Electronic Supplementary Material (ESI) for Inorganic Chemistry Frontiers.

Supporting Information

Long-persistent far-UVC light emission in Pr^{3+}-doped $Sr_2P_2O_7$ phosphor for microbial sterilization

Yi Zhang,[a] Shao Yan,[a] Fang Xiao,*[b] Xihui Shan,[a] Xulong Lv,[a] Weili Wang[a] and Yanjie Liang*[a]

[a]*Key Laboratory for Liquid-Solid Structure Evolution and Processing of Materials, Ministry of Education, Shandong University, Jinan 250061, China*

[b]*Department of Cadres Medical Care and Geriatrics, the Second Hospital of Shandong University, Jinan 250033, China*

*Corresponding author: Yanjie Liang, Fang Xiao

E-mail: yanjie.liang@sdu.edu.cn; xiaofangqshdd@163.com.

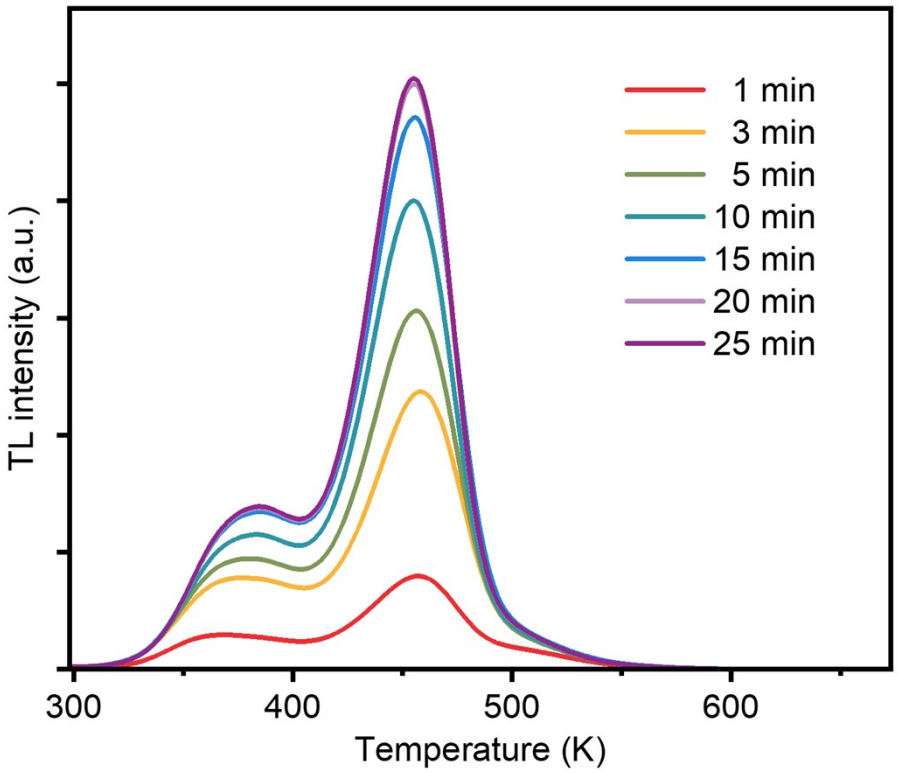

Figure S1. Thermoluminescence spectra of the $Sr_2P_2O_7:Pr^{3+}$ phosphor with varying the excitation duration of X-ray beam from 1 min to 25 min.

