Two–photon interference with two (and only two) independent photons

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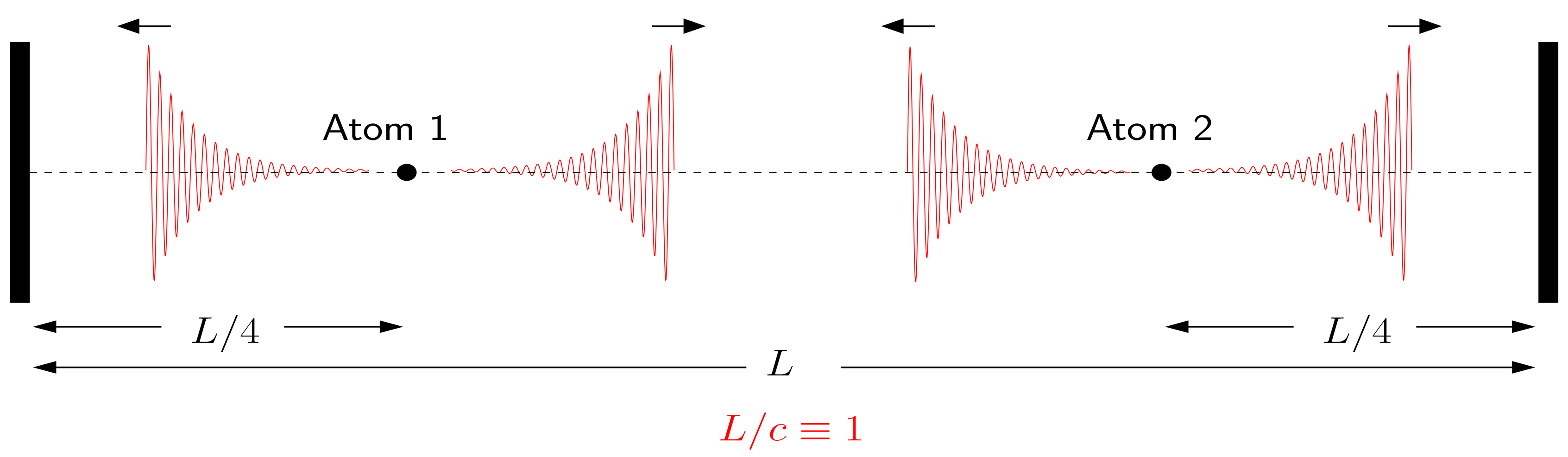
A new take on some old quantum optics



Localized Spontaneously Emitted Quantum Fields (Photons)

vs.

Classical Fields From Random Phase Dipole Oscillators

Initial State: Two Excited Atoms

Interference/Correlation in Regions of Field Overlap?

Model Features:

- "Modes of the universe" (1-D); Quantized standing wave modes
- Multiple modes (201) $\longrightarrow$ quasi-continuum
- Spontan. emission via interaction with multiple empty modes.
- Schrödinger picture.
- $\longrightarrow$ "Localized" photons.

Basis States:

$\lvert e\,e;0\rangle$:	both atoms excited, no photons
$\lvert e\,g;1_k\rangle$:	atom 1 excited, atom 2 in g.s., 1 photon (mode k)
$\lvert g\,e;1_k\rangle$:	atom 1 in g.s. atom 2 excited, 1 photon (mode k)
$\lvert g\,g;1_k,1_{k'}\rangle$:	both atoms in g.s., 2 photons in distinct modes
$\lvert g\,g;2_k\rangle$:	both atoms in g.s., 2 photons in same mode

Initial State: $\lvert\psi(0)\rangle = \lvert e\,e;0\rangle$

Time-Dependent State:

$$\begin{aligned}\lvert\psi(t)\rangle &= a(t)\lvert e\,e;0\rangle + \sum_k b_{1k}(t)\lvert e\,g;1_k\rangle + \sum_k b_{2k}(t)\lvert g\,e;1_k\rangle \\ &\quad + \sum_{k,k'<k} c_{k,k'}(t)\lvert g\,g;1_k,1_{k'}\rangle + \sum_k d_k(t)\lvert g\,g;2_k\rangle\end{aligned}$$

Hamiltonian: Two-level atoms, RWA, multimode.

