Enhancement of entanglement by a local filtration of thermal noise

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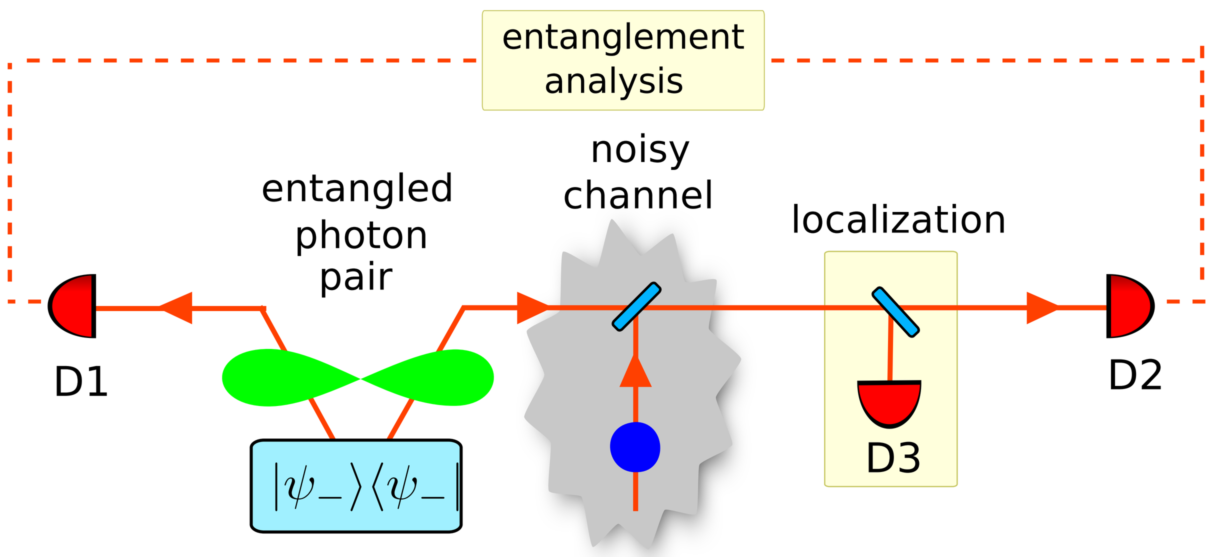
Motivation

Entanglement is a crucial resource for QIP. It gets inevitably degraded when distributed through noisy channels. In this project we study highly entangled signal state that is mixed with an uncorrelated noise originating from completely independent source - halogen lamp. Noise mixed with the signal causes a relevant decoherence mechanism leading to an entanglement decrease or loss. We have developed and experimentally demonstrated a procedure for entanglement enhancement or recovery in the presence of realistic polarized and unpolarized noise.

Theory



$|\psi_-\rangle\langle\psi_-|$ mixed with polarized noise $\rightarrow \rho_{\rm p}$

$|\psi_-\rangle\langle\psi_-|$ mixed with unpolarized noise $\rightarrow \rho_{\rm u}$

Polarized noise $|H\rangle\langle H|$

$$\rho_{\rm p} = \frac{1}{2+r_N}\left(|\psi_-\rangle\langle\psi_-| + (1+r_N)\frac{\mathbb{1}}{2}\otimes|H\rangle\langle H|\right)$$

$$C(\rho_{\rm p}) = \frac{1}{2+r_N}$$

$$\rho_{\rm pf} = \frac{1}{\frac{3}{2}+r_N}\left(|\psi_-\rangle\langle\psi_-| + \frac{1}{2}|VH\rangle\langle VH| + r_N\frac{\mathbb{1}}{2}\otimes|H\rangle\langle H|\right)$$

$$C(\rho_{\rm pf}) = \frac{1}{\frac{3}{2}+r_N}$$

Unpolarized noise $\frac{\mathbb{1}}{2}$

$$\rho_{\rm u} = \frac{1}{2+r_N}\left(|\psi_-\rangle\langle\psi_-| + (1+r_N)\frac{\mathbb{1}}{2}\otimes\frac{\mathbb{1}}{2}\right)$$

$$C(\rho_{\rm u}) = \frac{1-r_N}{2(2+r_N)}$$

$$\rho_{\rm uf} = \frac{1}{\frac{3}{2}+r_N}\left(|\psi_-\rangle\langle\psi_-| + \frac{1}{2}|VH\rangle\langle VH| + r_N\frac{\mathbb{1}}{2}\otimes|H\rangle\langle H|\right)$$

$$C(\rho_{\rm uf}) = \frac{1}{2+r_N} - \frac{1}{2}\sqrt{\frac{r_N}{2+r_N}}$$

Relevant parameters

$$r_N = \frac{2R_S R_N \tau}{R_{|\psi_-\rangle}}$$

R_N noise rate

R_S signal rate (singles)

