# 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

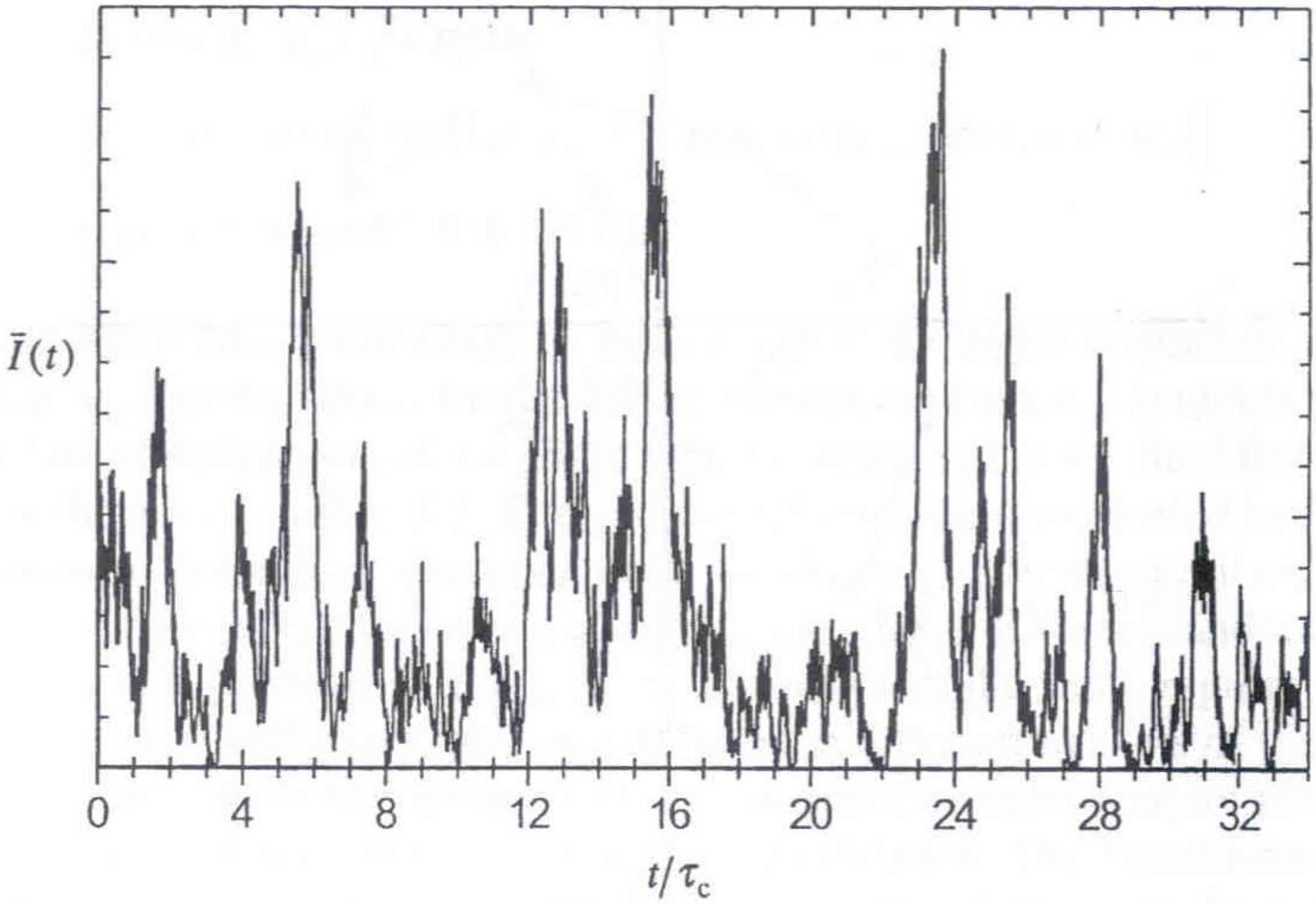
# $g^{(2)}(\tau)$
## *2nd order correlation function*

