DIRECT OBSERVATION OF PHASE SENSITIVE HONG-OU-MANDEL INTERFERENCE

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HONG -OU-MANDEL INTERFERENCE WITH HOMODYNE DETECTION

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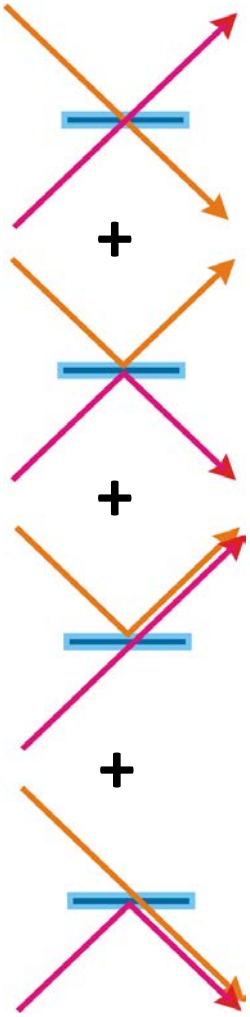
Hong-Ou-Mandel interference



Two photons meet on a balanced beam splitter:

- If distinguishable, they ignore each other:

$$(|1,0\rangle_a + |0,1\rangle_a) \otimes (|1,0\rangle_b - |0,1\rangle_b)$$

- If indistinguishable, they bunch

$$|2,0\rangle - |0,2\rangle$$

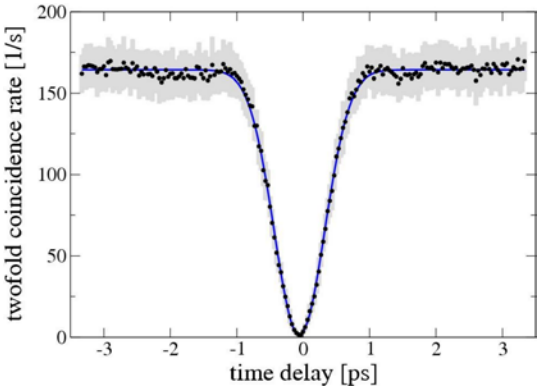
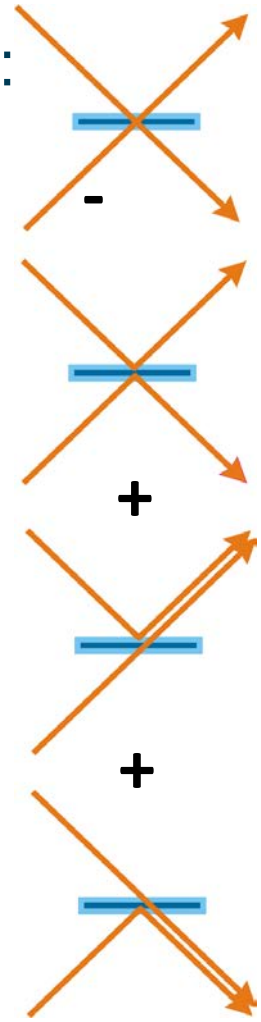


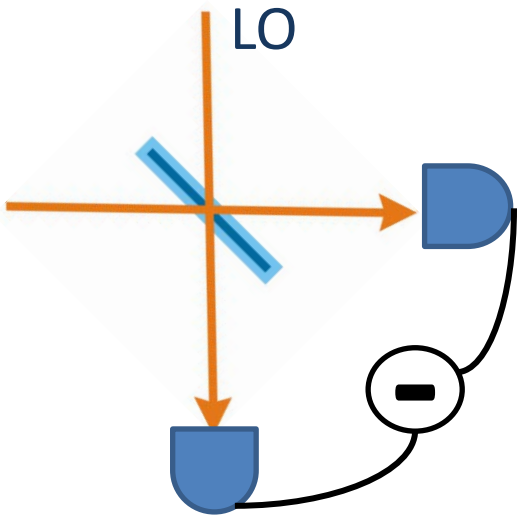
Image: Quantum Optics Lab Olomouc

Visibility of the HOM dip quantifies the ability to interfere

$$V = \frac{\max C - \min C}{\max C + \min C}$$



Can we do it with homodyne detection?

