

Luminescence and Faraday rotation properties of Tb₂O₃ and Tb:Y₂O₃ single crystals

Philippe Veber¹, Grégory Gadret², Yannick Guyot³, Gabriel Bușe¹, Richard Moncorgé³ and Matias Velázquez^{4,*}

¹Faculty of Physics, West University of Timisoara, Bd. Vasile Parvan 4, Timisoara, 300223, Romania

²Laboratoire Interdisciplinaire Carnot de Bourgogne, UMR 6303 CNRS-Université de Bourgogne, Faculté des Sciences Mirande, 9 avenue Alain Savary, BP 47 870, 21078 Dijon cedex, France

³Université de Lyon, CNRS, Institut Lumière Matière, 10 rue Ada Byron, F-69622, Villeurbanne, France

⁴Univ. Grenoble Alpes, CNRS, Grenoble INP (Institute of Engineering Univ. Grenoble Alpes), SIMAP, 38000 Grenoble, France

Over the last years, many Tb-based crystals (TGG, TAG, TSLAG, TbVO₄, CALTO, STB, LTB, TbCOB, TLF, etc.), were obtained and investigated for their Faraday rotation property, noticeably in the near infrared spectral range, and their utilization in high intensity linearly polarized laser chains to protect the optics from deleterious longitudinally scattered and reflected laser lights [1–4]. Indeed, when such a transparent material is submitted to a longitudinal magnetic field and when a linearly polarized light beam is propagating forward through it, its polarization is rotated in a direction (left or right) by an angle θ_F which is proportional to the applied magnetic field H and the thickness t of the material according to the expression $\theta_F = k_V \times t \times H$, where k_V is the Verdet constant. This effect is also crucial for several high-performance photonic devices such as in telecommunications, light detection and ranging, and even quantum platforms. Crystal-based optical isolators and circulators are key components for high-performance optical systems, especially for demanding applications such as coherent telecom transceivers, optical switches for data centers, light detection and ranging (LiDAR) systems or quantum interconnects where fleeting quantum states transfer between different parts of quantum communication platforms [5]. Due to their larger transparency, as compared with 3d transition metal-based materials, Tb-based crystals are prospective materials in the visible spectral range for more compact implementations of high-performance photonic circuits, which could make their way inside integrated photonic engines.

Heavily-doped and fully concentrated 2.78 % Tb:Y₂O₃ and Tb₂O₃ single crystals with high optical quality and very low levels of impurities have been grown and studied for their luminescence and Faraday rotation properties. Absorption, emission and fluorescence decay measurements performed vs excitation wavelength and temperature and their confrontation with Judd-Ofelt and crystal-field calculations show the contributions of two types of luminescent centers: dominant ones with a ⁵D₄ emission lifetime of 23 μ s corresponding to coupled near-neighbor Tb³⁺ ions, all in C₂ symmetry sites, and minority ones with a ⁵D₄ emission lifetime of about 2 ms corresponding to coupled Tb³⁺ ions in C₂ and C_{3i} near-neighbor symmetry sites. Faraday rotation measurements confirm Tb₂O₃ as the Tb-based Faraday crystalline material with the largest ever measured Verdet constant, at all temperatures and from the visible to the near-infrared. They also show that the dominant luminescent centers contribute more particularly to this large Verdet constant thanks to a favorable crystal-field splitting of their ⁷F₆ ground multiplet and also to the contributions of both types of spin-allowed and spin-forbidden 4f-5d absorption bands.

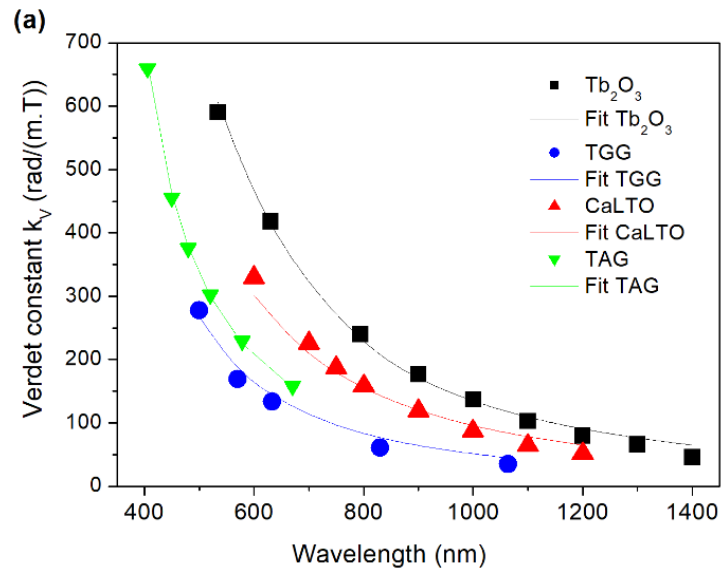


Figure 1: Absolute values of the Verdet constant versus wavelength of Tb_2O_3 , CaLTO, TGG, and TAG crystals along with fits of data values.

Keywords: Tb_2O_3 , luminescence, Faraday rotation.

References:

- [1] M. J. Weber, *Handbook of Optical Materials*, CRC Press, 2003.
- [2] D. Rytz, K. Dupré, A. Gross, Ch. Liebald, M. Peltz, P. Pues, S. Schwung, V. Wesemann, *Rare-Earth Chemistry*, De Gruyter Publ., Chap 4.4, pp. 415–438 (2020).
- [3] M. Mei, L. L. Cao, Y. He, R. R. Zhang, F. Y. Guo, N. F. Zhuang, J. Z. Chen, *Adv. Mater. Res.* **306**, 1722 (2011).
- [4] Y. Xu, M. Duan, *Phys. Rev. B* **46** (18), 11636–11641 (1992).
- [5] J. Lapointe, C. Coia, A. Dupont, *et al.*, *Nat. Photon.* **19**, 248–257 (2025).