Photon Statistics

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Motivation

Measuring the diameter of a star:

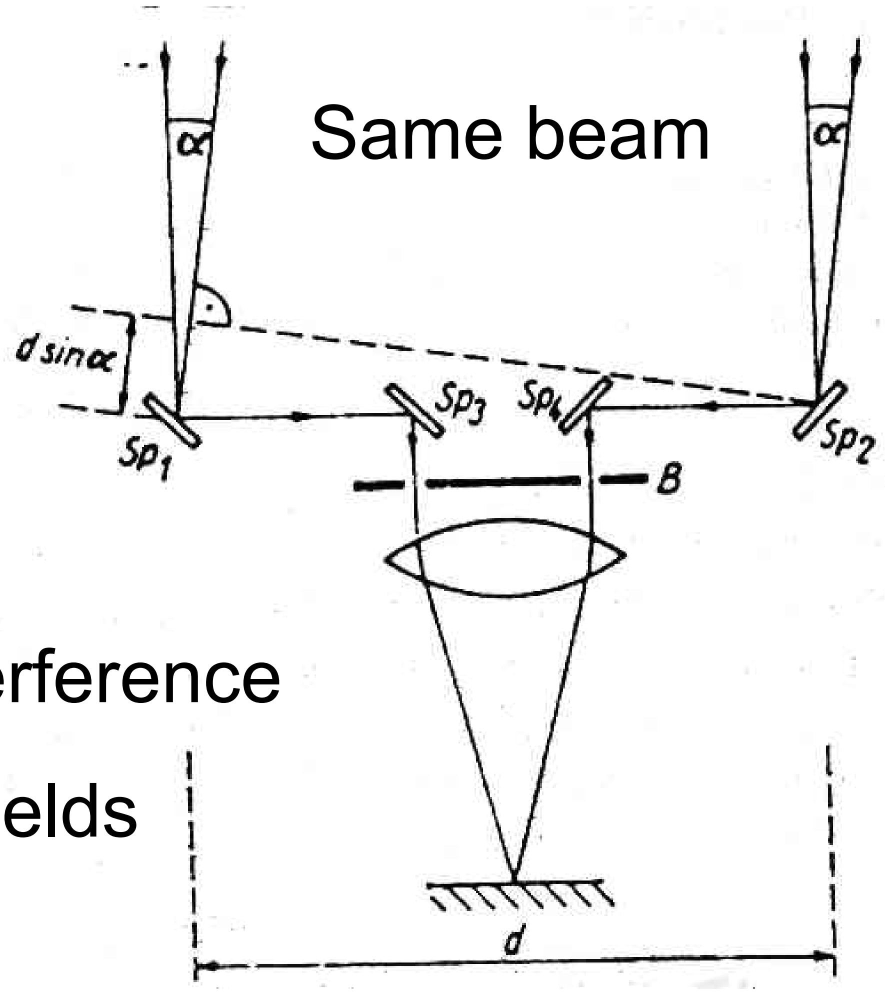
Michelson Stellar Interferometer

$\lambda \approx d_{coh}\, \alpha$

Same beam

Problem:

