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Scintillation and Radiation Damage Performance of Yttrium Doped BaF_2 Crystals

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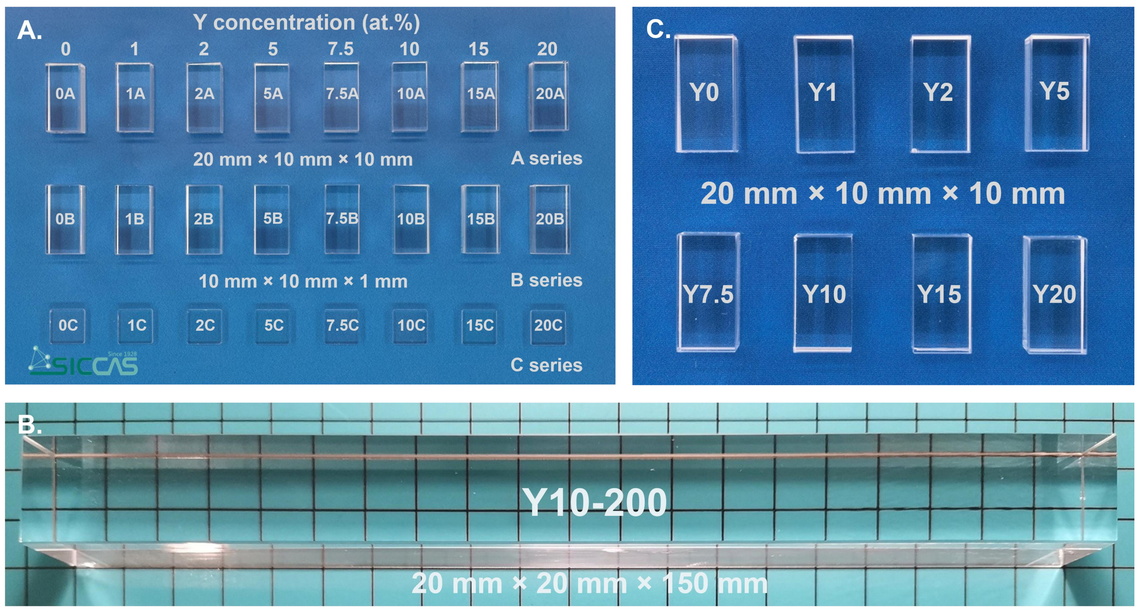
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Introduction

■ **Barium fluoride (BaF_2) is a classic ultrafast scintillator with a sub-nanosecond fast component. Following our group's demonstration that yttrium (Y) doping effectively suppresses its intrinsic slow component [1-2], systematic investigations of the concentration-dependent scintillation performance and radiation tolerance are needed to guide its application in high-energy physics detectors.**