$$\begin{aligned}H &= H_{\text{atoms}} + H_{\text{field}} + H_{\text{interaction}} \\ &= \hbar\omega_{eg}^{(1)}\sigma_3^{(1)} + \hbar\omega_{eg}^{(2)}\sigma_3^{(2)} + \sum_k \hbar\omega_k\left(a_k^\dagger a_k + \frac{1}{2}\right) \\ &\quad + \sum_k \hbar\left(\Omega_1\sigma_+^{(1)}a_k + \Omega_1^*\sigma_-^{(1)}a_k^\dagger\right)\sin\left[(k_0+k)\frac{\pi x_1}{L}\right] \\ &\quad + \sum_k \hbar\left(\Omega_2\sigma_+^{(2)}a_k + \Omega_2^*\sigma_-^{(2)}a_k^\dagger\right)\sin\left[(k_0+k)\frac{\pi x_2}{L}\right],\end{aligned}$$

Intensity

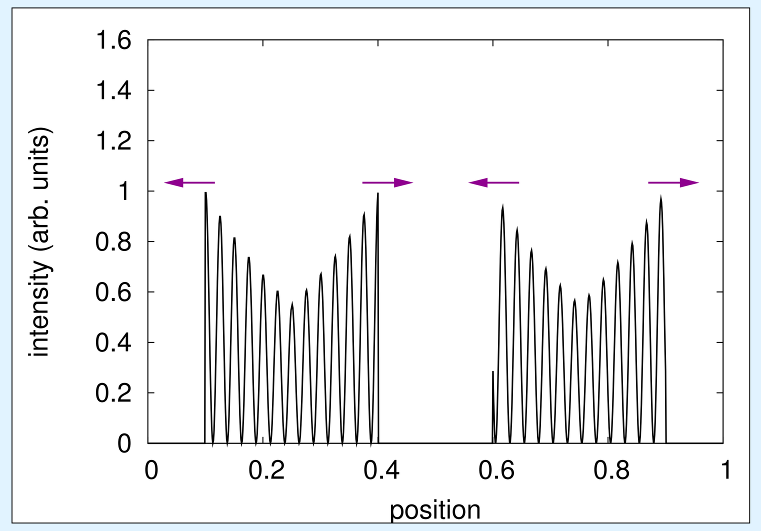
Classical Field

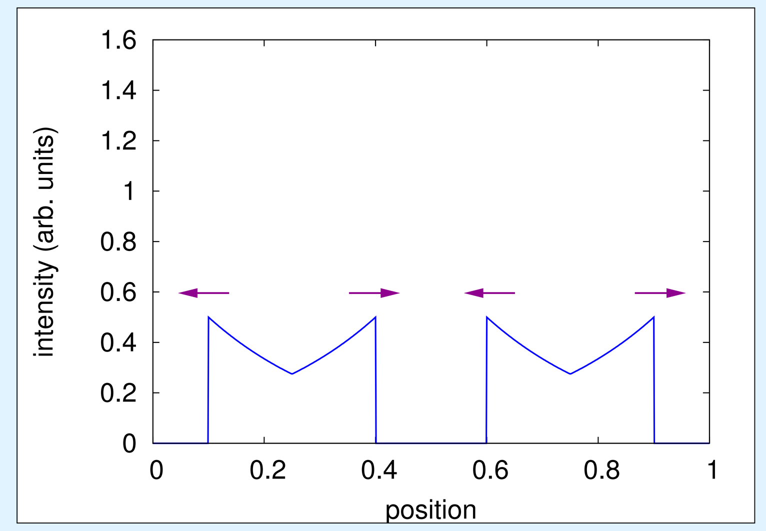
Instantaneous

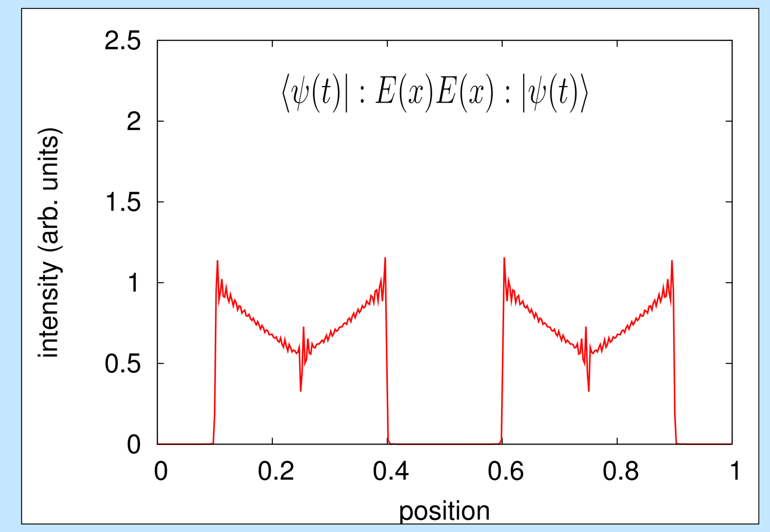
Avg. Over Optical Cycle and Phases

Quantum Field

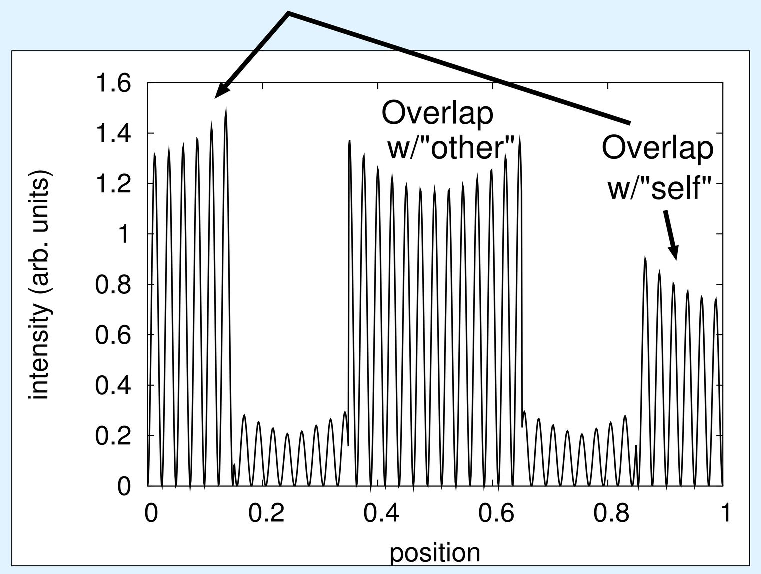
$t = 0.15$
No overlap

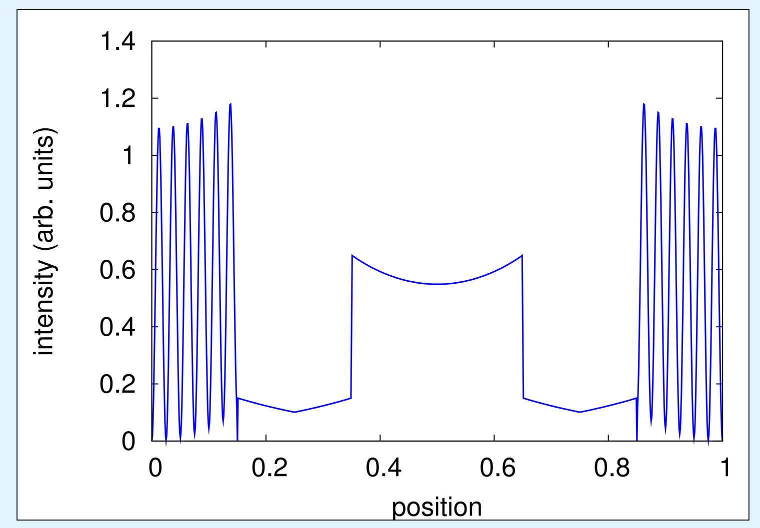


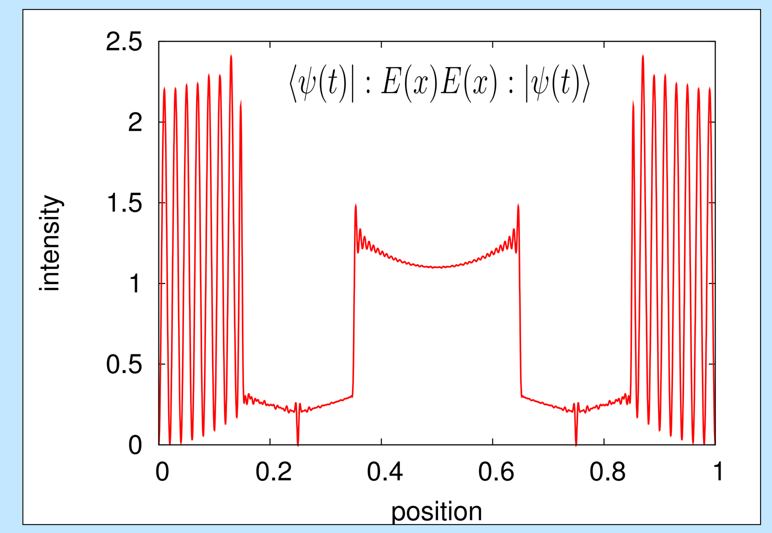




$t = 0.4$
Overlap







Spatial Intensity Correlation at $t = 0.45$

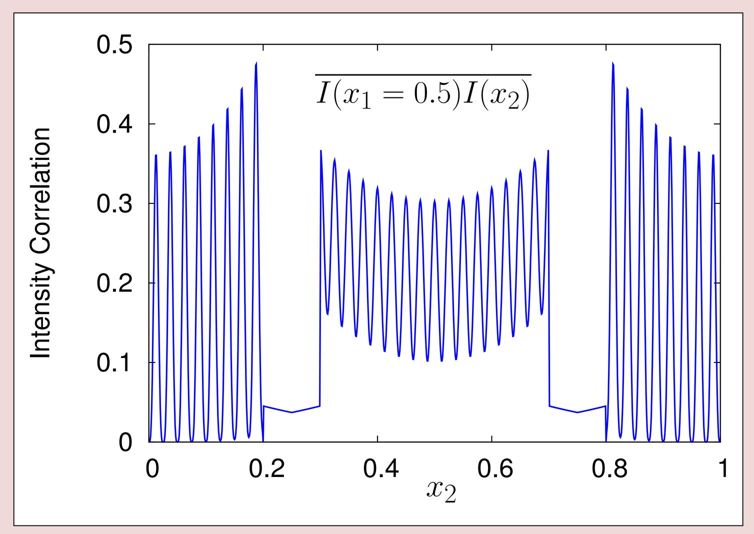
Classical Field