phase fluctuations



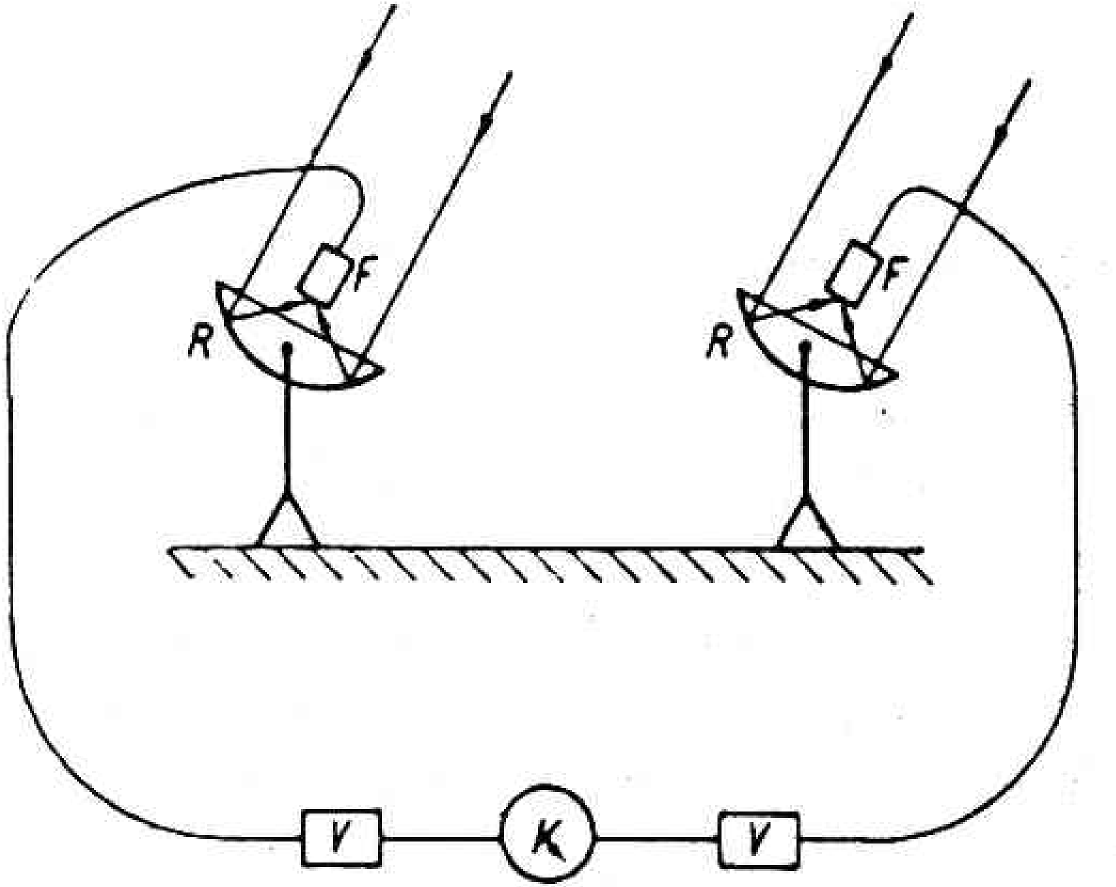
Interference

of fields

H. Paul, Photonen, Teubner 1995

Motivation

Hanbury Brown and Twiss Interferometer



Intensity

→ Photon statistics

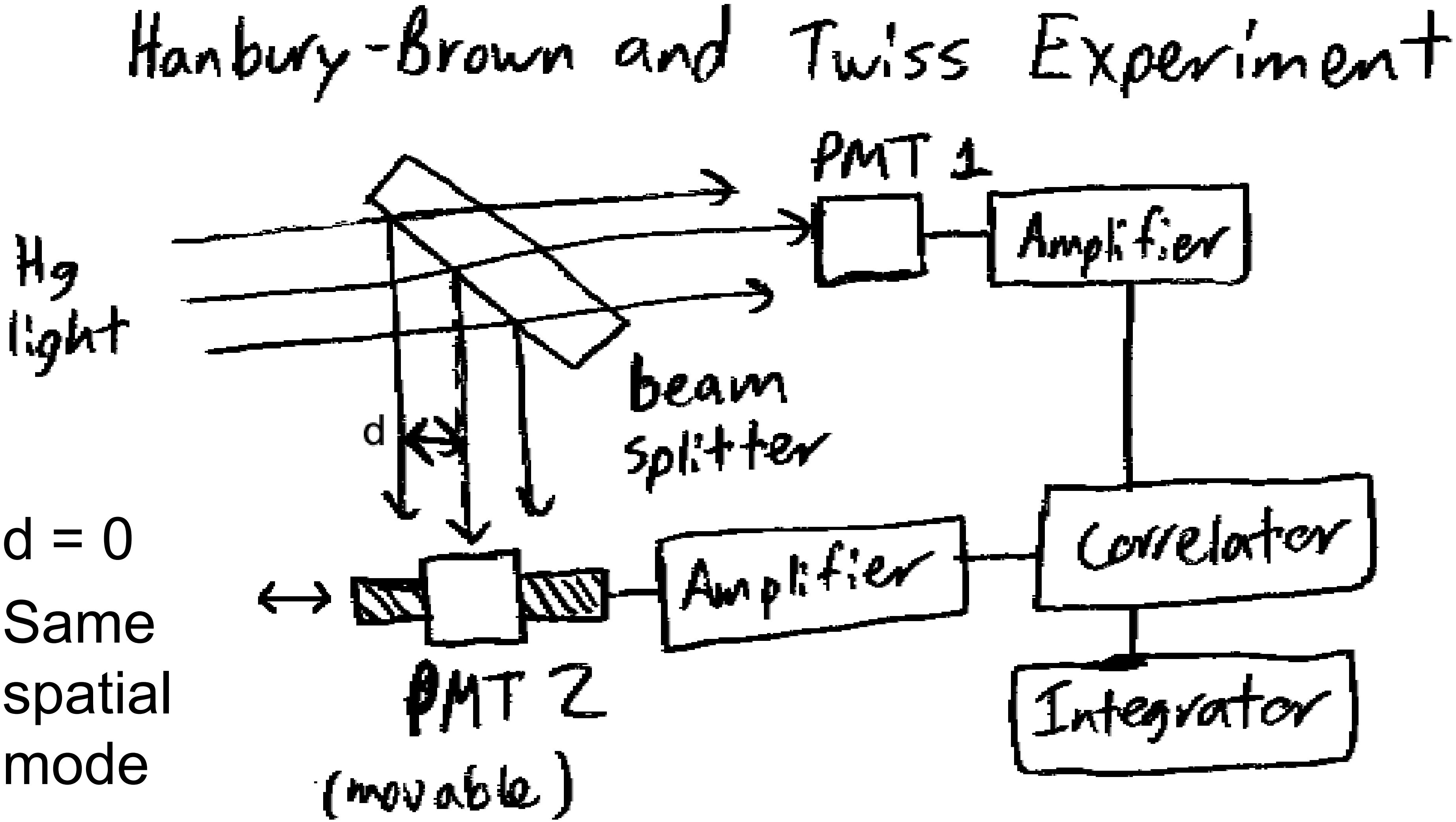
H. Paul, Photonen, Teubner 1995

Outline

- First glance on coherence: HBT experiment 1956
- Characterization of Light: 1965
- Bunching: 1966
- Antibunching: 1977

Coherence: HBT experiment

Lab experiment:



d = 0

Same spatial mode

HBT experiment

Results:

- Positive normed correlation in all cases
- This correlation disappeared for $d \geq d_{coh}$

HBT experiment

Conclusions:

- Photoelectric emission preserves correlation
- Photons in coherent thermal light correlated more than random
- Setup for measurement of photon statistics

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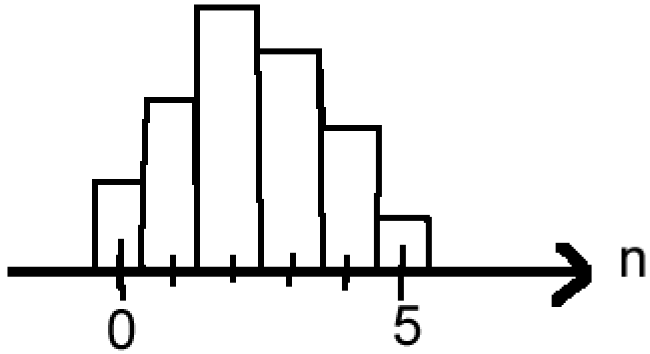
Characterization of Light