$R_{|\psi_-\rangle}$ rate of singlets

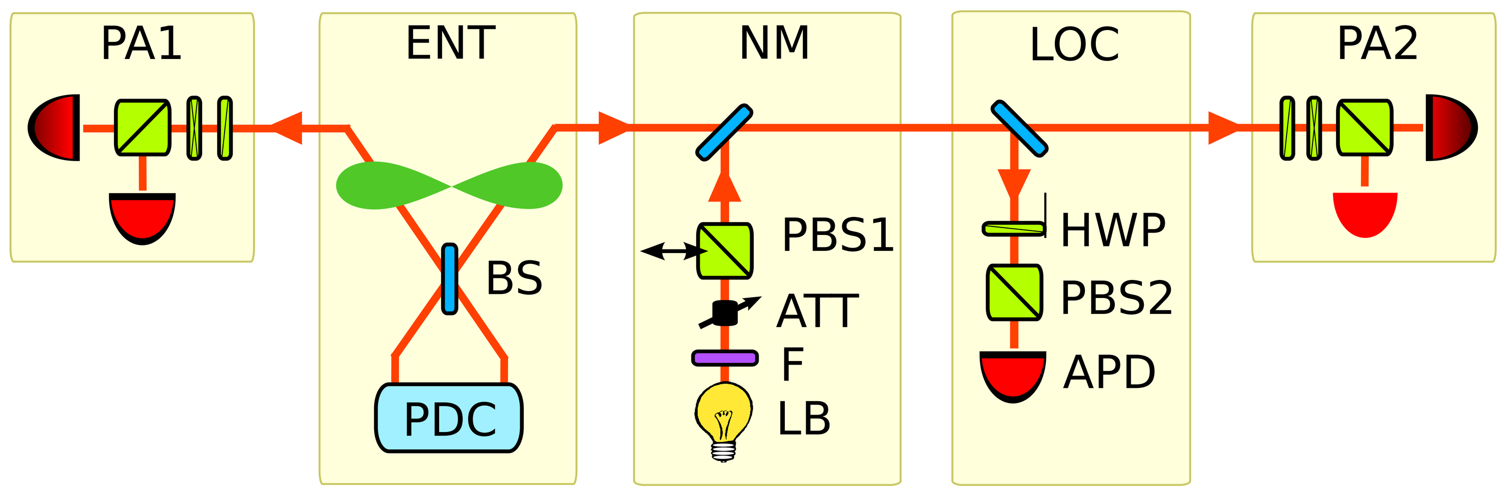
τ coincidence window

Concurrence

$$C(\rho) = \max\{0, \lambda_1 - \lambda_2 - \lambda_3 - \lambda_4\}$$

where λ_i's are eigenvalues of $\rho\tilde{\rho}$ in descending order and $\tilde{\rho} = (\sigma_y\otimes\sigma_y)\rho(\sigma_y\otimes\sigma_y)$

