SEM observations on the cross section of LMAGS: Ce^{3+} PiG film-on-SP with different film thickness.

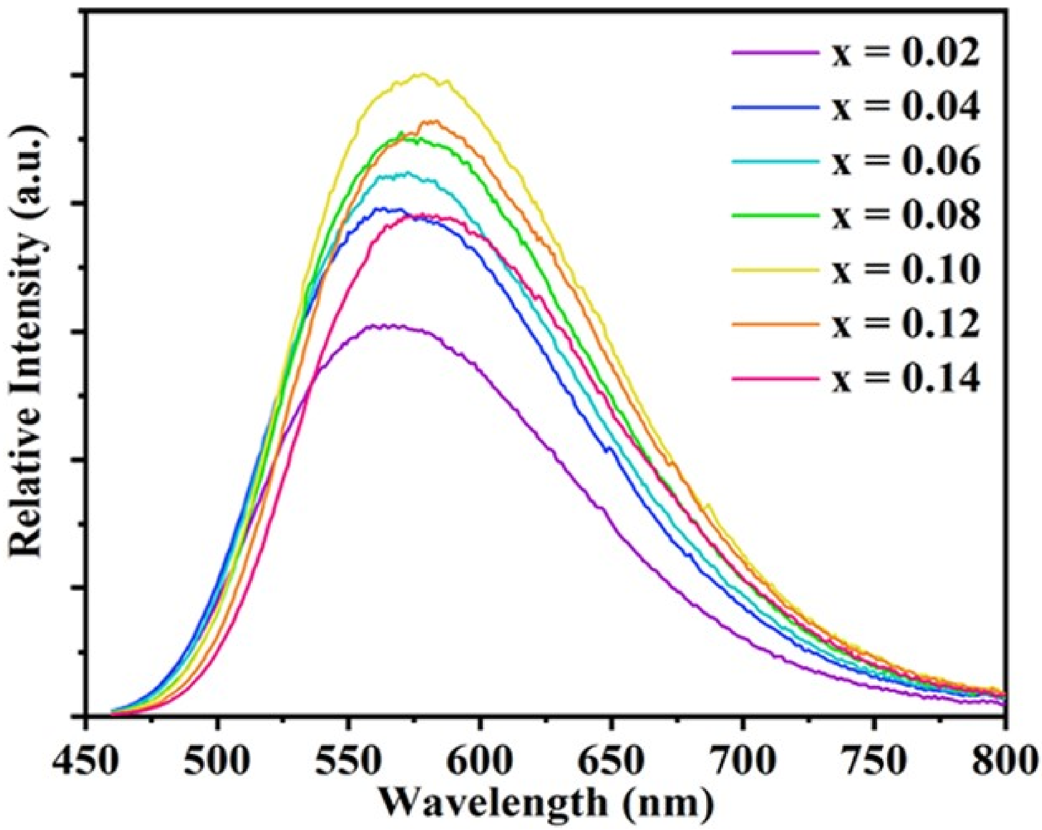

Figure S6. PL spectra of $Lu_{2.0-x}Mg_2Al_{1.5}Ga_{0.5}Si_2O_{12}$: xCe^{3+} PiG film-on-SP under 450 nm excitation.

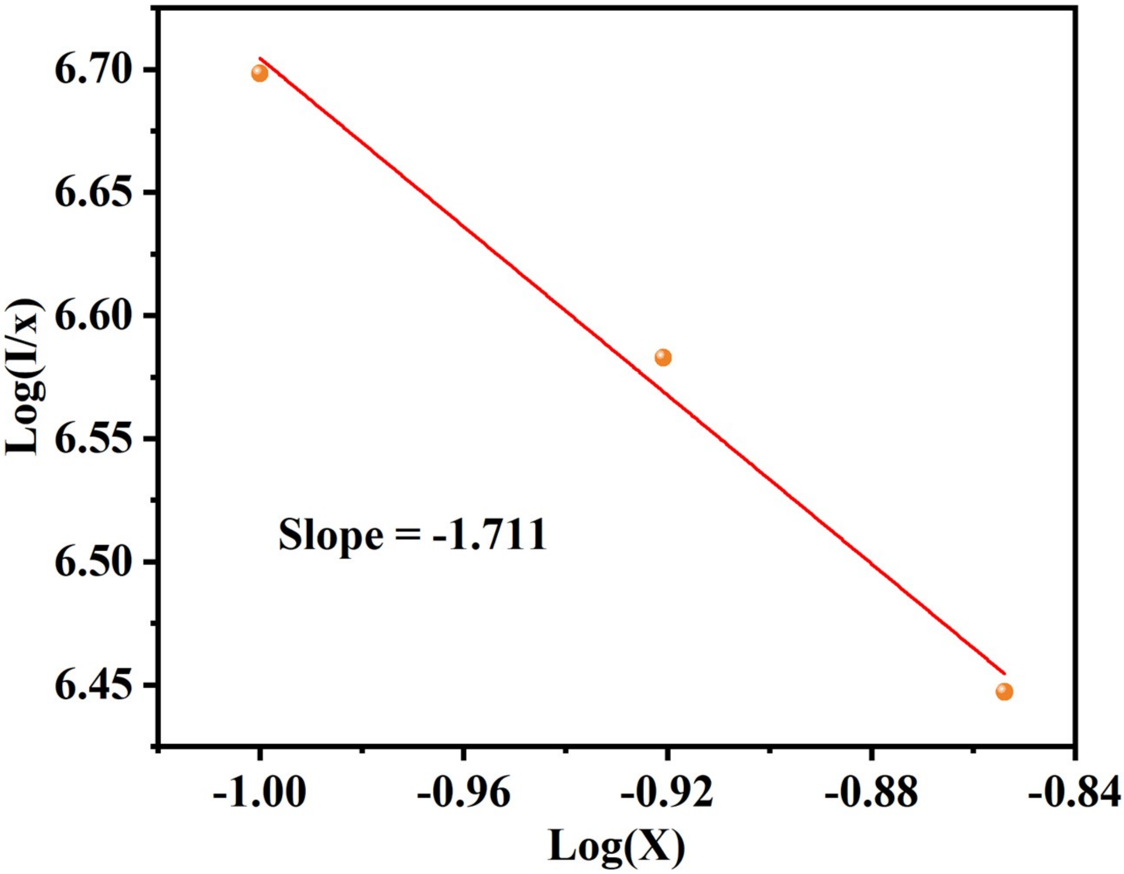

Figure S7. Relationship between log(x) and log(I/x) in the $Lu_{2.0-x}Mg_2Al_{1.5}Ga_{0.5}Si_2O_{12}$: xCe^{3+} phosphor.