Different light source

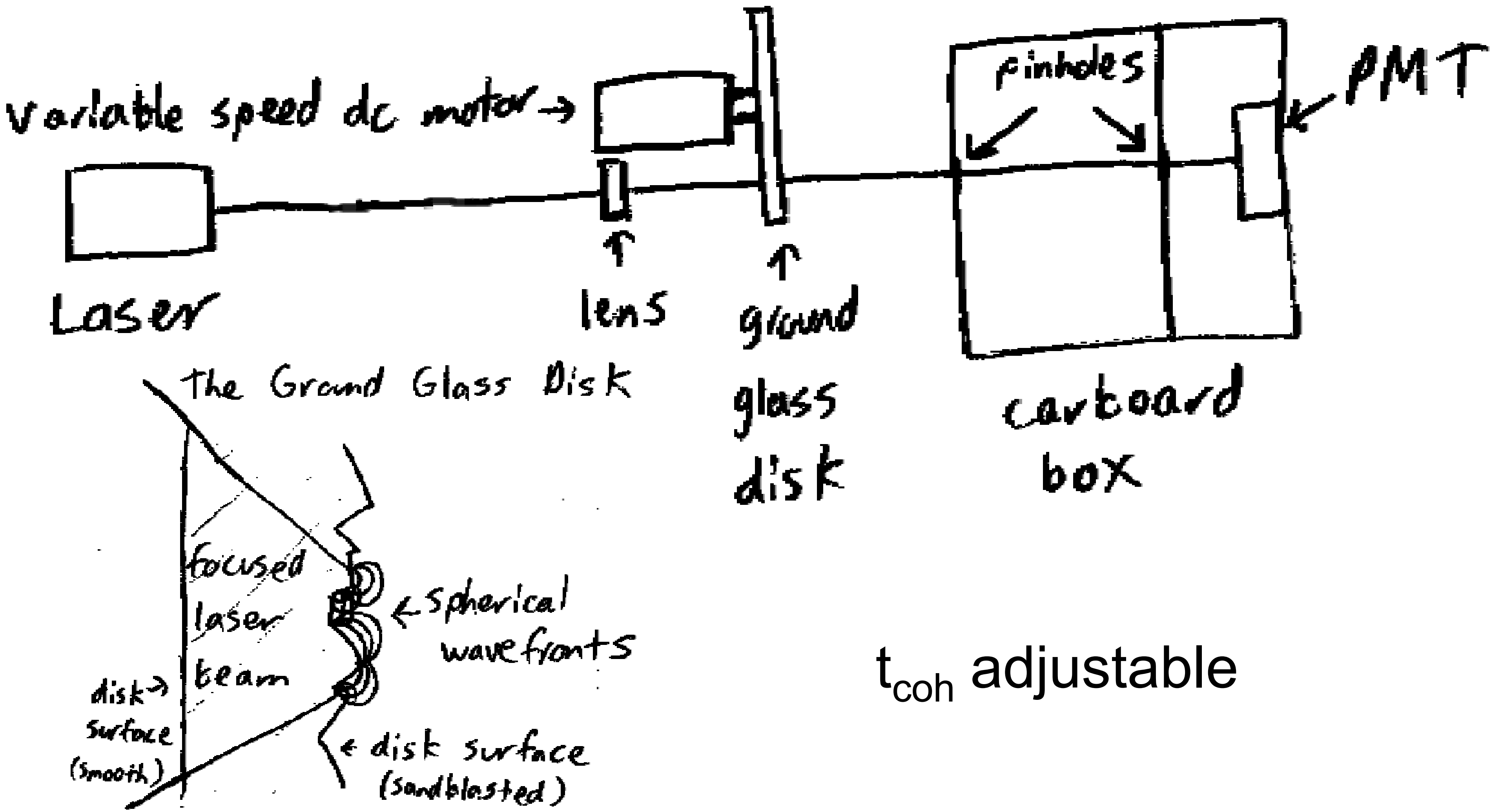
→ different photon statistics



$$T \leq t_{coh}$$

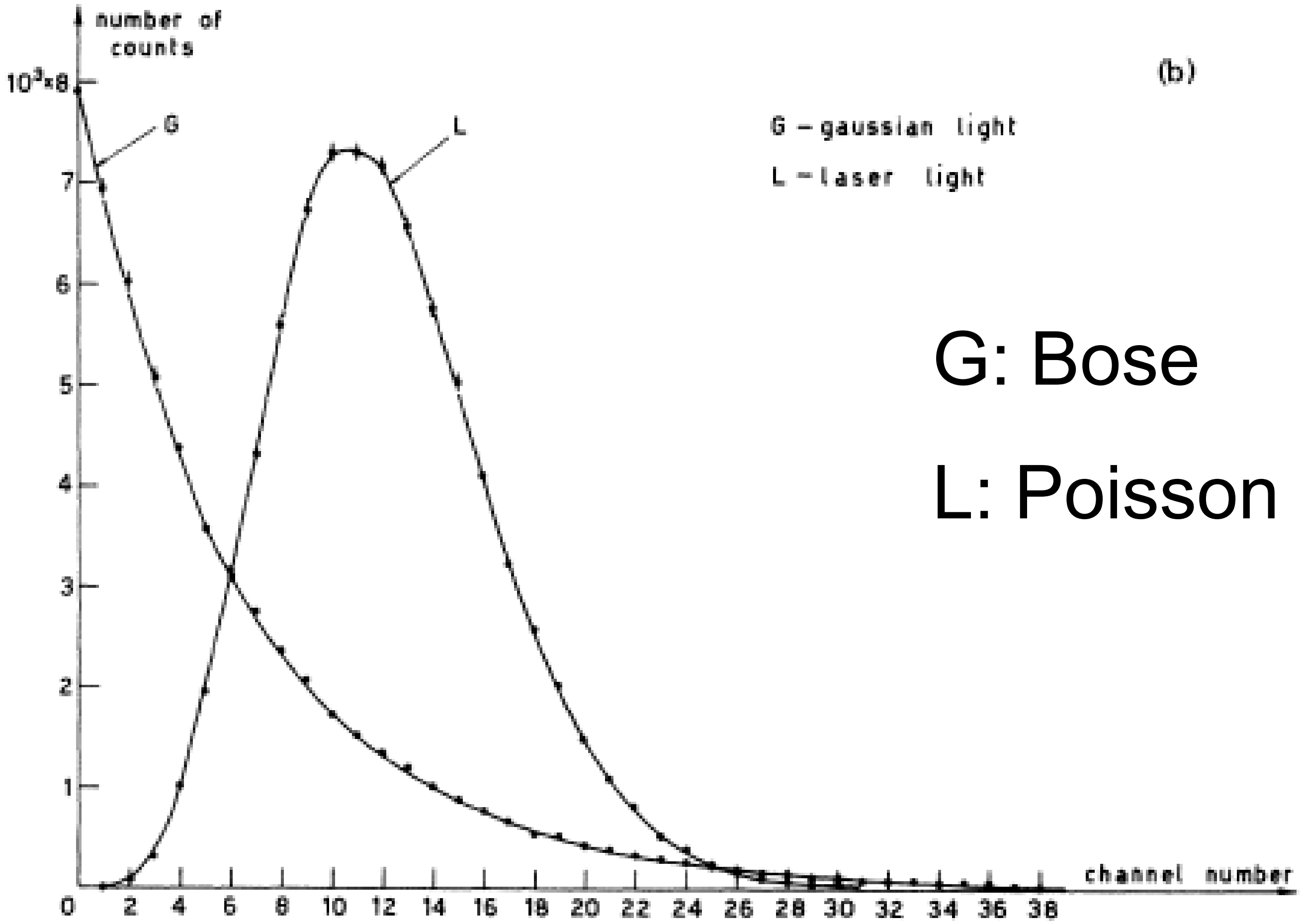
Characterization of Light

Generation of quasi-thermal light:



