# Radiative and non-radiative transitions: Different and yet so similar

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Usually, photoluminescence is concerned with an optimization of the spontaneous radiative decay pathway, whose foundations were already laid down by the advent of (cavity) quantum electrodynamics. In contrast, the non-radiative pathway, i.e. the coupling of the transition dipole moment to vibrational modes, has only got into a closer focus since the early 1970s [1]. One major finding was the energy gap law for multi-phonon transitions with a limited temperature dependence [2], while broad-band emission is thermally very labile due to a so-called non-radiative crossover [3]. Theoretical approaches to the non-radiative channel have ever been tackled but often require very sophisticated techniques and still do not satisfactorily agree even in the order of magnitude with experimental data. An interesting impetus was given by Burshtein in 2010 [4] that, after pioneering works by Orlovskii and Pukhov [5] as well as Ermolaev and Sveshnikova [6], indicated that non-radiative transition rates should also be related to transition oscillator strengths. From a quantum field theoretical perspective, this would be very intuitive and implies that many control parameters known for radiative transitions should also hold for non-radiative transitions. Such an understanding is key to the design of luminescent thermometers [7], but could even open up new avenues to control the quantum efficiency of phosphors in general.

Within this lecture, I want to give a brief historical account on major theoretical and experimental breakthroughs in the understanding of radiative and non-radiative decay in phosphors and demonstrate how theoretical approaches to the non-radiative transition can be explicitly verified by careful experiments [8]. This is supposed to break with the paradigm that radiative and non-radiative decay channels are two different but indeed are much more related than may be actually expected.

[1] a) Bixon, M., Jortner, J. (1968), *J. Chem. Phys*. 48, 715–726; b) Englman, R., Jortner, J. (1970), *Mol. Phys.*, 18, 145–164.
[2] a) L. A. Riseberg, L. A., Moos, H. W. (1968), *Phys. Rev*. 174, 429–438; b) van Dijk, J. M. F., Schuurmans, M. F. H. (1983), *J. Chem. Phys*. 78, 5317–5323.
[3] a) Englman, R., Barnett, B. (1970), *J. Lumin.* 3, 37–54; b) Struck, C. W., Fonger, W. H. (1975). *J. Lumin.* 10, 1–30.
[4] Burshtein, Z. (2010), Opt. Engin., 49, 091005.
[5] a) Pukhov, K. K., Sakun, V. P. (1979), *Phys. Stat. Sol. B*, 95, 391. b) Orlovskii, Y. V., Reeves, R. J., Powell, R. C., Basiev, T. T., Pukhov, K. K. *Phys. Rev. B* 1994, 49, 3821.
[6] a) Ermolaev, V. L., Sveshnikova, E. B. (1979), *J. Lumin.*, 20, 387–395; b) Sveshnikova, E. B., Ermolaev, V. L. (2011), *Opt. Spectrosc.*, 111, 34–50.
[7] a) Suta, M., Meijerink, A. (2020), *Adv. Theory Simul*., 3, 2000176; b) Brites, C. D. S., Marin, R., Suta, M., Neto, A. N. C., Ximendes, E., Jaque, D., Carlos, L. D. (2023), *Adv. Mater.* 35, 2302749.
[8] a) Geitenbeek, R. G., de Wijn, H., Meijerink, A. (2018), *Phys. Rev. Appl.*, 10, 064006; b) Suta, M., Antić, Ž., Đorđević, V., Kuzman, S., Dramićanin, M. D., Meijerink, A. (2020), Nanomaterials, 10, 543; c) van Swieten T. P., Steenhoff, J. M., Vlasblom, A., de Berg, R., Mattern, S. P., Rabouw, F. T., Suta, M., Meijerink, A. (2022), *Light: Sci. Appl.* 11, 343.

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