Discussions on Figure S7:

In order to study the concentration quenching mechanism, the parameter of R_c reflecting the average distance of Ce^{3+} is introduced by using the following expression [1]:

$$R_c \approx 2\left[\frac{3V}{4\pi x_c N}\right]^{1/3} \tag{1}$$

where V is the volume of unit cell, x_c the critical concentration of activator and N the number of available sites for the dopant in a unit cell. Taken V=1688.219 Å^3, x_c=0.10, and N=8, R_c is evaluated to be ~16 Å. The electronic exchange interaction should be only effective at R_c＜5 Å to achieve energy transfer among Ce^{3+} ions. As such, the electric multipolar-multipolar interaction should be the main mechanism. Then, we adopted the Dexter theory to analyze the type of multipolar-

multipolar interaction by the following equation [2]:

$$I/x = K\left[1+\beta(x)^{\frac{\theta}{3}}\right]^{-1} \tag{2}$$

where K and β are constants, θ=6, 8. 10 means the electric multipole index corresponding to the dipole-dipole (d-d), dipole-quadrupole (d-q) and quadrupole-quadrupole (q-q) interaction, respectively. By plotting log(I/x) versus log(x), θ is calculated as 5.13, indicating that the main mechanism for concentration quenching in LMAGS: Ce^{3+} is the d-d electric multipolar-multipolar interaction.

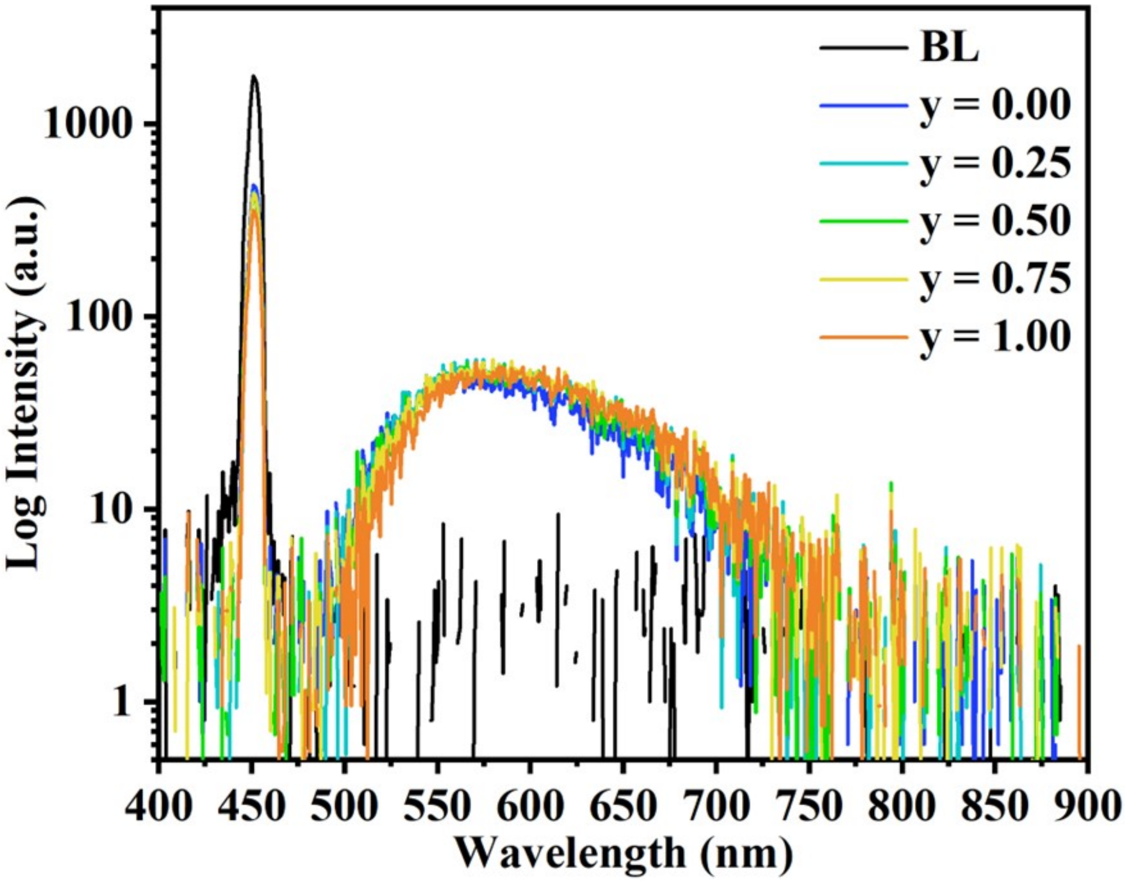

Figure S8. The measured luminescent curves of $Lu_{1.9}Mg_2Al_{2.0-y}Ga_ySi_2O_{12}$: $0.1Ce^{3+}$ PiG film-on-SP to calculate quantum efficiency.

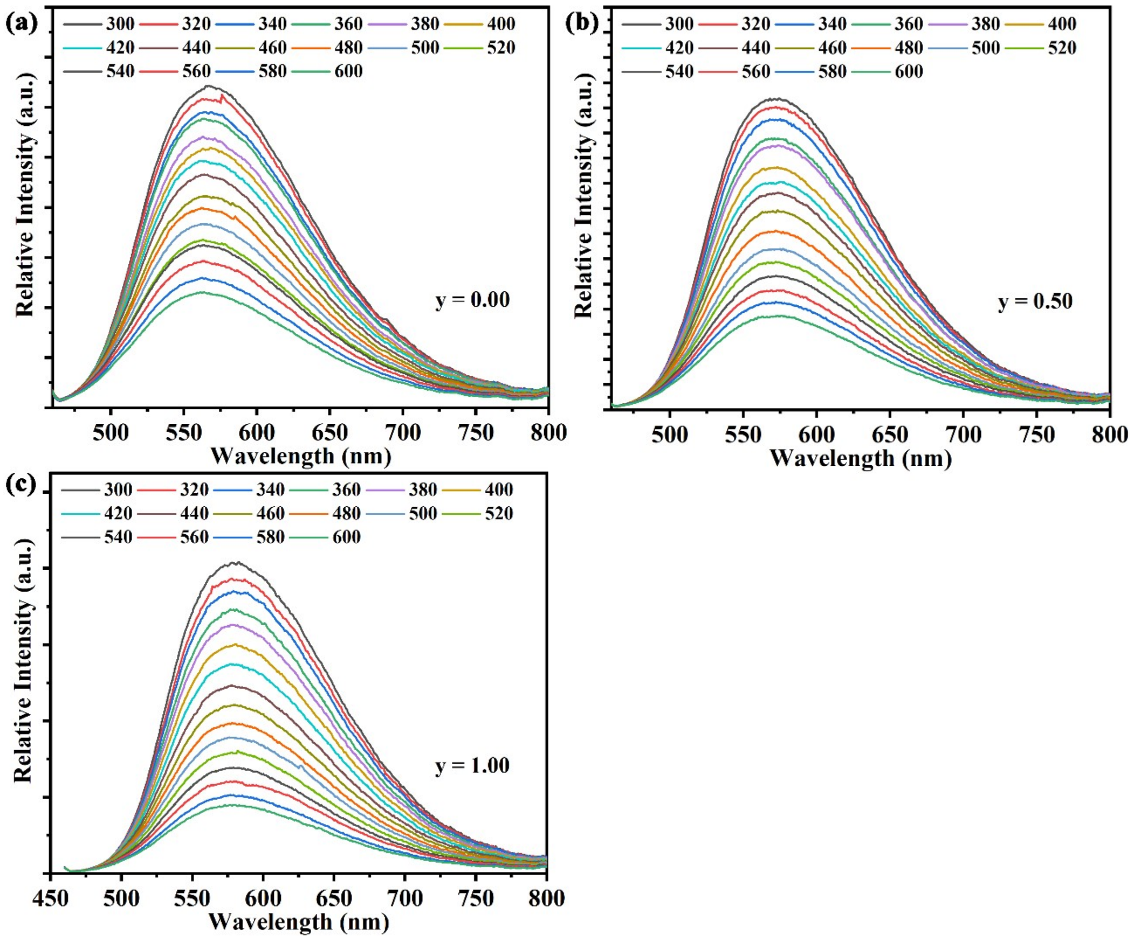

Figure S9. Temperature-dependent PL spectra in $Lu_{1.9}Mg_2Al_{2.0-y}Ga_ySi_2O_{12}$: $0.1Ce^{3+}$ PiG film-on-SP from 300 to 600 K under 450 nm excitation.

