# Supporting information

## A thermal-sensitizing phosphor

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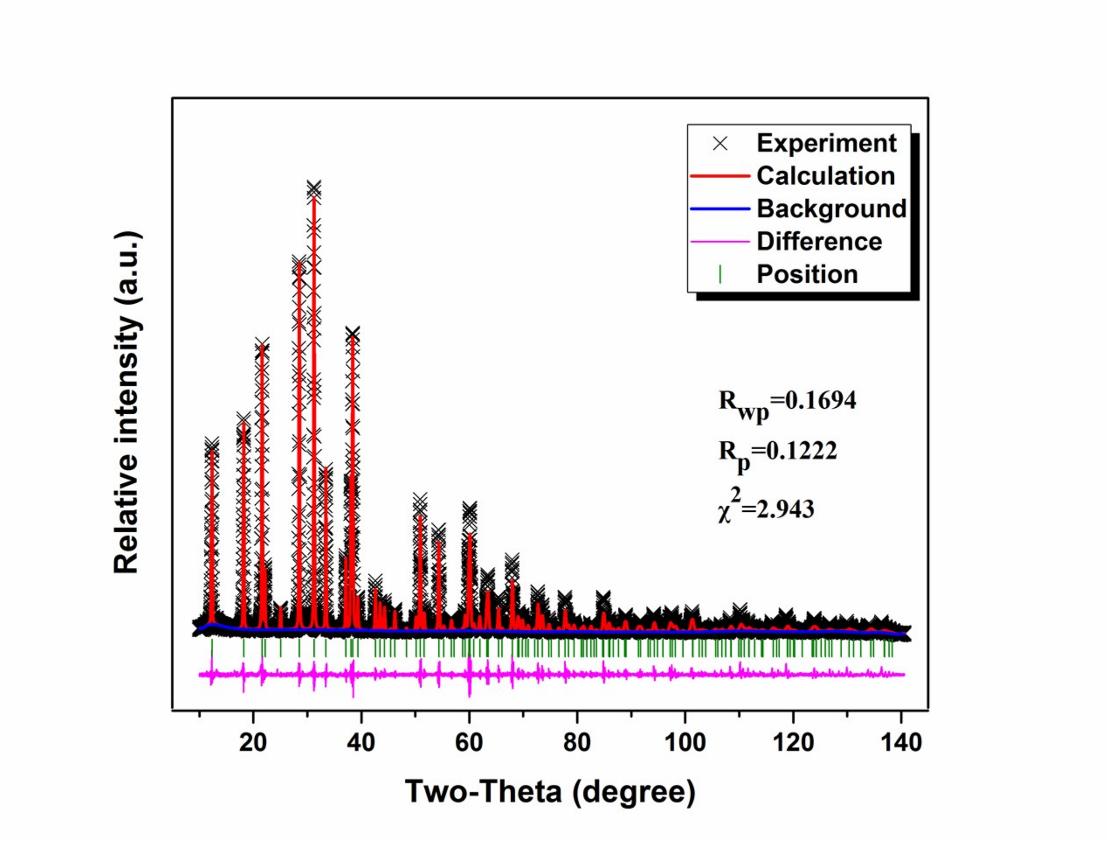


Figure S1, the Rietveld refinement of the $Na_2CaGe_6O_{14}$ host.

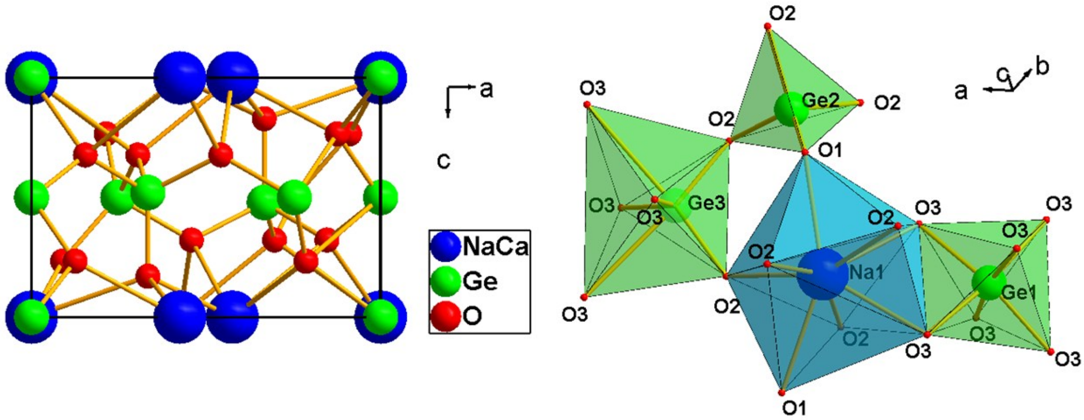


Figure S2a, the crystal structure of the $Na_2CaGe_6O_{14}$ host and the coordination environment of the $Na^+/Ca^{2+}$, and $Ge^{4+}$ sites.

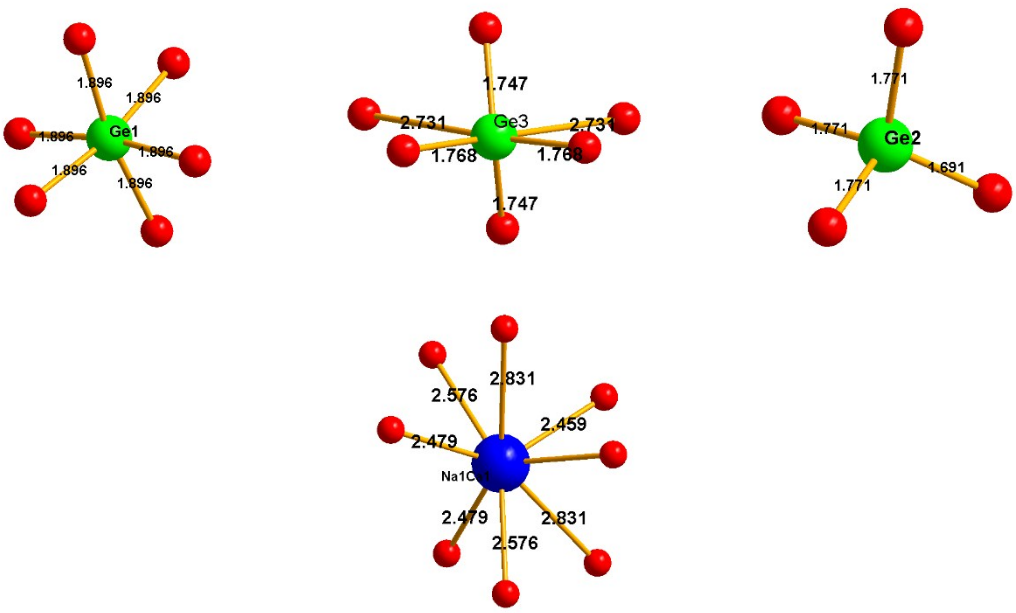


Figure S2b, the distances of the Na–O bonds, Lu–O bonds and Ge–O bonds.

