

# Molecular upconversion

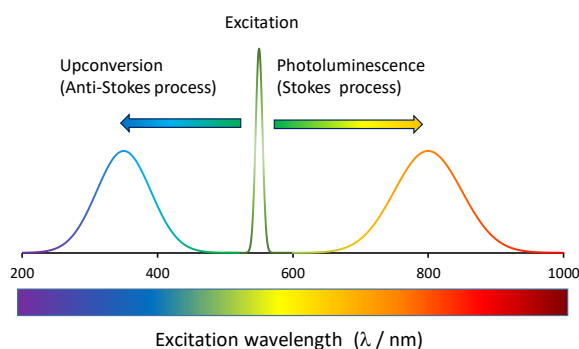
Or

## How to pile photons in lanthanide complexes

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Upconversion (UC) is the process by which the energy of two or more photons are stored in a compound and restored in the form of luminescence at a higher energy than the excitation beam. If the process is known for more than 60 years in solid compounds,<sup>1</sup> it is only some ten years ago that the first examples were described in discrete molecules at very low temperature (30K) in organic solvents.<sup>2</sup>



**Figure 1:** representation of conventional and non-conventional (Anti-Stokes) luminescence process

Through the rational design of heteropolynuclear lanthanide complexes, we succeeded to demonstrate that molecular UC can not only be observed at room temperature,<sup>3</sup> but also in aqueous solvents,<sup>4</sup> and even in pure water,<sup>5</sup> opening the space to a brand new family of luminescent labels.

Additionally, supramolecular architectures enlarged the perspectives of yet unexplored UC mechanism at the molecular level, such as the observation of cooperative sensitization in Yb/Tb nonanuclear clusters,<sup>6</sup> cooperative sensitization of Yb dimers,<sup>7</sup> or Yb to Ru UC energy transfer in hetero-polynuclear d-f complexes.<sup>8</sup>

<sup>1</sup> Auzel, F. *Chem. Rev.* **2004**, *104*, 139.

<sup>2</sup> Piguet, C. et al *Angew. Chem. Int. Ed.* **2011**, *50*, 4108.

<sup>3</sup> Nonat et al. *Nature Comm.* **2016**, *7*, 11978.

<sup>4</sup> Souri et al. *J. Am. Chem. Soc.* **2017**, *139*, 1456.

<sup>5</sup> Nonat et al. *J. Am. Chem. Soc.* **2019**, *141*, 1568.

<sup>6</sup> Knighton, R. *Angew. Chem. Int Ed.* **2022**, *61*, 202113114.

<sup>7</sup> Knighton, R. et al. *Adv. Opt. Mater.* **2023**, doi: 10.1002/adom202202307.

<sup>8</sup> Knighton, R.J. *Am. Chem. Soc.* **2022**, *144*, 13356.

Since my very first contact with UC at the university of Geneva with Pr Jørgensen's book,<sup>9</sup> up to the latest advances of our group, I will present a little journey into molecular UC.

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<sup>9</sup> Reisfeld, R., Jørgensen, C. K, in "lasers and excited states of rare earths", Springer, 1977.