# Achieving Color-tunable Luminescence in $CaF_2$: Eu Phosphor for Multimode Anti-counterfeiting

*Linglu Kuang [a], Feng Zhang [b], Jian Zhang [a], Xiaodie Zhu [a], Xu Tian [c], Jianxiong Shao[d], Yichun Liu [a*], Xuhui Xu [a], Zhichao Liu [a*],*

*[a] Yunnan Joint International Laboratory of Optoelectronic Materials and Devices, Faculty of Materials Science and Engineering, Kunming University of Science and Technology, Kunming 650093, Yunnan, China*

*[b] School of Future Technology, Henan University, Kaifeng 475001, Henan, China*

*[c] School of Materials and Energy, Yunnan University, Kunming 650504, Yunnan, China*

*[d] Department of Modern Physics, Lanzhou University, Lanzhou 730000, Lanzhou, China.*

** Corresponding Author: Zhichao Liu, E-mails: liuzhichzo1028@126.com*

*Yichun Liu, E-mails: spsjtu@163.com*

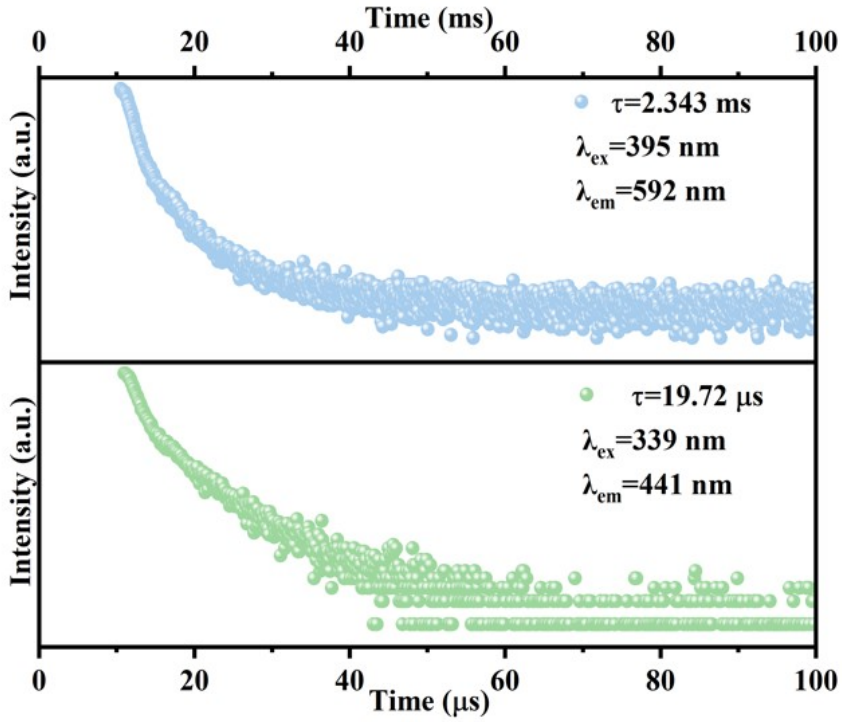


**Fig. S1.** Time luminescence decay curves of $CaF_2$: 0.5% Eu under the emissions at 592 and 441 nm, respectively.

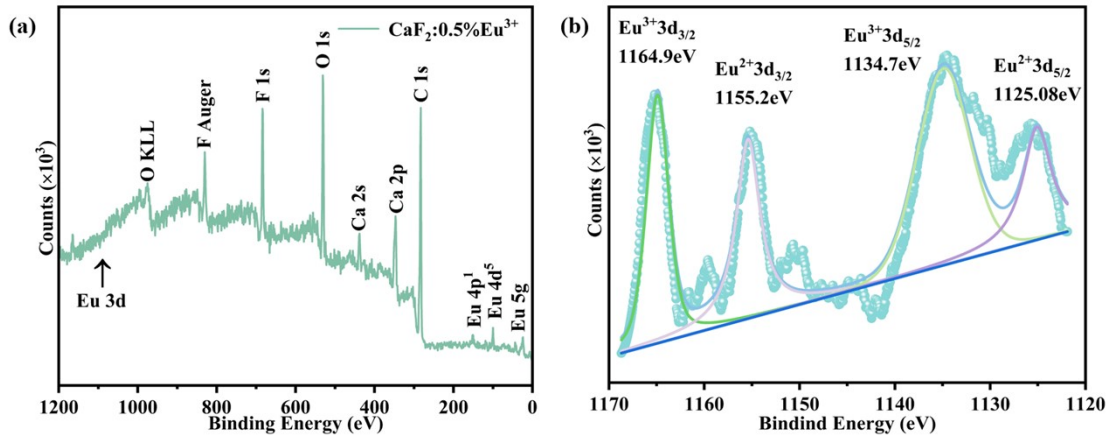


**Fig. S2.** XPS spectra of $CaF_2$: 0.5% Eu: (a) survey, (b) high-resolution scans of Eu 3d.

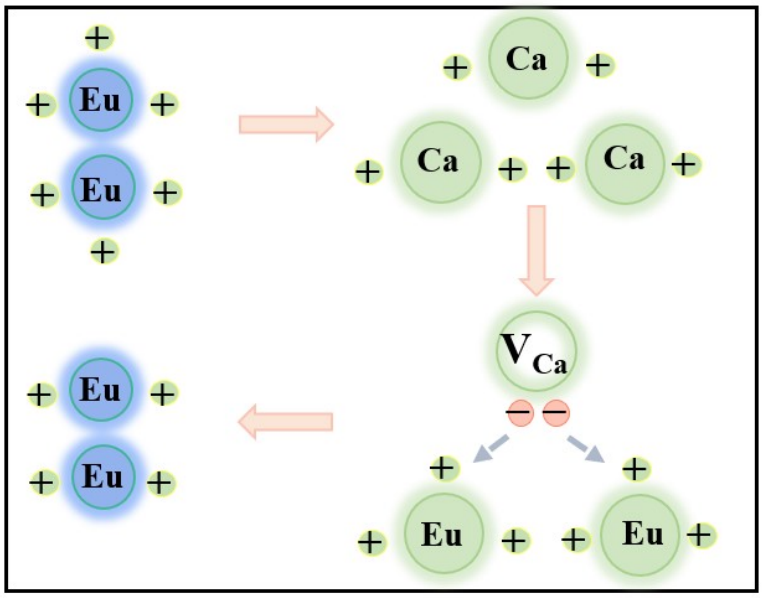


**Fig. S3.** The schematic diagram of the $Eu^{3+}$ self-reduction principle.

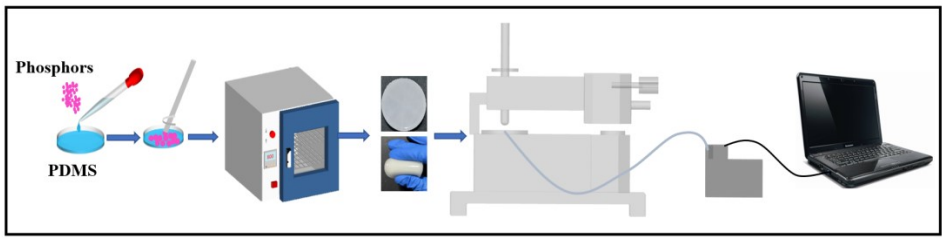


**Fig. S4.** Schematic diagram depicting the ML measurement for the $CaF_2$: x% $Eu^{3+}$ @ PDMS (x = 0.1, 0.25, 0.5%, 0.75, and 1) film.