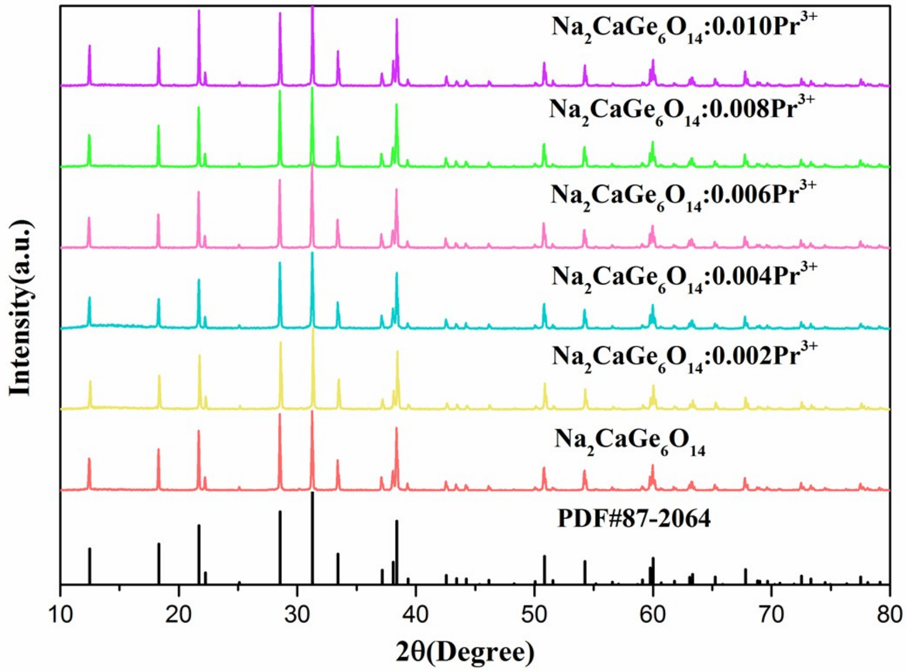


Figure S3, the XRD patterns of the $Na_2CaGe_6O_{14}$:$x$$Pr^{3+}$ samples with the different $Pr^{3+}$ doping contents.

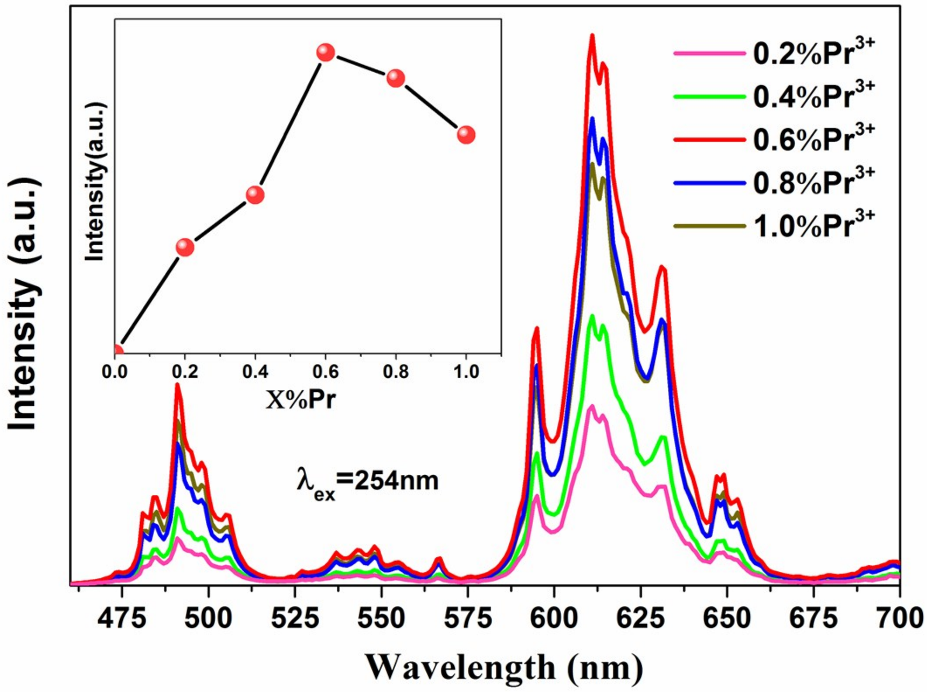


Figure S4, the PL emission spectra of the $Na_2CaGe_6O_{14}$:$x$$Pr^{3+}$ samples with the different $Pr^{3+}$ doping contents under 254 nm excitation, and the emission intensity of the samples as a function of the $Pr^{3+}$ contents (inset).

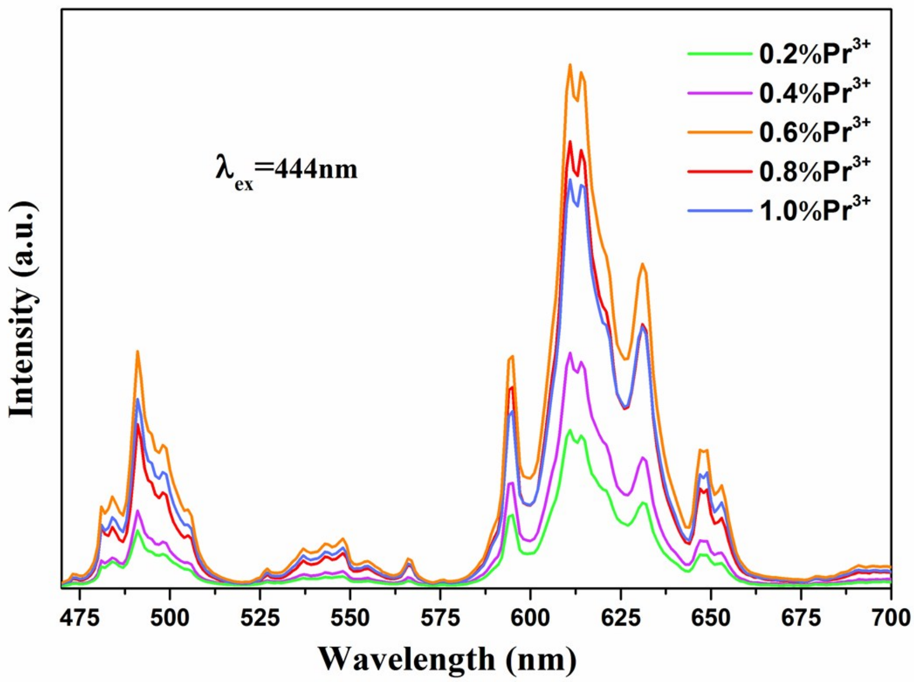


Figure S5, the PL emission spectra of the $Na_2CaGe_6O_{14}$:$x$$Pr^{3+}$ samples with the different $Pr^{3+}$ doping contents under 444 nm excitation.