Definition:

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

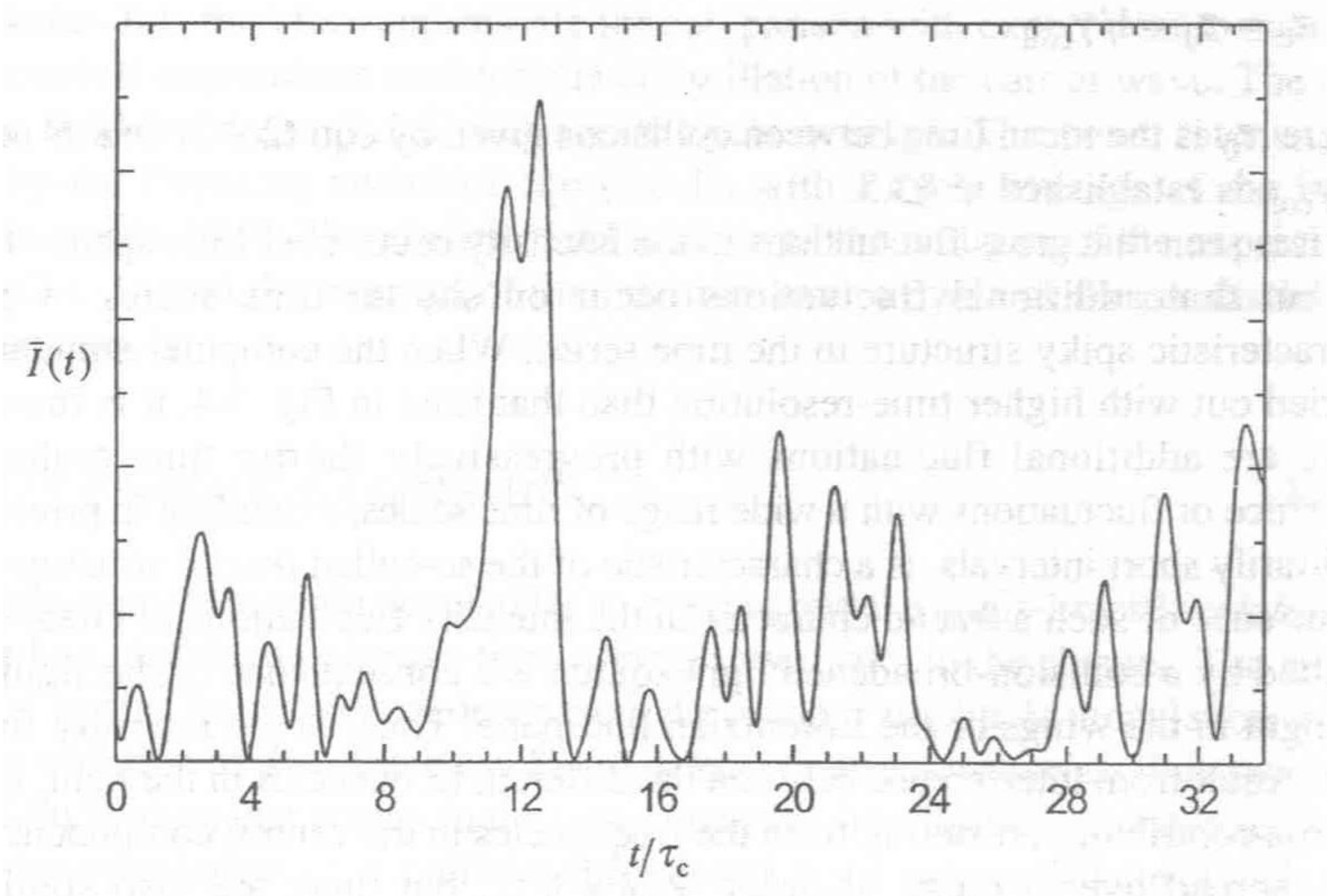
It measures **correlations in the intensity** of the light, instead of correlations in the electric field.

