2nd Order Coherence

1. Degree of second order coherence
2. Classical view: Time-domain
3. Quantum view: Coincidence measurements
4. Thermal Light vs. Laser Light
5. Coherence of atomic sources
**Definition:**

\[ g^{(2)}(\tau) = \frac{\langle I(t) \cdot I(t + \tau) \rangle}{\langle I(t) \rangle \langle I(t + \tau) \rangle} = \frac{\langle I(t) \cdot I(t + \tau) \rangle}{\langle I(t) \rangle^2} \]

It measures **correlations in the intensity** of the light, instead of in the electric field.
Random Phase Chaotic Light Source (Lorentzian)

[computer simulation, from Quantum Theory of Light, by R. Loudon (2000)]
Gaussian Spectrum Chaotic Light Source

[computer simulation, from Quantum Theory of Light, by R. Loudon (2000)]
Quantum $g^{(2)}(\tau)$: single-photon detection

If you can detect single photons (i.e. PMT or avalanche photodiode), then for very low light levels

$$g^{(2)}(\tau) = \frac{\langle I(t) \cdot I(t+\tau) \rangle}{\langle I(t) \rangle^2} = \frac{\langle n_1(t) \cdot n_2(t+\tau) \rangle}{\langle n_1(t) \rangle \cdot \langle n_2(t+\tau) \rangle}$$

[figure adapted from Quantum Theory of Light, by R. Loudon (2000)]
Quantum $g^{(2)}(\tau)$: single-photon detection

If you can detect single photons (i.e. PMT or avalanche photodiode), then for very low light levels

$$g^{(2)}(\tau) = \frac{\langle I(t) \cdot I(t+\tau) \rangle}{\langle I(t) \rangle^2} = \frac{\langle n_1(t) \cdot n_2(t+\tau) \rangle}{\langle n_1(t) \rangle \cdot \langle n_2(t+\tau) \rangle} \propto P(t+\tau | t)$$

[figure adapted from Quantum Theory of Light, by R. Loudon (2000)]
Thermal photons exhibit “bunching” at short correlation times

Thermal wave-particles

random classical particles

G²(τ)

COUNTS/min.

84

80

76

72

INTerval τ₁ in n sec.

1 2 3 4 5 6

LORENTZIAN SPECTRUM with Δν ≈ 200 Mc/s

[Figure from Morgan & Mandel, Phys. Rev. 16, 1012 (1966).]
Laser light exhibit NO “bunching”.

\[ g^2(\tau) = 1 \]
Thermal bosonic atoms are statistically identical to thermal photons !!!

[figure from A. Öttl, S. Ritter, M. Köhl, T. Esslinger, Phys. Rev. Lett. 95, 090404 (2005)]
In a **Bose-Einstein Condensate (BEC)** all the atoms are in the same state. It is the analog of a laser but with atoms (coherent matter waves).

Atoms in a BEC are statistically identical to laser photons !!!

[figure from A. Öttl, S. Ritter, M. Köhl, T. Esslinger, Phys. Rev. Lett. 95, 090404 (2005)]