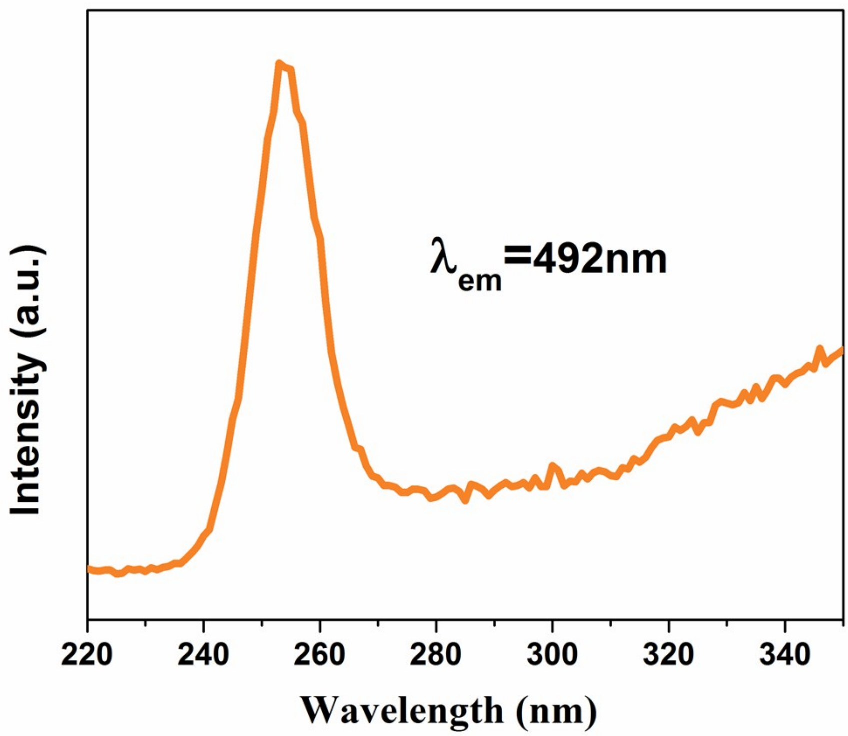


Figure S6, the PL excitation spectrum of the typical $Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample monitored at 492 nm.

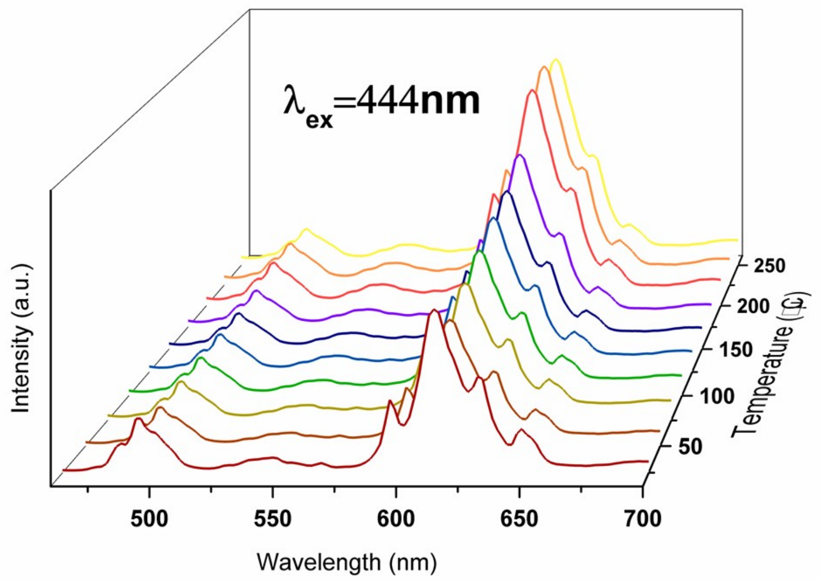


Figure S7a, the PL emission spectra excited at 444 nm of the typical $Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample at different temperature.

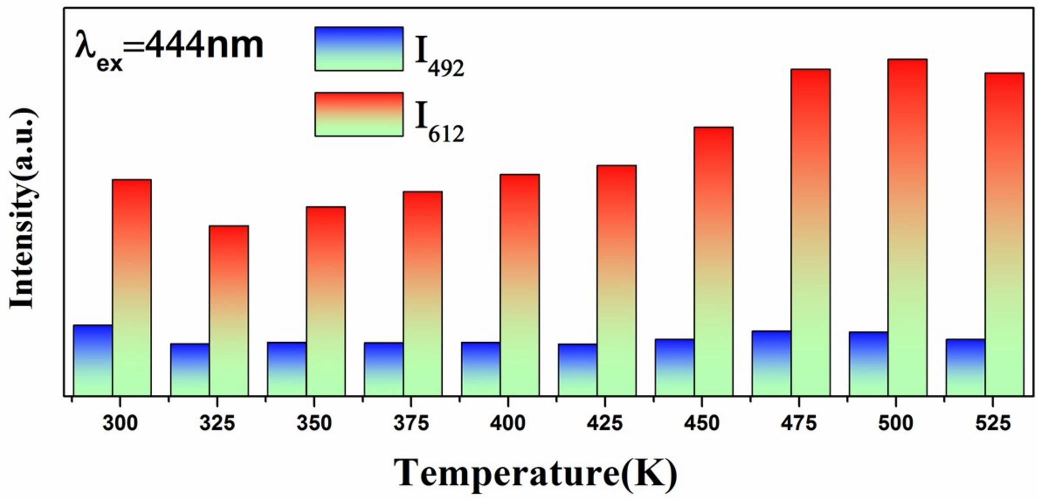


Figure S7b, the PL emission intensity excited at 444 nm of the typical

$Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample at different temperature.

