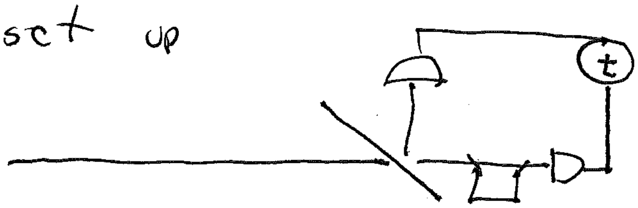
7.5 Antibunching

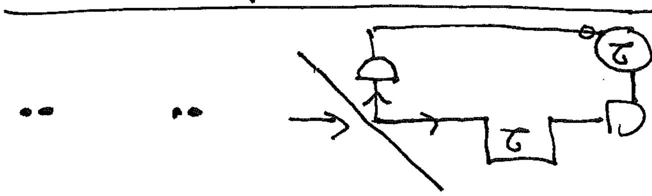
From Sect 5.4 we discussed the temporal two-photon correlation function $g_2(\tau)$ typically measured in a Hanbury Brown Twiss set up

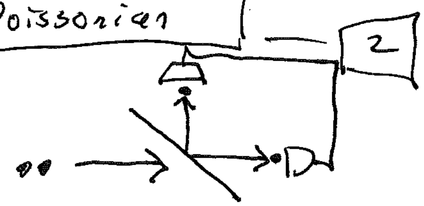


where (t) compares the arrival time and the delay line is used to adjust the arrival time

We distinguish <u>three</u> cases

Thermal Light / Bunched | / SUPER Poissonian | $g_2(\tau) < g_2(0)$

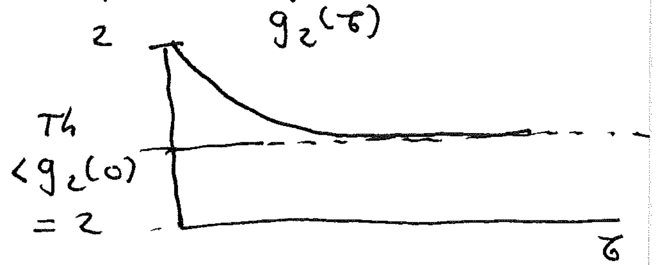




$g_2^{Th}(0) = 2$ No delay means photons on top of each other H.B.T. effect.

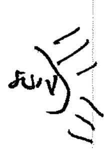
Recall Eq. 5.98

$$g_2^{Th}(\tau) = 1 + e^{-2|\tau|/\tau_0}$$



where τ_0 is the coherence time

So if you detect one photon probability of detecting another right away is high



•• •• •• Bunched

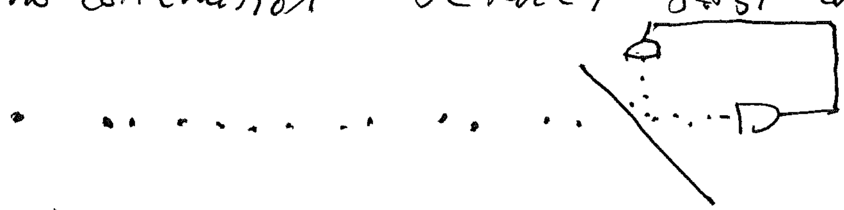
Bunched light from a thermal source is called "classical."

Coherent Light / Random | Poissonian | $g^2(\tau) = g^2(0)$

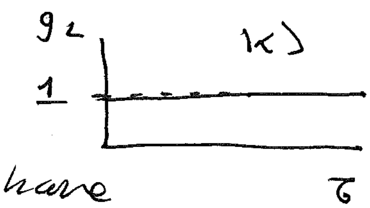
A coherent state we saw $|\alpha\rangle$ has Eq. 5.94

$$g_2^{|\alpha\rangle}(\tau) \equiv 1 = g_2^{|\alpha\rangle}(0) \quad \forall \tau$$

The light arrival time is <u>random</u> that is no correlation between first and second photon.



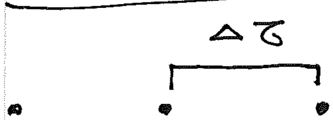
$g_2(\tau) \equiv 1$

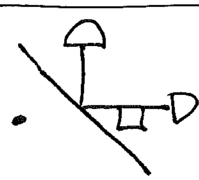


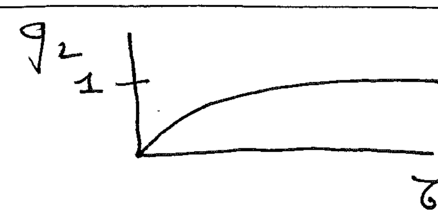
These are review of chapter 5

with number squeezed light we have a new possibility $g_2^{|s\rangle}(\tau) > g_2(0)$ which is <u>anti</u> bunching