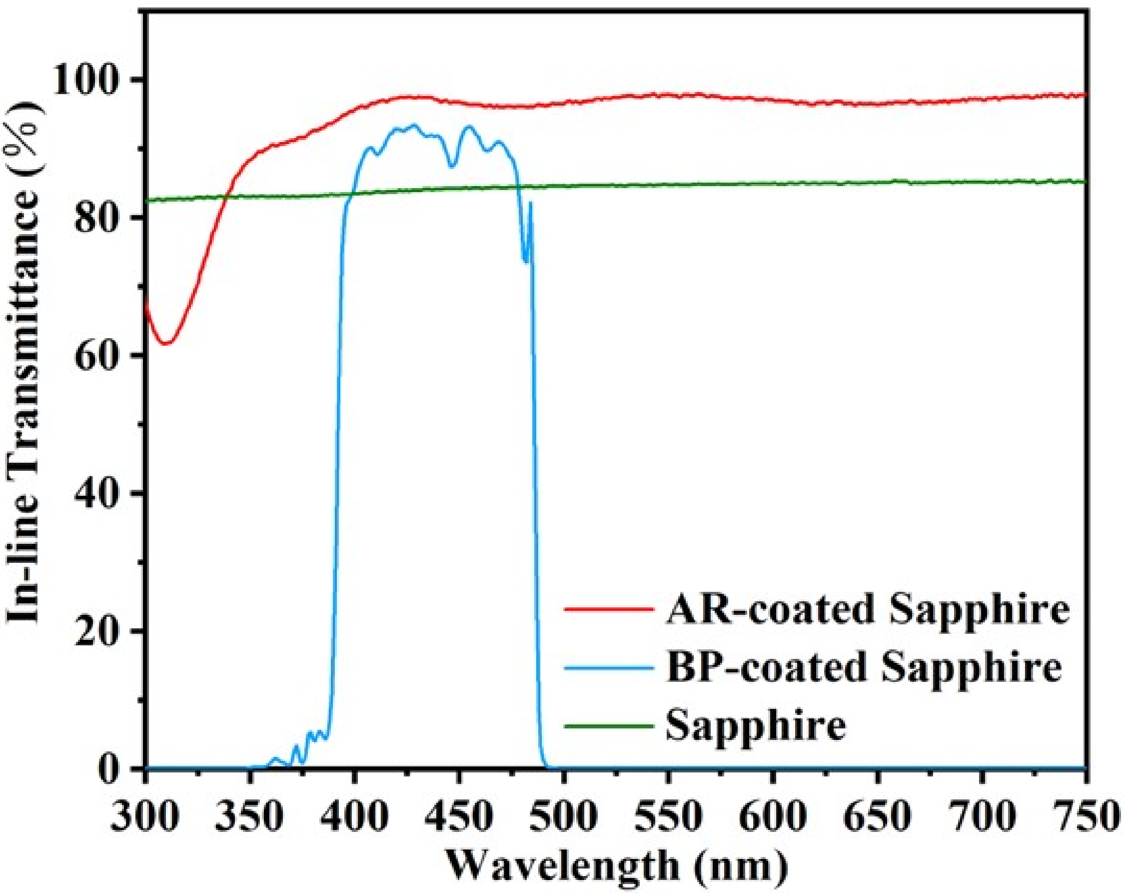

Figure S10. In-line transmittance spectra of sapphire, AR-coated sapphire and BP-coated sapphire.

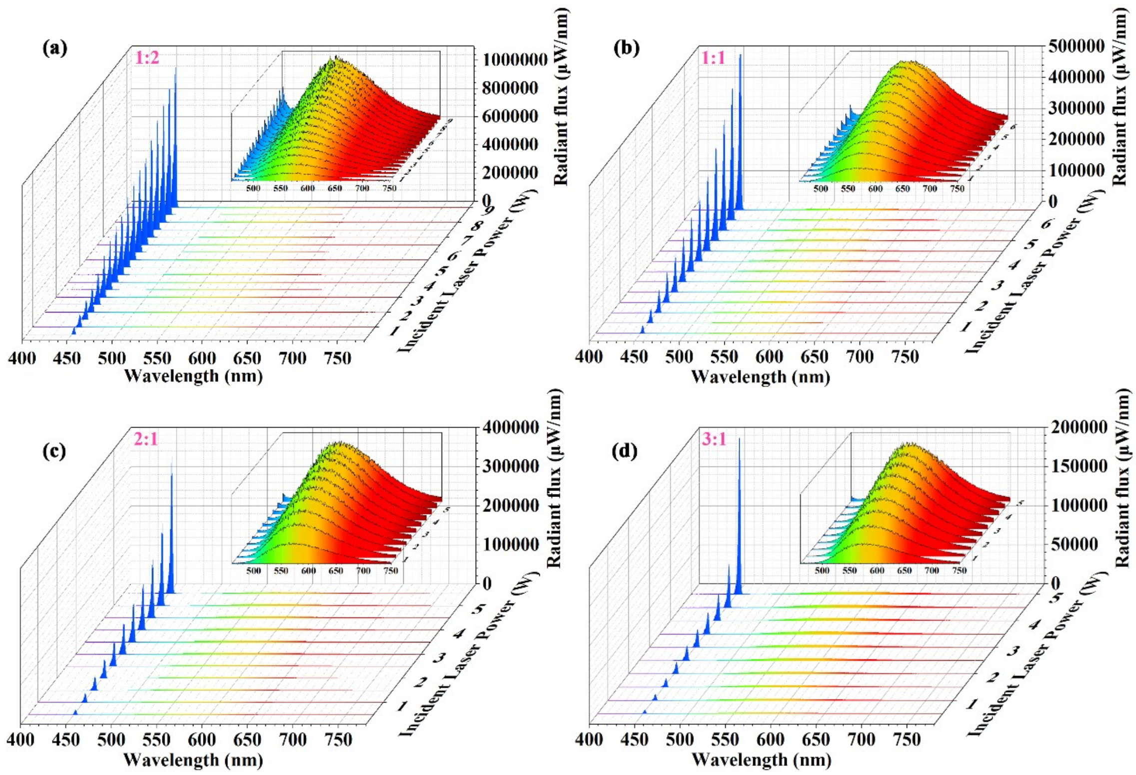

Figure S11. P_{in} dependent electroluminescent spectra of LMAGS: Ce^{3+} PiG film-on-SP with different mass ratios of LMAGS: Ce^{3+} phosphor to glass powders.