t_{coh} adjustable

Characterization of Light



G: Bose

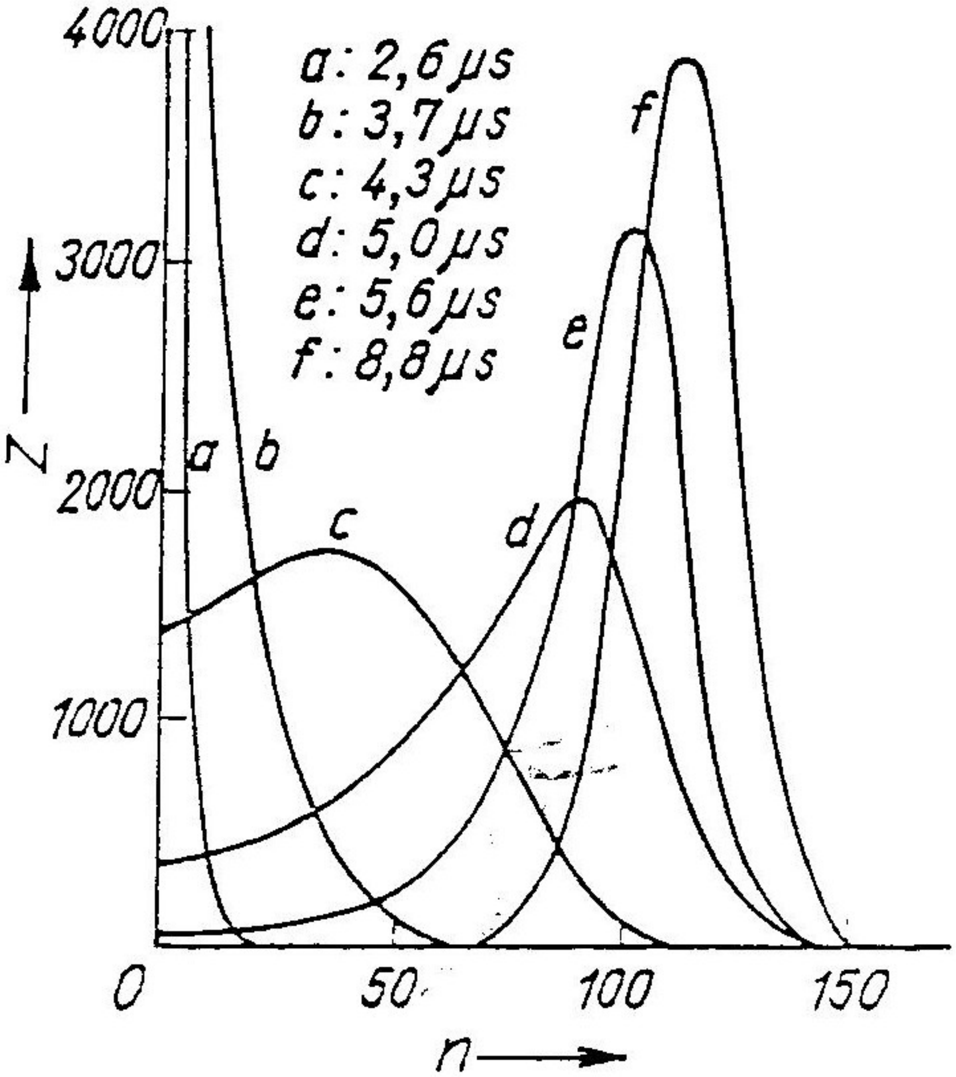
L: Poisson

→ complete statistical information of the radiation field

F.T. Arecchi, PRL 15, 912 (1965)

Characterization of Light

Switching on of a Laser:



F.T. Arecchi, PRL 19, 1168 (1967)

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Bunching

HBT experiment

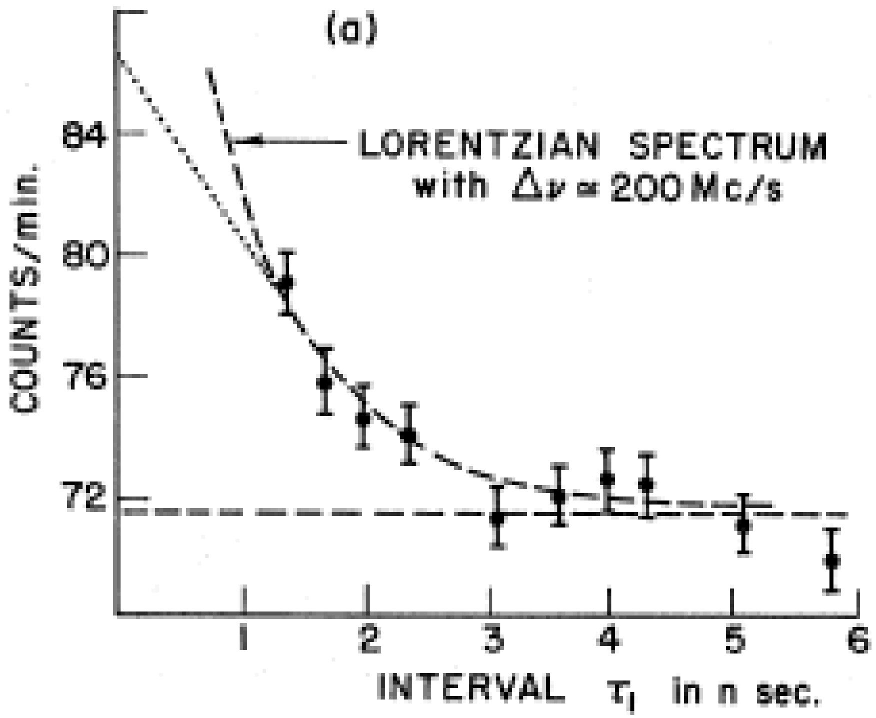
→ photons of a thermal light do not arrive completely at random

Distribution of time intervals between successive counts

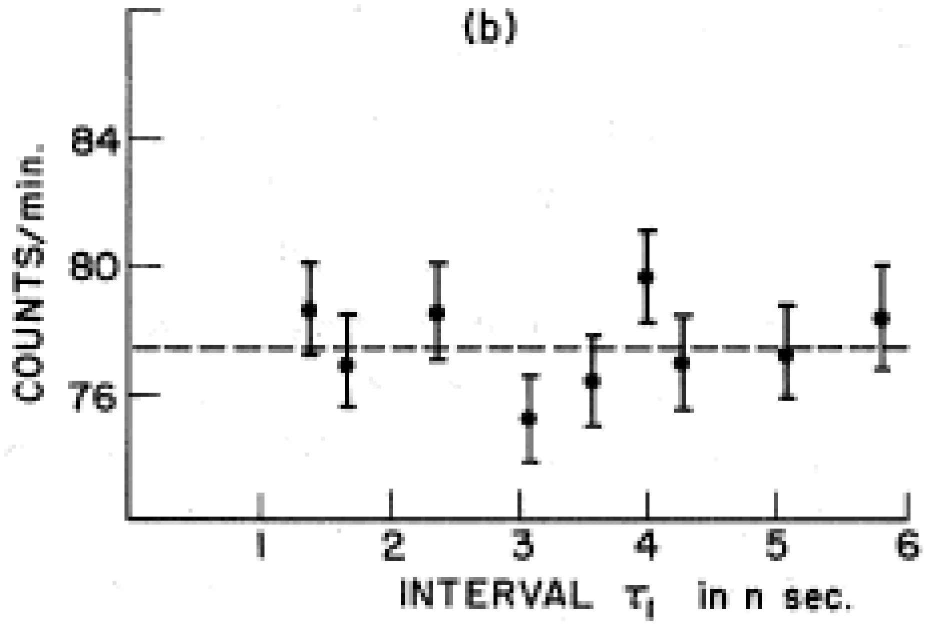
→ spectral profile ($t_{coh}\Delta\nu \approx 1$)