squeezed light / <u>Sub</u> Poisson / Antibunch / $g_2(\tau) > g_2(0)$

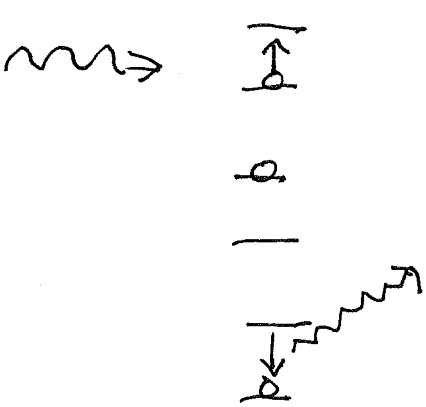






No coincidence until $\tau \approx \Delta\tau$

Typical output of a <u>single</u> atom under going repeated excitations



$\Delta\tau$ is <u>dead</u> time between emissions — on order of $\gamma = 1/\Delta T$ the atomic lifetime

For a single mode $\hat{a}_{\vec{k},\omega} e^{i(\vec{k}\cdot\vec{r}-\omega t)}$

we showed Eq. 5.93 that t cancells out

$$g^{(2)}_{SM}(\tau) = \frac{\langle a^+a^+aa\rangle}{\langle a^+a\rangle^2} = 1 + \frac{\Delta n^2 - \langle\hat{n}\rangle}{\langle\hat{n}\rangle^2} = g^2_{SM}(0)$$

which is independent of τ

so formally $g^2_{SM}(\tau) \equiv g^2_{SM}(0)$ and so

is never bunched or antibunched.

[Filtered state acts coherent.]

Recall $$Q \equiv \frac{\Delta n^2 - \langle\hat{n}\rangle}{\langle\hat{n}\rangle}$$

$$\Rightarrow \quad g^{(2)}_{SM}(\tau) = g^{(2)}_{SM}(0) = 1 + \frac{Q_{SM}}{\langle\hat{n}\rangle}$$

$$\Rightarrow \quad \boxed{Q_{SM} = (g^2_{SM}(0) - 1)\langle\hat{n}\rangle}$$

So for a single mode photons are <u>random</u> (no bunch/antibunch) and Q_{SM} is simply related to $g^2_{SM}(0)$

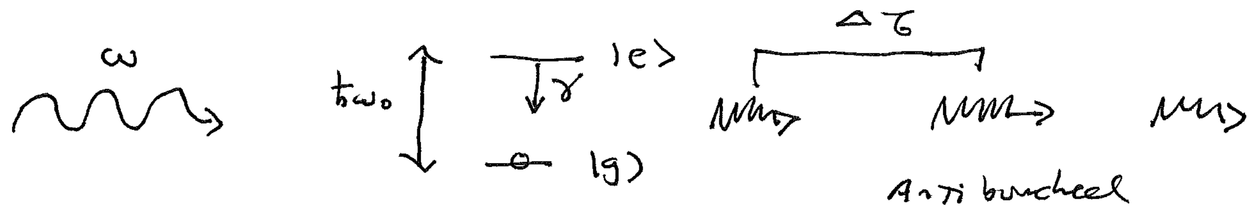
A simple modle for antibunching — using multimode average — is emission from single atom.

Recall $\Omega = \sqrt{\Delta^2 + \nu^2/\hbar^2}$.

is Rabi Frequency, sect. 4.4, single atom (quantized) driven by strong classical field: $\vec{\mathcal{E}}$

where $\Delta = \omega - \omega_0$, $\nu = \langle e | \hat{H}_{INT} | g \rangle$

$\hat{H}_{int} = -\hat{\vec{d}} \cdot \vec{E}$



Assuming pump and emission are in free space and use F.S. DOM $\rho(\omega) = \frac{\omega^2}{\pi^2 c^3}$ (multimode) integrate over $\vec{k}$ and you get

$$g^{(2)}(\tau) = [1 - \exp(-\gamma\tau/2)]^2 > g^2(0) = 0 \quad \Omega \ll \gamma$$

$$g^{(2)}(\tau) = 1 - \exp\left(-\frac{3\gamma}{4}\tau\right)\cos[\Omega\tau) > g^2(0) = 0 \quad \Omega \gg \gamma$$

where $\gamma = \frac{1}{T_0}$ is decay rate proportional to spontaneous emission or Einstein A coefficient.

Hence it takes about $\tau = T = 1/\gamma$ time for the atom to emit, be reexcited, and emit again so if $\tau \approx 0$ you will never see two photons but $\tau \gtrsim 1/\gamma = T_0$ you will be more likely