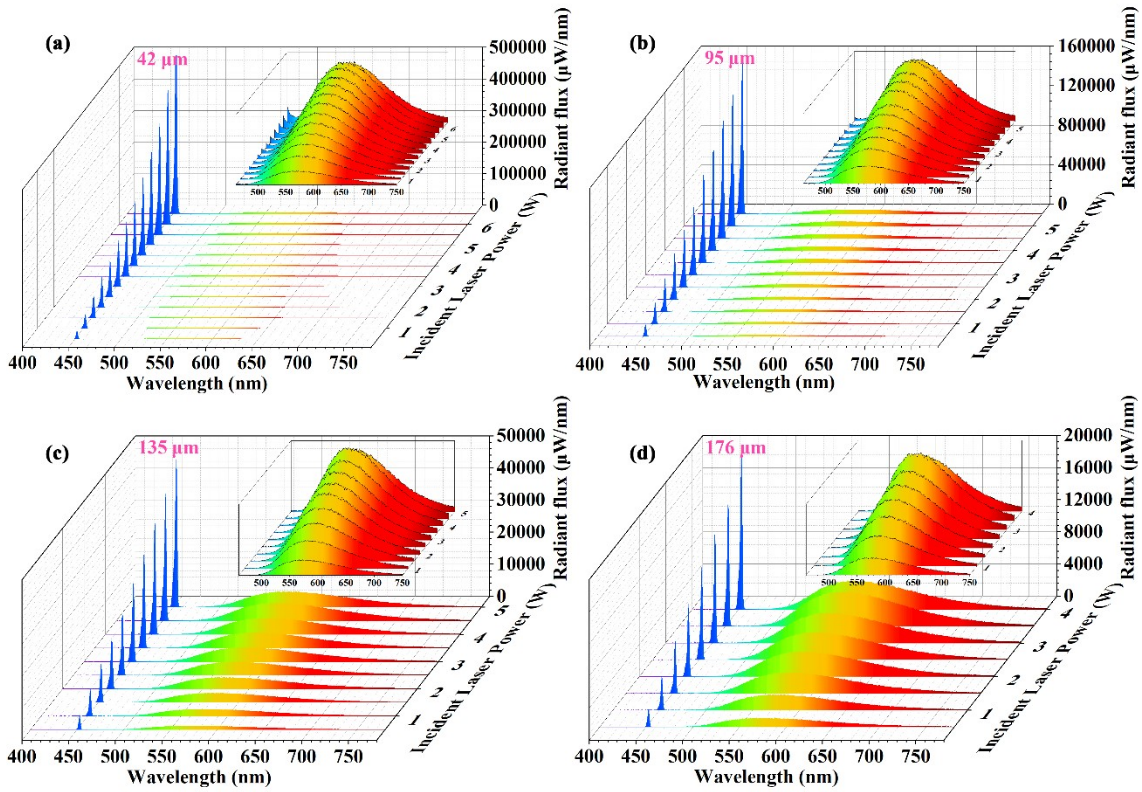

Figure S12. P_{in} dependent electroluminescent spectra of LMAGS: Ce^{3+} PiG film-on-SP with different film thickness.

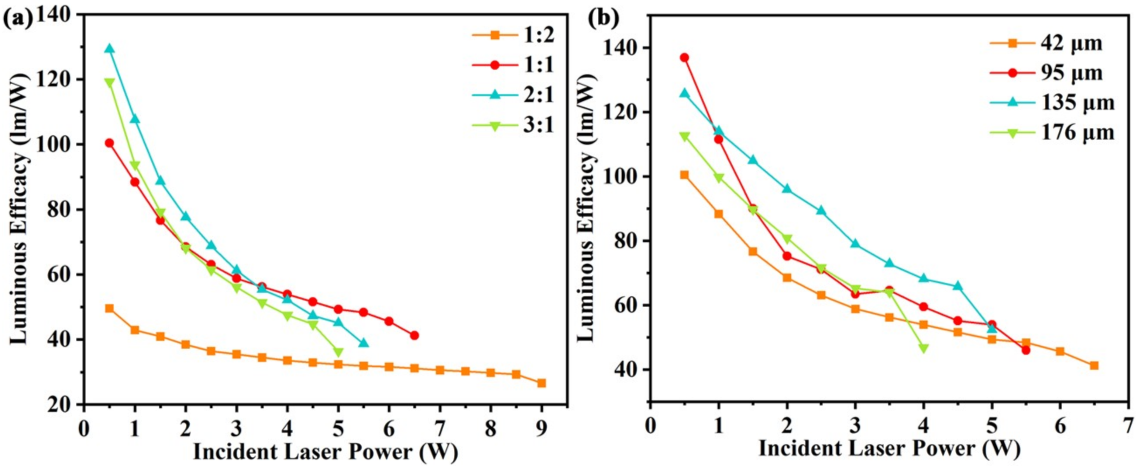

Figure S13. Pumping power dependent luminous efficacy of the LMAGS: Ce^{3+} PiG film-on-SP with (a) different weight ratios of LMAGS: Ce^{3+} phosphor to glass powders and (b) different film thicknesses.