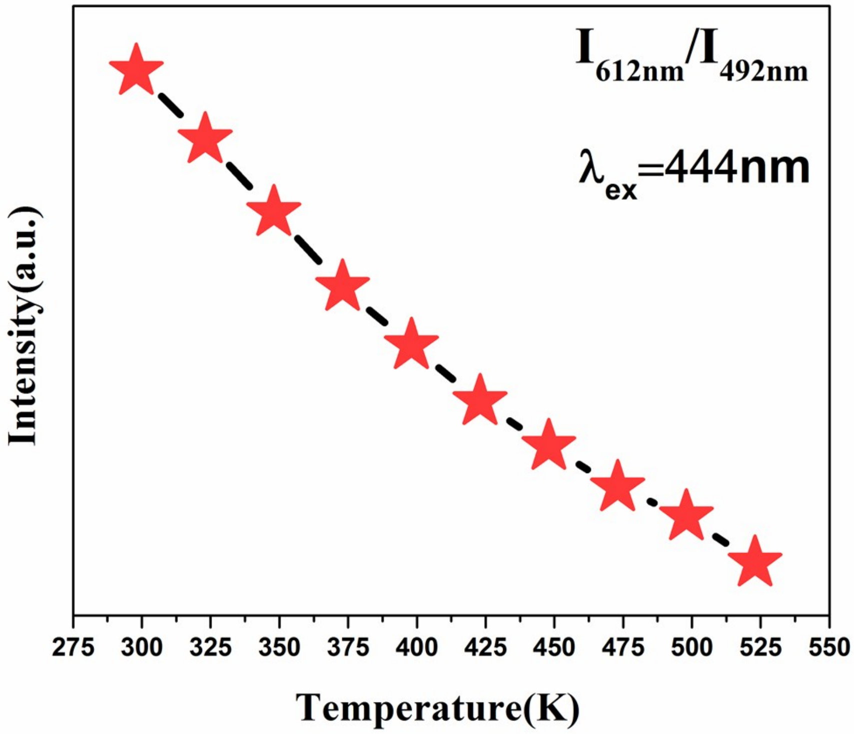


Figure S8, the emission intensity ratio ($I_{612}/I_{492}$, $\lambda_{ex}$ = 444 nm) of the typical $Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample as a function of temperature.

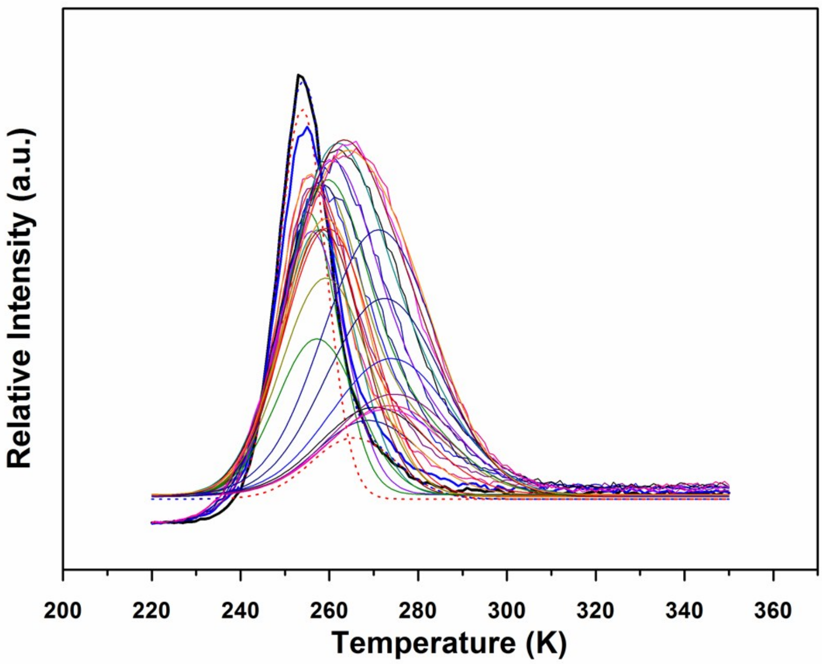


Figure S9, the excitation components at about 254 nm and 266 nm of the typical $Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample recorded at different temperatures.

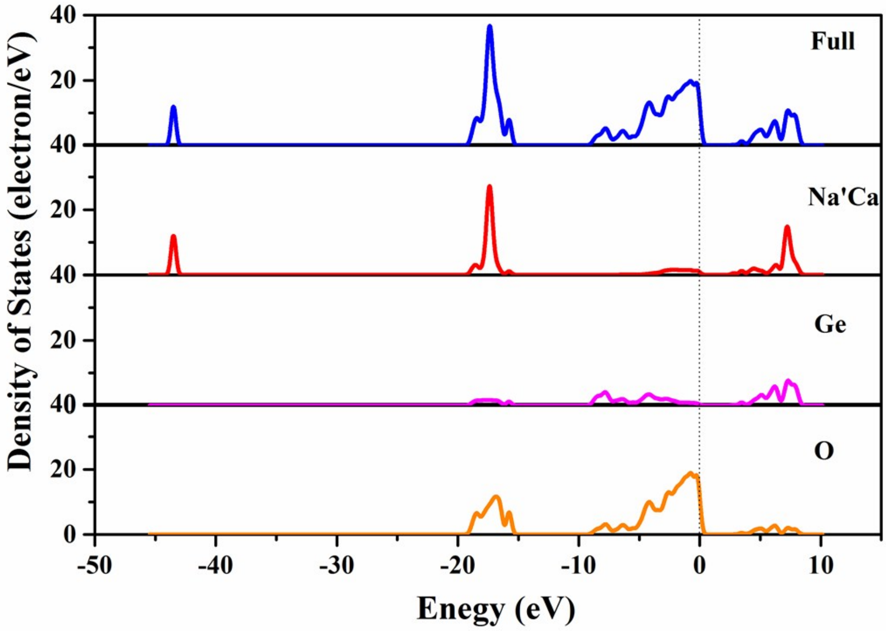


Figure S10, the partial density of the states of the typical $Na_2CaGe_6O_{14}$ sample.