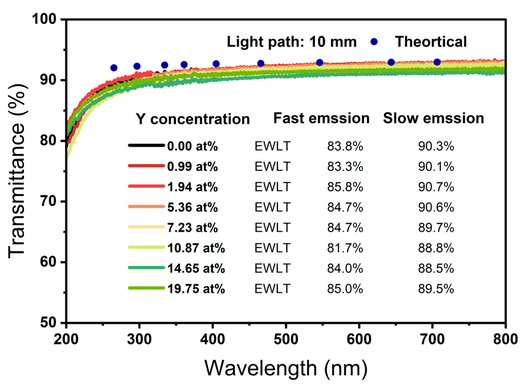
Material Characterization

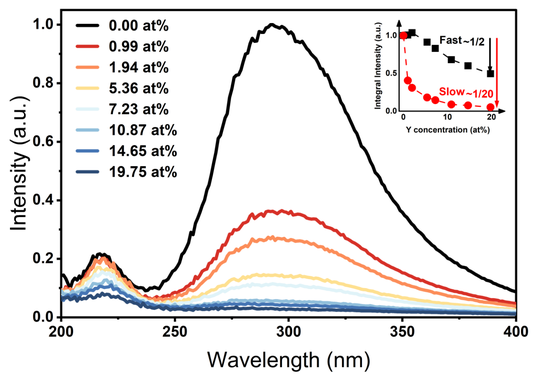


➢ **BaF_2 crystals with nominal Y concentrations of 0–20 at.% were systematically characterized in terms of optical transmittance, radioluminescence, light output (LO), fast-to-slow component ratio (F/S), energy resolution, and decay kinetics. Radiation damage was assessed after γ-ray irradiation at cumulative doses of 10 krad–10 Mrad. A 200-mm-long BaF_2:Y crystal with a nominal Y concentration of 10 at.%, obtained via vertical Bridgman growth, was also characterized to evaluate its optical and scintillation properties and light-response uniformity (LRU).**

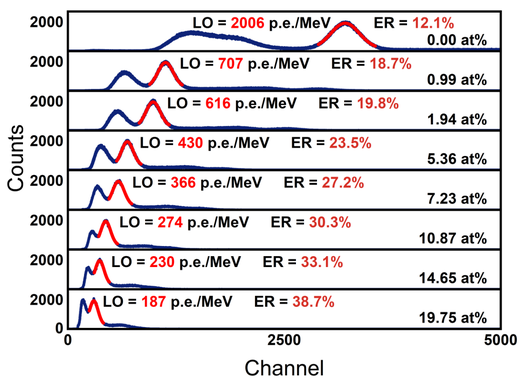
A. Scintillation Performance of BaF_2: Y crystal

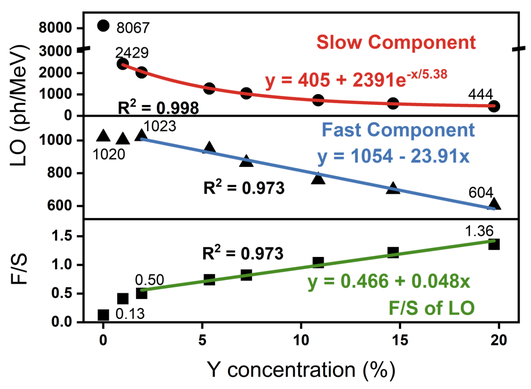
■ **Transmittance and Radioluminescence**