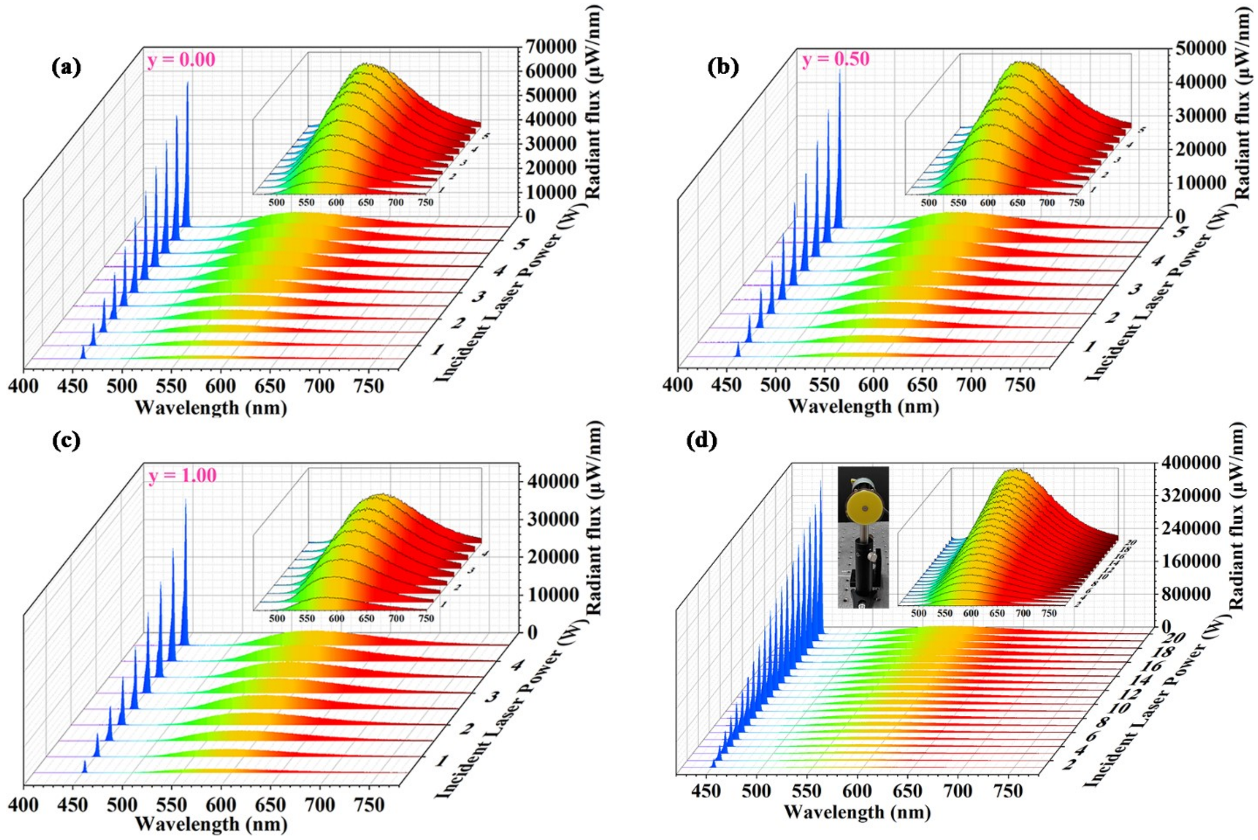

Figure S14. P_{in} dependent EL spectra of LMAGS: Ce^{3+} PiG film-on-SP with different Ga-concentration: (a) y=0.00, (b) y=0.50, and (c) y=1.00; insets are the corresponding magnified spectra in the range of 500-700 nm. (d) P_{in} dependent EL spectra of $Lu_{1.9}Mg_2Al_2Si_2O_{12}$: $0.1Ce^{3+}$ PiG film-on-SP "phosphor wheel" measured under rotatory-reflective mode; insets are the digital photo of phosphor wheel (left) and the enlarged spectra in the region of 500-800 nm (right).

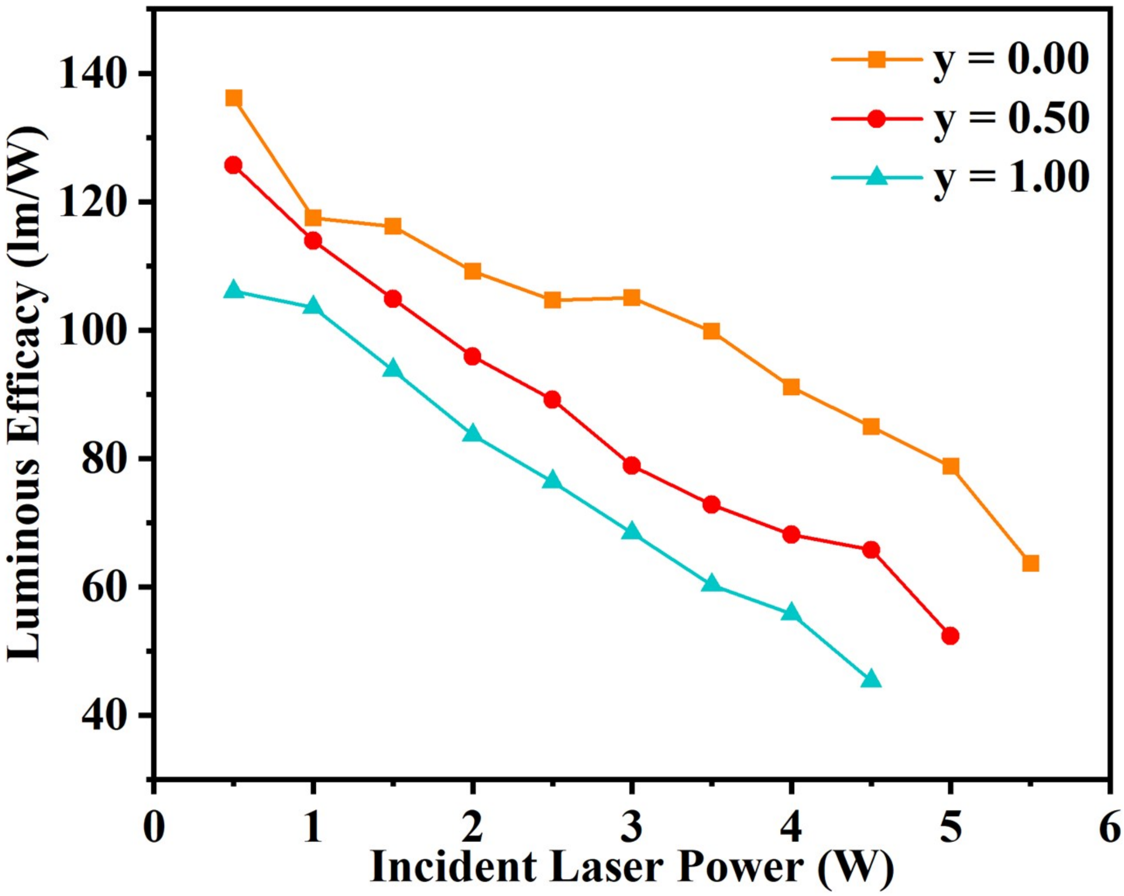

Figure S15. Pumping power dependent luminous efficacy of the LMAGS: Ce^{3+} PiG film-on-SP with different Ga-concentration.