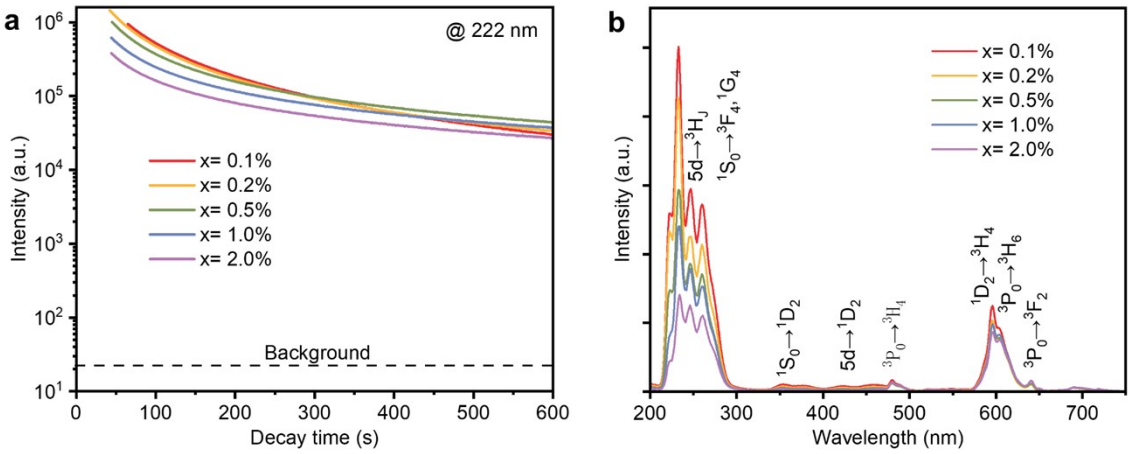

Figure S2. Effects of Pr^{3+} doping concentration on the persistent luminescence performance of $Sr_2P_2O_7:Pr^{3+}$ phosphors. (a) Persistent luminescence decay curves, and (b) persistent luminescence emission spectra of the $Sr_{2-x}P_2O_7:xPr^{3+}$(x = 0.001, 0.002, 0.005, 0.01, 0.02) phosphors. The samples were pre-irradiated by X-ray for 20 min.

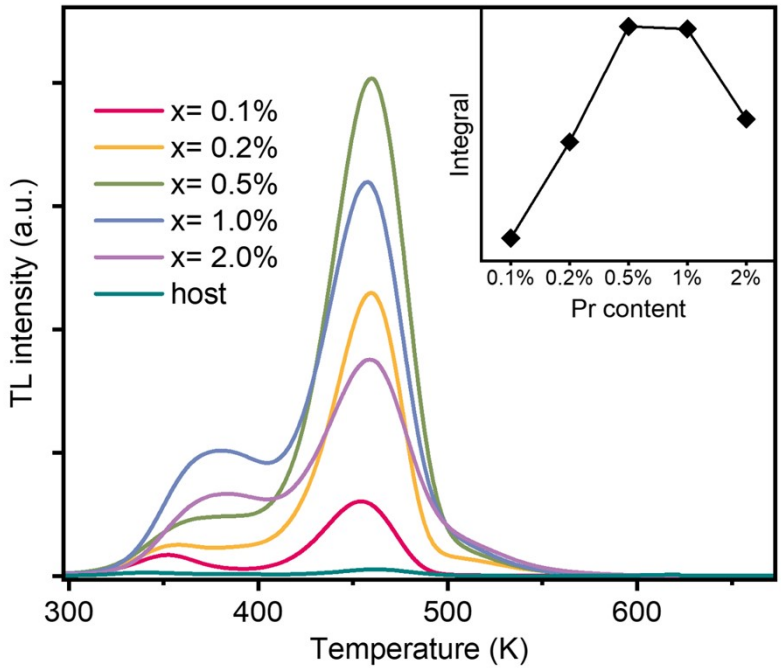

Figure S3. TL curves of the $Sr_{2-x}P_2O_7$:$x$$Pr^{3+}$($x$ = 0, 0.001, 0.002, 0.005, 0.01, 0.02) phosphors. The samples were pre-irradiated by X-ray for 20 min.