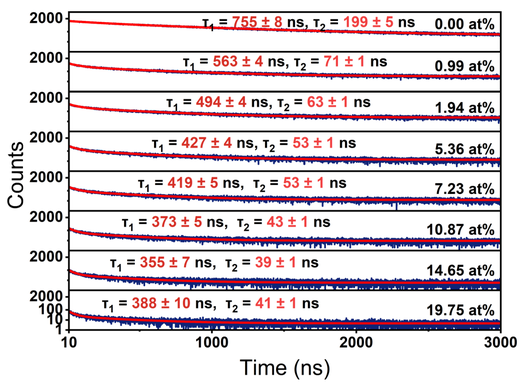


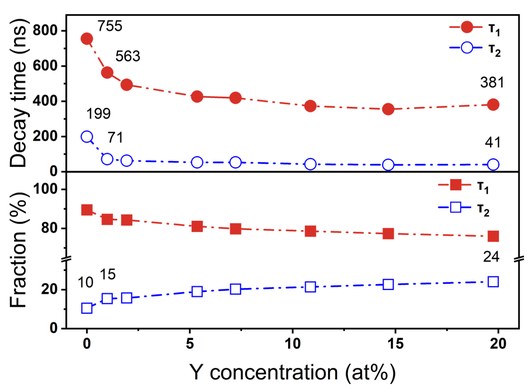
■ **Light Output (LO) and F/S of LO**





■ **Slow Components' Decay Times and relative Fractions**





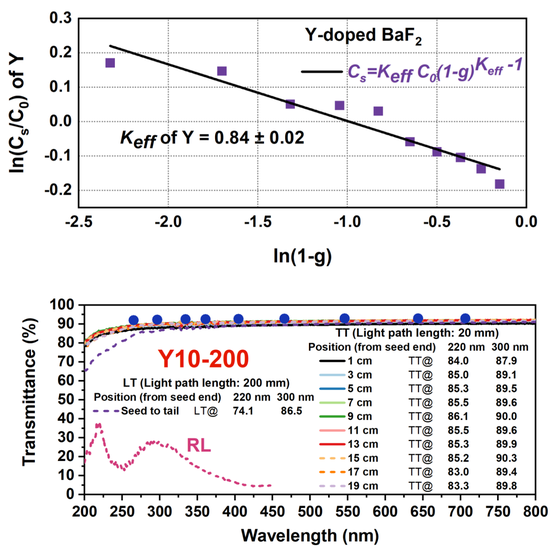
➢ The transmittance of samples showing that Y doping has no significant effect on the optical performances of BaF_2 crystal. Both the slow and fast component intensities evolve in two distinct stages.

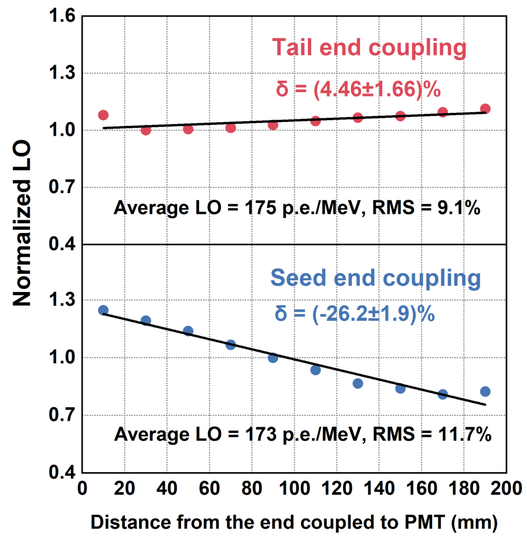
➢ At 20 at.% Y, the fast- and slow-component LOs decreased to 60% and 6% of those of undoped BaF_2, respectively, increasing the F/S ratio from 0.13 to 1.36, while the energy resolution at 511 keV deteriorated from 12.1% to 38.7%.

➢ The two decay times of the slow component shortened from 755 to 381 ns and from 199 to 41 ns with increasing Y concentration.