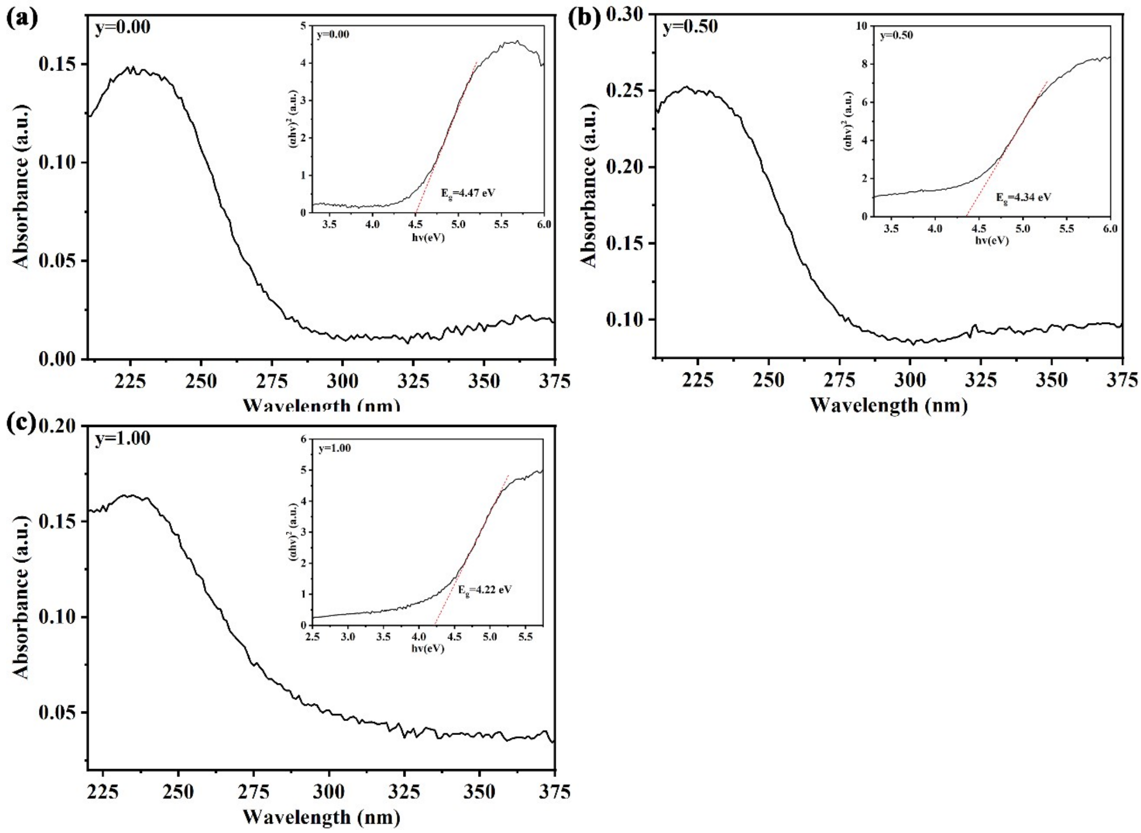

Figure S16. Diffuse-reflectance spectrum of the un-doped LMAGS, inset shows the relationship of $[\alpha h\upsilon]^2$ versus photon energy *hv* to determine the optical bandgap of LMAGS.

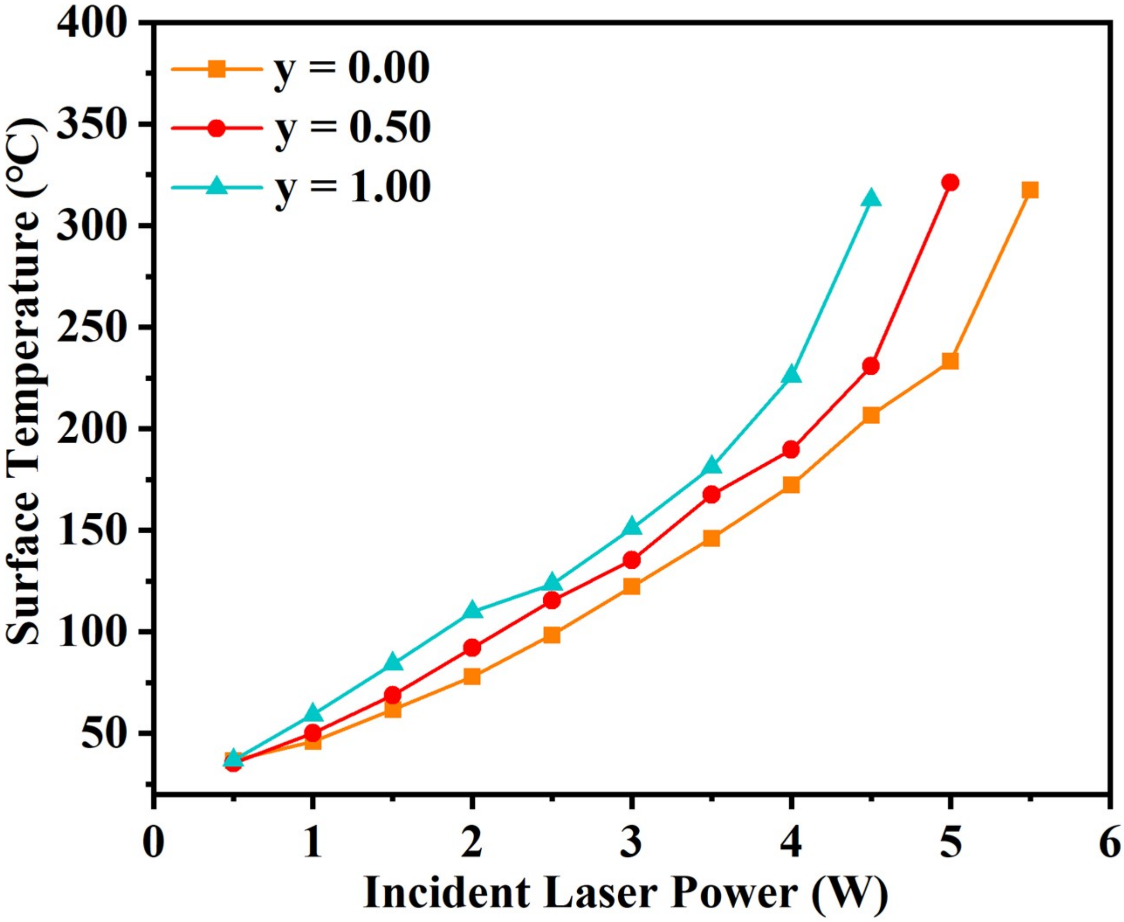

Figure S17. Local temperature of LMAGS: Ce^{3+} PiG film-on-SP with different Ga-concentration at the laser spot.

