Universidad de los Andes Colombia

Grupo de investigacion de óptica cuántica
Facultad de ciencias | Departamento de física

Controlling and coupling different degrees of freedom of light to study quantum dynamics

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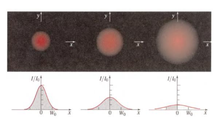
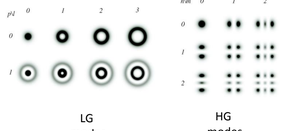
Introduction

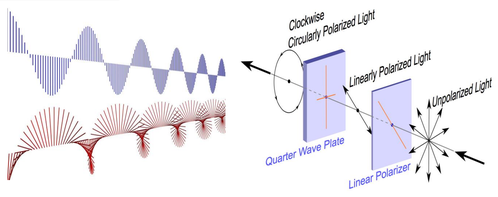
Light has different degrees of freedom of light

Position – Transverse momentum

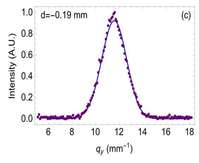




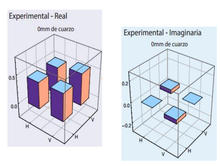
Polarization



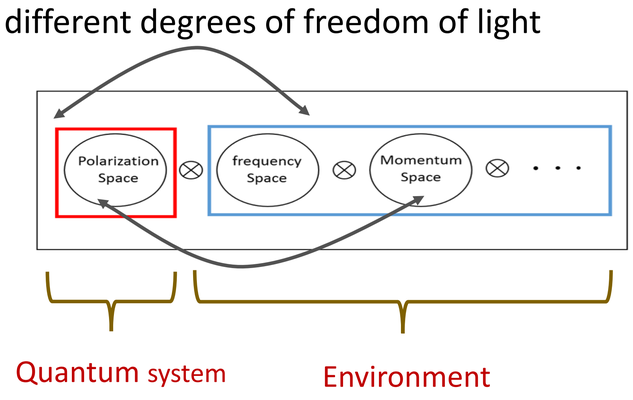
$|f(q)|^2$ Laser — 2-f system



$|\varphi\rangle = \alpha|H\rangle + \beta|V\rangle$ Laser — HWP - QWP



To study quantum dynamics
by coupling different degrees of freedom of light

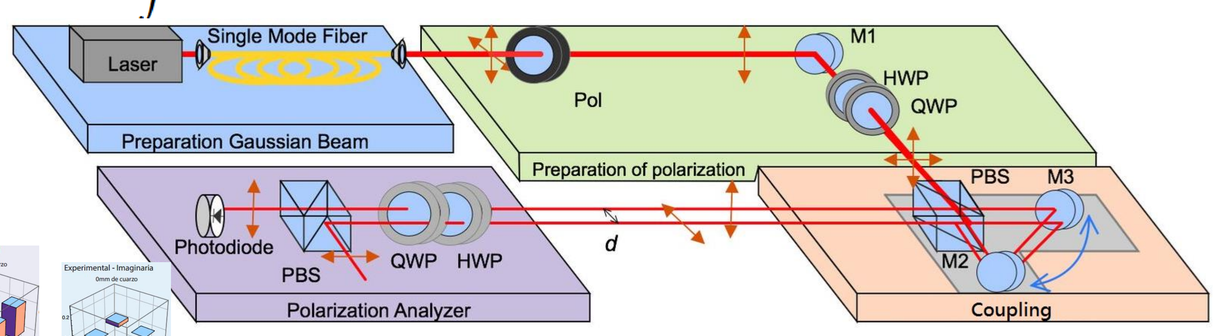


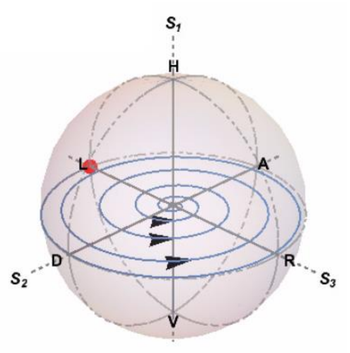
Studying quantum dynamics with polarization and transverse momentum

Dynamics
$t \rightarrow y$

$|\chi\rangle = \int dq f(q)|q\rangle$

$|\varphi\rangle = \alpha|H\rangle + \beta|V\rangle$





Dephasing channel

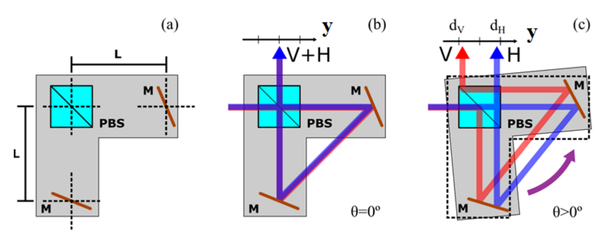
$$\hat{\rho}(y) = \begin{pmatrix} |\alpha|^2 & \alpha\beta^*\kappa(y) \\ \alpha^*\beta\kappa^*(y) & |\beta|^2 \end{pmatrix}$$

