

Supporting Information

Temperature invariant lifetime based luminescent manometer on Mn⁴⁺ ions

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KEYWORDS luminescent manometer, pressure sensor, Mn⁴⁺, average lifetime, luminescence
intensity ratio, optical manometry

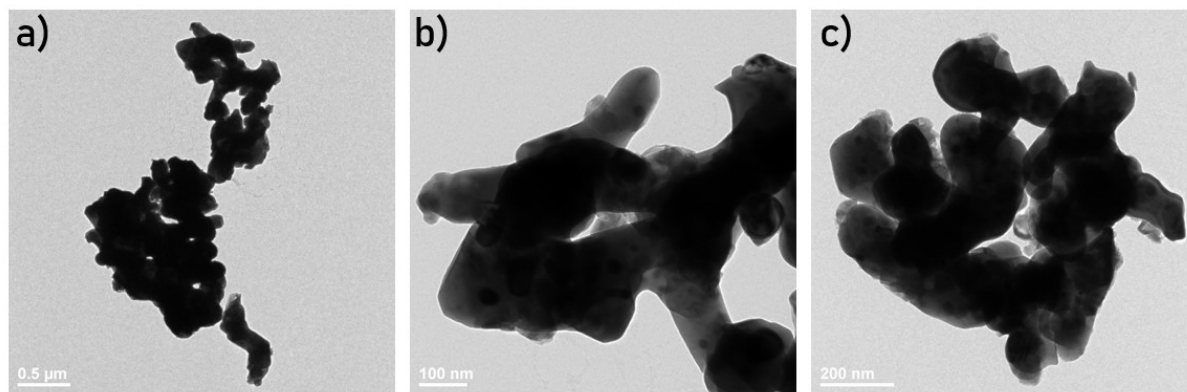


Figure S1. The representative TEM images of SrGdAlO₄: 0.2% Mn⁴⁺

Table S1. Estimated energies (peak centroids) of the main Raman modes at low pressure, and the corresponding pressure shift rates of the corresponding bands for the SrGdAlO₄ material.

Peak centroid at ambient pressure (cm ⁻¹)	Shift rate (cm ⁻¹ /GPa)
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≈ 230	3.58 ± 0.25
≈ 370	3.71 ± 0.09
≈ 440	3.69 ± 0.37
≈ 575	3.67 ± 0.31
≈ 740	4.51 ± 0.17

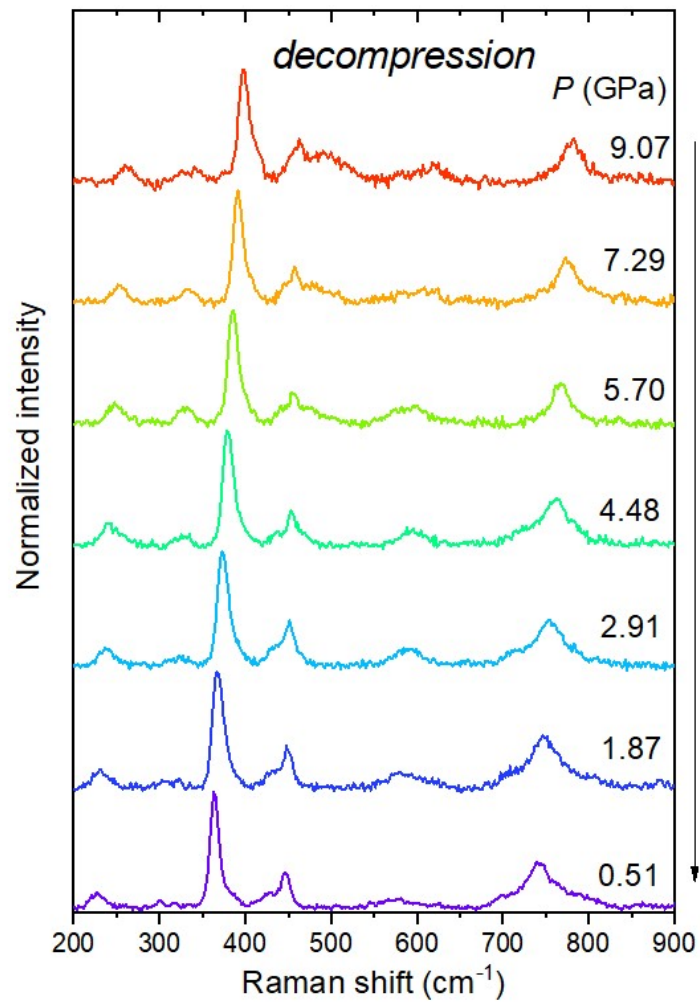


Figure S2. Normalized Raman spectra for the SrGdAlO₄ material measured for different pressure values, during the decompression cycle.

