For light and atoms

$g^{(2)}(0)$ normalizes probability to detect two photons (particles) simultaneously.

So far: Light

Thermal/chaotic/classical light $g^{(2)} > 2$ bunching

Laser / coherent light $g^{(2)} = 1$

Single photon $g^{(2)} = 0$

Is $g^{(2)} = 2$? Is this a classical or a quantum effect?

4 different views

1. Random intensity fluctuations, Gaussian distribution

   $p(I) = \frac{1}{\langle I \rangle} \exp\left(-\frac{I}{\langle I \rangle}\right)$

   $\langle I^n \rangle = n! \langle I \rangle^n$  \hspace{1cm} n=2, $\langle I^2 \rangle = 2 \langle I \rangle^2$
\[ g^{(2)} = \frac{\langle I^2 \rangle}{\langle I \rangle^2} = 2 \]

Every photon is more likely to be detected when intensity fluctuations give high intensity.

(2) Wave interference

One mode (class, BEC)\(\psi(\omega t - \mathbf{k}\cdot \mathbf{r})\)

Single wave\(e\)

all correlation functions factorize\(\Rightarrow \langle I^n \rangle = \langle I \rangle^n\)

\[ g^{(n)} = 1 \quad \text{for all } n \]

two (or more) modes

"simple model"

two modes (both of i=0, 1 \(\Rightarrow \langle I \rangle = 2 \)

interference \(\Rightarrow \) intensity varies between 0 and 4\(\frac{I^2}{\langle I \rangle^2} = 0.8216\)

\[ g^{(2)} = 8 = 2 \cdot \langle I \rangle \]

\[ g^{(2)} = 2 \]

Demonstrates that \(g^{(2)} = 2\) has its deep origin in wave interference

Expt. intensity distribution in \(D\) is the result of interference
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(5) Classical vs quantum statistics

In particles, \( N \) quantum states \( \neq N \) classical:

- Find 1 particle \( P_1 = \frac{n}{N} \)
- 2 particles \( P_2 = P_1^2 \)

Indistinguishability of particles:

- \( P_1 \) reduced by \( n! \)
- \( P_2 = 2 \left( \frac{n}{n!} \right)^2 \)

Application to collisions in a box gas:

- 2-body collisions \( \Gamma_2 \) or \( g^{(2)} \)
- 3-body collisions \( \Gamma_3 \) or \( g^{(3)} \)

At the same density:

\[
\frac{\Gamma_2_{\text{Hill}}}{\Gamma_2_{\text{PEC}}} = 2 = 2!
\]
\[
\frac{\Gamma_3_{\text{Hill}}}{\Gamma_3_{\text{PEC}}} = 6 = 3!
\]
4. QNI explanation

detection \( (\text{collision}) \) of two particles

- two maxons \( q_1, q_2 \)
- has exchanged ten \( q_2 \times q_1 \)

\[ \rightarrow \text{factor of 2 bosons} \quad g^{(2)} = 2 \]

\[ \rightarrow \text{factor of 0 fermions} \quad g^{(2)} = 0 \]

Single mode: \( q, q \), has no exchange

\( \text{term (Casimir, etc.)} \rightarrow g^{(2)} = 1 \)

Measurement of \( g^{(2)} \)

Common denominator

Detection of particles in

- one quantum state
- one mode
- one coherence volume
- one phase space cell
Probability to find one particle

\[ p^2 \quad \text{classical} \]
\[ 2p^2 \quad \text{bosons} \]
\[ 0 \quad \text{fermions} \]

\[ \text{to find two particles} \]

\[ \text{Atom cloud} \]
\[ (A \alpha)^3 \]

Coherence volume \( \frac{\Delta}{h^3} \) one phase space cell

\[ \text{Diffuse and expand} \]

\[ \text{diverse cell} \]

\[ \text{Detection law} \]

\[ \text{Temporal resolution} \]

\[ \text{Selects one phase-space cell} \]