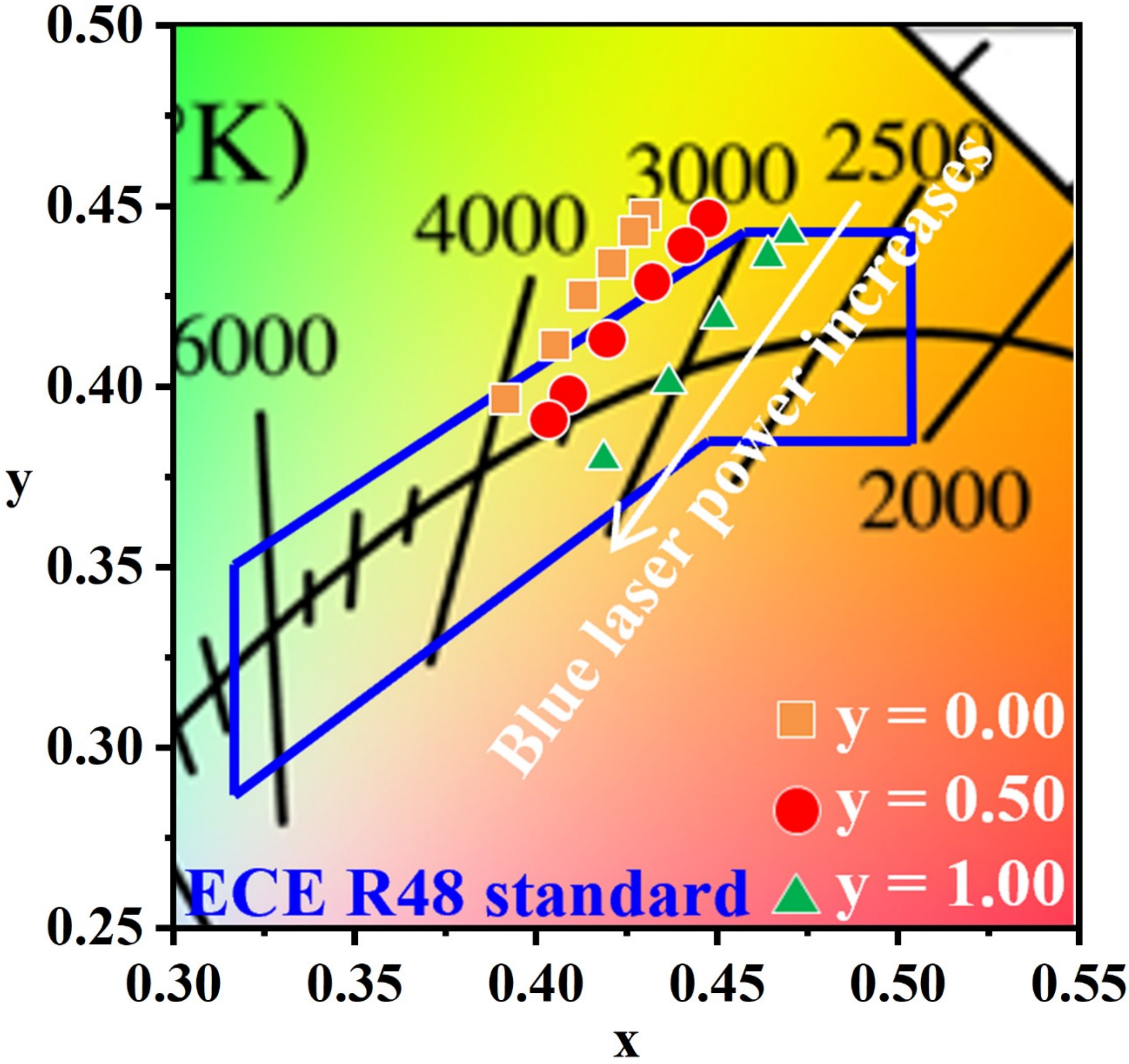

Figure S18. the variations in chromaticity coordinates of LMAGS: Ce^{3+} PiG film-on-SP with different Ga-concentration.

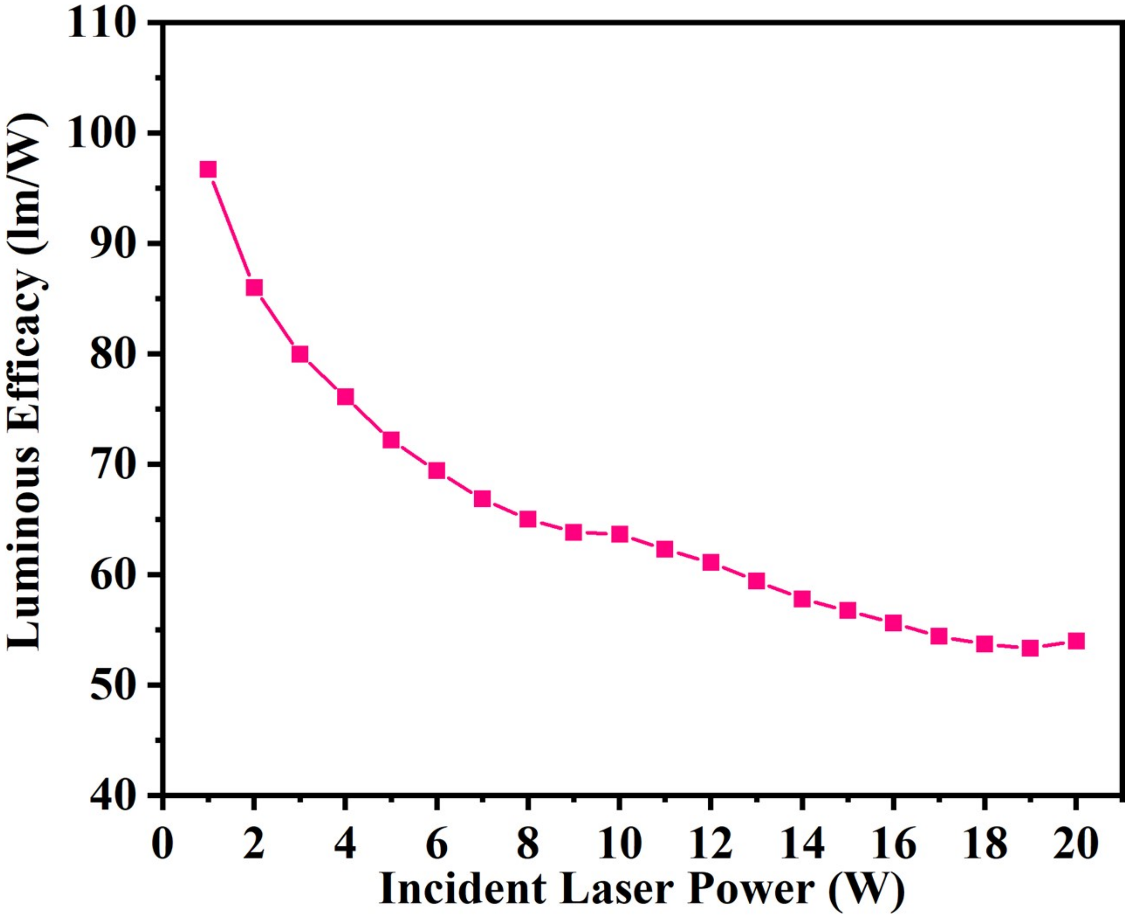

Figure S19. The derived P_{in} dependent luminous efficacy in rotatory-reflective mode.