Bunching

Mercury lamp:



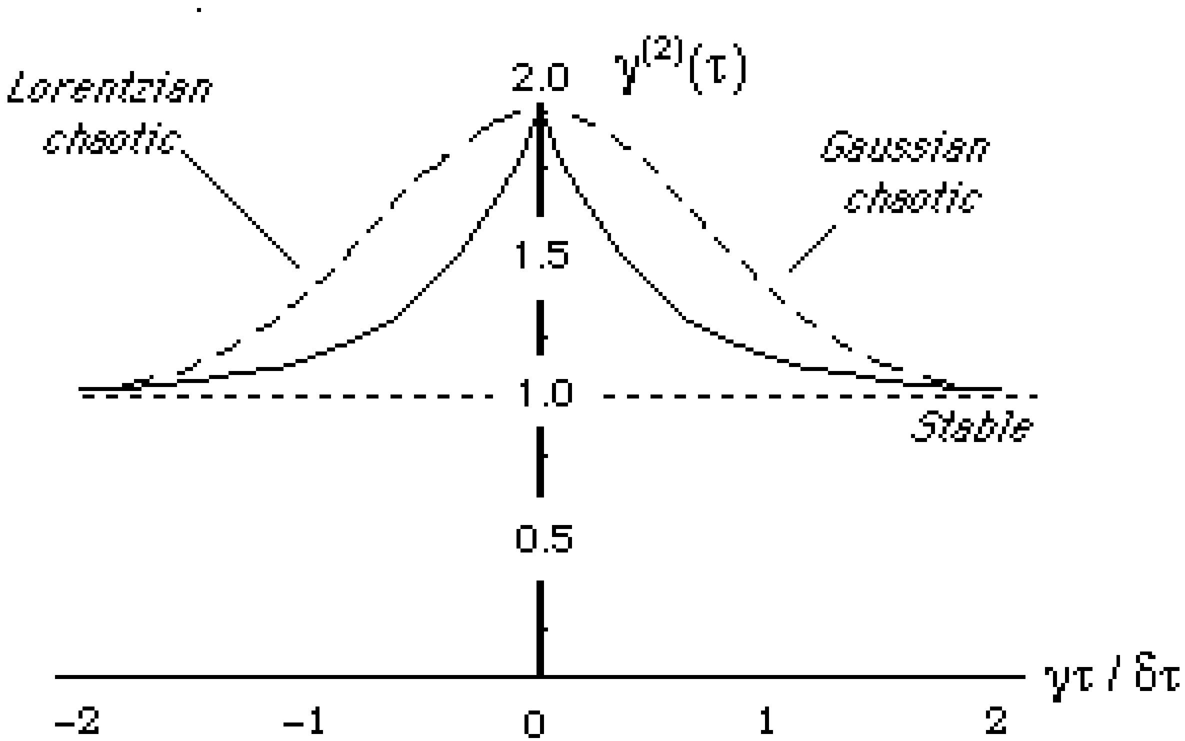
Tungsten lamp:



B.L. Morgan and L. Mandel, PRL 16, 1012 (1966)

Bunching

Auto-correlation function



→ spectral profile of thermal light

harvard.edu

Bunching

Why is there bunching in thermal light?

- Wave character of photons
- Radiation field is smooth function

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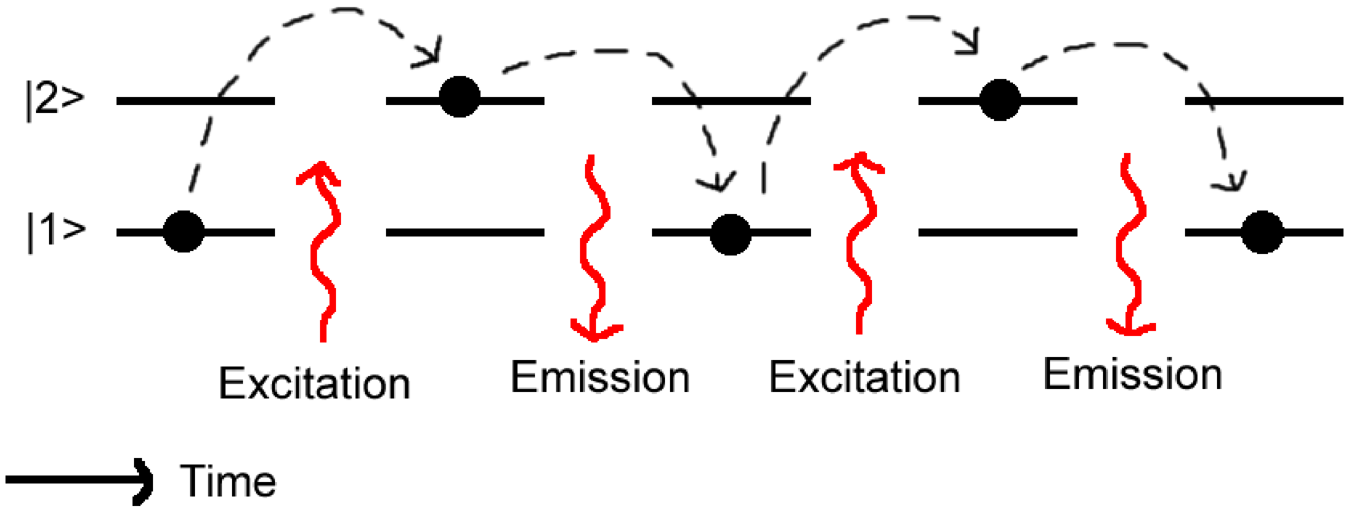
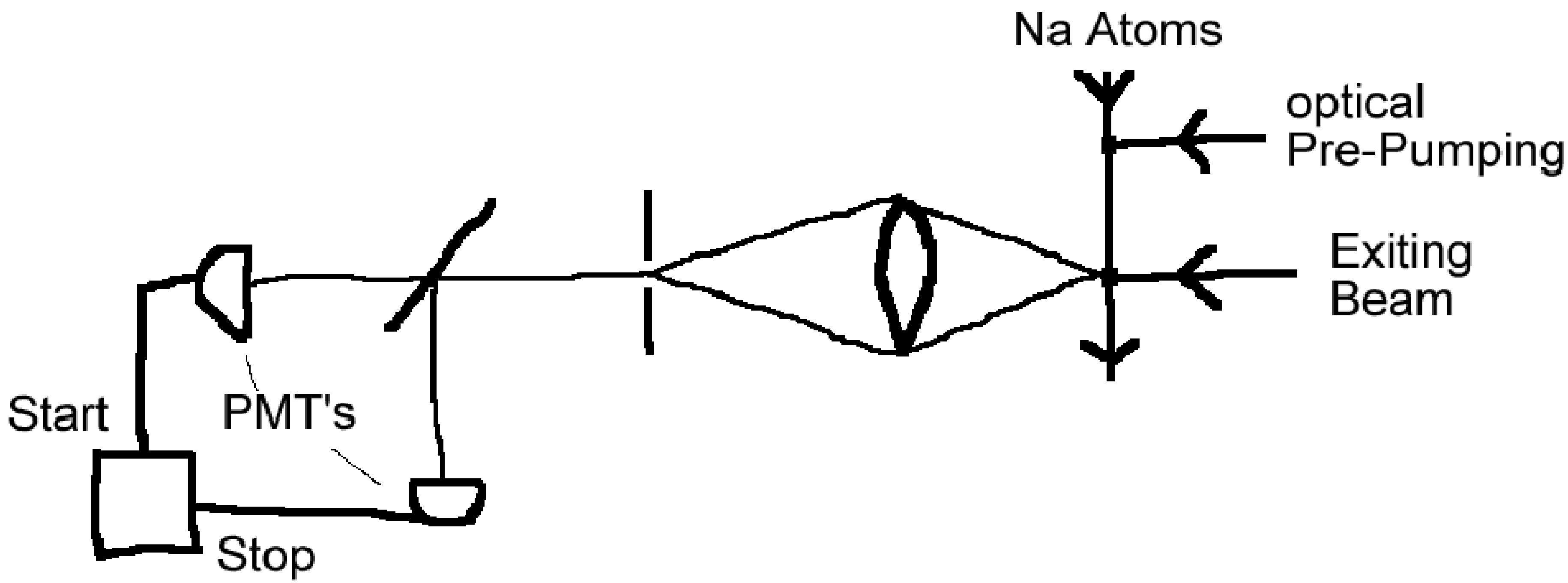
Antibunching