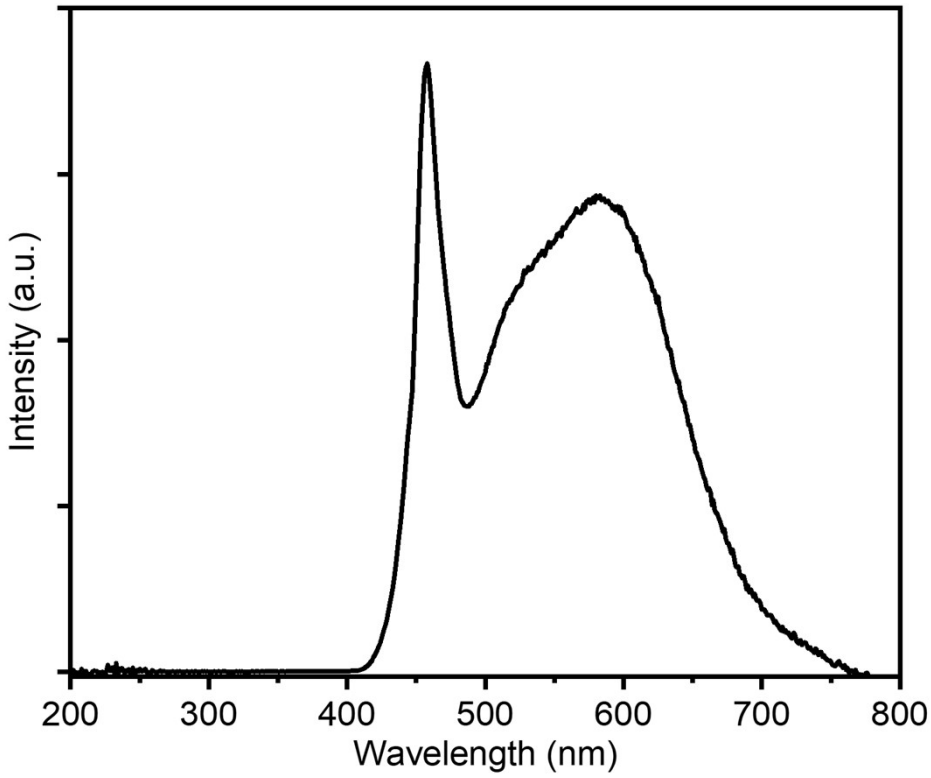

Figure S4. The emission spectrum of the used commercial white LED.

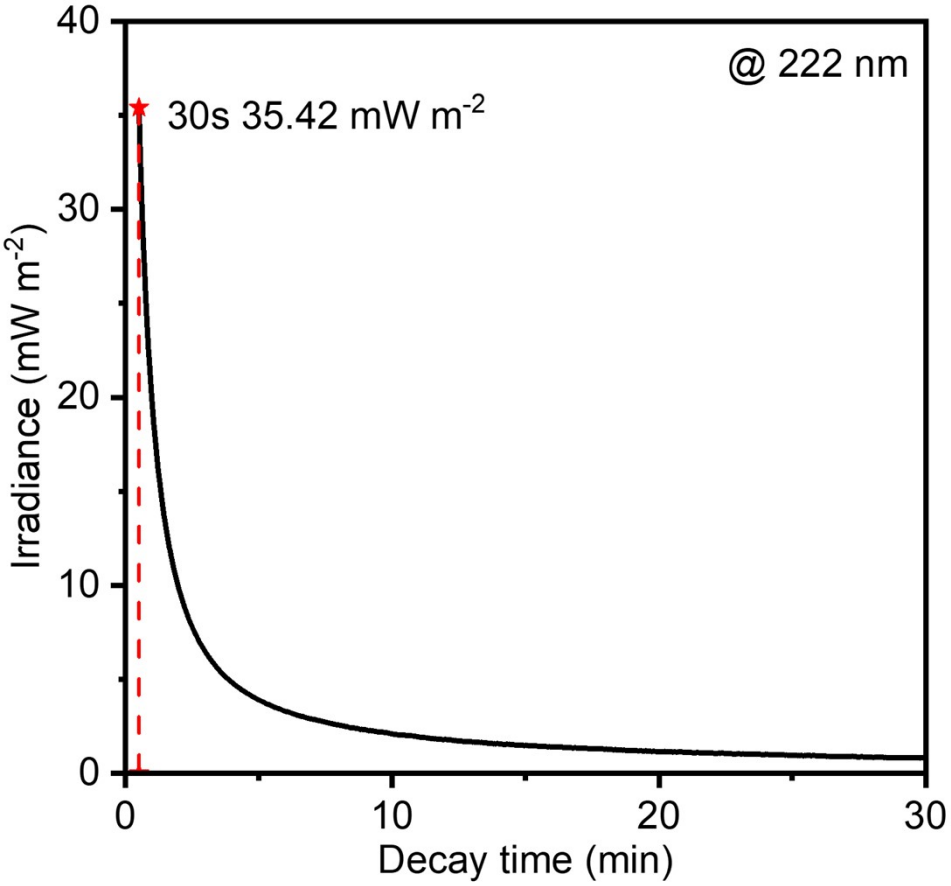

Figure S5. Far-UVC persistent luminescence power density decay curve of the SPO:0.005Pr^{3+} phosphor measured by Newport power meter. The sample was pre-irradiated by X-ray for 20 min.

