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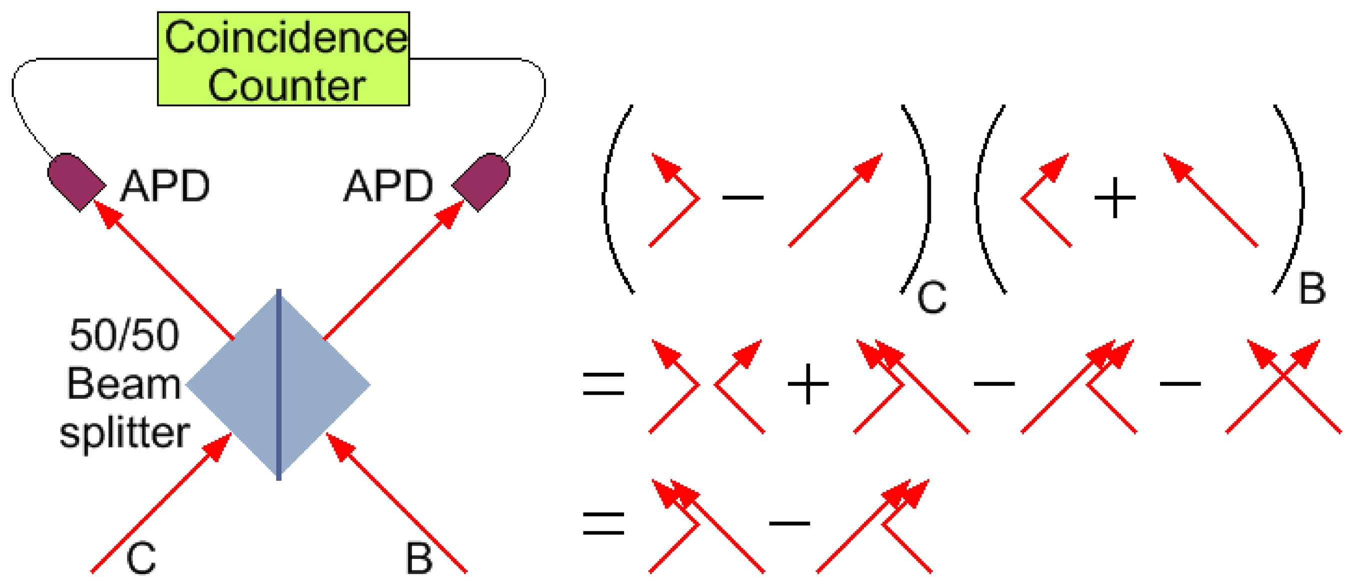
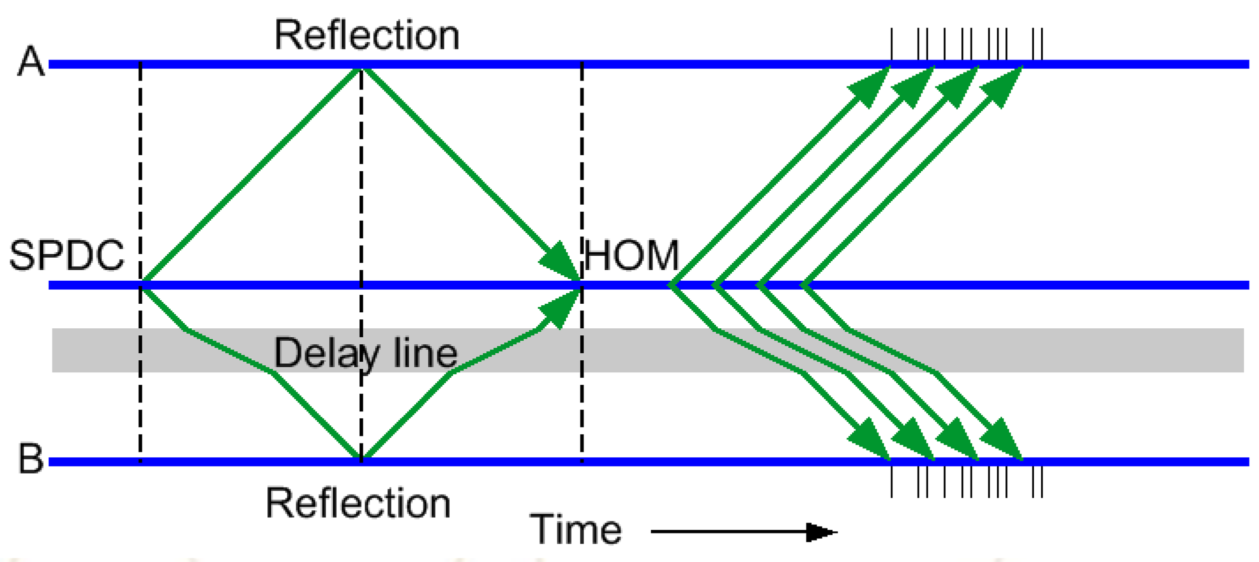
The effect of turbulence in free-space synchronization, using second-order quantum interference