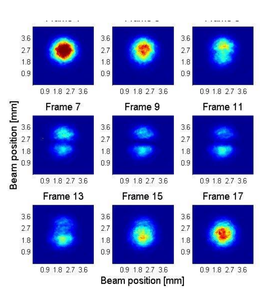
$$\kappa(y) = \int dq |f(q)|^2 e^{i2qy}$$

Time evolution

$$|\psi(y)\rangle = \hat{U}(y)|\psi(0)\rangle$$

Coupling polarization with environment





L. J. Salazar Serrano, A. Valencia, and J. P. Torres, "Tunable beam displacer", Rev. Sci. Instrum. **86**, 033109 (2015).

Experimental Results

Stokes Parameters

$$S_0 = |U_0|^2(|\alpha|^2 + |\beta|^2),$$

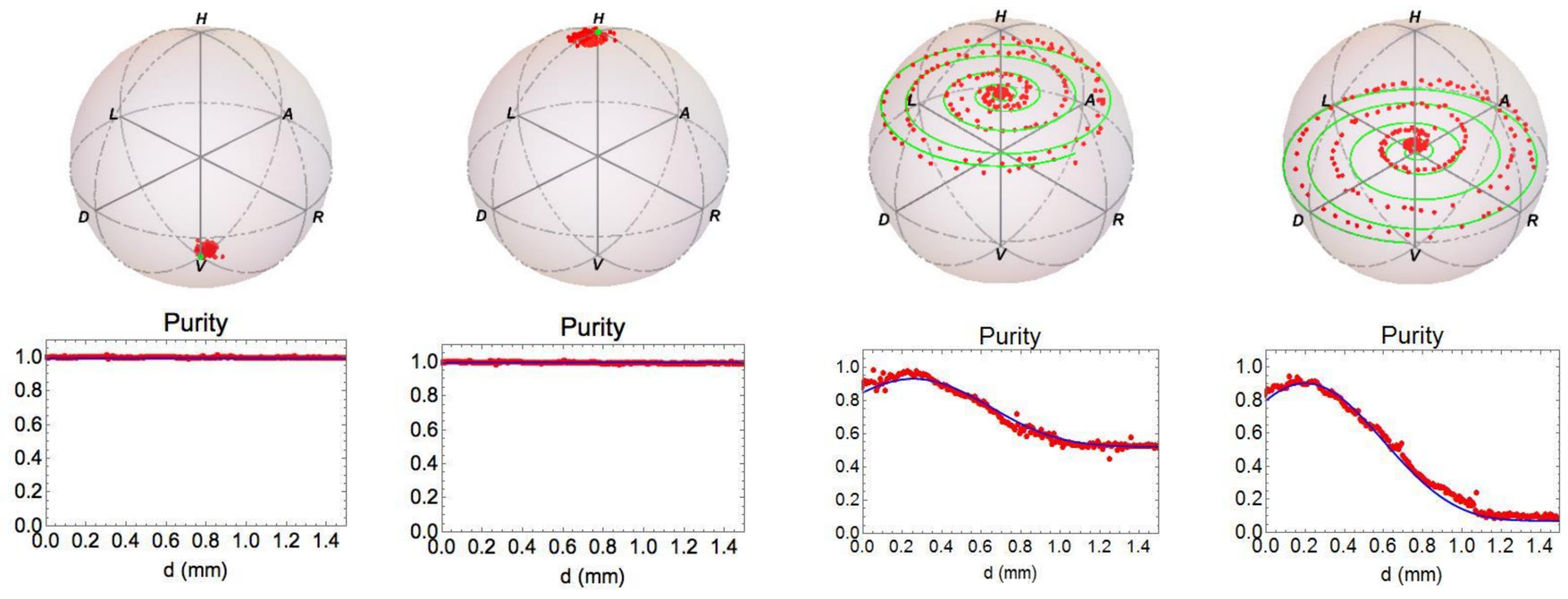
$$S_1 = |U_0|^2(|\alpha|^2 - |\beta|^2),$$

$$S_2(d) = 2|U_0|^2|\alpha\beta^*|e^{-\frac{d^2}{8w^2}}\cos(-q_{oy}d + \varphi)$$

$$S_3(d) = 2|U_0|^2|\alpha\beta^*|e^{-\frac{d^2}{8w^2}}\sin(-q_{oy}d + \varphi)$$