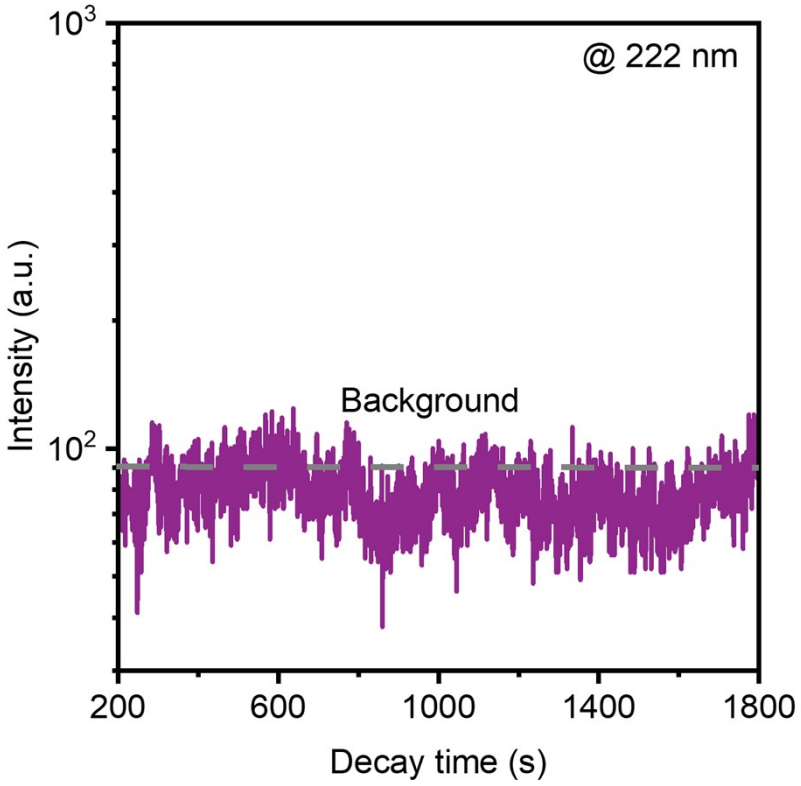

Figure S6. Persistent luminescence decay curve of the SPO:0.005Pr^{3+} phosphor at 77 K. The sample was pre-irradiated by X-ray for 20 min at room temperature.