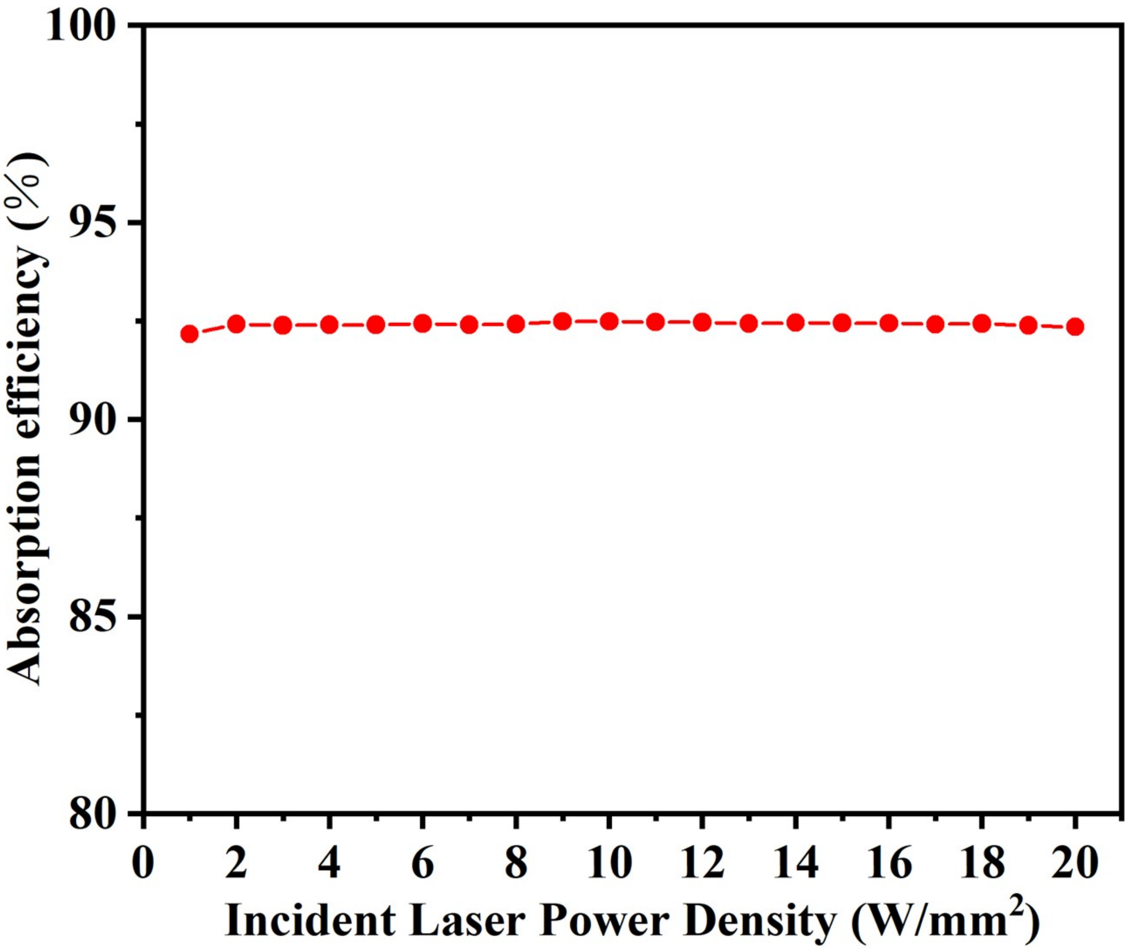

Figure S20. The incident power dependent absorption efficiencies of the LMAGS: Ce^{3+} PiG film-on-SP under rotatory-reflective mode.

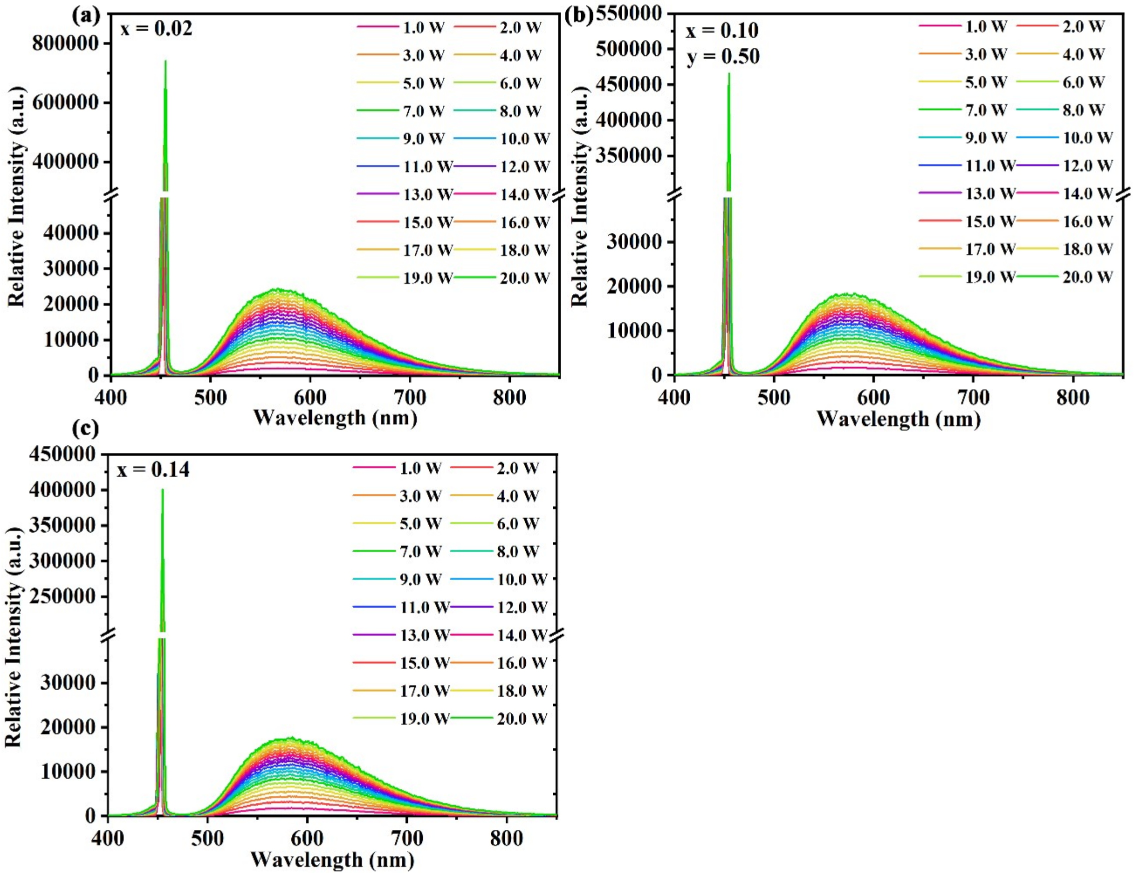

Figure S21. EL spectra of LMAGS: Ce PiG film-on-SP with different Ce-concentration under different input power density in rotatory-reflective mode.

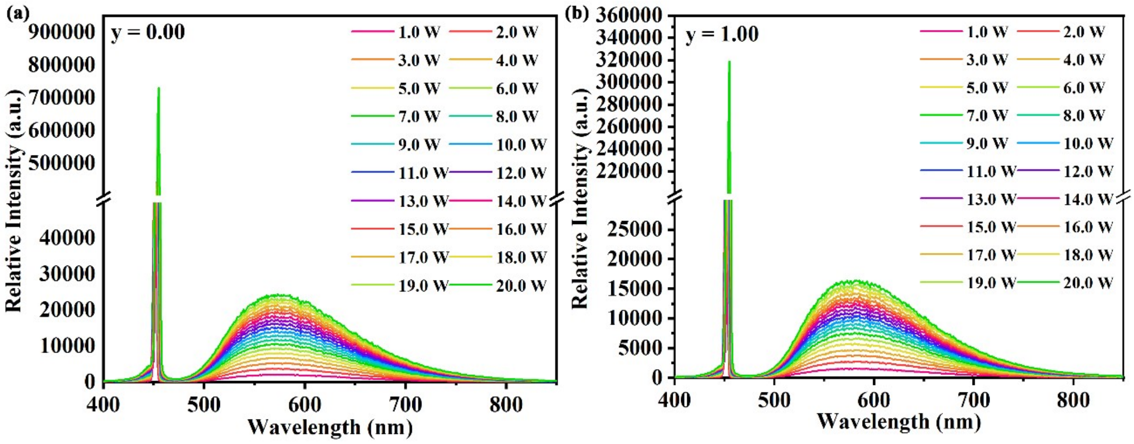

Figure S22. EL spectra of LMAGS: Ce PiG film-on-SP with different Ga-concentration under different input power density in rotatory-reflective mode.

References

[1] G. Blasse, Luminescence of inorganic solids: from isolated centres to concentrated systems, Prog. Solid State Chem. 18 (1988) 79-171.

[2] D.L. Dexter, A theory of sensitized luminescence in solids, J. Chem. Phys. 21 (1953) 836-850.