Simulation of complex quantum networks with quantum multimode resources based on optical frequency combs

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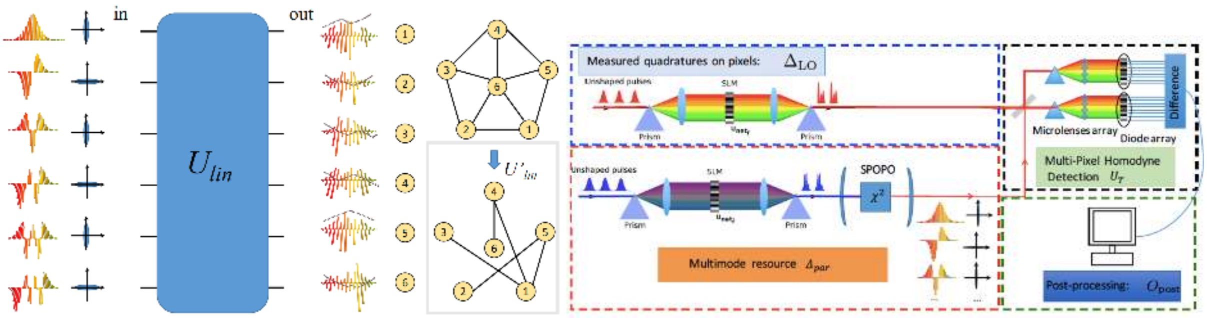
We are currently developing a versatile experimental photonic platform for simulating complex quantum networks. The platform consists of intrinsically multimode systems based on parametric processes pumped by optical frequency combs. The spectrum of these lasers is constituted by hundreds of thousands of frequency components. The parametric process in the non-linear crystal couples all these optical frequencies, and generates non-trivial multimode Gaussian quantum states [1]. These can be equally described as a set of different spectral-temporal modes of light, which can be individually addressed and simultaneously occupied by squeezed vacuum. This resource can be pictured as a network where each node is an electromagnetic-field mode and the connection are entanglement relations involving the quadratures of the field. The structure of the network will be controlled by shaping the pump in the parametric process and by multimode homodyne measurements. The strategy has partly been used for implementing cluster states in a measurement based quantum computing scenario [2,3]. The Bloch-Messiah reduction of the multimode state, which (for pure states), describe the resource as an ensemble of single-mode squeezers and multiport-interferometers is at the core of the method I will present to establish the mapping between our resource and complex networks [4]. We will study the optimization of quantum information protocols in complex structures and we will simulate the dynamics of complex finite quantum environment [5]. Finally, a particular implementation of the parametric process allowing multiplexing in wavelength and time, will simulate networks exhibiting community structures.



Left: The resource can be described as a collection of squeezed vacua and a basis change like the one given by a multiport-interferometer. The graphical representation of entanglement connections between the output modes shows the network structure. By changing U_{lin}, different kind of networks can be realized. Right: Experimental implementation of the network in the frequency domain.

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[2] R. Medeiros de Araujo et al. Phys. Rev A 89, 053828 (2014)
[3] J. Roslund, R. M. de Araujo, S. Jiang, C. Fabre, and N. Treps, Nat. Photonics 8, 109 (2014)
[4] J. Nokkala, F. Arzani, F. Galve, R. Zambrini , S. Maniscalco, J. Piilo, C. Fabre, N. Treps, V. Parigi, in preparation.
[5] J. Nokkala, F. Galve, R. Zambrini, S. Maniscalco and J. Piilo, Scientific Reports 6, 26861 (2016)