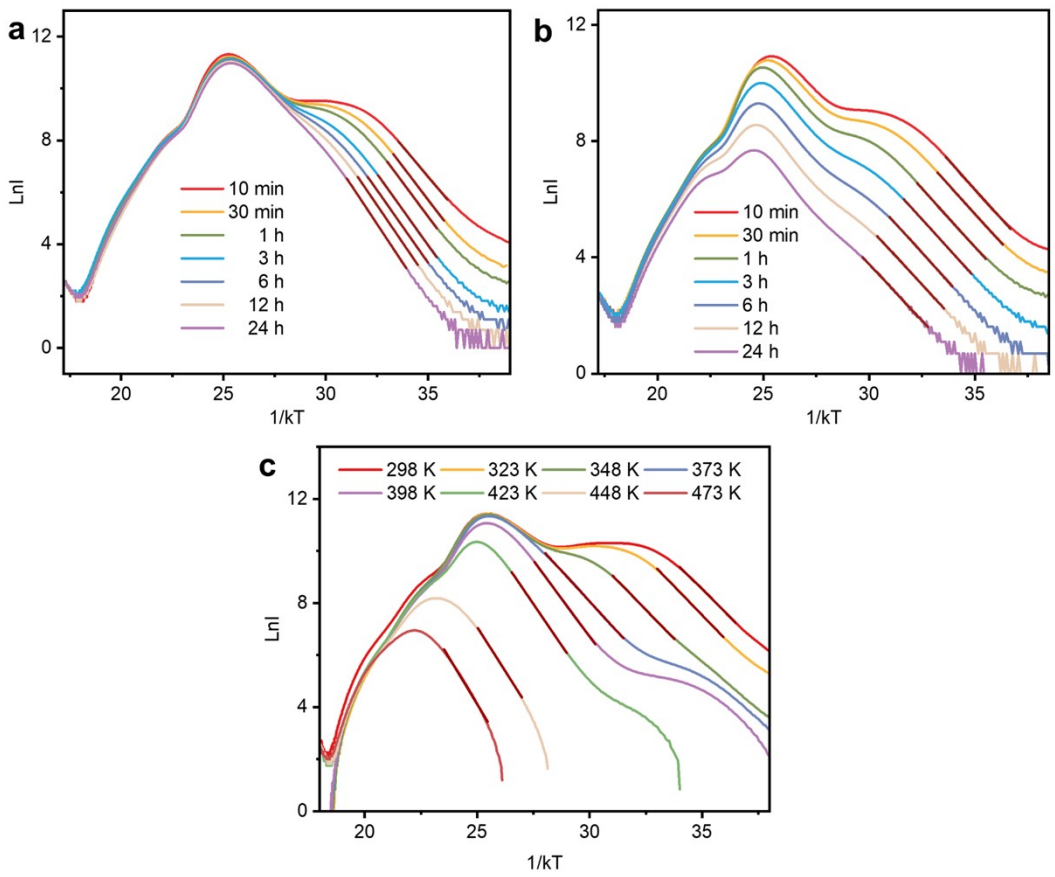

Figure S7. (a) Initial rising analysis for the TL curves of the SPO:0.005Pr^{3+} phosphor at different decay instants in the darkness after X-ray charging. (b) Initial rising analysis for the TL curves of the SPO:0.005Pr^{3+} phosphor upon white LED (300 lux) photostimulation. (c) Initial rising analysis for the TL curves of the SPO:0.005Pr^{3+} phosphor with thermal cleaning procedure. The red lines represent the fitting results. The samples were pre-irradiated by X-ray for 20 min.

