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Luminescence efficiency of a Gadolinium Aluminium Gallium Garnet (GAGG:Ce) single crystal scintillator: Temperature dependence

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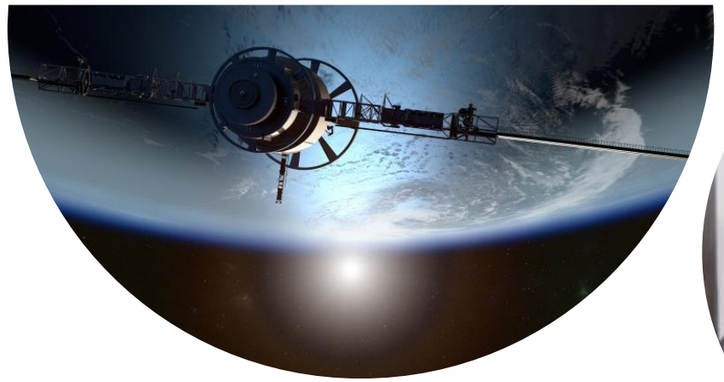
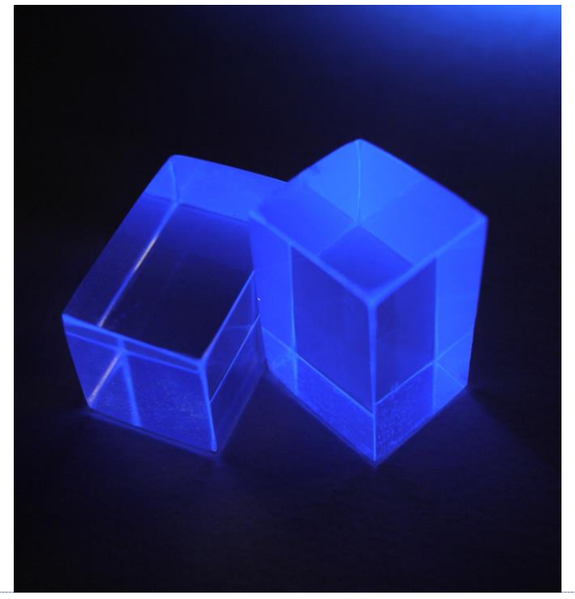
1. Background-Aim



- Applications of scintillators in harsh environments (i.e. high temperatures or radiation fluxes), such as radiation chemistry, nuclear reactor monitoring, non-destructive testing (NDT), in geophysical detectors for deep geology boreholes, of pipelines in oil and gas industry, space and marine exploration, etc. show increasing interest.

- In this framework, the aim of this study was to examine the influence of temperature on the luminescence efficiency of a Gadolinium Aluminium Gallium Garnet ($Gd_3Al_2Ga_3O_{12}$-GAGG:Ce) single crystal scintillator.

- The crystal output was compared with various crystal scintillators of equal dimensions, in similar experimental conditions.



2. Materials & Methods

- For the experiments, a CPI series CMP 200 DR medical X-ray source was set to fixed high voltage (90kVp), to expose the sample with X-ray radiation, under different temperature conditions (23-150 ^{o}C).

- 20 mm Al was added in addition to the inner filter of the X-ray tube, to simulate attenuation from a human chest.

- The GAGG:Ce crystal under investigation has fast decay (<50ns) and light yield (45000 photons/MeV).

- The crystal sample was heated using a Perel 3700-9 2000W heating gun.

- The temperature on the crystal surface was monitored using an Agilent Technologies U1253A digital multimeter, coupled to a U1185A thermocouple (J-Type) with temperature probe adapter.

3. Materials & Methods

- The efficiency of a scintillator to emit light, after X-ray exposure, can be experimentally determined under clinical conditions by the absolute luminescence efficiency (AE), defined in terms of emitted light energy flux (Ψ_λ) per unit of incident exposure rate, i.e. (Michail et al., 2019):

$$\eta_{\mathrm{A}} = \dot{\Psi}_{\lambda} / \dot{X}$$

- Where X is the exposure rate measured with a Piranha P100B (RTI) dosimeter.
- AE is expressed in efficiency units (E.U.)

