The control of correlations of paired photons in different degrees of freedom has been of interest for its role in practical applications. In this work, we report the experimental control of the spatial correlations of paired photons and exploit this capability to study the effects of having different spatial correlations on open quantum systems and imaging procedures.

- **Experimental control**: We control the spatial correlations of paired photons produced by spontaneous parametric down conversion (SPDC) by using the waist of the pump beam as the tuning parameter.

- **Two-photon imaging**: We take advantage of the experimental capability of controlling the spatial correlations in a unique setup and observe the effects of different types of spatial correlations.

- **Open quantum system dynamics**: We propose an all-optical setup in which a pair of entangled polarization photons is coupled with their transverse momentum degree of freedom, that plays the role of a bosonic environment, to simulate an open quantum system dynamics.

We have found that controlling the initial transverse correlations, the evolution of the central system can exhibit a Markovian or non-Markovian behavior.

- **Spatial correlations on open quantum systems and imaging procedures**: The direction in which the correlation is been studied, the momentum distribution is also affected by the polarization post-selection.

### The Source: Type II Non-collinear SPDC

- **The state at the output face of the crystal**
  \[
  |\psi\rangle = \sum_{i,j} \phi_i(q_i, u_i, q_j) \phi_j(q_j, u_j, u_i) |i,j\rangle
  \]
  with polarizations \(e\) and \(s\).

- **Mode function**
  \[
  \phi_{\omega}(q_i, u_i, q_j, \Omega) = \mathcal{N} \phi_i(q_i, u_i) \phi_j(q_j, \Omega)
  \]
  \[\exp \left\{ -\frac{\lambda_0^2}{\lambda_e^2} - \left( \frac{\Delta u}{\Delta u_e} \right)^2 \right\} \]

- **Phase matching conditions**
  \[
  \Delta u = \frac{\Delta u_e}{\lambda_e^2} u_i + \frac{\Delta u_e}{\lambda_e^2} u_j
  \]
  \[
  \Delta u = \frac{\Delta u_e}{\lambda_e^2} u_i + \frac{\Delta u_e}{\lambda_e^2} u_j
  \]
  \[
  \Delta u = \frac{\Delta u_e}{\lambda_e^2} u_i + \frac{\Delta u_e}{\lambda_e^2} u_j
  \]

- **Spatial-Type-II-SPDC quantum state**
  \[
  |\psi\rangle = \sum_{i,j} \phi_i(q_i, u_i, q_j) |i,j\rangle
  \]
  \[\exp \left\{ -\frac{\lambda_0^2}{\lambda_e^2} - \left( \frac{\Delta u}{\Delta u_e} \right)^2 \right\} \]

### Mode Function and Correlation control

- **Degree of correlation**
  \[
  \sigma^2 = \frac{C^2}{\bar{C}^2}
  \]
  \[\rho_i(\xi, \phi) = \rho_i(\xi, \phi) \rho_i(\xi, \phi) \]

- **Mode function orientation**: The angle between the major axis of the biphoton ellipse and the corresponding horizontal axis.

### Lens-less Ghost Imaging

- **Propagated MF**
  \[
  \phi_{\omega}(p_x, p_y) = \int dp_x dp_y \phi_i(p_x, p_y) \phi_j(p_x, p_y) \phi_{\omega}(q_i, q_j)
  \]

- **Spatial-Type-II-SPDC quantum state**
  \[
  |\psi\rangle = \sum_{i,j} \phi_i(q_i, u_i, q_j) |i,j\rangle
  \]

### Quantum Dynamic - Markovian vs non-Markovian

- **Horizontal Biphoton as an initial system-environment state**: Coaxialing

- **Reduced polarization density matrix**
  \[
  \rho = \text{tr}_{W} \left( \phi_i(q_i, u_i, q_j, \Omega) \phi_j(q_j, \Omega) \right)
  \]

- **Purity and Purification**
  \[
  \mathcal{P}_{\rho} = \frac{1}{2} \text{tr} \left( \rho^2 \right)
  \]

- **Trace distance evolution**
  \[
  D_{\rho, \rho_{0}}(\tau) = 2 \text{tr} \left( \sqrt{\rho_{0} \rho} \right)
  \]

### Final Remarks

- **We have experimentally showed here DOC and orientation of MF exhibit different behaviors depending on the pump beam waist and the direction in which the correlation is been studied. The momentum distribution is also affected by the polarization post-selection.**

- **We conclude that controlling the initial correlations, the evolution of the central system can exhibit a Markovian or non-Markovian behavior, indicating a non-local quantum memory effect that allows to recover the purity (and entanglement) in the central system when the has been degraded by local interactions.**

### References