B. 200-mm-long BaF_2: Y crystal

■ **Segregation, Transmittance and Light Response Uniformity (LRU)**

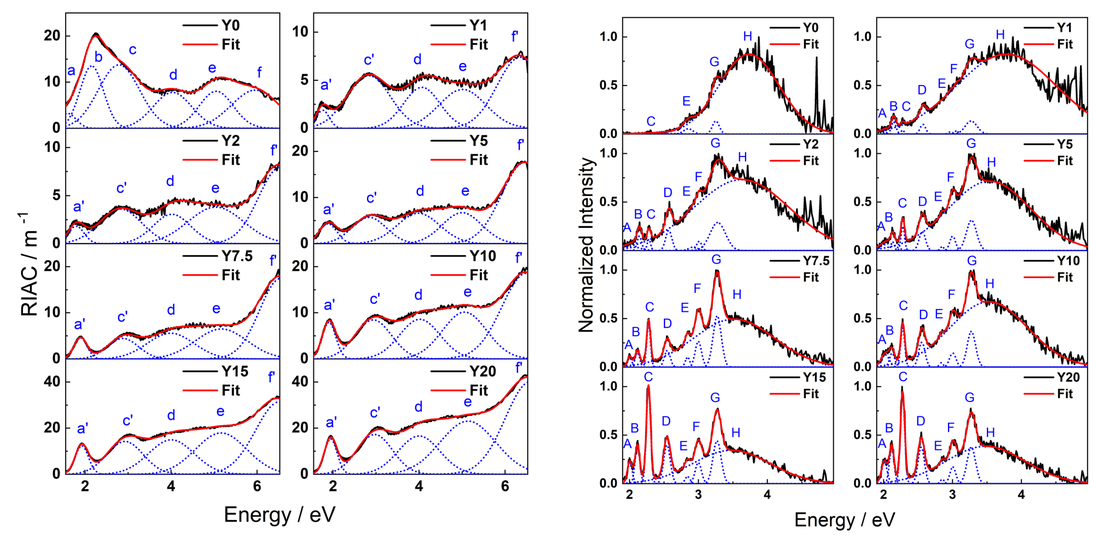




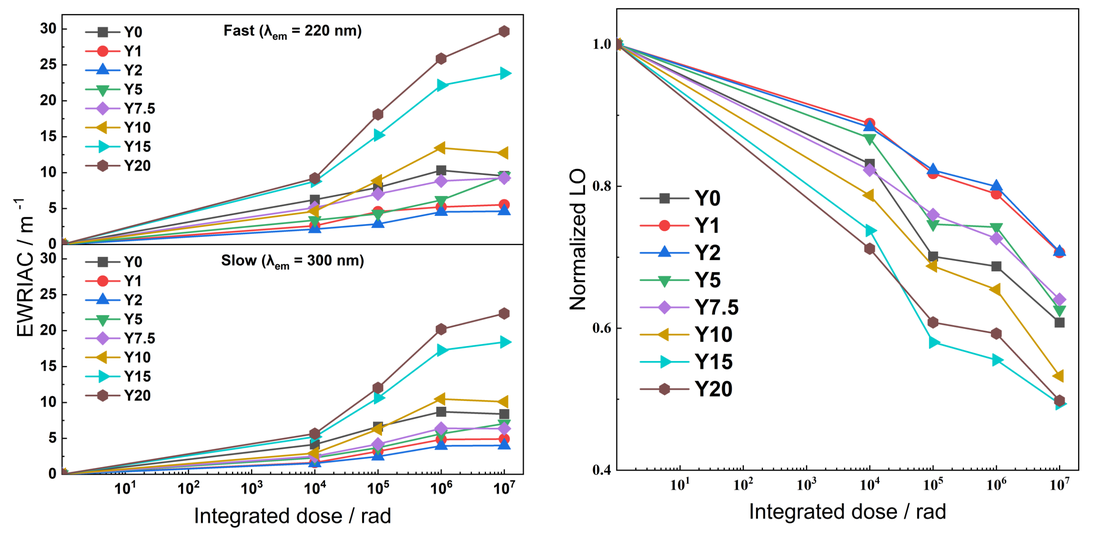
➢ For the 200-mm-long, 10 at.% Y-doped crystal, the effective Y segregation coefficient was 0.84. The crystal exhibited good optical transmittance and LRU, with its slow-component intensity suppressed by approximately one order of magnitude relative to undoped BaF_2.

C. Radiation Damage of BaF_2: Y crystal

■ **Radiation-Induced Absorption and Phosphorescence**



■ **EWRIAC and LO losses**



➢ Y doping causes the broad absorption band in the 400–700 nm (1.77-3.1 eV) range to transform into discrete absorption peaks, with some peaks disappearing and some peaks gradually blue-shifting as the doping concentration increases. Besides the broad band at ~330 nm (3.7 eV) [3], Y-doping induces additional narrow phosphorescence peaks that intensify proportionally with Y concentration.

➢ When the Y concentration reaches 7.5 at.% (with an optimal concentration of 2 at.%), the radiation resistance of BaF_2 is improved. When the Y concentration is ≥10 at.%, the damage level significantly increases compared to undoped BaF_2.

Acknowledgments

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References

[1] J. Chen, et al., *IEEE Trans. Nucl. Sci.*, vol. 65, no. 8, pp. 2147-2151, 2018.
[2] C. Peng, et al., *IEEE Trans. Nucl. Sci.*, vol. 69, no. 9, pp. 2083-2088, 2022.
[3] C. L. Woody, et al. *IEEE Trans. Nucl. Sci.*, vol. 39, no. 4, pp. 515–523, 1992.