Near infrared light induced visible emission in inorganic nanostructures

Hong Zhang[1,2], Langping Tu[2], Xiaomin Liu[2]

[1] Van't Hoff Institute for Molecular Sciences, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands

[2] State Key Laboratory of Luminescence and Applications, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130033, China

E-mail: h.zhang@uva.nl

Besides multistep excitation based on excited state absorption (ESA), another robust mechanism was found in 1970's pioneered by Franois Auzel which was termed as APTE effect (addition de photon par transferts d'energie)[1] and later termed as ETU (energy transfer upconversion)[2]. The interest on upconversion emission in various materials, typically lanthanide ions doped materials, was re-boosted in 2000's with the advent of nanotechnology application in biology/biomedicine. The anti-Stokes scheme and excitation falling in so-called "optical window" were expected to improve significantly the quality of luminescence biomedical imaging, labelling and therapy. Another attractive point is that they can form nanoplatforms to integrate specific targeting, imaging and therapeutic functions in relative deep tissue. In these years proof-of-concept reports continue to emerge. Despite these progresses, the unsatisfactory upconversion efficiency remains one of the main hurdles on its way to actual and broad applications.

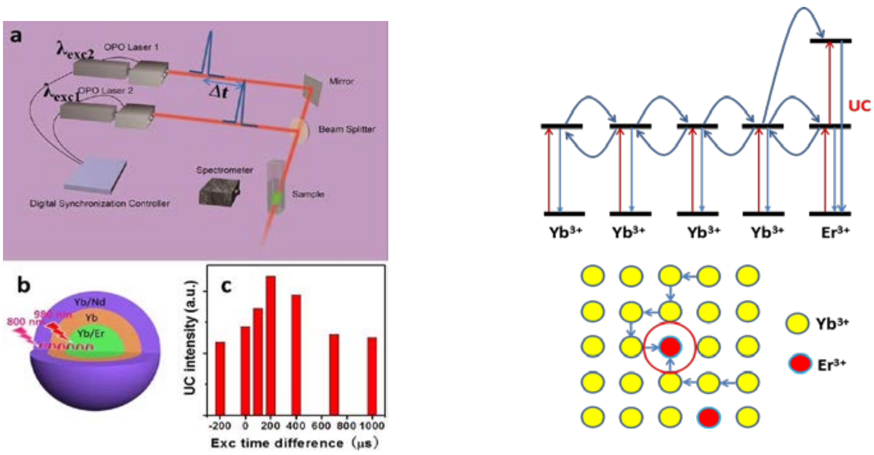

Figure 1. a). Scheme of multi-wavelength excitation upconversion luminescence. B). Typical sample structure of spatial separation doping. c) Upconversion luminescence intensity subjected to two wavelength excitation. Right: Monte Carlo simulation model.

With the advance of our understanding of upconversion in lanthanide ions doped nanosystems, it was realized that energy migration upconversion termed as EMU, *i.e.* upconversion realized in the activators without sensitizers in close vicinity, could also be very effective. Based on this discovery, plenty of smart upconversion nanostructures have been designed.[3] Despite these progresses, the lack of distinct dynamic picture of the EMU remains a great challenge. In this aspect, we have made some progresses via a specially designed nonlinear spectroscopic setup to monitor the time behavior of EMU process and performed relevant Monte Carlo simulation. Our study has upgraded the understanding of the time behavior of the upconversion luminescence which enables fine tuning either the rise or decay edge of upconversion dynamics in a broad range and further improving the upconversion efficiency via tailoring the energy migration path, which may facilitate better designs of functional upconversion nanostructures ranging from biological application to anti-counterfeiting and high density storage.

Funding: European union MSCA-ITN-2015-ETN Action program, Netherlands Organisation for Scientific Research, Netherlands Minister of Economy, Joint research program between Royal Academy of Art and Science of the Netherlands and Chinese Academy of Sciences, European Commission COST program, Natural Science Foundation of China, Innovation program of the State Key Laboratory of Luminescence and Applications of China.

Acknowledgement: We thank W.J. Buma, X.G. Kong, F. Wu, D.P. Sun, E.J. Meijer for their collaboration.

References:

[1] F. Auzel, *Proc. IEEE* **1973**, 61, 758

[2] J. Wright, Up-conversion and excited-state energy transfer in rare-earth doped materials. In Radiationless *Processes in Molecules and Condensed Phases*; Fong, F. K., Ed.; Topics in Applied Physics; Springer: New York, **1976**; Volume 15, p 239

[3] F. Wang, R. R. Deng, J. Wang, Q. X. Wang, Y. Han, H. M. Zhu, X. Y. Chen and X. G. Liu, *Nature Mater.*, **2011**, 10, 968

[4] L.P. Tu, X.M. Liu, F. Wu, H. Zhang, *Chem. Soc. Rev.* **2015**, 44 (6), 1331