# Random Phase Chaotic Light Source *(Lorentzian)*




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

# Gaussian Spectrum Chaotic Light Source

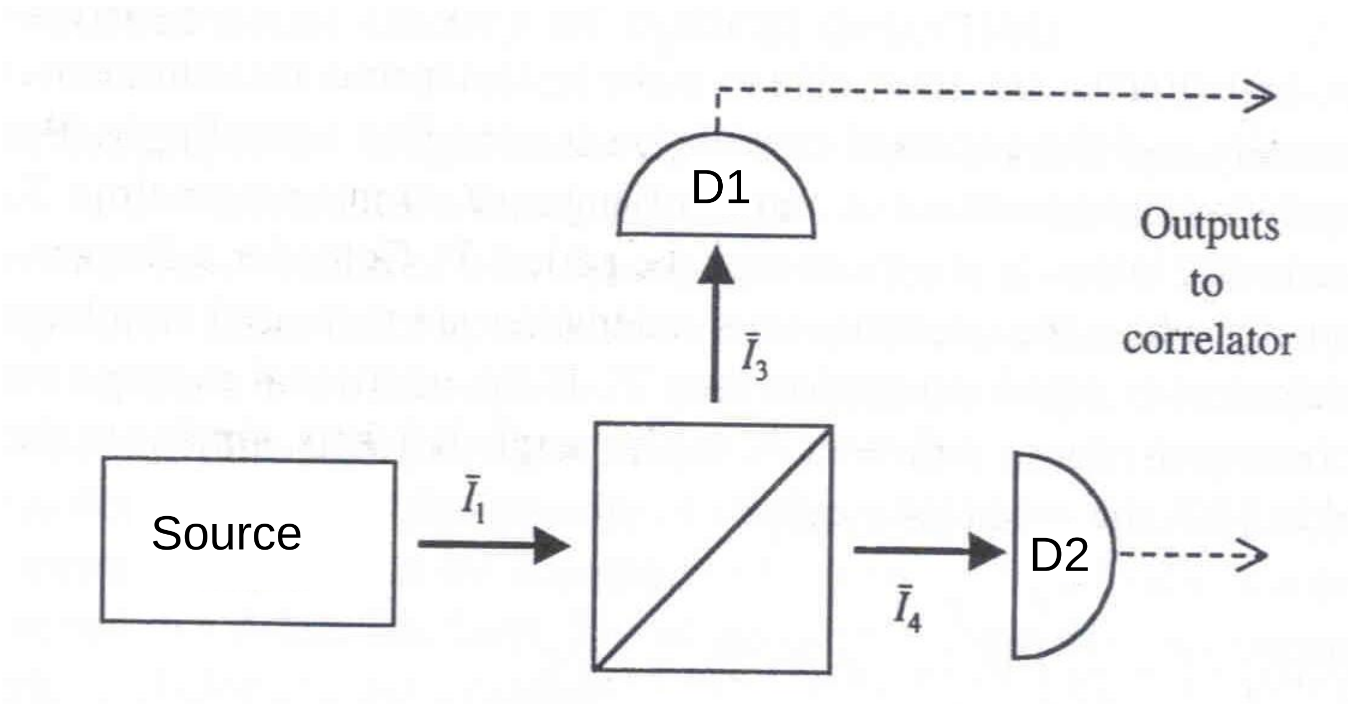



[computer simulation, from Quantum Theory of Light, by R. Loudon (2000)]

