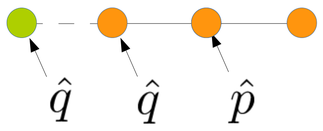
Shaping the Pump of a Synchronously Pumped Optical Parametric Oscillator for Continous-Variable Quantum Information

Francesco Arzani*, Nicolas Treps, Claude Fabre

Laboratoire Kastler Brossel, Université Pierre et Marie Curie Paris 6, CNRS, ENS, Collège de France, Paris, France

Continuous-Variable Quantum Information Protocols

Quantum computing

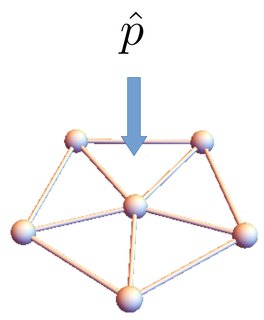


In **measurement-based** quantum computation, information is processed through **local measurements** on an entangled resource state (**cluster state**).

Secret sharing

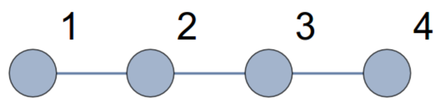
Cluster states are also useful in other quantum information protocols, such as secret-sharing.

In SS, a **dealer** shares information with several **players** in such a way that they can only retrieve the initial message if they **collaborate**.



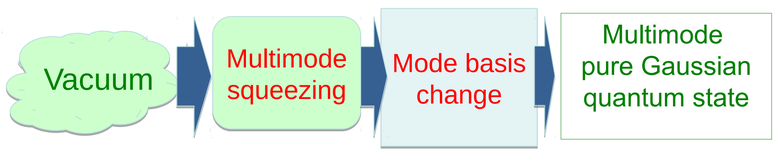
Cluster states

Cluster states can be represented as graphs and are characterized by **nullifier operators**.

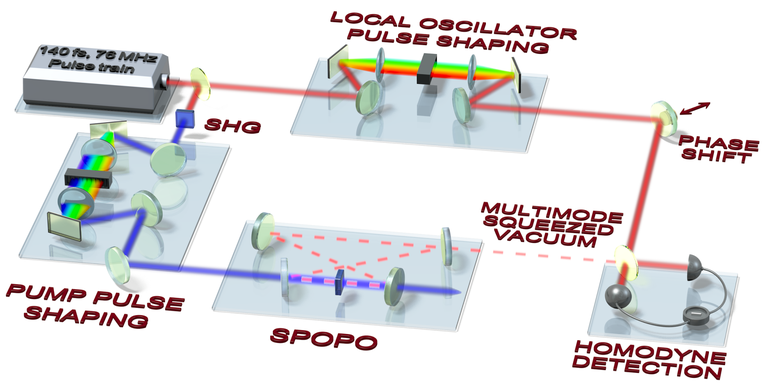


$$\begin{aligned}\hat{\delta}_1 &= \hat{p}_1 - \hat{q}_2 \\ \hat{\delta}_2 &= \hat{p}_2 - \hat{q}_1 - \hat{q}_3 \\ \hat{\delta}_3 &= \hat{p}_3 - \hat{q}_2 - \hat{q}_4 \\ \hat{\delta}_4 &= \hat{p}_4 - \hat{q}_3\end{aligned}$$

$$\exp\left(i\sum_{i>j} V_{ij}\hat{q}_i \otimes \hat{q}_j\right)|0\rangle_p^{\otimes N}$$

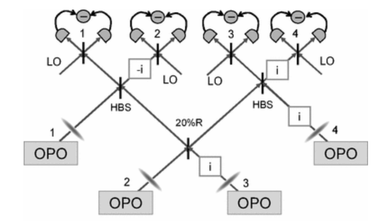


Experimental setup



An **SPOPO** pumped below threshold acts as set of independent squeezers in a basis of modes with a broad spectral profile, called **supermodes**.

