CEWQO 2019
Invited

Quantum Frequency comb for Quantum Complex Networks

Valentina Parigi[1],
[1] Laboratoire Kastler Brossel, Sorbonne Universiteé, CNRS,
ENS-PSL Research University, Collège de France; CC74 4 Place Jussieu, 75252 Paris, France

Abstract

We show experimental procedures based on optical frequency combs for the generation of quantum complex networks, having both Gaussian and non-Gaussian statistics and that can be exploited in quantum information and communication technologies based on Continuous Variables.

We show experimental procedures based on optical frequency combs and parametric processes able to produce quantum states of light involving large number of modes in the frequency and time domain. The protocols, along with mode selective and multimode homodyne measurements, allow for the implementation of reconfigurable entanglement connections between the involved modes. This can be exploited for fabricating entanglement structures with regular geometry as cluster states [1], which are considered a universal resource for continuous variables measurement-based quantum computing. Also graphs with more complex topology: recently, quantum complex networks, i.e. collections of quantum systems arranged in a non-regular topology, have been explored leading to significant progress in a multitude of diverse contexts including, e.g., quantum transport, open quantum systems, quantum communication, extreme violation of local realism, and quantum gravity theories. We demonstrated that our strategy allows for deterministic implementation of networks with all-to all connection and full reconfigurability [2]. Additional non-Gaussian operations are necessaries to reach a form of quantum advantage in this scenario; a coherent-mode dependent single photon subtraction has been recently demonstrated in our setups. When applied to the graph structure a special entanglement [3] properties appear, and the non-Gaussian features are spread out with particular geometrical properties [4]. Moreover, the merging of non-Gaussian operations and complex network structures disclose peculiar properties of the quantum states, which can also be investigated to simulate quantum transport. Finally, coherent single-photon subtraction on Gaussian multimode quantum states can be exploited as a high-dimensional encoding, which is suitable for mapping arbitrary classical data in quantum mechanical form [5].

[1] Y. Cai, J. Roslund, G. Ferrini, F. Arzani, X. Xu, C Fabre and N. Treps, *Multimode entanglement in reconfigurable graph states using optical frequency combs*, Nature Communications **8**, 15645 (2017).

[2] J. Nokkala, F. Arzani, F. Galve, R. Zambrini, S. Maniscalco, J. Piilo, N. Treps and V. Parigi, *Reconfigurable optical implementation of quantum complex networks*, New Journal of Physics **20**, 053024 (2018).

[3] M. Walschaers, C. Fabre, V. Parigi and N. Treps, *Entanglement and Wigner function negativity of multimode non-Gaussian states*, Physical Review Letters **119**, 183601 (2017).

[4] M. Walschaers, S. Sarkar, V. Parigi, and N. Treps, *Tailoring non-Gaussian continuous-variable graph states*, Phys. Rev. Lett. **121**, 220501(2018).

[5] F. Arzani, A. Ferraro, and V. Parigi, *High-dimensional quantum encoding via photon-subtracted squeezed states* Phys. Rev. A **99**, 022342 (2019).