Work Group 3 Quantum Coherence at the Nanoscale. COST 1403 NQO

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I. WG 3, quantum coherence at the nanoscale, COST 1403 Action.

Quantum Coherence at the Nanoscale: a transversal topic.
On the roadmap[1] of the COST action 1403, the section devoted to the WG3: Nanoscale Quantum Coherence contains five sections:

- 1. Quantum coherence and dephasing as a sensing tool
- 2. Coherent quantum transport for energy harvesting
- 3. Fundamental aspects of quantum coherence at the nanoscale
- 4. Interaction of entangled light with nanostructures
- 5. Strong light-matter interaction at ambient conditions

[1] http://www.cost-nqo.eu/support/documents/ see also special issue Nuovo Cimento: Nanoscale Quantum Optics, 2019, in press.

I. WG 3, quantum coherence at the nanoscale, COST 1403 Action.

All these topics were addressed in various meetings and workshops

- 1. Kick off meeting Belgrade, Serbia, local organizer Brana Jelenkovic; April 2015 **Transversal**
- 2. NQO WG3 meeting at the European Laboratory for Nonlinear Spectroscopy in Florence, Italy, July 2015, organized by Mario Agio, in parallel with Quantum Efffects in Biological Systems (QuEBS 2015), organised by F. Caruso **Transport-Metrology**
- 3. NQO WG2 WG3 Joint Workshop in Marseille, France, May-June 2016, local organizer Thomas Durt, together with workshop of GDR Ondes on Non Linear and Quantum Plasmonics organized by G. Bachelier and FQXI workshop about non-linearity at the quantum scale organized by T. Durt **Foundations, Spin Chains, Entangled Photons Spectroscopy**

I. WG 3, quantum coherence at the nanoscale, COST 1403 Action.

All these topics were addressed in various meetings and workshops (continued)

- 4. NQO WG2 WG3 Joint Workshop in Troyes (UTT); local organizer Christophe Couteau, together with Single Photons Single Spins (SPSS) Meeting 2017 **Strong Coupling, Metrology**
- 5. Nanoscale Quantum Optics Conference and MC Meeting, Prague, Czech Republic, local organizers A. Kromka, M. Ferus and I. Richter **Transversal**

II. Short overview: 1. Quantum coherence and dephasing as a sensing tool.

cfr. P. Maletinsky[2] (Basel SW)

- basic idea: use a single spin (e.g. NV-center) as a probe to detect extremely small magnetic fields at extremely small distance via decoherence-based sensing
- mix of nanotechnologies/nanosensing and quantum control/quantum logics
- extreme metrologic accuracy: makes it possible to detect the magnetic field of a single molecule
- promising applications in life sciences and solid-state physics...

[2] http://www.cost-nqo.eu/support/documents/ see also special issue Nuovo Cimento: Nanoscale Quantum Optics, 2019, in press.

II. Short overview: 2. Coherent quantum transport for energy harvesting.

cfr. I. D' Amico (York, U.K.)

- It has been established that the response of light harvesting complexes involved in photosynthesis exhibits some temporal coherence.
- This observation stimulated intensive research concerning the role played by (quantum) coherence in transport and light harvesting.
- *...In the end, the final aim of current research in this field is to develop self-organized, and self-sustained artificial photosynthetic cells for future applications...*[3]
- Also related to new emerging research fields such as spin-chains and quantum thermodynamics... **(see presentation of I. D' Amico, very soon).**

[3] quoted from special issue Nuovo Cimento: Nanoscale Quantum Optics, 2019, in press.

II. Short overview: 3. Fundamental aspects of quantum coherence at the nanoscale.

cfr T. Durt[4] (Marseille, France)

- Gedanken experiments that were supposed to be utopic in the first quantum revolution (1925-1930) are now everyday practises in the lab.: it is actually possible to excite one photon at a time, to see light emitted by a single atom, to let interfere massive objects with themselves, to measure non-local correlations between distant entangled quantum objects (atoms, photons and so on).
- The quantum superposition principle has been tested for a large range of quantum objects (e.g. photons, electrons, neutrons, atoms, molecules, aggregates up to 10^4atomic mass units), confirming the dual nature of quantum objects (waves and particles) prophetised by the founding fathers of the quantum theory (Einstein, de Broglie).

[4] http://www.cost-nqo.eu/support/documents/ see also special issue Nuovo Cimento: Nanoscale Quantum Optics, 2019, in press.

II. Short overview: 3. Fundamental aspects of quantum coherence at the nanoscale-continued.

T. Durt[5] (Marseille, France)

- Present day technologies will make it possible in the coming years to test quantum interferences exhibited by nanobeads, nanorods and so on, hopefully reaching the 10^6 to 10^9 atomic mass units regime...
- In principle, these experiments will allow us to answer to fundamental questions regarding the quantum-classical transition (quantum decoherence, gravity-induced non-linearity, spontaneous collapse models and so on).
- Quantum Nano Optics can be considered here as a tool for testing the limits of the quantum theory...
- It will also open new perspectives in sensing and metrology, by realizing quantum interferences in the mesoscopic regime.

[5] http://www.cost-nqo.eu/support/documents/ see also special issue Nuovo Cimento: Nanoscale Quantum Optics, 2019, in press.

II. Short overview: 4. Interaction of entangled light with nanostructures.

- The term entanglement was first introduced by Schrödinger [6] who described it as "the characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought".
- *...The biggest challenges and goals regarding applications of entangled light include the development of the new spectroscopic schemes using entangled light and possibility to transfer entanglement from light to large collective structures and atomic systems for future quantum memories and quantum repeaters...*[7]
- see also WG1 (F. Bussières) for Quantum Memories, and WG4 (P. Rabl) for collective quantum effects...

[6] E. Schrödinger, Proc. Cambridge Philos. Soc. 31, (1935) 555.

[7] quoted from special issue Nuovo Cimento: Nanoscale Quantum Optics, 2019, in press.

II. Short overview: 5. Strong light-matter interaction at ambient conditions.

- **see presentation of Branko Kolaric, right now...**