quED Alignment

1 Full Alignment Procedure

First of all, please make sure, you have read and understood all the safety briefings in the quED Manual [1] and also section 3.4.1 of said manual to familiarise yourself with how to use the kinematic mirror mounts.

Whether the quED is completely mis-aligned or not, you can always start fresh with the full alignment procedure. To this end, please refer to section 3.4.3 of the quED Manual [1] and follow the steps described there.

Having completed the full alignment procedure, it is time to switch to the next part of the task:

2 Optimisation of the Alignment of the quED

Please follow the instructions in section 3.4.2 of the quED manual [1] to enhance the alignment of the quED. Here are some hints:

- Make sure the half-wave plate is inserted in the pump beam, so that you generate a $|\Phi^+\rangle$ state. You should see correlations, also in the $+/-$ basis. You should see a distinct increase in coincidence counts when you have the polarisers both set to $+45°$ or $-45°$ and you rotate the half wave plate the correct way (so that you generate the $|\Phi^+\rangle$ state).
- The polarisers should be inserted and both set to $+45°$ or $-45°$ when you are trying to optimise the coupling.
- Coincidence count rates are not the only important parameter. Check the visibility, especially in the $+/-$ basis (see below).

3 (Entanglement) Visibility

While the CHSH inequality (a Bell's inequality) [2] is the real deal, there is a quicker and simpler check to see, whether the entanglement is most likely good enough or not. To this end, we assume that the polarisation correlations between the two arms are sinusoidal. Then, this sinusoidal curve can be expressed like this (for more information, please have a look at section A.1 of [1]):

$$c = \frac{A}{2} \cdot (1 + V \cdot \cos(\theta)) \tag{1}$$

with A being the amplitude of the curve and experimentally determined by maximum (C_{max}) minus minimum (C_{min}) of coincidence counts

$$A = C_{max} - C_{min} \tag{2}$$

and V being the visibility (or contrast) of the curve, which can be determined like this:

$$V = \frac{C_{max} - C_{min}}{C_{max} + C_{min}} \tag{3}$$

The amplitude is not really important in this case, but the visibility is.

$C_{\parallel}$	$C_{\perp}$	$V = \frac{C_{\parallel} - C_{\perp}}{C_{\parallel} + C_{\perp}}$

$c_{\parallel}$ means both polarisers are parallel, while $c_{\perp}$ means the polarisers are perpendicular to each other. This is optimised for the $|\Phi^{+}\rangle$ state, in case of the $|\Phi^{-}\rangle$, is anti-correlated in the $+/-$ basis and the visibility is calculated like $V = \frac{C_{\perp} - C_{\parallel}}{C_{\parallel} + C_{\perp}}$.

References

[1] quED Manual V1.1, (2017), https://www.qutools.com/files/quED/quED_manual.pdf

[2] quED Bell Work Sheet https://www.qutools.com/files/quED/worksheets/qutools_quED-Worksheet_Bell.pdf

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