Scalable source of entanglement, if compared with:



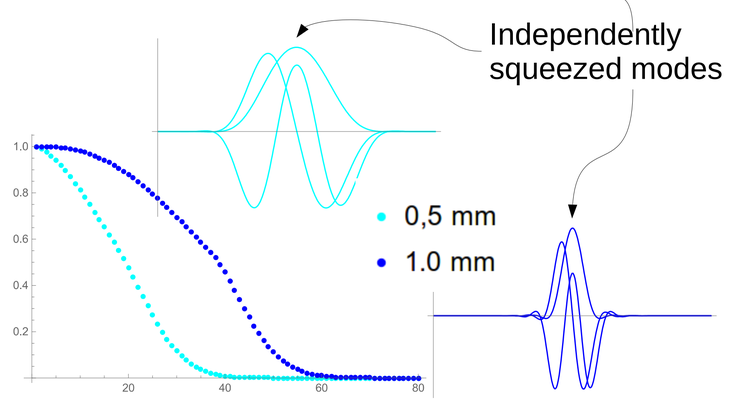
Pump Shaping for State Engineering

Supermodes

$$\hat{H} = i\frac{\hbar}{2}k\left(\hat{\vec{a}}^\dagger\right)^T \mathcal{L}\hat{\vec{a}}^\dagger + \text{h.c.}$$ Interaction Hamiltonian

$$\mathcal{L}_{mq} = \text{sinc}\left[\left(k_{p,m+q} - k_{s,m} - k_{s,q}\right)\frac{l}{2}\right]\alpha_{m+q}$$

$$U\mathcal{L}U^T = \Lambda \quad \vec{\hat{S}} = U\vec{\hat{a}} \quad \Rightarrow \quad \hat{H} = i\hbar\sum_j \Lambda_{jj}\left(\hat{S}_j^\dagger\right)^2 + \text{h.c.}$$

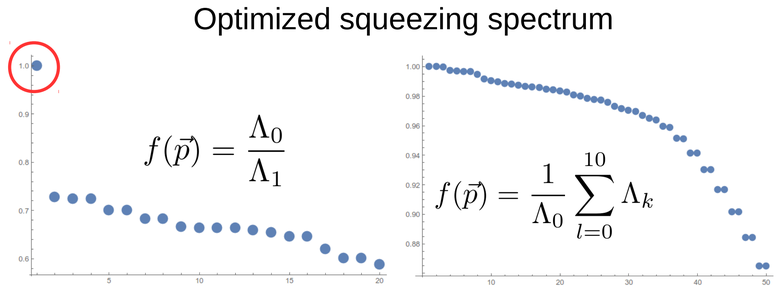


Tweaking the squeezing

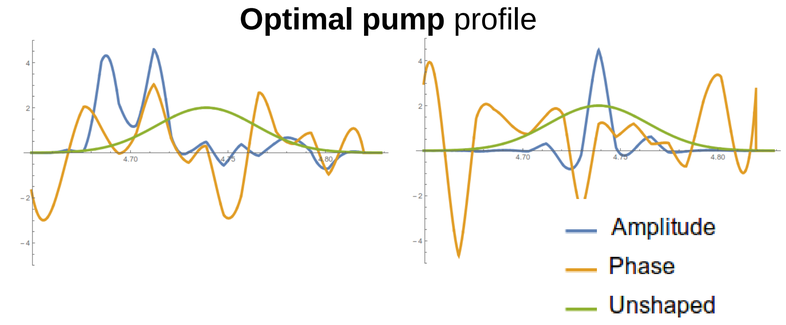
The shape of the pump can be adjusted to **optimize the squeezing spectrum**.

An evolutionary algorithm can be used to find the **optimal pump shape**.

Optimized squeezing spectrum



Optimal pump profile



Arbitrary modes' variance

Given the covariance matrix of the frequency modes, the covariance matrix of an arbitrary set of orthogonal modes can be computed.

$$\vec{\hat{n}} = V\vec{\hat{a}} \quad \Rightarrow \quad \Gamma_n = O_V\Gamma_a O_V^T$$

Nullifiers

Nullfiers can be written as the quadrature of specific modes.

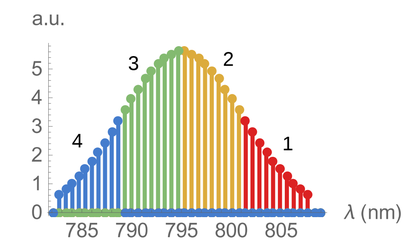
$$\hat{\delta}_i = \hat{p}_{n,i} - \sum_{j\in N(i)} \hat{q}_{n,j}$$