# 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)]

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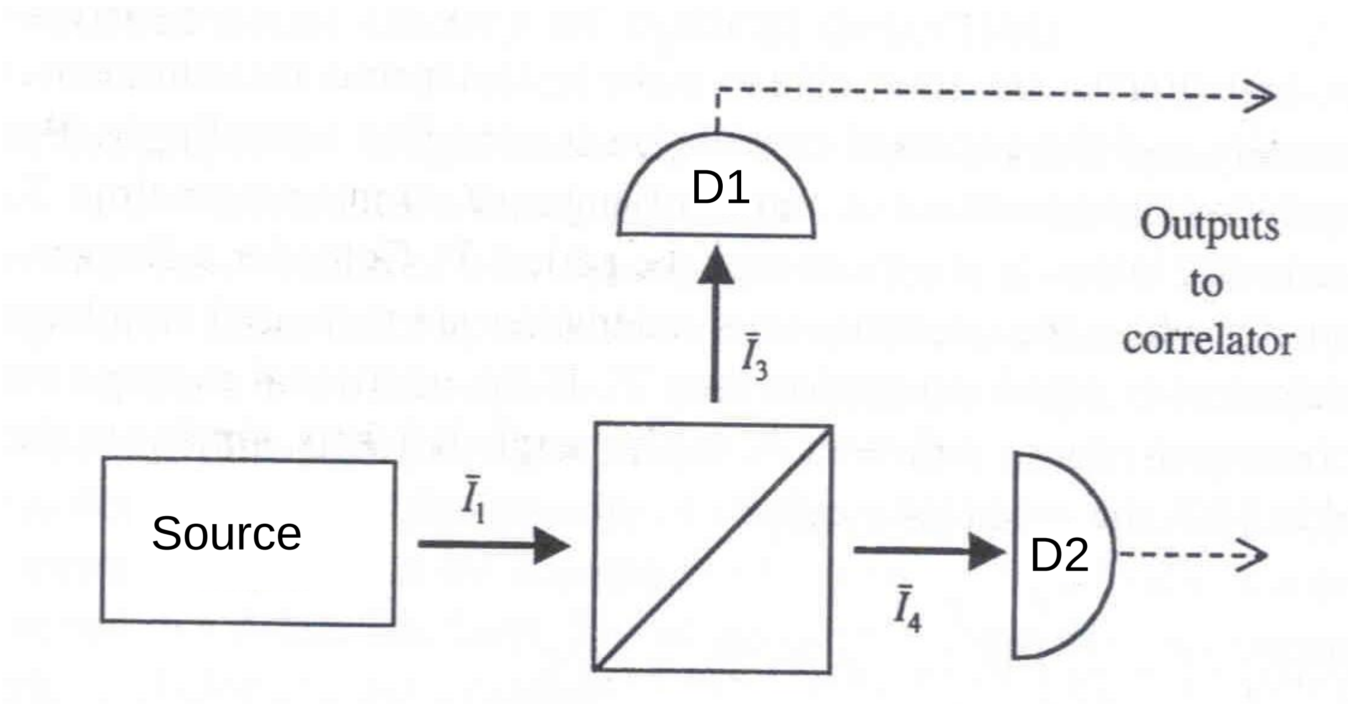
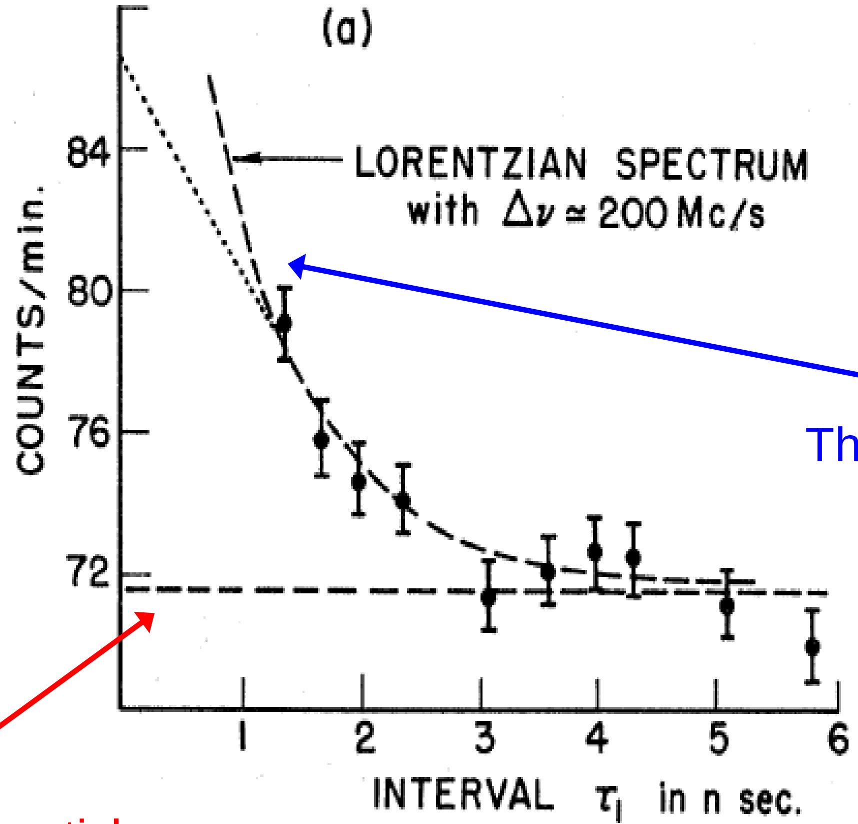
$$\propto \mathrm{P}(\mathrm{t}+\tau \,|\, \mathrm{t})$$