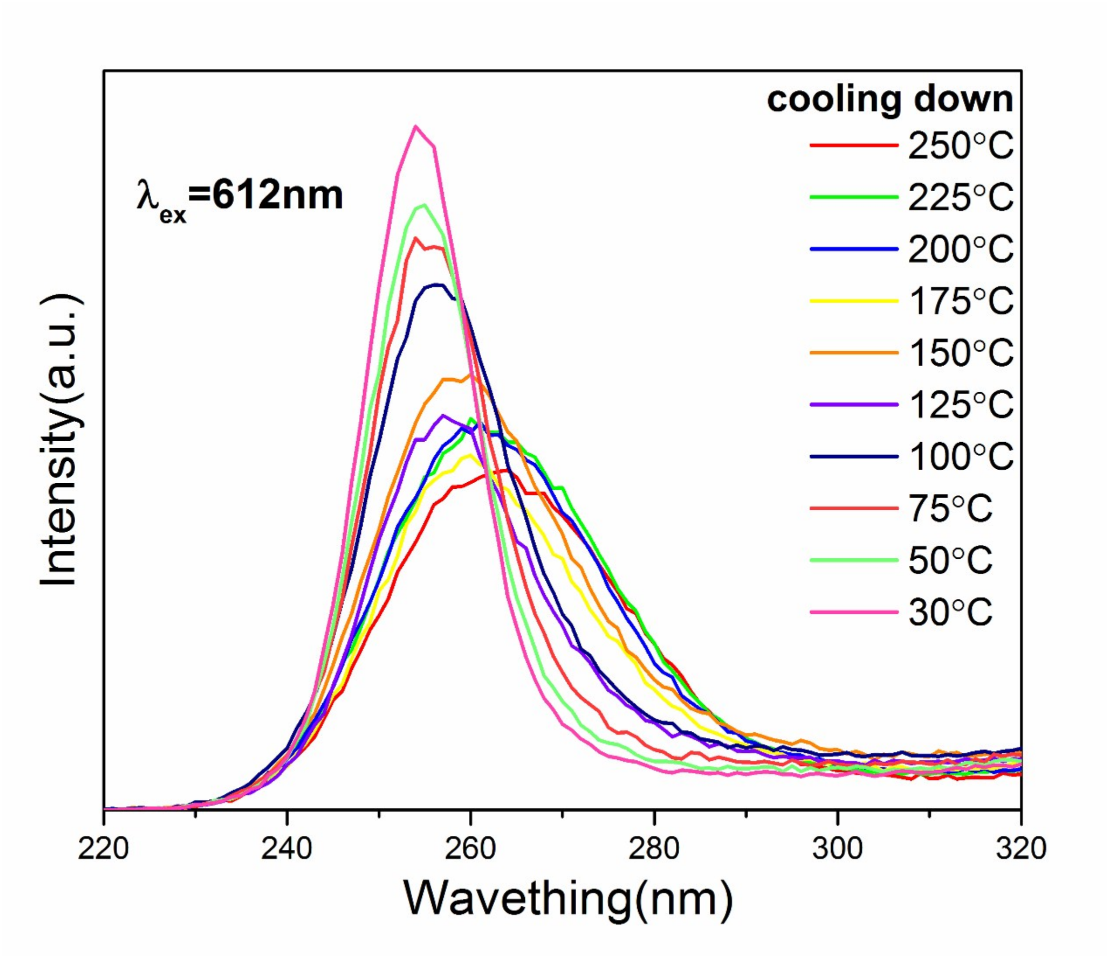


Figure S11,The temperature dependence PL excitation spectra ($\lambda_{em}$ = 612 nm) of the

$Na_2Ca_{0.994}Ge_6O_{14}$:0.6%$Pr^{3+}$ sample.

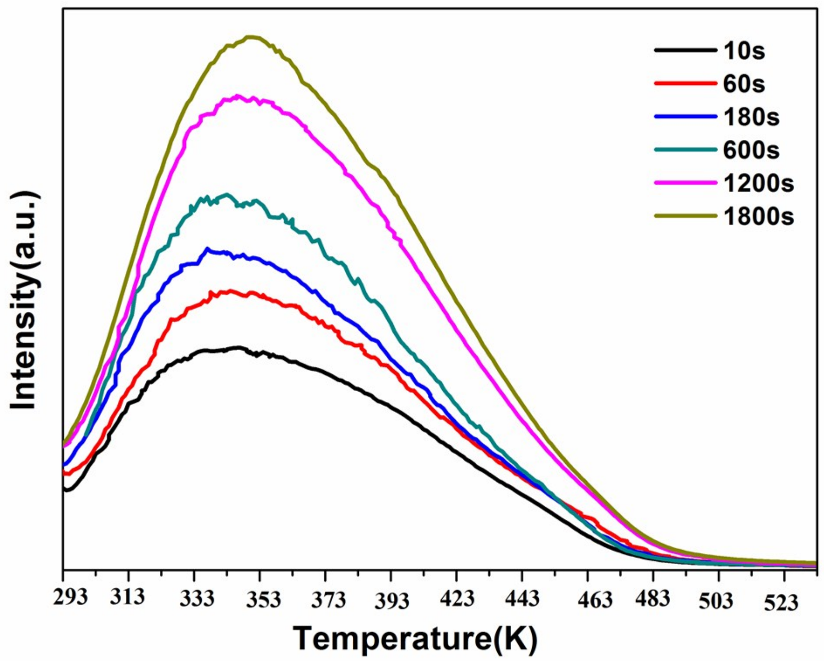


Figure S12, a serial of the TL charging experiments of the typical

$Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample.

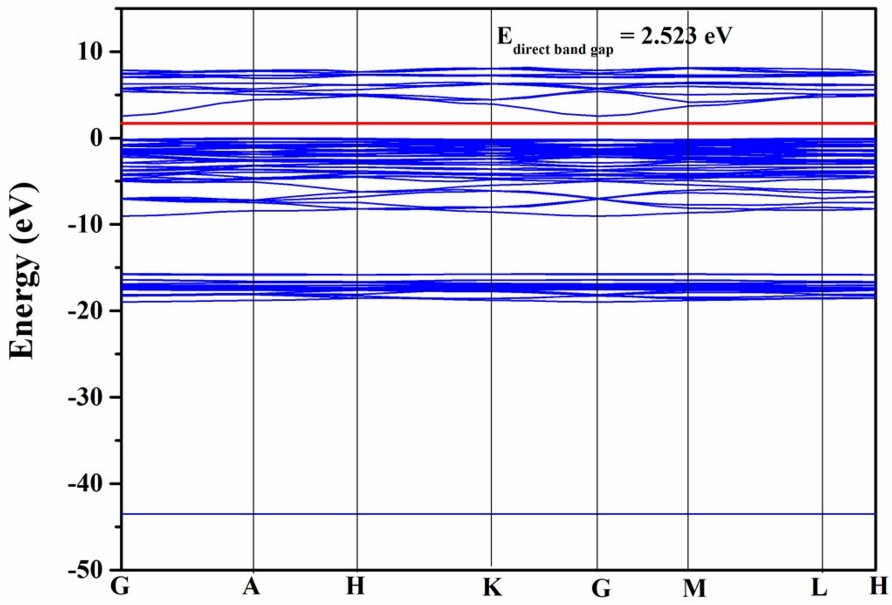


Figure S13, the optimized density functional theory (DFT) calculations on the imperfect crystal of the $Na_2CaGe_6O_{14}$ with $Na^+$ vacancy.