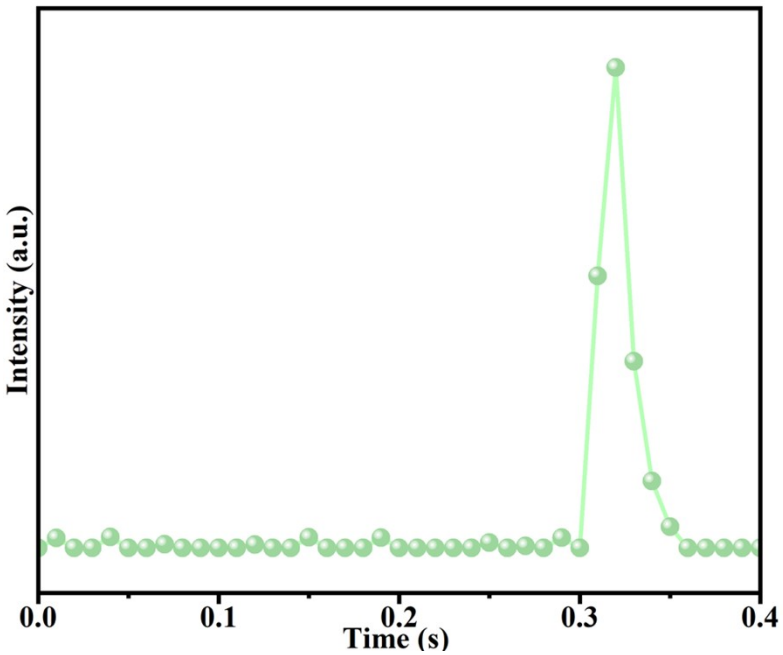


**Fig. S5.** The response speed of $CaF_2$: 0.5% Eu @ PDMS to mechanical stimuli.

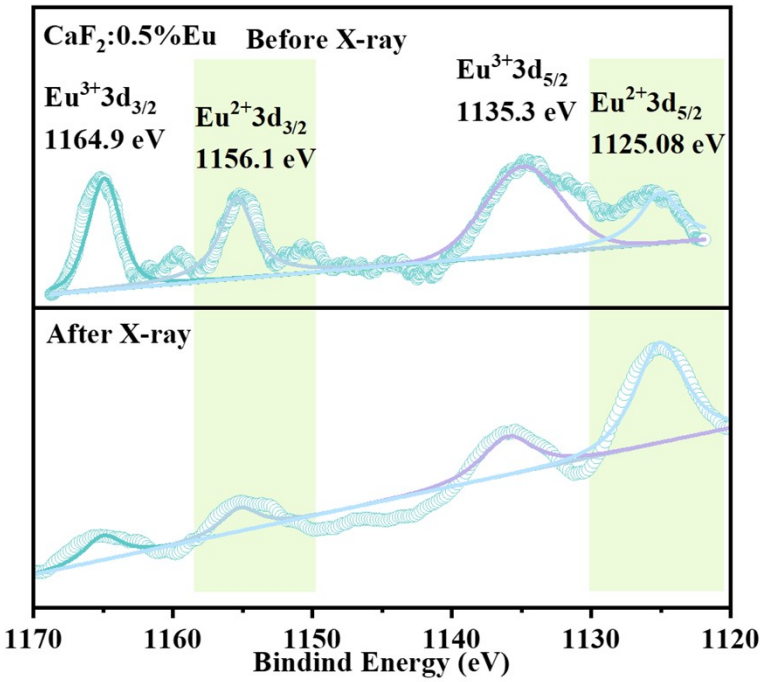


**Fig. S6.** XPS spectra of $CaF_2$:0.5%Eu before and after x-ray irradiation.

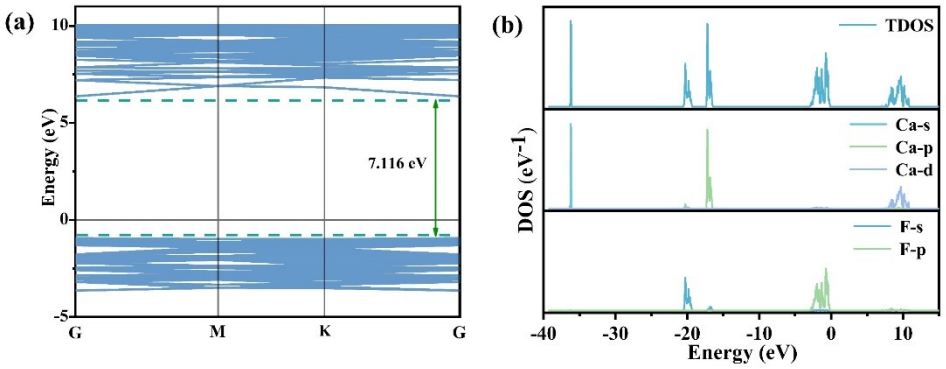


**Fig. S7.** (a) The band structure, (b) the total DOS and partial DOS of the $CaF_2$ host.

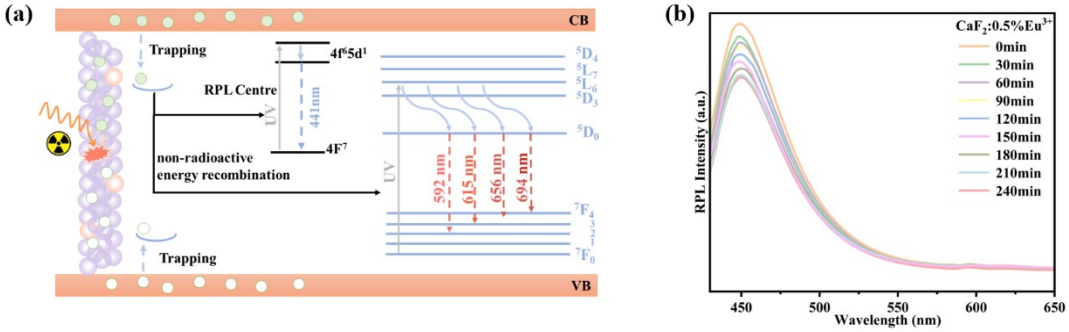


**Fig. S8.** (a) The mechanism of RPL phenomenon. (b) Standing for different times after X-ray irradiation.