[figure adapted from Quantum Theory of Light, by R. Loudon (2000)]

# Thermal Photons




$G^2(\tau)$

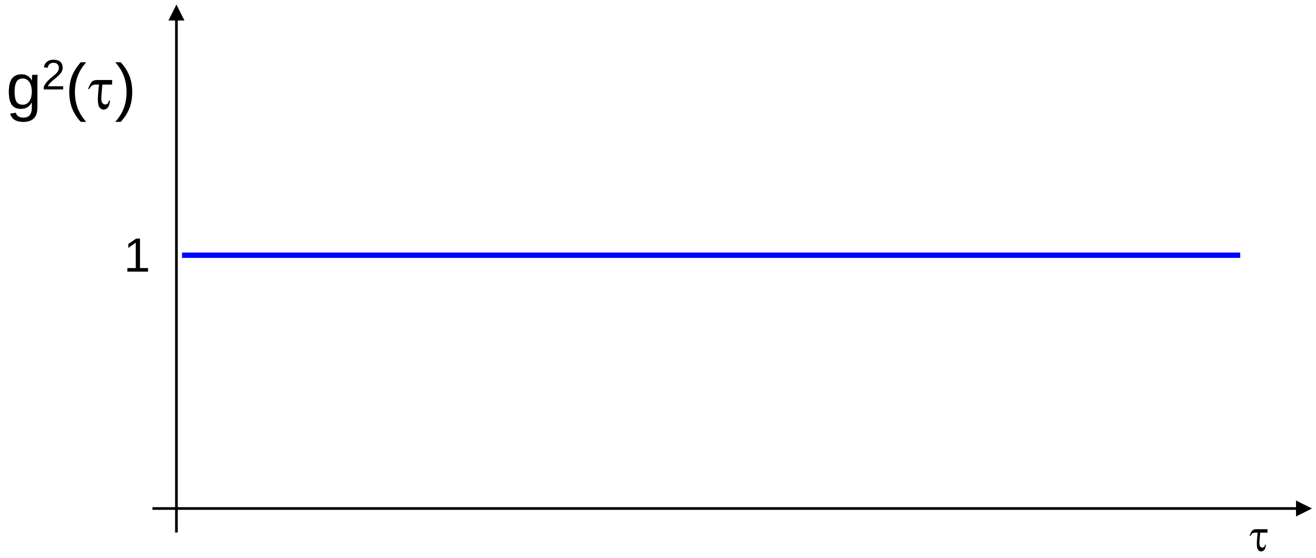
Thermal wave-particles