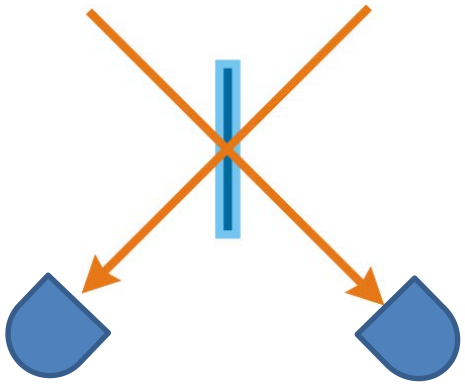


$$X(\theta) = X\cos\theta + P\sin\theta$$

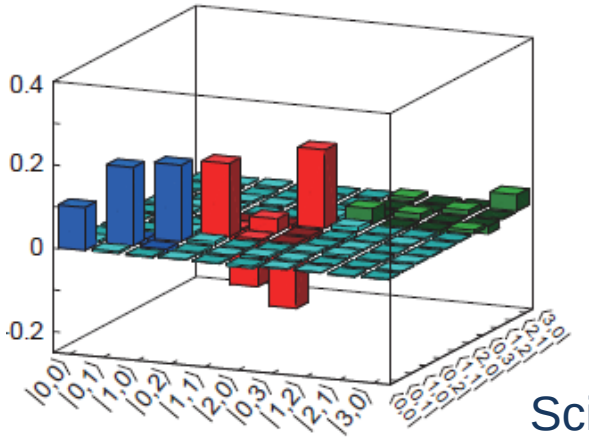
- Why do we care?
  - It is omnipresent in hybrid and CV optics
  - It can be available where PNRs or APDs aren't
  - It is a `wave-like' rather than 'particle-like' measurement

Complete tomography with homodyne detection

$|1,1\rangle$



$|2,0\rangle - |0,2\rangle$



- Good
  - Gives full information
- Bad
  - Many measurements
  - Many measurement bases
  - Requires reconstruction

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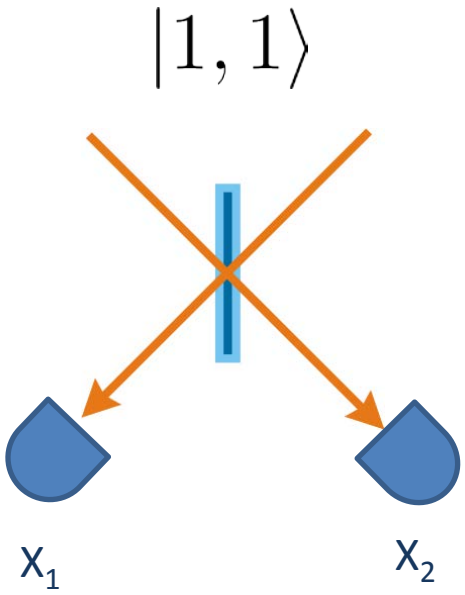
Different approach?



- We need to single out :

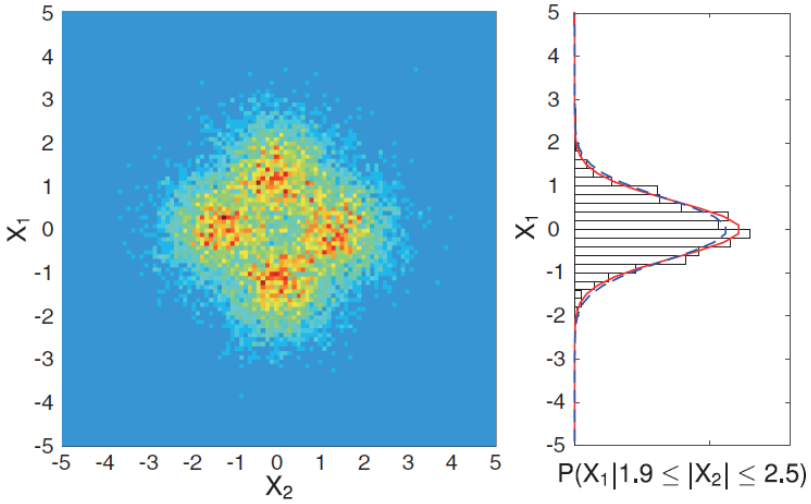
$$|2,0\rangle - |0,2\rangle$$

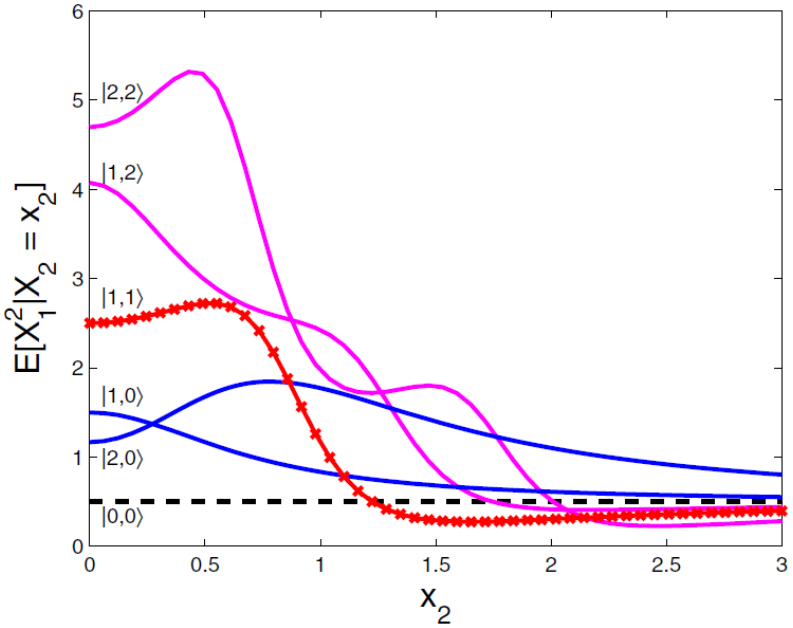
- Consider homodyne detection of quadrature X_2