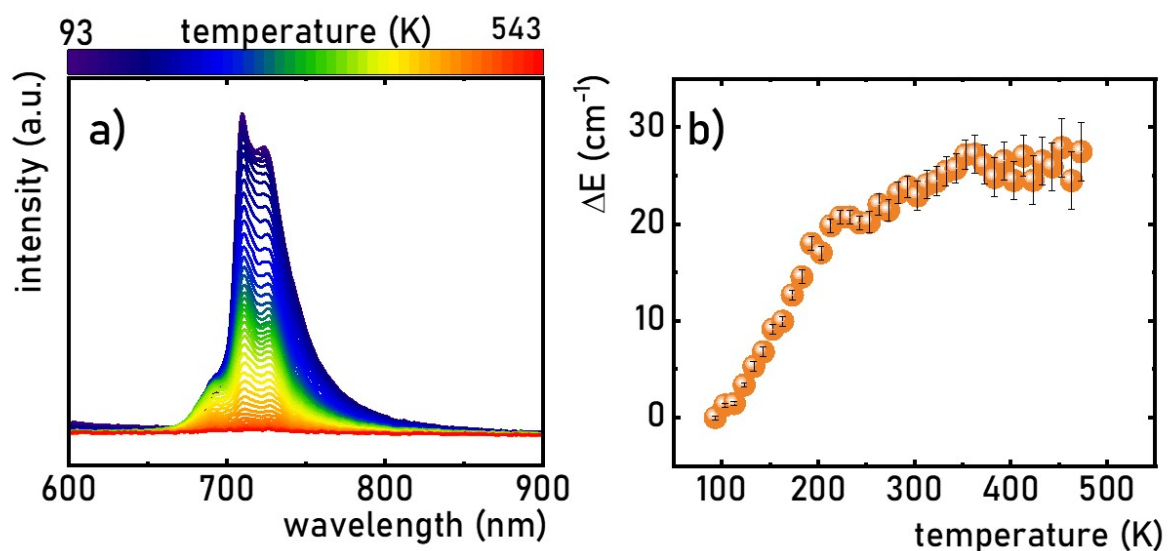


Figure S3. Emission spectra of SrGdAlO₄:0.2%Mn⁴⁺ measured as a function of temperature -a); change of the energy of the emission band maxima as a function of temperature-b).