random classical particles

Thermal photons exhibit “bunching” at short correlation times

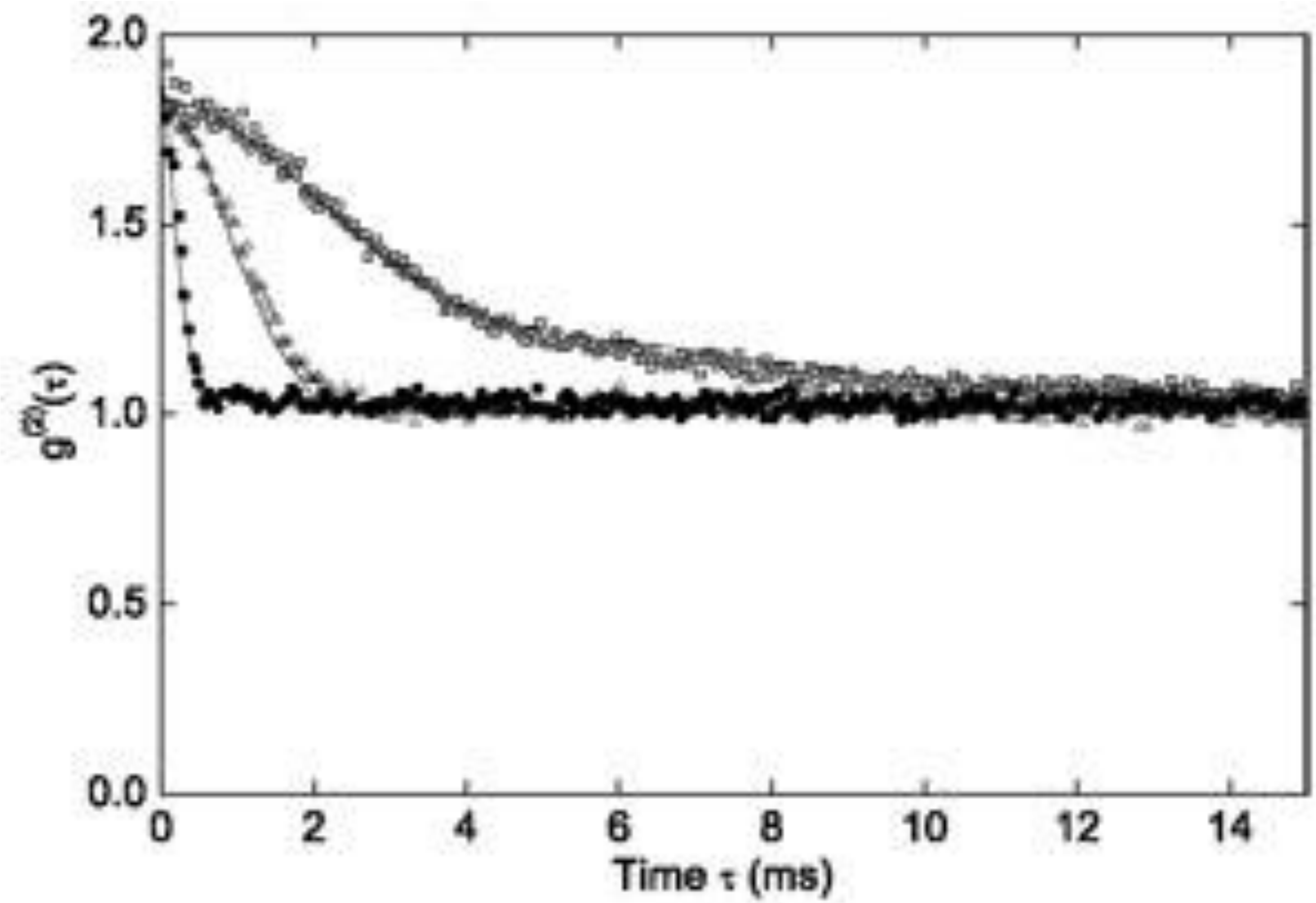
[Figure from Morgan & Mandel, Phys. Rev. 16, 1012 (1966).]