Experiment



Signal

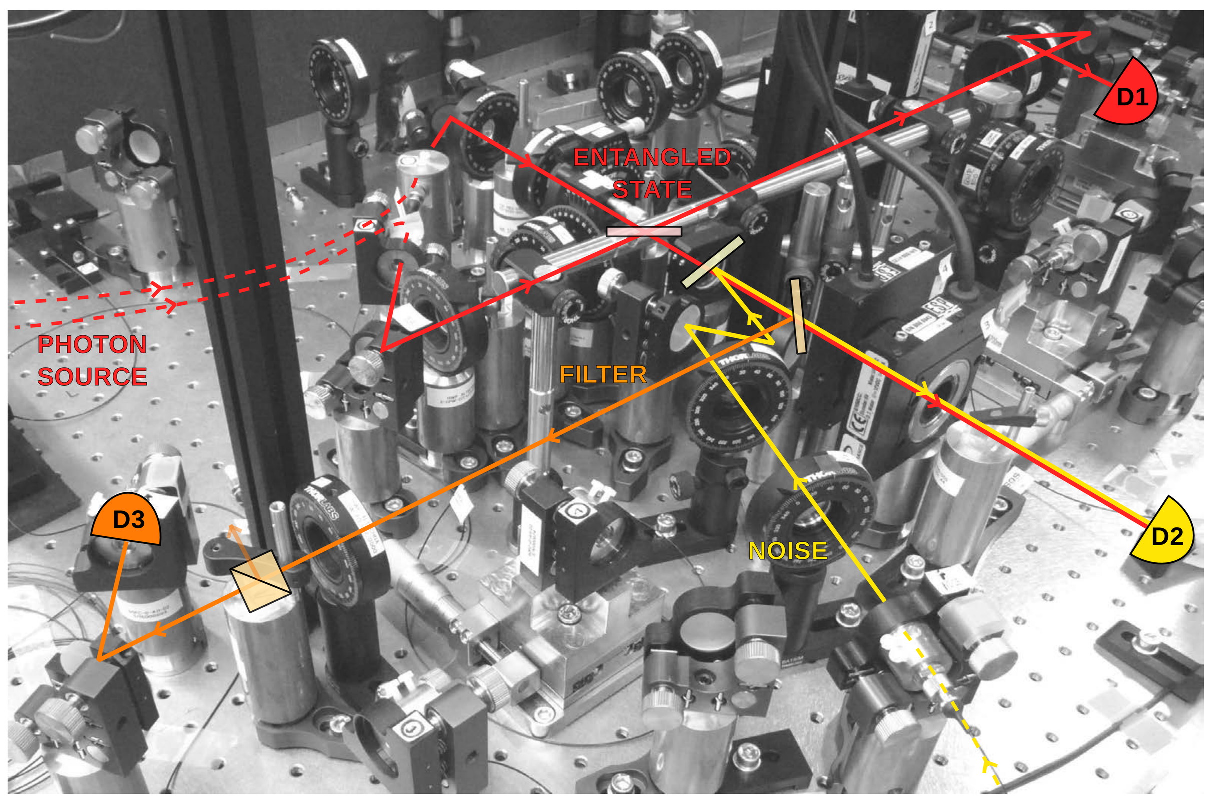
- singlet pair generated by SPDC
- pump cw at 405 nm
- type II degenerated process in BBO crystal
- polarization singlet prepared by 50:50 BS

Noise

- generated by halogen lamp
- multiphoton
- multimode
- polarized or unpolarized
- effectively Poissonian statistics

Measurement

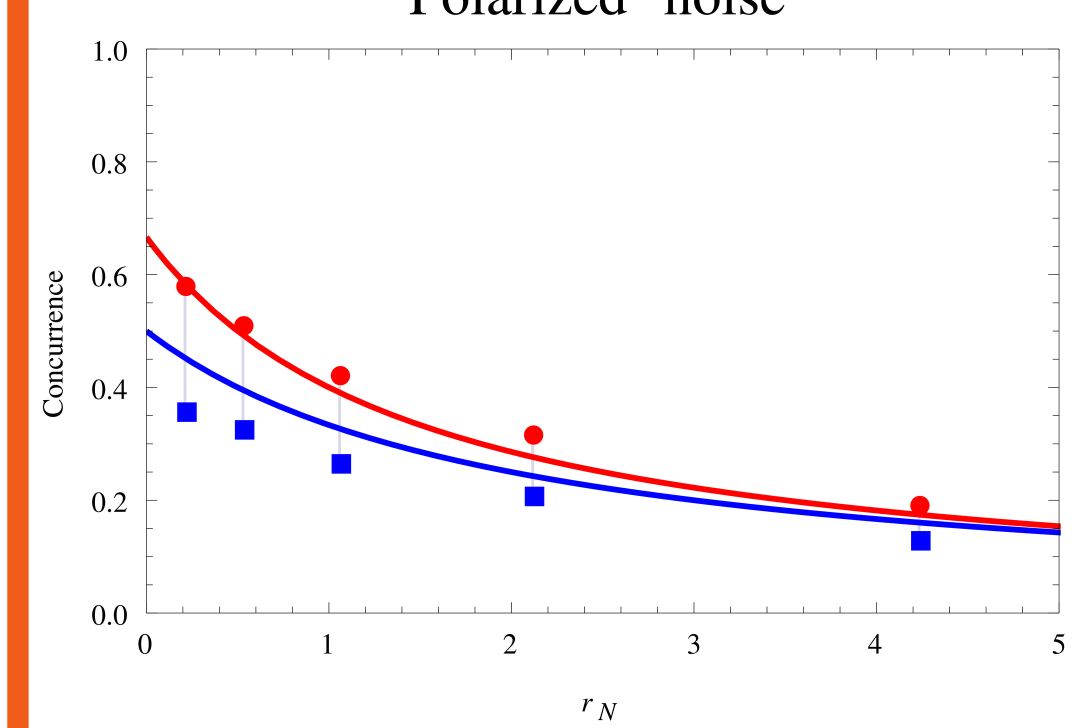
- 3 photon coincidences
- polarization analysis PA1, PA2
- quantum state tomography of ρ
- concurrence calculated from ρ