Avg. Over Optical Cycle and Phases

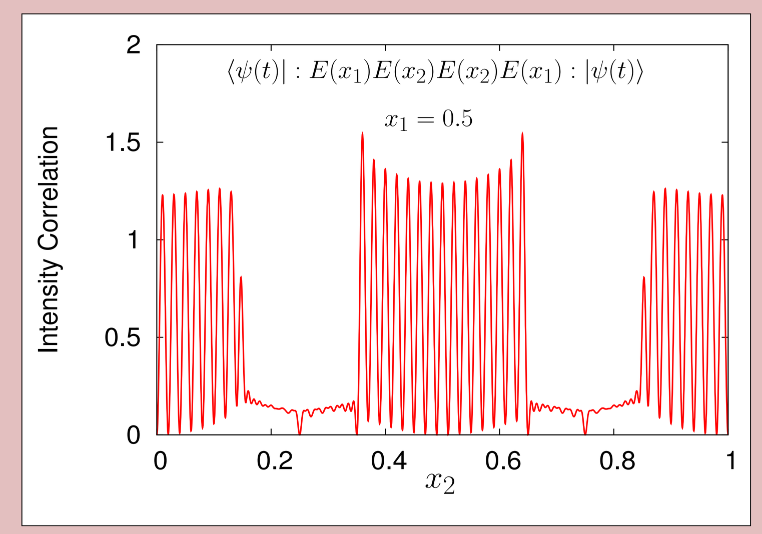
Quantum Field

$\boldsymbol{x_1 = 0.5}$ (Fixed)

Correlation as a function of $\boldsymbol{x_2}$

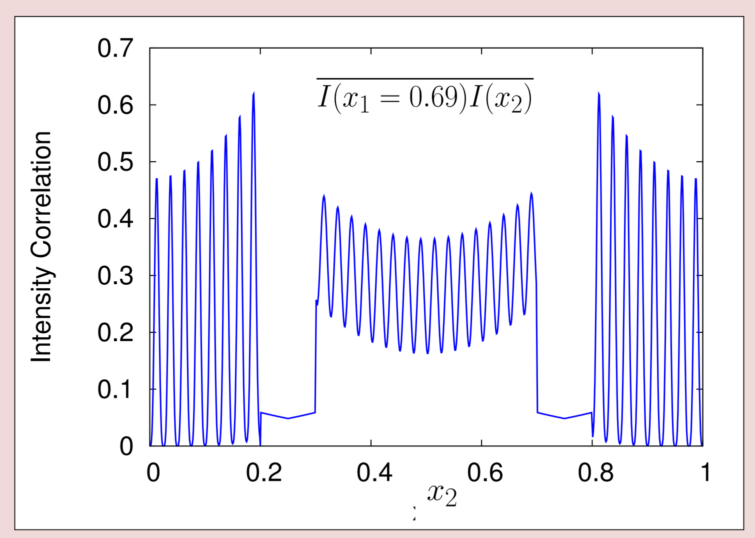


Classical vs. Quantum:
Interference in Both
Modulation Depths Differ



$\boldsymbol{x_1 = 0.69}$ (Fixed)

Correlation as a function of $\boldsymbol{x_2}$



Classical vs. Quantum:
Interference in Both
Modulation Depths Differ
& Different Shapes
Quantum amplitudes add;
Intensities don't.