Multimode Quantum States for Continuous Variable Quantum Information

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The rapid advancement of quantum technologies, including quantum communication, quantum computation, and quantum metrology, has emphasized the need for the generation of robust and reliable quantum states. Employing continuous variable (CV) encoding of quantum information, it is possible to harness the inherent properties of light fields to generate tailored quantum states on demand. In this paradigm, CV multimode light presents itself as a remarkable platform for quantum technologies: a large number of modes –spectral and spatial degrees of freedom– can be used to encode large amounts of information, while the modes can straightforwardly be entangled and measured to process the information [1].

At the Multimode Quantum Optics group – LKB (MQO-LKB), we specialize in generating CV-multimode states by using frequency combs and second-order nonlinear interactions. In this talk, I will discuss two main approaches to our research. Firstly, we implement the double-homodyne detection to certify the non-Gaussian features of a state generated via mode-selective photon subtraction [2]. The CV-multimode state is produced by a Synchronously Pumped-OPO (SPOPO fig 1.a). We derived experimental witnesses such as Wigner negativity and stellar rank [3, 4]. These tools provide a reliable operational characterization of the measured state in terms of its non-Gaussian properties, eliminating the need for a full tomography.

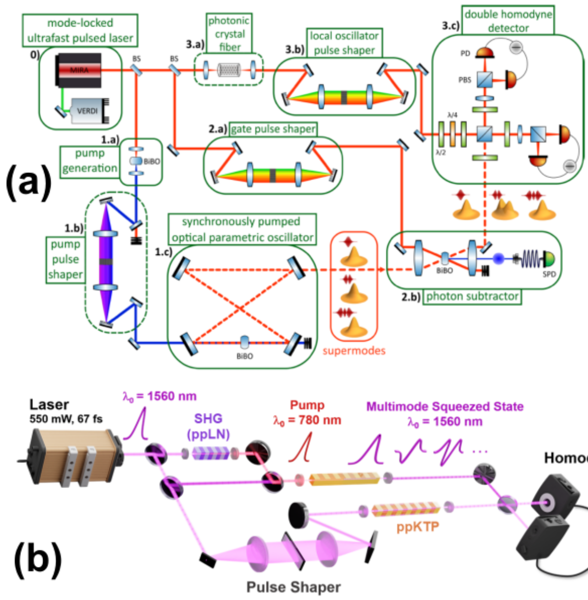

Figure 1: **(a)** SPOPO setup. (b) Generation of multimode states using waveguides

Secondly, in the pursuit of scalability, we employ PPKTP waveguides to produce pulse-by-pulse multimode states, generating states within the near-infrared C-Band [5] (fig. 1.b). This approach enables the creation of multimode state accessible and manipulable. Therefore, we can tailor 2-dimensional CV-networks [6], and perform node-selective non-Gaussian operations, as well as temporal multiplexing.

References

[1] V Ansari, J M Donohue, B Brecht and C Silberhorn, Optica **5**, 534 (2018)

[2] Y-S Ra, A Dufour, M Walschaers, C Jacquard, T Michel, C Fabre and N Treps, Nat. Phys. **16**, 144 (2020)

[3] U Chabaud, G Roeland, M Walschaers, F Grosshans, V Parigi, D Markham and N Treps, Phys. Rev. X Quantum **2**, 020333 (2021)

[4] U Chabaud, D Markham and F Grosshans, Phys.Rev.Lett. **124**, 063605 (2020)

[5] V Roman-Rodriguez, D Fainsin, G L Zanin, N Treps, E Diamanti and V Parigi, arXiv:2306.07267 (2023)

[6] M V Larsen, X Guo, C R Breum, J S Neergaard-Nielsen and U L Andersen, Science **366**, 369 (2019)