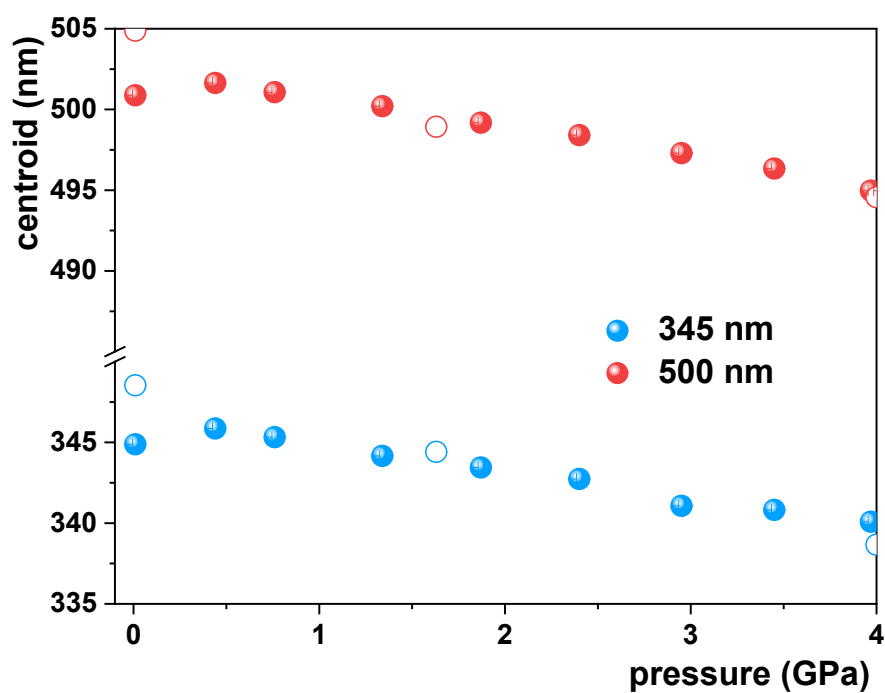


Figure S4. The change of the excitation band centroid of Mn⁴⁺ ion in SrGdAlO₄:0.2%Mn⁴⁺ as a function of pressure during the compression (full points) and decompression (open points).

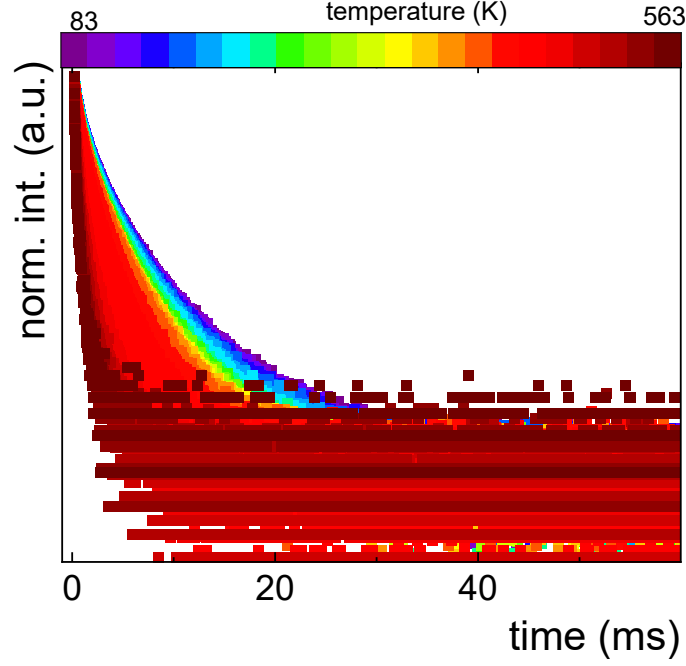


Figure S5. The luminescence decay profile of the Mn⁴⁺ ion emission for the SrGdAlO₄:0.2%Mn⁴⁺ measured as a function of temperature.

The crystal field parameter Dq and Racah parameters for Mn⁴⁺ of 3d³ electron configuration were defined based on experimental excitation and emission spectra data. For this purpose, the energies of ${}^4A_2 \rightarrow {}^4T_1$ and ${}^4A_2 \rightarrow {}^4T_2$ bands obtained from excitation spectra and zero phonon line (R-line) of ${}^2E \rightarrow {}^4A_2$ band from emission spectra. The empirical equations take the following form:

$$E({}^4A_2 \rightarrow {}^4T_2) = 10Dq \quad (\text{Eq. S1})$$

$$\frac{Dq}{B} = \frac{15\left(\frac{\Delta E}{Dq} - 8\right)}{\left(\frac{\Delta E}{Dq}\right)^2 - 10 \cdot \frac{\Delta E}{Dq}} \quad (\text{Eq. S2})$$

$$\frac{E({}^2E \rightarrow {}^4A_2)}{B} = \frac{3.05 \cdot C}{B} + 7.90 - \frac{1.80 \cdot B}{Dq} \quad (\text{Eq. S3})$$

where ΔE was predefined as:

$$\Delta E = E({}^4A_2 \rightarrow {}^4T_1) - E({}^4A_2 \rightarrow {}^4T_2) \quad (\text{Eq. S4})$$