Non-classical light: single photon source



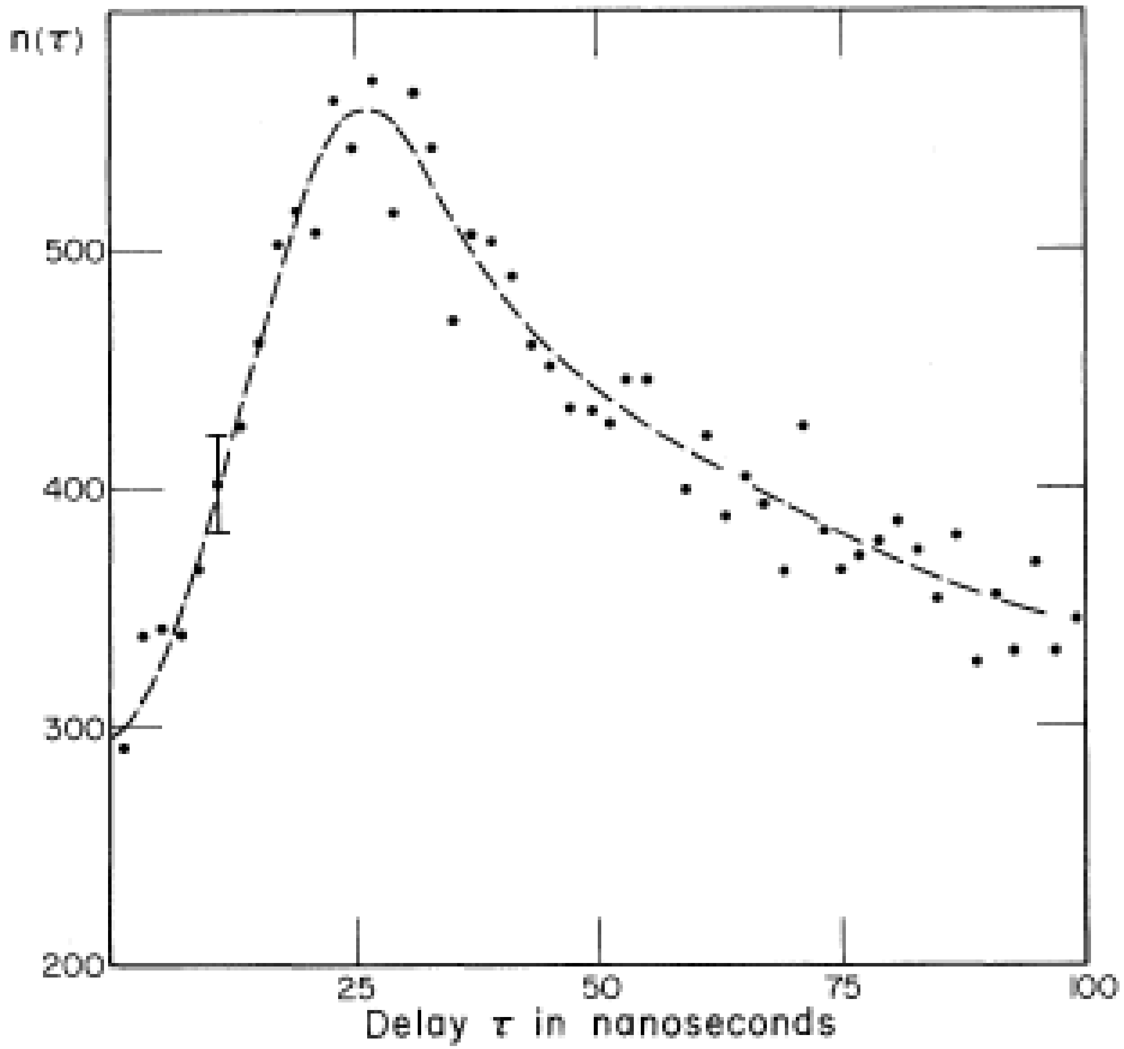
Antibunching

Experimental setup:



