TECHNISCHE UNIVERSITÄT WIEN

Q02

19.5.2016

## Practical considerations when measuring correlation functions

Previous two weeks: Correlation functions

Experimentally remarkable:

It is possible to make detectors that are sensitive at the single-photon level (Hadfield 2009)

- Photo-multiplier tubes
- Avalanche photo diodes
- Super-conducting nanowire SPD
- Transition-edge sensors

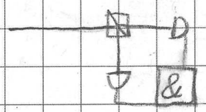
Efficiencies up to ~90% (SNSPDs since 2013), but typically 10-50%

But: Dark counts, dead time
No (or limited) number resolution (link: efficiency)

So under what conditions can we really measure, e.g., quantum correlation functions of order 2?

$$\frac{\langle a^+ a^+ a\, a\rangle}{\langle a^+ a\rangle^2} = 1 - \frac{1}{n} \sim \text{probability to simultaneously have two photons}$$

In experiment: split up modes.




$g^{(2)} = \frac{P_{12}}{P_1 P_2}$ probabilities per detection window

Good approximation if $P_x \ll 1$ (avoid saturation)

$P_x \gg P_{dark}$ (negligible dark counts)

Note: A more realistic detection operator (Skarbi

$\hat{D} = \hat{\mathbb{1}} - (1-P_{dc})(1-\eta)^{\hat{n}}$ : 1 minus probability of having neither photon nor dark count

Note also: Normalized correlation functions factor out the loss of photons (conditional measurements, post-selection)

## 13 Quantum Light Sources

Light with properties that cannot be explained by classical theory (exception: shot noise)

Examples (single-mode)

- Fock states ($g^{(2)} < 1$ non-classical)
- Squeezed states (continuous variables, not treated)

Examples (multi-mode)

- Entangled states (polarization, photon number, energy, orbital angular momentum...)

## 13.1 Single-photon sources

Requires single emitter. Possibilities:

- single molecule
- single atom
- NV-center or similar
- Quantum dots

Parameters:

- Yield (emitted photons per request)
- Collection efficiency
- Indistinguishability (photon and emitters)

Slides...

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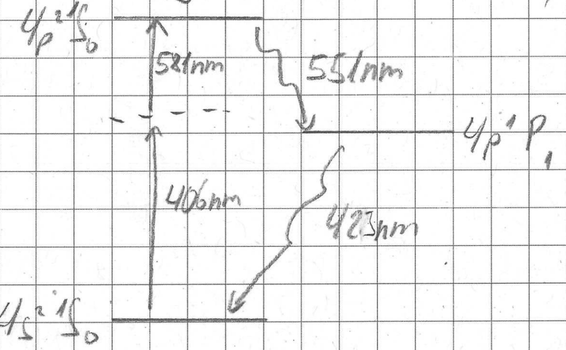
## 13.2 Photon-Pair sources

It is difficult to entangle two single photons.
⇒ easier to generate an entangled pair

Creating photon pairs by cascade decay (Aspect 1981)

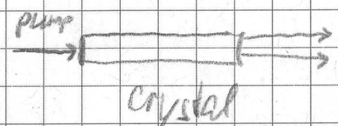



Atom decays back to ground state by emitting two photons.

Entangled in polarization!

Calcium atoms

### Photon-pair sources based on non-linear materials

Principle 

photons: signal, idler

Simple model:

Interaction Hamiltonian: $H = \hbar\chi\,(a b^\dagger c^\dagger + a^\dagger b c)$

pump, signal, idler

Hermitian!

Cannot be solved analytically (as far as I know).

Non-depleted (classical) pump approximation:

Assume pump in coherent state $|\alpha\rangle$ with $\alpha \gg 1$

$$\Rightarrow a|\alpha\rangle = \alpha|\alpha\rangle \quad \text{and} \quad a^\dagger|\alpha\rangle \simeq \alpha^*|\alpha\rangle$$

$$\Rightarrow H \simeq \hbar\chi\left(\alpha\, b^\dagger c^\dagger + \alpha^* b c\right)$$

We want to know what happens to modes b and c, when they are initially in vacuum.