Purity of the State

$$P(d) = \sqrt{(|\alpha|^2 - |\beta|^2)^2 + 4|\alpha\beta^*|^2 e^{-\frac{d^2}{4w^2}}}$$

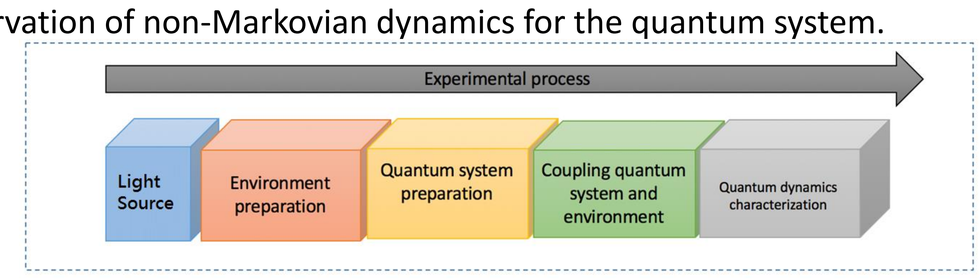


Conclusions

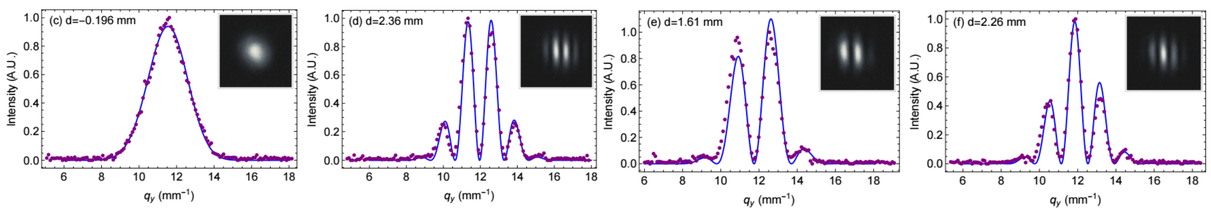
- Starting from a known state, it was possible to generate any polarization state either in the surface or inside the Bloch sphere.
- The possibility to have polarization states inside the Bloch sphere (low purity) is a clear indication that a controllable decoherence process is taking place in our setup. In particular, by observing the evolution of the polarization purity in the poles and Equator of the Bloch sphere, we can conclude that in our experimental setup the decoherence corresponds to the one induced by a dephasing channel.
- From the behavior observed in the Bloch sphere, we can conclude that the dynamics of our system is Markovian.

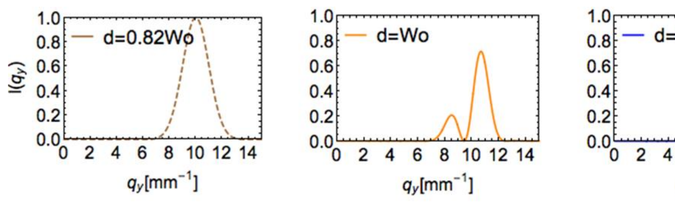
Perspectives

Observation of non-Markovian dynamics for the quantum system.



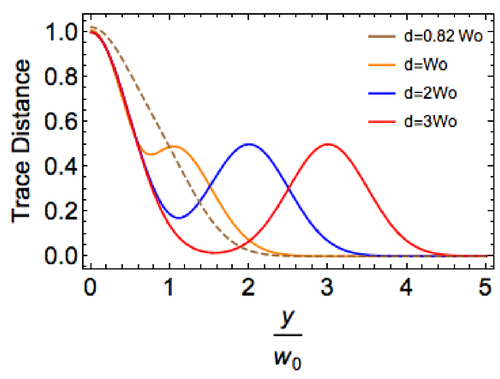
Environment preparation $|f(q)|^2$





Trace Distance

$$D(\hat{\rho}_1(y), \hat{\rho}_2(y)) = \frac{1}{2}\mathrm{Tr}\{|\hat{\rho}_1(y) - \hat{\rho}_2(y)|\}$$



J. Flórez, J. R. Alvarez , O. Calderón-Losada, L.J. Salazar-Serrano and A. Valencia. "Interference of two pulse-like spatial beams with arbitrary transverse separation". Accepted for Journal of Optics
B.-H. Liu, L. Li, Y.-F. Huang, C.-F. Li, G.-C. Guo, E.-M. Laine, H.-P. Breuer, and J. Piilo, Nature Physics **7**, 931 (2011).