Femtosecond dynamics at the nanoscale: talking to antenna complexes one-by-one

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Abstract

Nature has developed photosynthesis to power life. Nanoscale networks of light harvesting antennas capture the sunlight to funnel the photonic energy towards reaction centres. Surprisingly, despite the complexity and ambient conditions, quantum coherences are observed in the energy transfer of antenna complexes, even at room temperature. Does *nature* exploit quantum concepts? Does the coherence help to find an optimal path for robust or efficient transfer? How are the coherences sustained? What is their spatial extent in a real light-harvesting network?

Specializing on femto-nanophotonics we aim to look ultrafast into the nanoscale, to see molecules in action. Addressing the antenna complex of purple bacteria, we have found glimpses of coherent oscillations of a single photo-synthetic complex, moreover non-classical photon emission of individual antenna complexes. These results, pave the way to address photosynthetic networks in real nano-space and on femtosecond timescale. We address the transport mechanism between adjacent light-harvesting complexes in tubular crystal sheets with few picosecond temporal resolution, to track the coherent light path in such photosynthetic networks.

For spatial control, the single complexes are brought in the near field of optical resonant antennas for nanoscale excitation and enhancement of the emission with full command of rates and polarization. With state-of-the-art antenna fabrication the excitation can be confined to 10 nm scale, while the emission can be enhanced up to 1000 times for a single molecule close to an antenna hotspot.

In conclusion I hope to apprise the CEN2016 audience as to the potential of nano-femto tools

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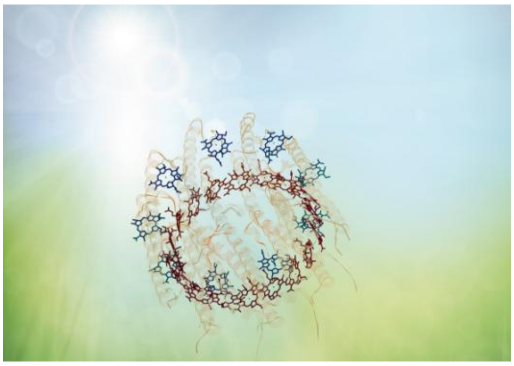
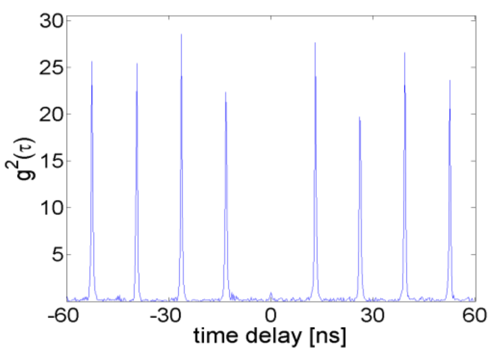
References

[1] Lukasz Piatkowski, Nicolò Accanto, Niek F van Hulst, “Ultrafast meets Ultrasmall: Controlling Nanoantennas and Molecules", *ACS Photonics* **3**, (2016).
[2] Emilie Wientjes, Jan Renger, Richard Cogdell, Niek van Hulst, "Pushing the Photon Limit: Nanoantennas Increase Maximal Photon Stream ", *J.Phys.Chem.Lett.* **7**, 1604 (2016)
[3] Lukasz Piatkowski, Esther Gellings and Niek van Hulst, "Broadband Single Molecule Excitation Spectroscopy", *Nature Communications* **7**:10411 (2016)
[4] Emilie Wientjes, Jan Renger, Alberto Curto, Richard Cogdell, Niek van Hulst, "Antenna-enhanced fluorescence of single LH complex shows photon anti-bunching". *Nature Comm*. **5**: 4236 (2014)
[5] Richard Hildner, Daan Brinks, Richard Cogdell, Niek F. van Hulst, Quantum coherent energy transfer over varying pathways in single light-harvesting complexes. *Science* **340**, 1448-1451 (2013)

Figures





Light harvesting antenna complex (LH2) of purple bacteria shows anti-bunching ($g^{(2)}(0)=0$), i.e. non classical photon statistics and single photon emission character.