The average lifetime of the excited states were calculated with the equation Eq. S5:

$$\tau_{avr} = \frac{A_1\tau_1^2 + A_2\tau_2^2}{A_1\tau_1 + A_2\tau_2} \quad (\text{Eq. S5})$$

where: τ_1, τ_2 are the decay parameters and A_1, A_2 are amplitudes of the bi-exponential function:

$$I(t) = I_0 + A_1 \cdot \exp\left(-\frac{t}{\tau_1}\right) + A_2 \cdot \exp\left(-\frac{t}{\tau_2}\right) \quad (\text{Eq. S6})$$

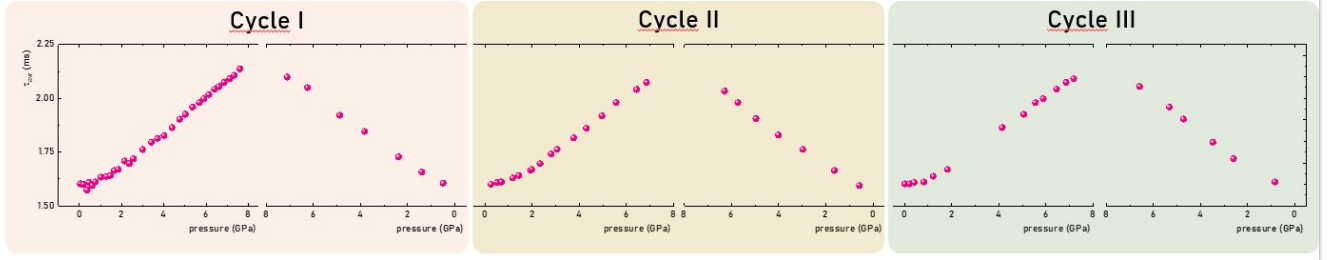


Figure S6. The room temperature τ_{avr} of $\text{SrGdAlO}_4:0.2\%\text{Mn}^{4+}$ measured within three compression and decompression cycles

The pressure determination uncertainty of the lifetime-based luminescence manometer was determined as follows:

$$\delta p = \frac{1}{S_{R,P}} \frac{\delta \tau_{avr}}{\tau_{avr}} \quad (\text{Eq. S7})$$

where $\delta \tau_{avr}/\tau_{avr}$ is the uncertainty in the determination of τ_{avr} (determined as a standard deviation in 30 measurements of τ_{avr}).

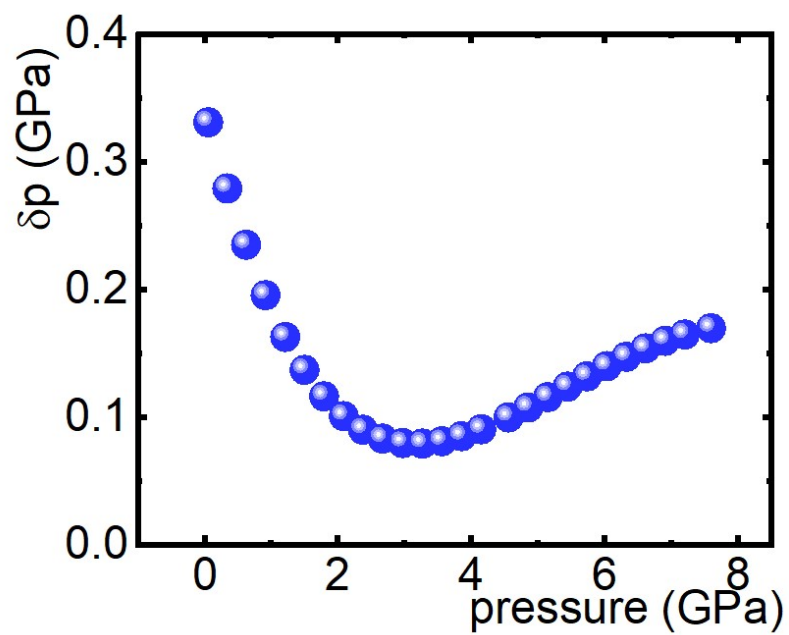


Figure S7. The pressure determination uncertainty as a function of applied pressure for the lifetime based luminescent manometer in $\text{SrGdAlO}_4:0.2\%\text{Mn}^{4+}$.