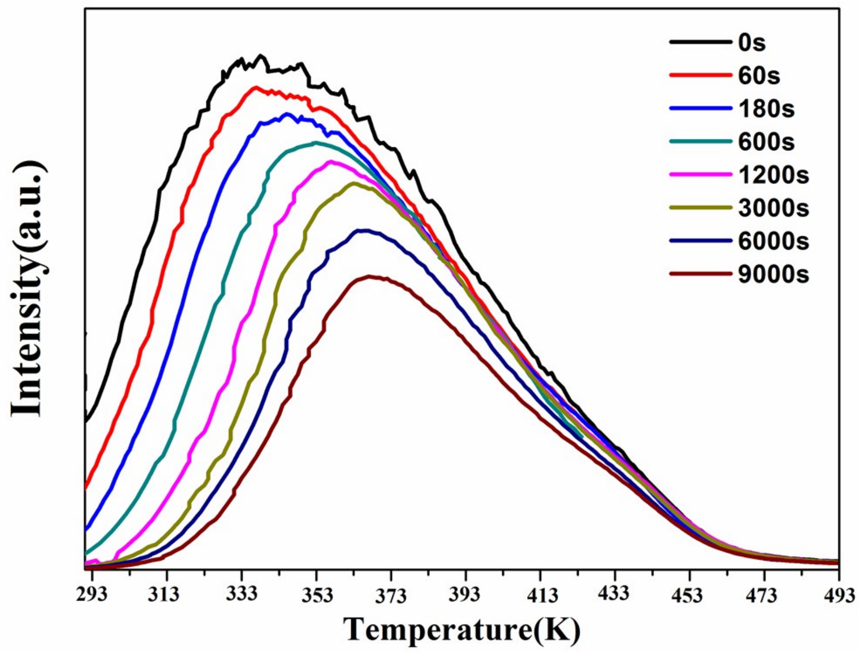


Figure S14, a serial of TL fading experiments of the typical $Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample at different delay time after stopping the irradiation.

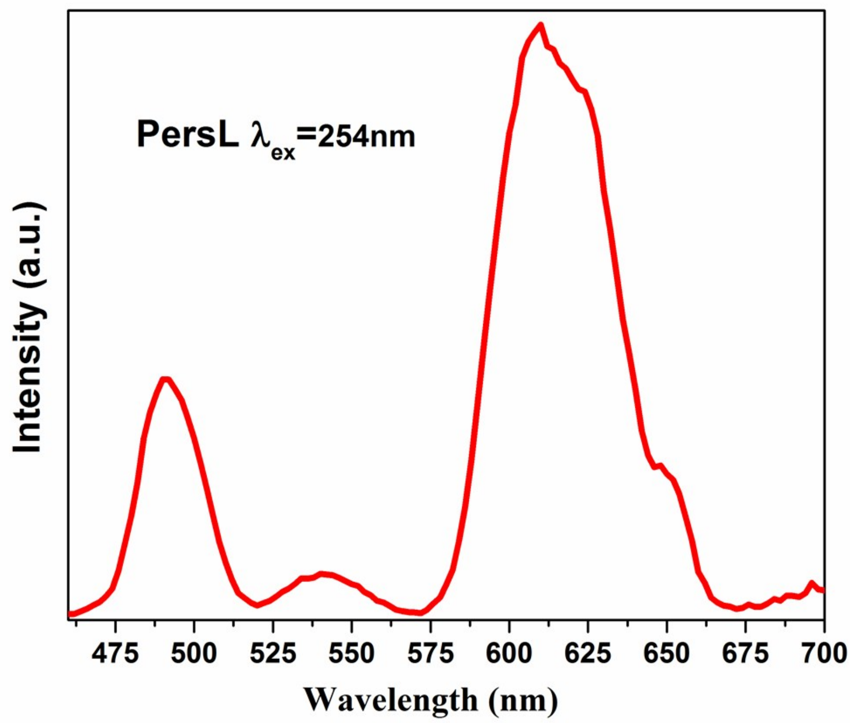


Figure S15a, the persistent luminescence spectrum of the typical $Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample recorded after 254 nm irradiation for 10 min at room temperature.

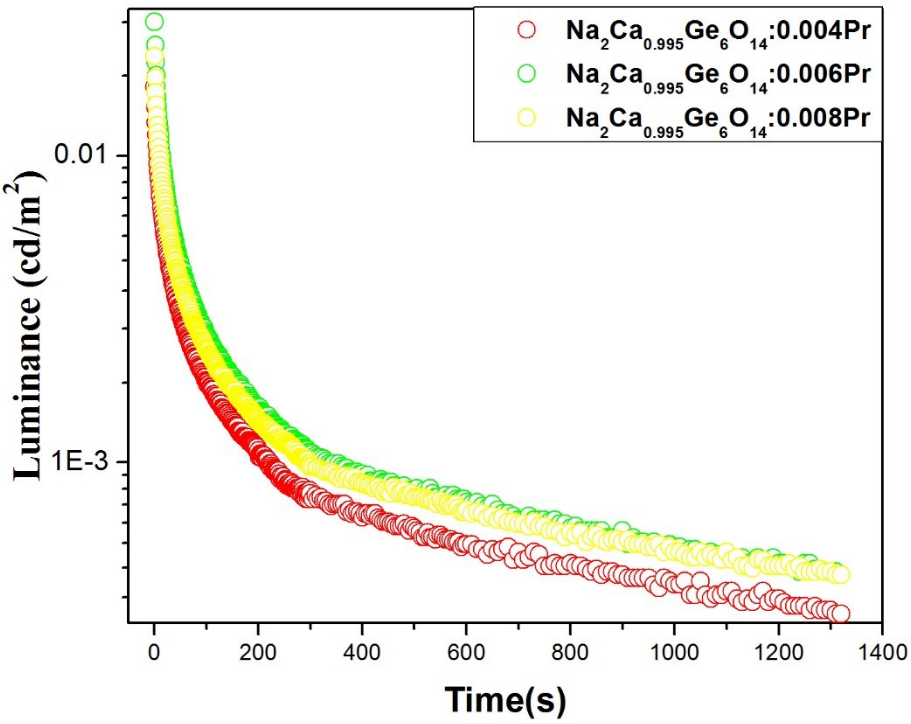


Figure S15b, the persistent luminescence decay curves of the typical $Na_2CaGe_6O_{14}$:$x$mol%$Pr^{3+}$ ($x$ = 0.4, 0.6 and 0.8) samples recorded after 254 nm irradiation for 10 min at room temperature.