Hong-Ou-Mandel (HOM) interference [1]



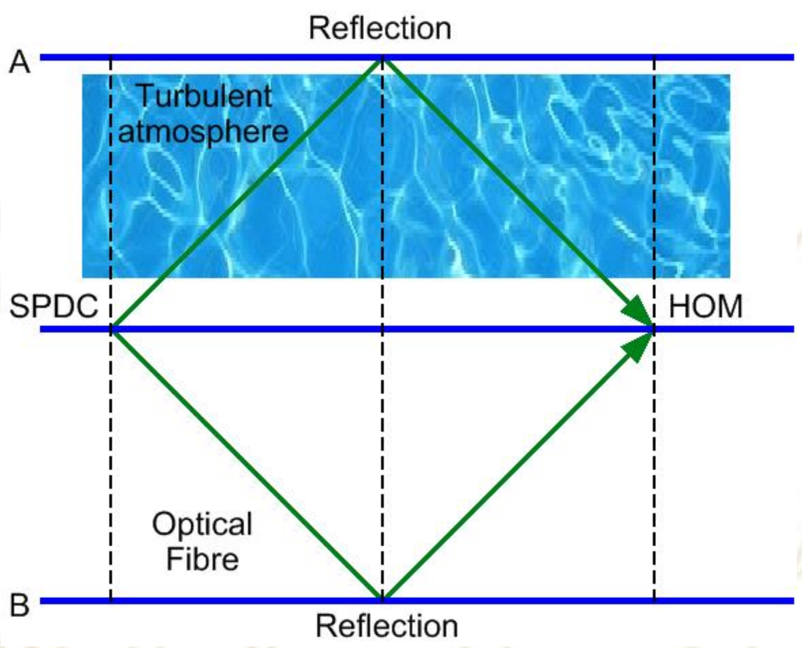
HOM synchronization protocol [2,3]



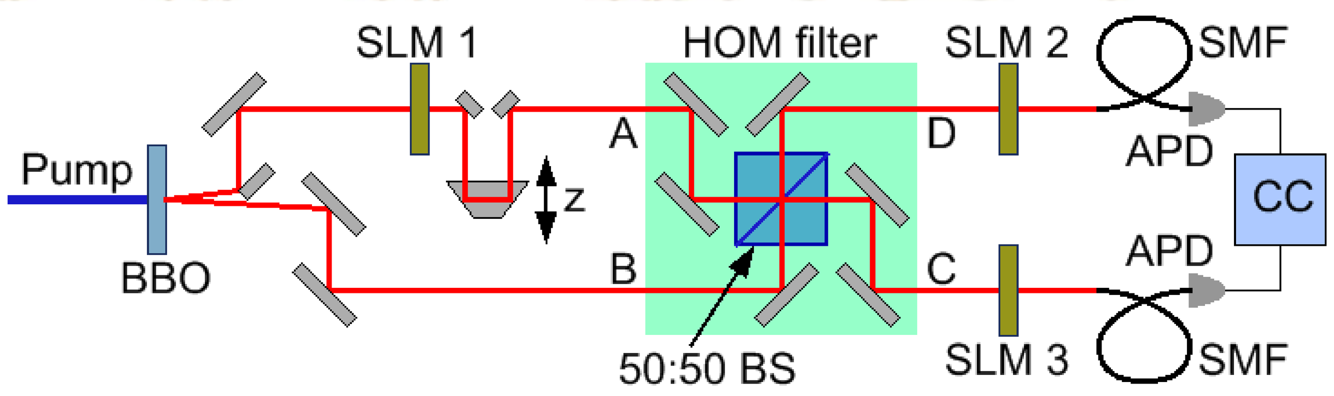
Free-space implementation

Turbulence!
→ Distortion of modes
→ Photons become distinguishable
→ HOM interference lost