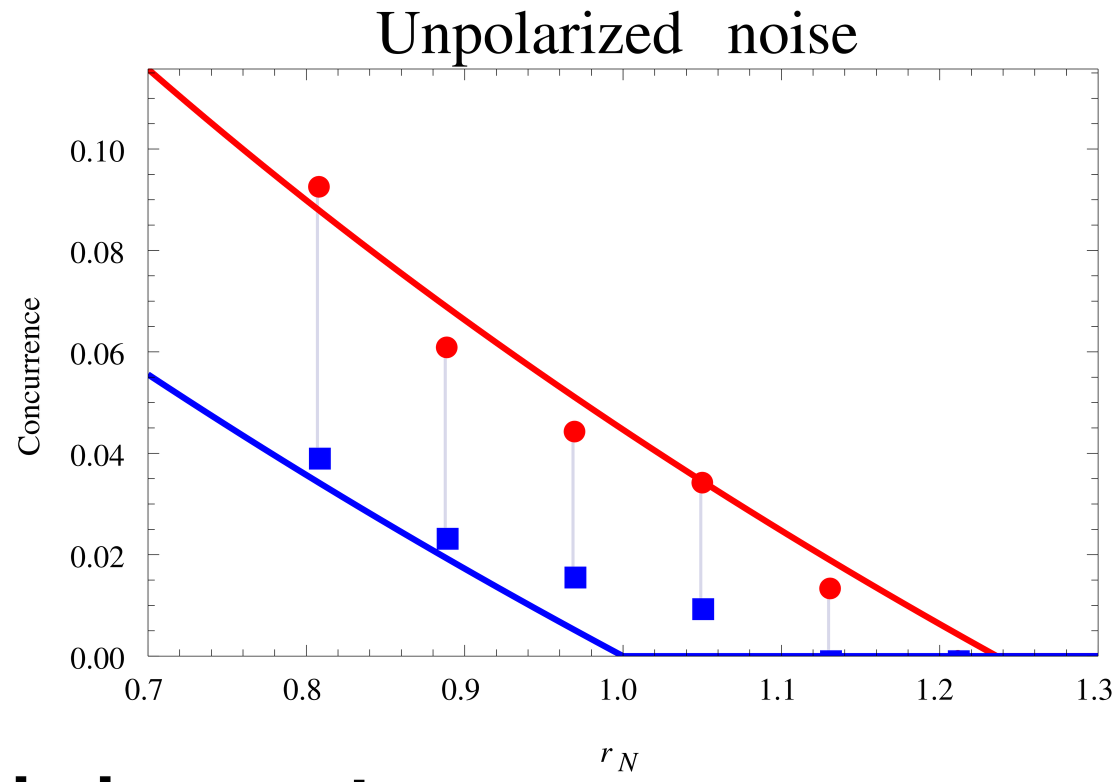


Results

● after filtration at D3

■ before filtration





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