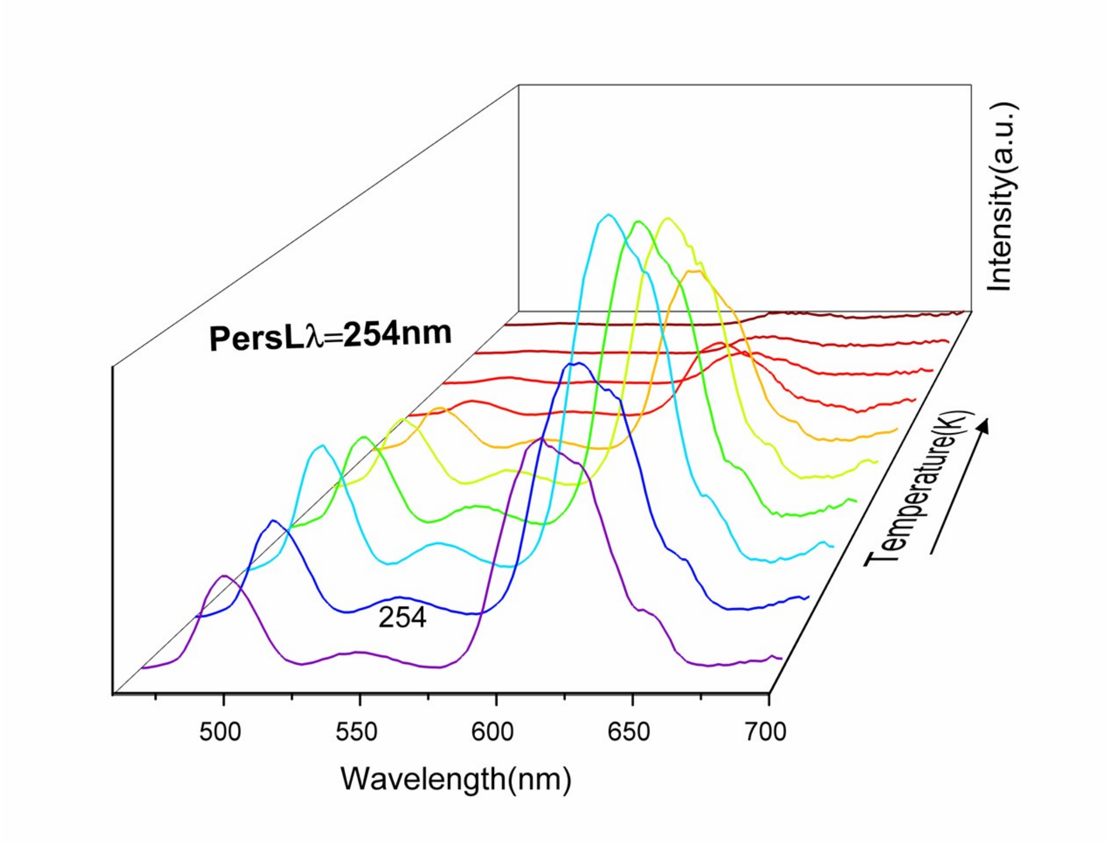


Figure S16, the persistent luminescence spectra of the typical $Na_2CaGe_6O_{14}$:0.6mol%$Pr^{3+}$ sample recorded at different temperatures after 254 nm irradiation for 10 min.

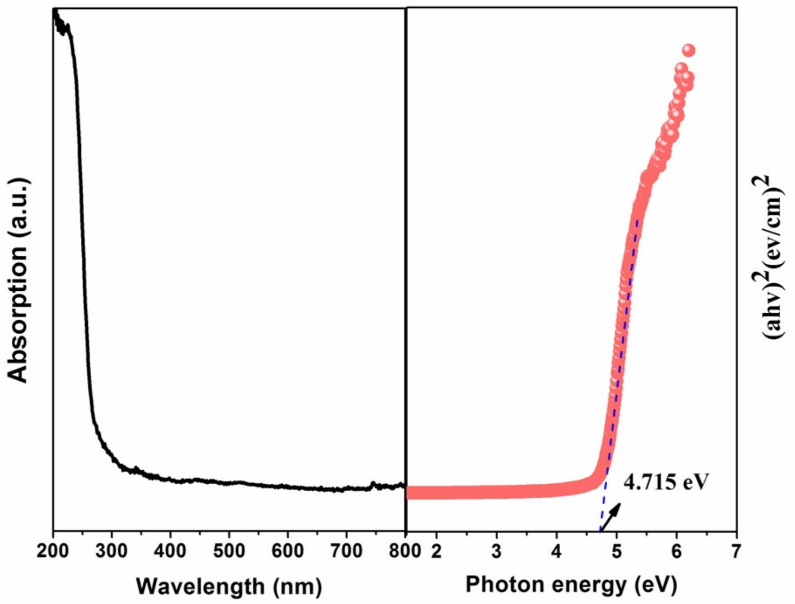


Figure S17, the diffusion reflectance spectrum of the $Na_2CaGe_6O_{14}$ host.

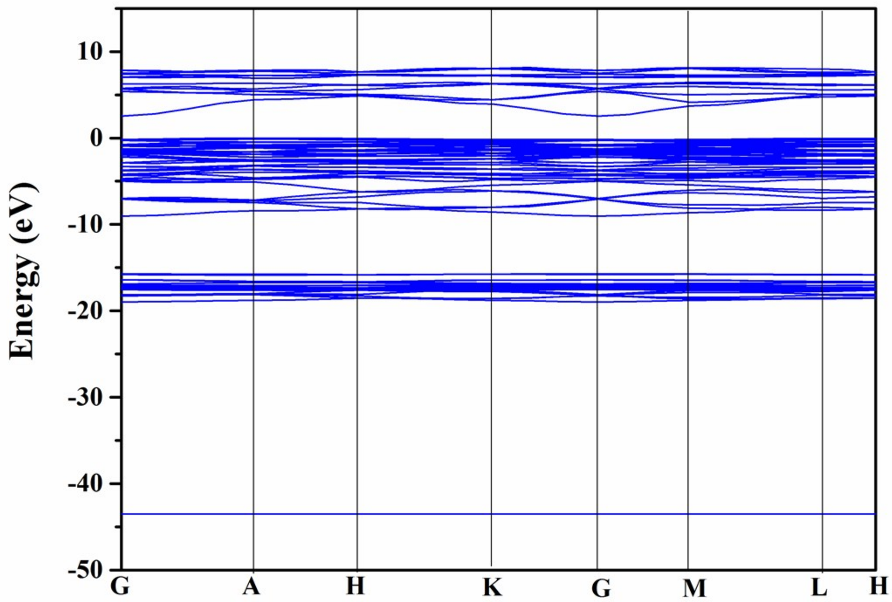


Figure S18, the density functional theory (DFT) calculations on the perfect crystal of the $Na_2CaGe_6O_{14}$ host.