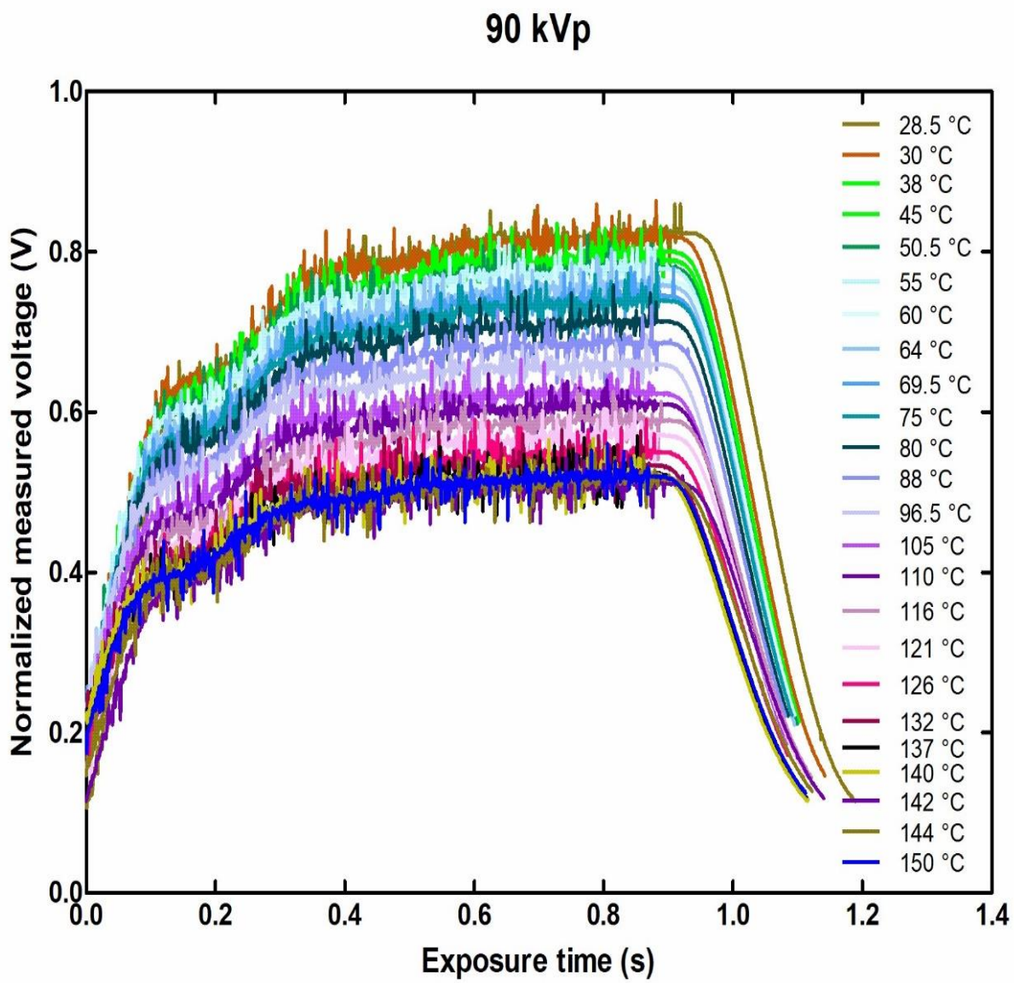
4. Results

- Figure shows the variation of the produced voltages, from the examined GAGG-45 crystal, after the reading of the PMT signal.

- The threshold voltage of the electrometer was set up to 1Vpp. with exposure time and temperature.

- All curves are within the examined temperature range (23-150 ^{o}C).