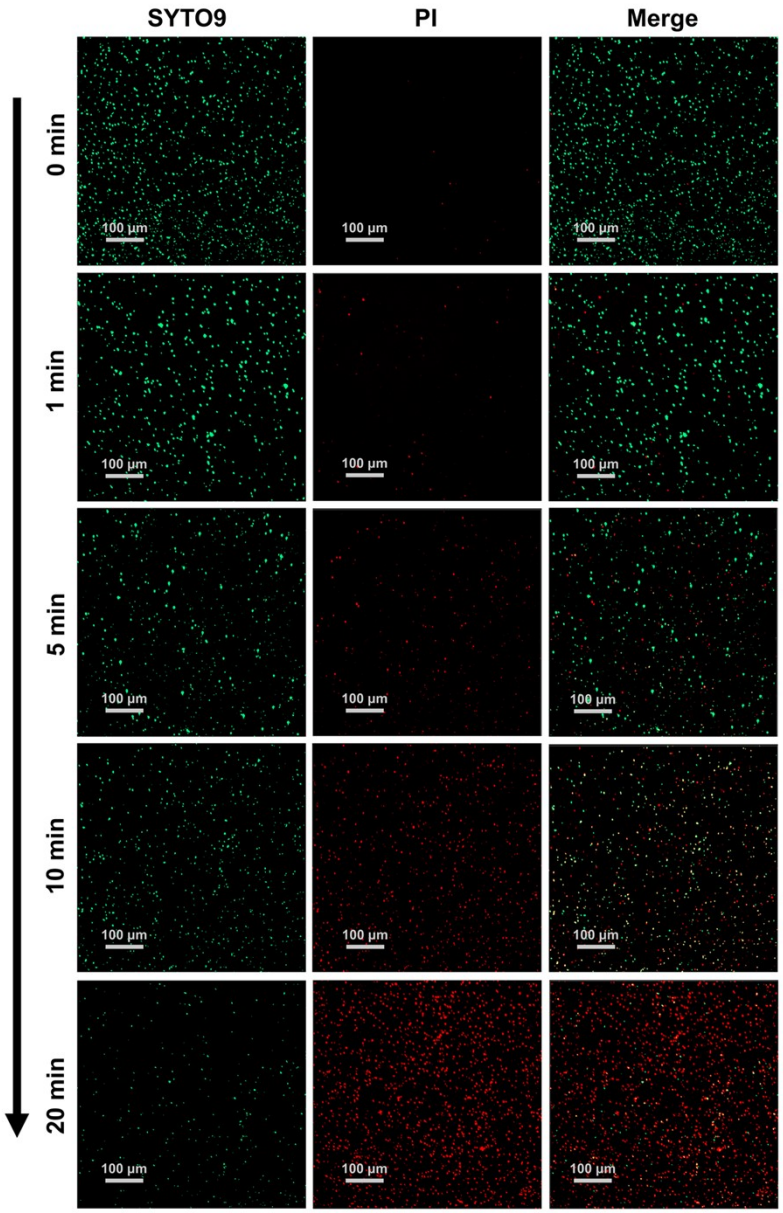

Figure S8. Confocal laser scanning micrograph of MRSA after irradiation of the SPO:0.005Pr^{3+} samples. The samples were pre-irradiated by X-ray for different times (0 min, 1 min, 5 min, 10 min, 20 min), then covered on the top of the 48 wells plate for 30 min.

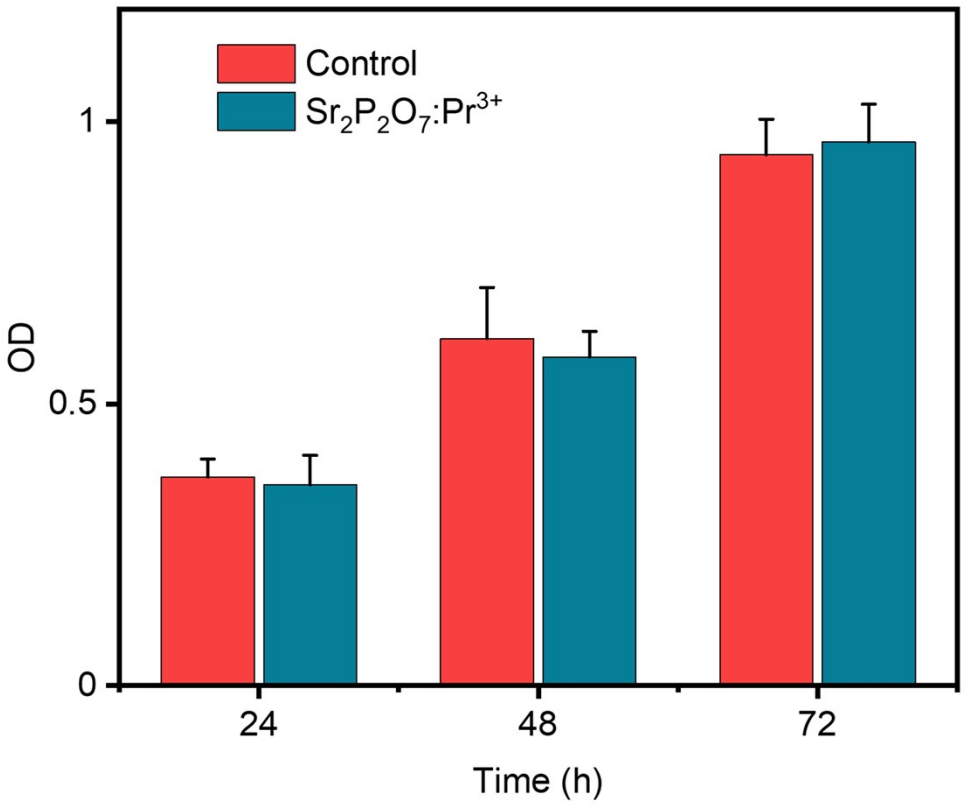

Figure S9. Cytotoxic effects of the SPO:0.005Pr^{3+} phosphor on mouse Dermal Fibroblasts (mDF) cells. OD value is showing for cells incubated with and without SPO:0.005Pr^{3+} phosphors. Bars represent the mean and standard deviation of threefold independent experiments.