# Laser light




Laser light exhibit NO “bunching”.

# Thermal Bosonic Atoms

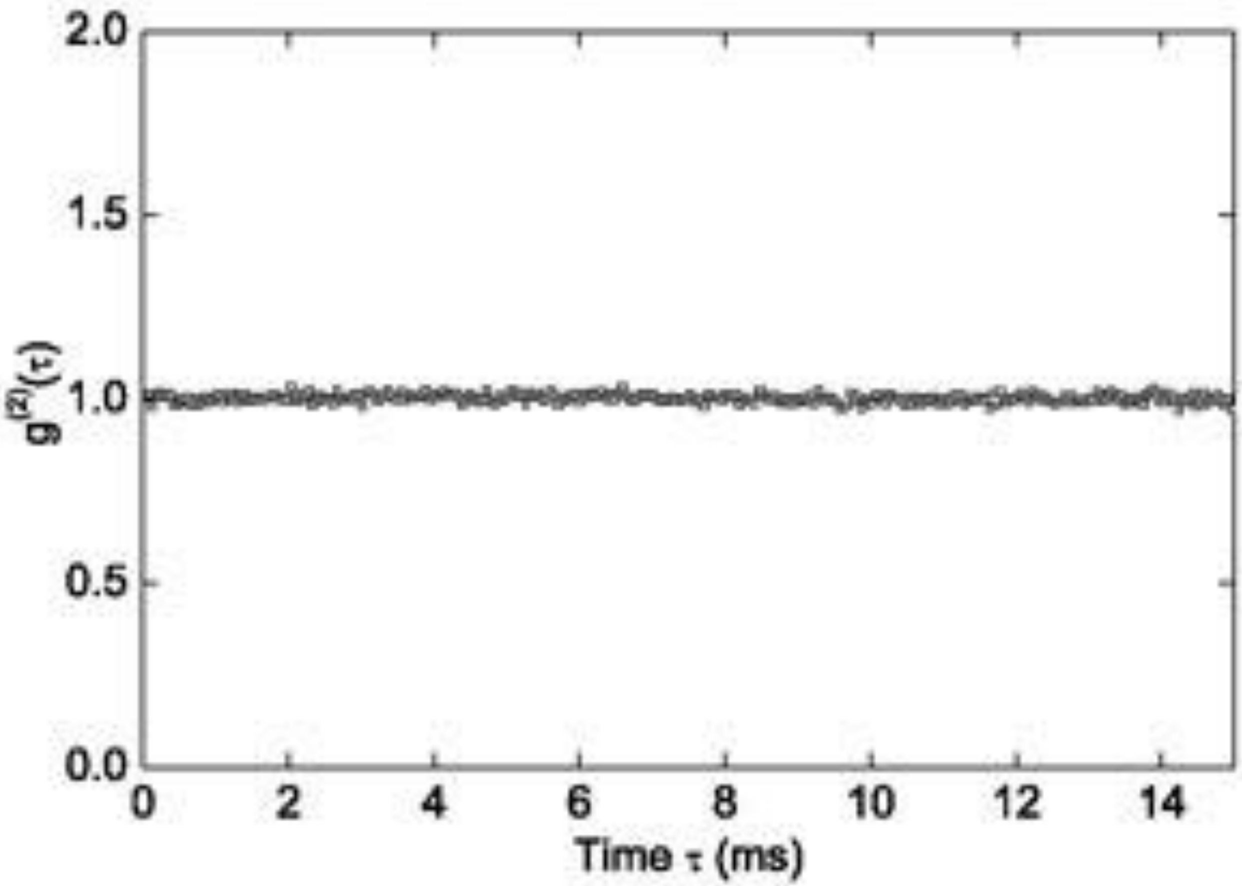



Thermal bosonic atoms are statistically identical to thermal photons !!!

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

# Coherent Bosonic Atoms (BEC)

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)]