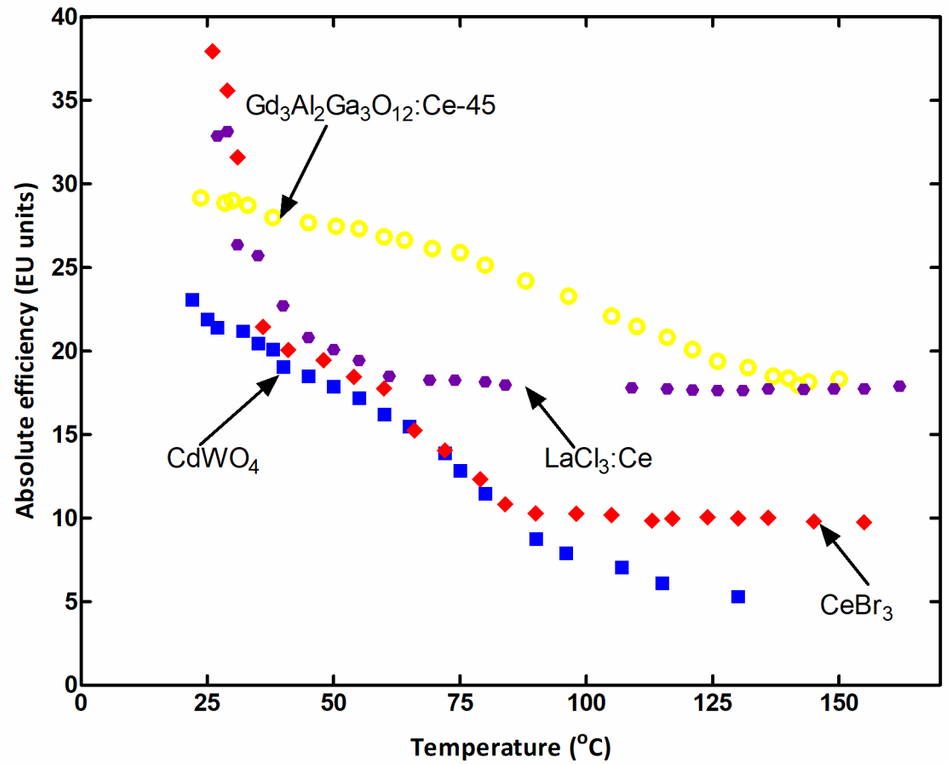
- The pulses produced during the irradiation show initially a sharp increase, followed by a plateau and finally a sharp decrease of the signal.



5. Results

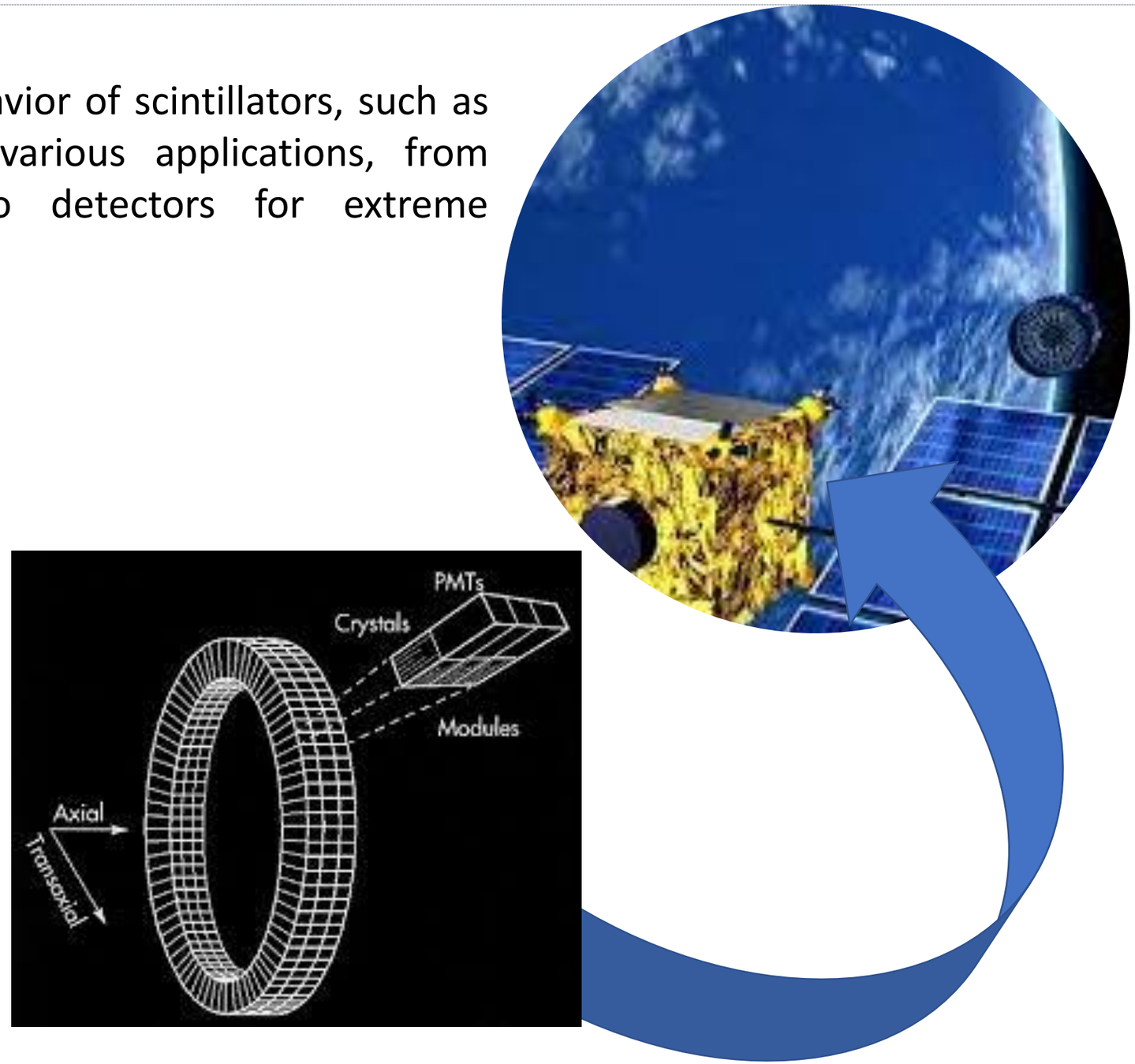
- The luminescence efficiency (LE) of $Gd_3Al_2Ga_3O_{12}$:Ce decreases constantly with increasing temperature, namely between 29.16 EU at 23.7°C to 18.30 EU at 150°C.