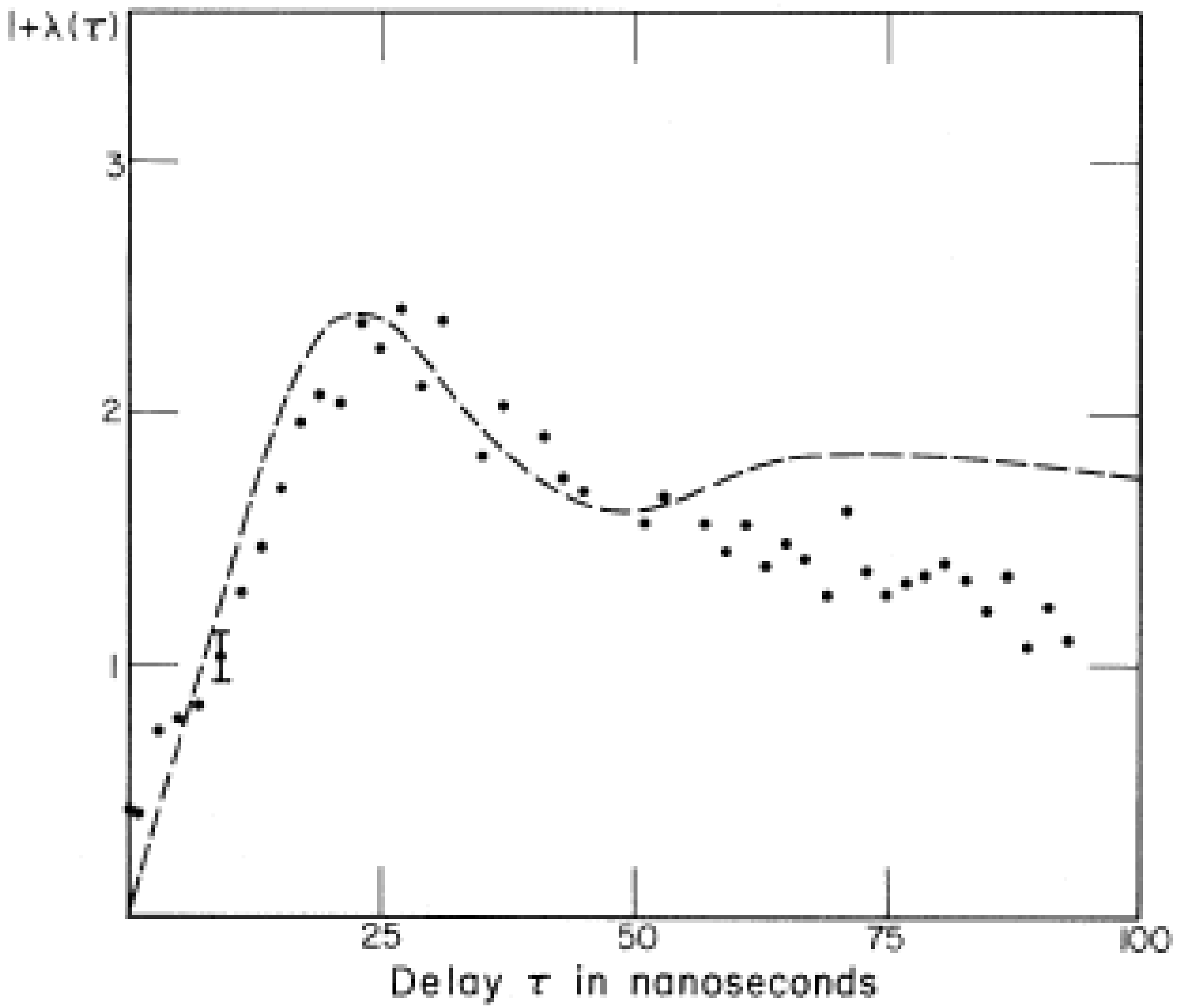
Antibunching

Less coincidences for short τ



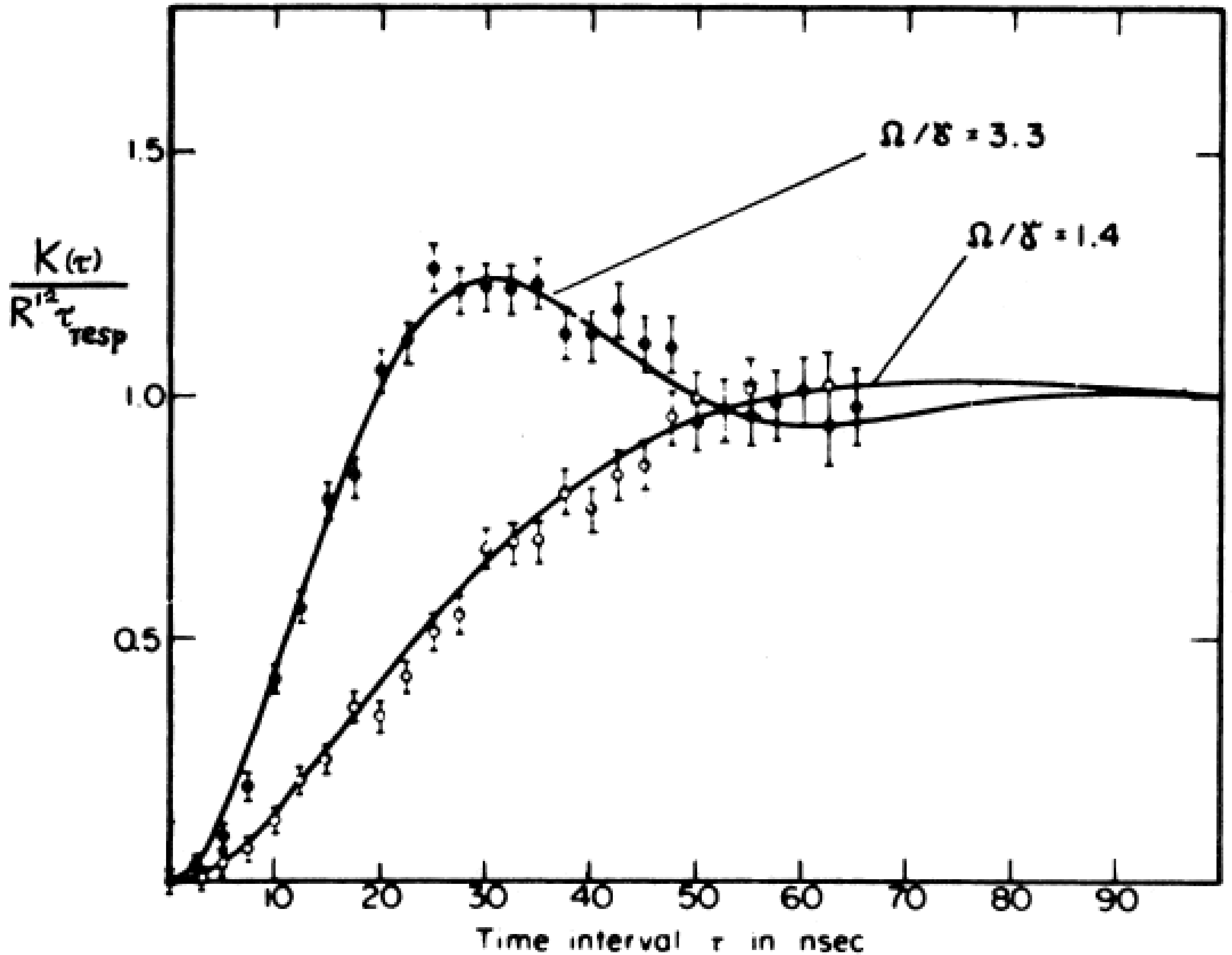
H.J. Kimble, M. Dagenais and L. Mandel, PRL 39, 691 (1977)

Antibunching



H.J. Kimble, M. Dagenais and L. Mandel, PRL 39, 691 (1977)