Table S1. Refined structural parameters and cell parameter values of $Sr_2P_2O_7:Pr^{3+}$ from the Rietveld refinement.

Formula	$Sr_2P_2O_7:Pr^{3+}$
Crystal system	Orthorhombic
Space group	*Pnma*
Cell parameters	a = 8.91161(8) Å b = 5.40472(6) Å c = 13.15116(13) Å
	Alpha = 90° Beta = 90° Gamma = 90°
Cell volume	V = 633.422(11) Å^3
Z	4
Reliability factors	R_p = 5.53%, R_{wp} = 7.94% and χ^2 = 2.739

Atom	x/a	y/b	z/c	Occupancy	Uiso
Sr1	0.169998	0.250000	0.739753	0.9537	0.02841
Sr2	0.124487	0.250000	0.414952	0.9260	0.01966
P1	-0.033342	-0.250000	0.818322	1.0786	0.04716
P2	-0.281963	-0.250000	0.961531	0.9938	0.03128
O1	-0.086522	-0.250000	0.938211	1.0853	0.06539
O2	-0.080897	-0.008017	0.765667	0.9054	0.03266
O3	-0.344362	-0.015821	0.924487	0.9888	0.04684
O4	-0.271164	-0.250000	1.079729	1.1720	0.08073
O5	0.135498	-0.250000	0.829587	0.9757	0.05268

Table S2. Far-UVC persistent luminescence power density of the SPO:0.005Pr^{3+} phosphor measured by Newport power meter. The sample was pre-irradiated by X-ray for 20 min.

Decay time (s)	Radiance (mW m^{-2})
30	35.42
60	19.62
300	3.90
600	2.09
1200	1.15
1800	0.82

Table S3. Persistent luminescence power densities comparison with the other reported UVC persistent phosphors.

Material	Irradiance (mW m^{-2})	Emission wavelength (nm)	Ref.
$Cs_2NaYF_6:Pr^{3+}$	14.9 (30 s)	270	1
$Ca_2Al_2SiO_7:Pr^{3+}$	4.8 (10 s)	268	2
$Lu_2SiO_5:Pr^{3+}$	6.98 (15 s)	270	3
$LiLuSiO_4:Pr^{3+}$	12.47 (10 s)	280	4
$Sr_2P_2O_7:Pr^{3+}$	35.42 (30 s)	222	This work

Reference

(1) Y. M. Yang, Z. Y. Li, J. Y. Zhang, Y. Lu, S. Q. Guo, Q. Zhao, X. Wang, Z. J. Yong, H. Li, J. P. Ma, Y. Kuroiwa, C. Moriyoshi, L. L. Hu, L. Y. Zhang, L. R. Zheng and H. T. Sun, X-ray-activated long persistent phosphors featuring strong UVC afterglow emissions, *Light: Sci. Appl.*, 2018, **7**, 88.

(2) X. Wang, Y. Chen, F. Liu and Z. Pan, Solar-blind ultraviolet-C persistent luminescence phosphors, *Nat. Commun.*, 2020, **11**, 2040.

(3) S. Yan, Y. Liang, Y. Chen, J. Liu, D. Chen and Z. Pan, Ultraviolet-C persistent luminescence from the $Lu_2SiO_5:Pr^{3+}$ persistent phosphor for solar-blind optical tagging, *Dalton Trans.*, 2021, **50**, 8457–8466.

(4) S. Yan, Y. Liang, Y. Zhang, B. Lou, J. Liu, D. Chen, S. Miao and C. Ma, A considerable improvement of long-persistent luminescence in $LiLuSiO_4:Pr^{3+}$ phosphors by Sm^{3+} co-doping for optical tagging applications, *J. Mater. Chem. C*, 2022, **10**, 17343–17352.