- (EU is the S.I. equivalent $\mu Wm^{-2}/(mGy/s)$. GAGG:Ce showed comparable or even better performance compared to the majority of previously examined crystals in our laboratory.



6. Conclusions

- Data on the thermal behavior of scintillators, such as GAGG:Ce is useful for various applications, from medical imaging up to detectors for extreme environments.



7. References

Advatech UK, 2024. GAGG(Ce) - Scintillator Crystal | Advatech UK [WWW Document]. URL https://www.advatech-uk.co.uk/gagg_ce.html (accessed 7.17.24).

Advatech UK, 2022. Advatech UK - $CeBr_3$ [WWW Document]. URL https://www.advatech-uk.co.uk/cebr3.html (accessed 3.4.22).

Bisong, M.S., Mikhailov, V.E., Lepov, V.V., Makharova, S.N., 2019. Microstructure influence on crack resistance of steels welded structures operated in an extremely cold environment. Procedia Structural Integrity, 1st International Conference on Integrity and Lifetime in Extreme Environment (ILEE-2019) 20, 37–41. https://doi.org/10.1016/j.prostr.2019.12.112

Loyd, M., Stand, L., Rutstrom, D., Wu, Y., Glodo, J., Shah, K., Koschan, M., Melcher, C.L., Zhuravleva, M., 2020. Investigation of $CeBr_{3-x}I_x$ scintillators. J. Cryst. Growth 531, 125365. https://doi.org/10.1016/j.jcrysgro.2019.125365

Melcher, C.L., Schweitzer, J.S., Manente, R.A., Peterson, C.A., 1991. Applications of single crystals in oil well logging. J. Cryst. Growth 109, 37–42. https://doi.org/10.1016/0022-0248(91)90155-X

Michail, C.M., Kalyvas, N., Bakas, A., Ninos, K., Sianoudis, I., Fountos, G., Kandarakis, I., Panayiotakis, G., Valais, I., 2019. Absolute Luminescence Efficiency of Europium-Doped Calcium Fluoride (CaF_2:Eu) Single Crystals under X-ray Excitation. Crystals 9, 234. https://doi.org/10.3390/cryst9050234

Seitz, B., Campos Rivera, N., Stewart, A.G., 2016. Energy Resolution and Temperature Dependence of Ce:GAGG Coupled to 3 mm x 3 mm Silicon Photomultipliers. IEEE Transactions on Nuclear Science 63, 503–508. https://doi.org/10.1109/TNS.2016.2535235

Xiang, R., Liang, X., Li, P., Di, X., Xiang, W., 2016. A thermally stable warm WLED obtained by screen-printing a red phosphor layer on the LuAG:Ce^{3+} PiG substrate. Chem. Eng. J. 306, 858–865. https://doi.org/10.1016/j.cej.2016.08.008

Yoneyama, M., Kataoka, J., Arimoto, M., Masuda, T., Yoshino, M., Kamada, K., Yoshikawa, A., Sato, H., Usuki, Y., 2018. Evaluation of GAGG:Ce scintillators for future space applications. J. Inst. 13, P02023. https://doi.org/10.1088/1748-0221/13/02/P02023