Table S1, the refined crystallographic data of the $Na_2CaGe_6O_{14}$.

| | $Na_2CaGe_6O_{14}$ |
|---|---|
| Crystal system | Trigonal |
| Space group | P 321 (150) |
| Lattice parameters | |
| a(Å) | 8.18493 |
| b(Å) | 8.18493 |
| c(Å) | 4.84076 |
| α°=β° | 90 |
| r° | 120 |
| Cell volume($Å^3$ ) | 280.850 |
| T/K | 289 |
| Diffractometer | Rigaku D/Max-2400 |
| Radiation/Å | Cu-Ka (λ= 1.5405) |
| Absorption correction | multi-scan |
| 2θ range°/ | 8-140 |
| Z | 1 |
| Calculated Density | 2.6552g/$cm^3$ |
| R-factors | |
| $R_{wp}$ | 0.1694 |
| $R_p$ | 0.1222 |

Table S2, the refined coordinates of the all atoms in the $Na_2CaGe_6O_{14}$.

| **Space group** | P321 (150) - trigonal | | | | |
|---|---|---|---|---|---|
| **Cell** | a = 8.18493(0) Å; b = 8.18493(0) Å; c = 4.84076(0) | | | | |
| **Ion coordinates** | **x** | **y** | **z** | **Occupancy** | **$U_{iso}$** |
| Na1 | 0.4238(7) | 0.0000(0) | 0.0000(0) | 1.000(0) | 0.002710) |
| Ca1 | 0.4237(8) | 0.0000(0) | 0.0000(0) | 1.000(0) | 0.009050) |
| Ge1 | 0.0000(0) | 0.0000(0) | 0.0000(0) | 1.000(0) | 0.041150) |
| Ge2 | 0.33330(0) | 0.6667(0) | 0.3451(16 | 1.000(0) | 0.503250) |
| Ge3 | 0.75299(20) | 0.0000(0) | 0.5000(0) | 1.000(0) | 0.052290) |
| O1 | 0.33330(0) | 0.6667(0) | 0.5260(5) | 1.000(0) | 0.070750) |
| O2 | 0.4139(9) | 0.2741(9) | 0.7412(12 | 1.000(0) | 0.050510) |
| O3 | 0.1851(9) | 0.0313(18) | 0.4216(27 | 1.000(0) | 0.413070) |

Table S3, the bond lengths of X-O and the unit cell parameters of the $Na_2CaGe_6O_{14}$ as determined by the GSAS program.

| The bond lengths of X-O | | | |
|---|---|---|---|
| **Vector** | **Length (Å)** | **Vector** | **Length (Å)** |
| Na1-O2 | 2.606(8) | Ge1_O3 | 2.538(15) |
| Na1-O2 | 2.483(7) | Ge1-O3 | 1.722(13) |
| Na1-O2 | 2.606(8) | Ge1_O3 | 2.478(11) |
| Na1-O3 | 2.923(12) | Ge2_O1 | 0.876(8) |
| Ca1-O2 | 2.606(8) | Ge2_O2 | 1.920(7) |
| Ca1-O2 | 2.483(8) | Ge3_O2 | 1.725(6) |
| Ca1-O2 | 2.606(8) | Ge3_O3 | 1.620(15) |
| Ca1-O3 | 2.923(12) | Ge3_O3 | 2.044(10) |
| Ge1-O3 | 2.478(11) | Ge3_O3 | 1.620(15) |

Table S4, the ion radius (8 coordinations) and the electronegativity of the $Na^{2+}$, $Ca^{2+}$, $Ge^{4+}$, $Pr^{3+}$ ions in the $Na_2CaGe_6O_{14}$.

| **Ion** | ***r* / Å** | ***r* difference / %** |
|---|---|---|
| $Na^+$ | 1.18 | 4.7% |
| $Ca^{2+}$ | 1.12 | 0.5% |
| $Ge^{4+}$ | 0.53 | 52.9% |
| $Pr^{3+}$ | 1.12 | -- |

$r$ difference = $(r_{solute}-r_{solvent}) / r_{solvent} \times 100\%$

Table S5, the relative sensitivities of some recently reported optical thermometry

| Phosphors | Relative sensitivities ($K^{-1}$) | References |
|---|---|---|
| $Y_3Al_5O_{12}$:$Eu^{3+}$/$Mn^{4+}$ | 0.441 | [1] |
| $Y_2O_3$:$Eu^{3+}$,$Nd^{3+}$ | 0.1 | [2] |
| $Zn_2SiO_4$:$Mn^{2+}$/$Gd_2O_3$:$Eu^{3+}$ | 0.07 | [3] |
| $Na_2La_2Ti_3O_{10}$:$Pr^{3+}$ | 0.4 | [4] |
| MgLa2TiO6:$Pr^{3+}$ | 0.054 | [4] |
| YNbO4:$Pr^{3+}$ | 0.105 | [4] |
| CaZnOS:$Er^{3+}$ | 0.0033 | [5] |


[1] D. Q. Chen, S. Liu, Y. Zhou, Z. Y. Wan, P. Huang, Z. G. Jia, *J. Mater. Chem. C*, 2016,4, 9044-9051.

[2] S. S. Zhou, X. T. Wei, X. Y. Li, Y. H. Chen, C. K. Duan, M. Yin, *Sens. Actuators B*, 2017, 246, 352-357.

[3] F. Huang, D. Q. Chen, *J. Mater. Chem. C*, 2017,5, 5176-5182

[4] Y. Gao, F. Huang, H. Lin, J. Xu, Y. S. Wang, *Sens. Actuators B*, 2017, 243, 137-143.

[5] H. L. Zhang, D. F. Peng, W. Wang, L. Dong, C. F. Pan, J. Phys. Chem. C, 2015, 119, 28136-28142.