$$\bar{\hat{q}}_{d,i} = \hat{\delta}_i / \sqrt{1 + \#N(i)}$$

Optimizing Cluster States

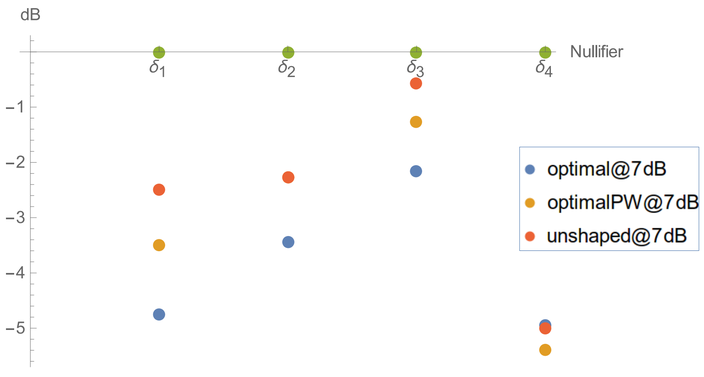
4-modes linear cluster

Measurement modes

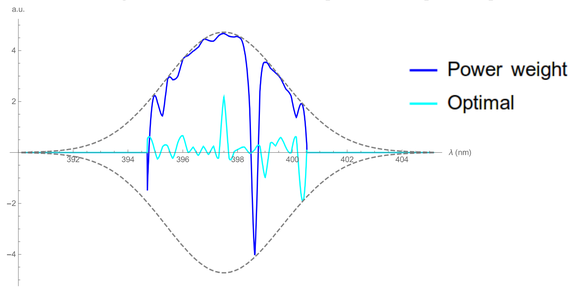


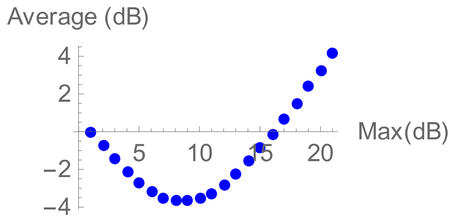
Best permutation

Reduction of nullifiers' noise (~1.3 dB)



Amplitude of the **optimal pump**

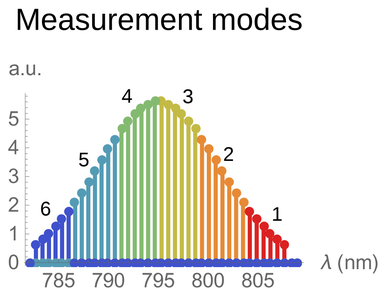




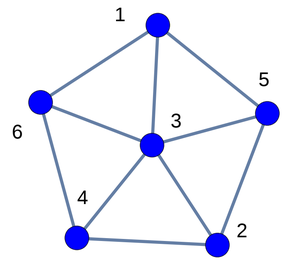
Nullifiers' squeezing is **not** monotonic with the squeezing in the resource.

Secret-sharing cluster

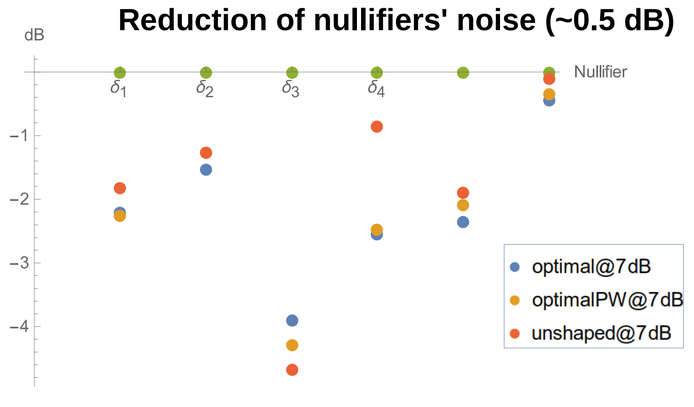
Measurement modes



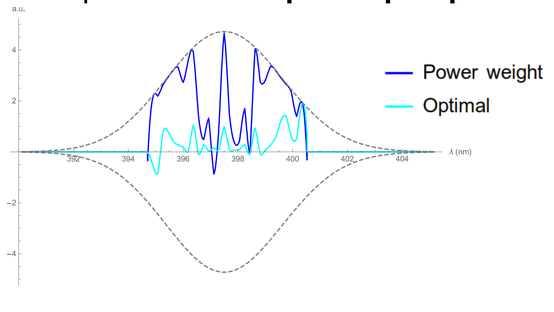
Best permutation



Reduction of nullifiers' noise (~0.5 dB)



Amplitude of the **optimal pump**



*francesco.arzani@lkb.upmc.fr

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