One-sided channel
Weak scintillation



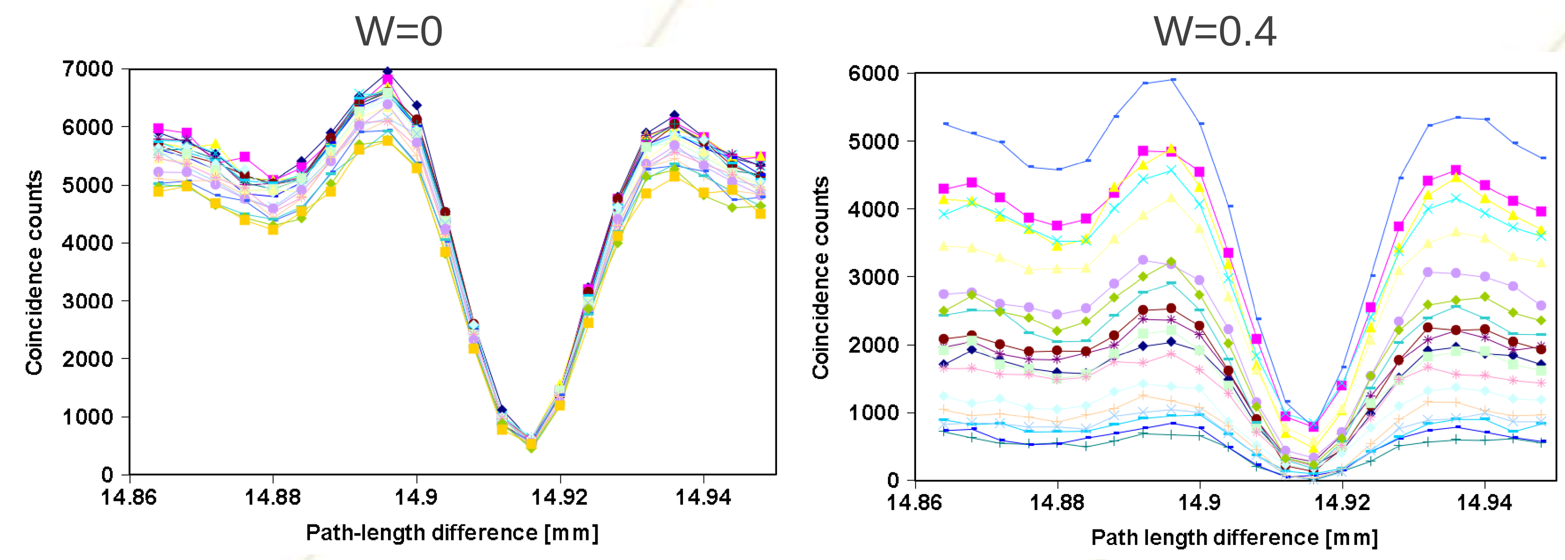
Experimental setup



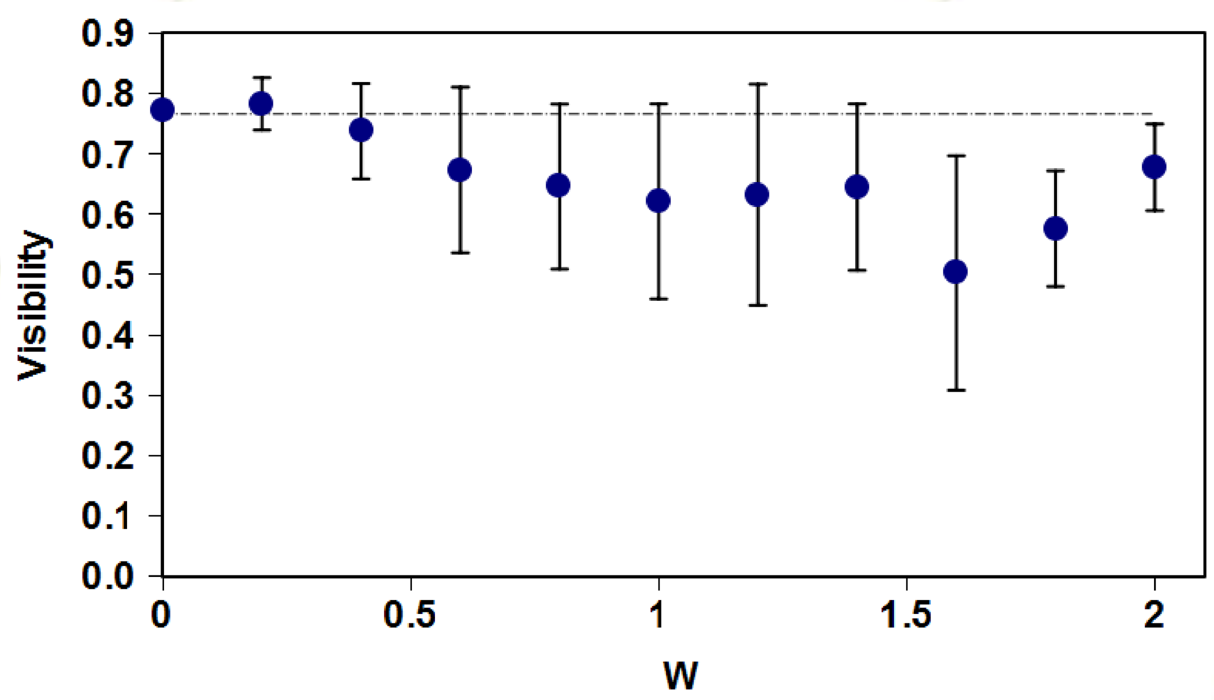
BBO – nonlinear crystal
SLM – spatial light modulator
BS – beam splitter
CC – coincidence counter
APD – avalanche photo diode
SMF – single mode fibre

Results

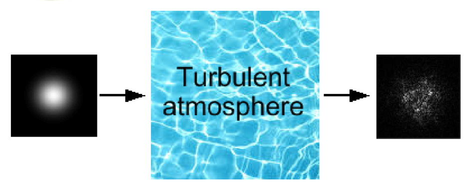
Scintillation strength: W = <modes size>/<Fried parameter> [4]

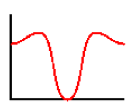


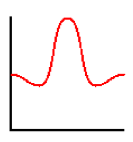
Visibility: (max-min)/(max+min)

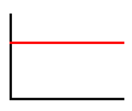


Why does it work like that?



$|\text{sym}\rangle = \frac{1}{\sqrt{2}}\left[|a\rangle|b\rangle + |b\rangle|a\rangle\right]$  dip

$|\text{anti}\rangle = \frac{1}{\sqrt{2}}\left[|a\rangle|b\rangle - |b\rangle|a\rangle\right]$  peak

$\frac{1}{\sqrt{2}}\left[|\text{sym}\rangle + |\text{anti}\rangle\right] = |a\rangle|b\rangle$  flat

$|\text{sym}\rangle$ → Turbulence → $|\text{anti}\rangle$

Trans. amp. $= \langle \text{anti}|\, I \otimes T\, |\text{sym}\rangle$

$= \langle \ell | T | \ell \rangle - \langle \bar{\ell} | T | \bar{\ell} \rangle$

$= \langle \ell | \exp(i\theta) | \ell \rangle - \langle \bar{\ell} | \exp(i\theta) | \bar{\ell} \rangle$

$= R^2(r)\exp(i\theta) - R^2(r)\exp(i\theta)$

$= 0$

Laguerre-Gauss modes: $|\ell\rangle|\bar{\ell}\rangle$

Conclusion

→ **HOM synchronization can be used over free-space despite turbulence, for one-sided channel in weak scintillation.**

References

[1] C. K. Hong, Z. Y. Ou and L. Mandel, Phys. Rev. Lett. 59, 18 (1987).
[2] T. B. Bahder and W. M. Golding, AIP Conf. Proc. 734, 395-398 (2004).
[3] R. Quan, et al., Science Reports 6, 30453 (2016).
[4] A. Hamadou Ibrahim, F. S. Roux and T. Konrad, Phys. Rev. A 90, 052115 (2014).