Antibunching



H. Paul, Reviews of Modern Physics, Volume 54, Issue 4, October 1982, pp.1061-1102

Antibunching

$$I(t) = I_0 + \delta I(t) \qquad <I(t)> = <I_0> + <\delta I(t)>$$

$$<I(t)\, I(t+\tau)> = <I_0\, I_0> + <\delta I(t)\, \delta I(t+\tau)>$$

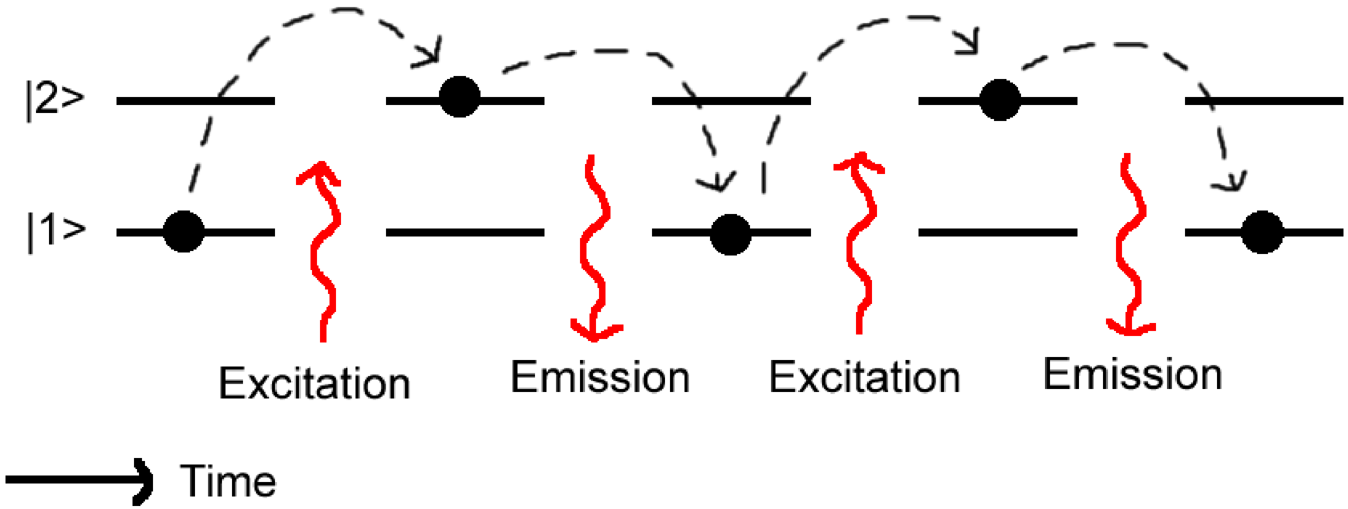
$$<\delta I(t)\, \delta I(t+\tau)> = 0 \qquad \text{for } \tau >> 0$$

$$<\delta I(t)\, \delta I(t+\tau)> = <\delta I(t)>^2 \qquad \text{for } \tau \longrightarrow 0$$

$$<\delta I(t)>^2 > 0$$

Antibunching

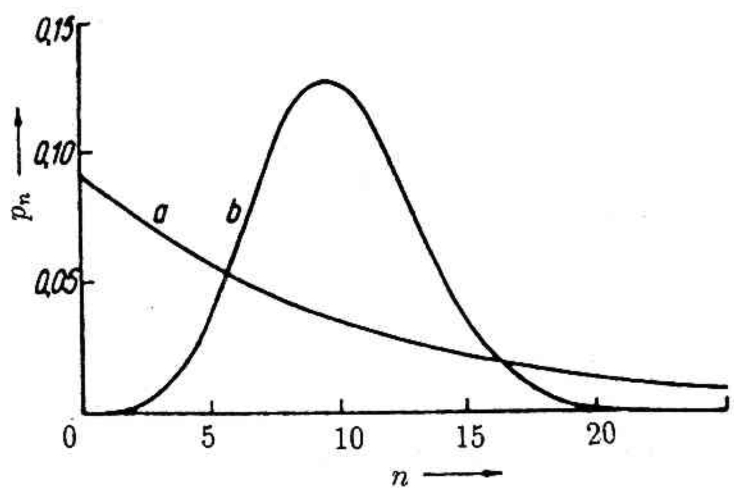
Antibunching is direct evidence for the quantisation of the electromagnetical field.

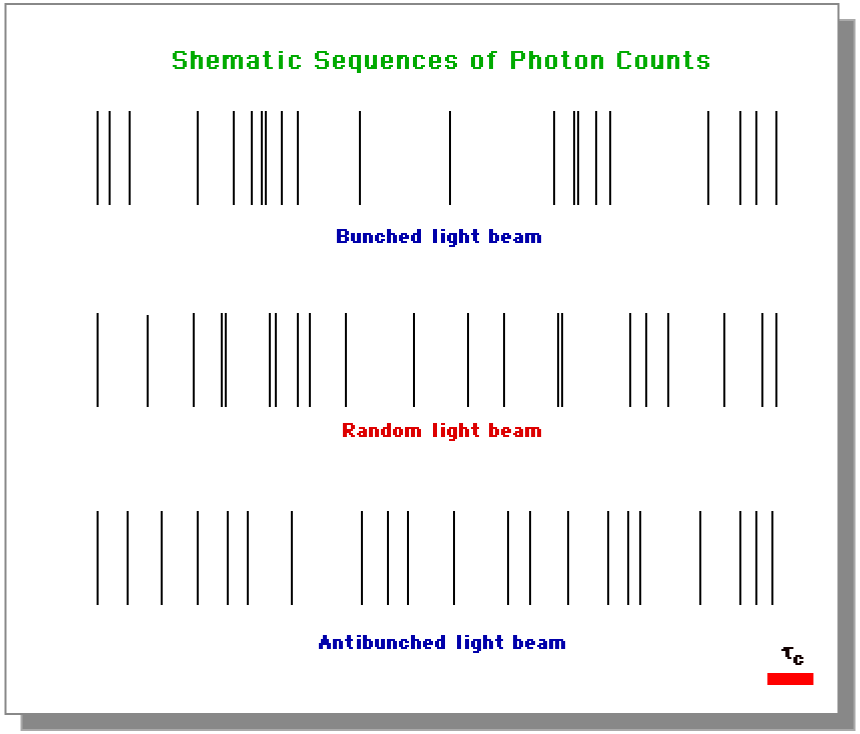


It also shows that the atom is undergoing a quantum jump.

Summary

Light source:	thermal	Laser	Single-photon
Statistics:	Bose	Poisson	Sub-Poisson
Correlation:	Bunching	flat	Antibunching





H. Paul, Photonen, Teubner 1995
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Sources

- H. Paul, Photonen, Teubner 1995
- R. Hanbury Brown and R.Q. Twiss, Nature 177, 27 (1956)
- F.T. Arecchi, PRL 15, 912 (1965)
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