$$|\psi\rangle \propto \langle x_2|2\rangle|0\rangle - \langle x_2|0\rangle|2\rangle$$

$$|\psi\rangle \propto c_0|0\rangle + c_2|2\rangle$$

Conditional squeezing





- Quadratures X_1 and X_2 are measured
- Indistinguishable single photons show central squeezing

$$E[X_1^2|X_2 = x_2] < \frac{1}{2}$$

- Other states do not, at least for the selected range of X_2 values

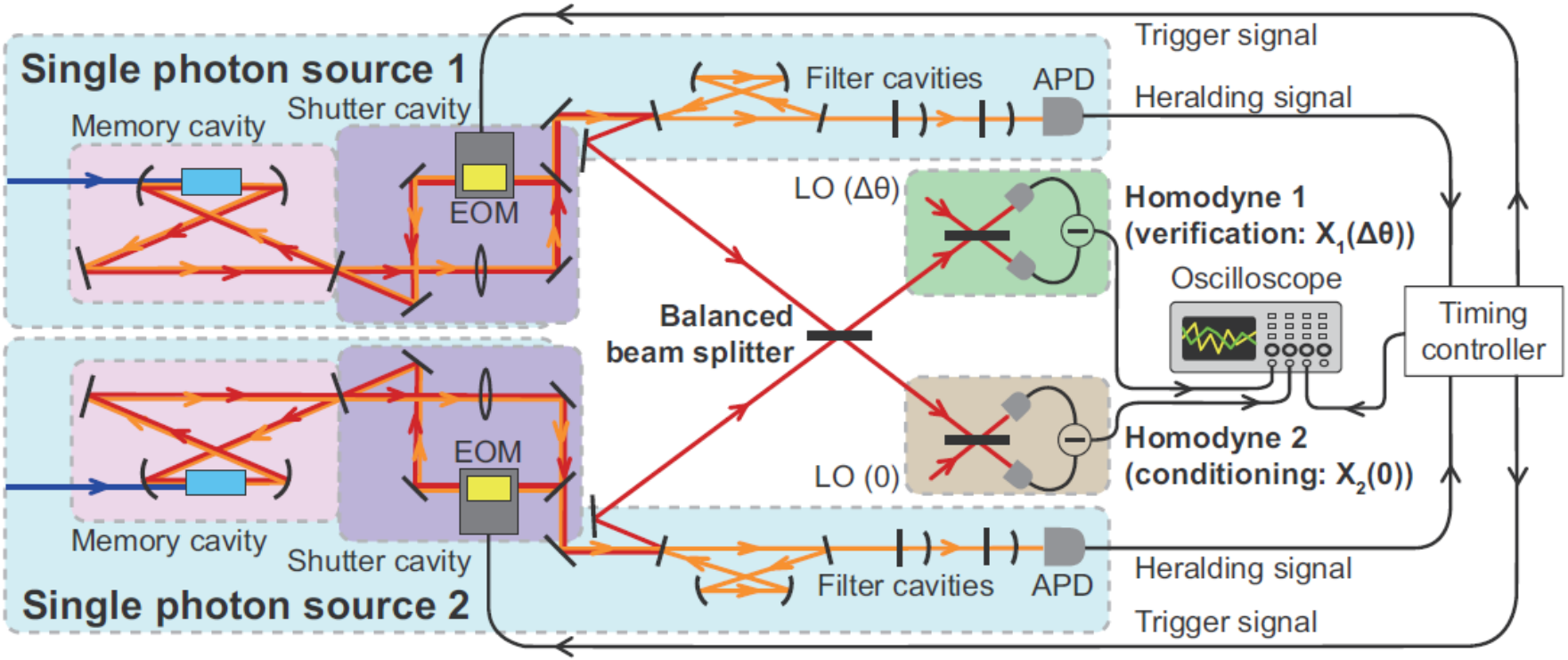
The witness:

- Interfere two fields at the balanced beam splitter
- Measure values of quadratures X_1 and X_2
- Evaluate conditional moments

- The "right" squeezing indicates:

  - There were two single photons
  - They were indistinguishable
  - They had good mode match with the LO
  - The phase after the beam splitter was locked

Experimental test:



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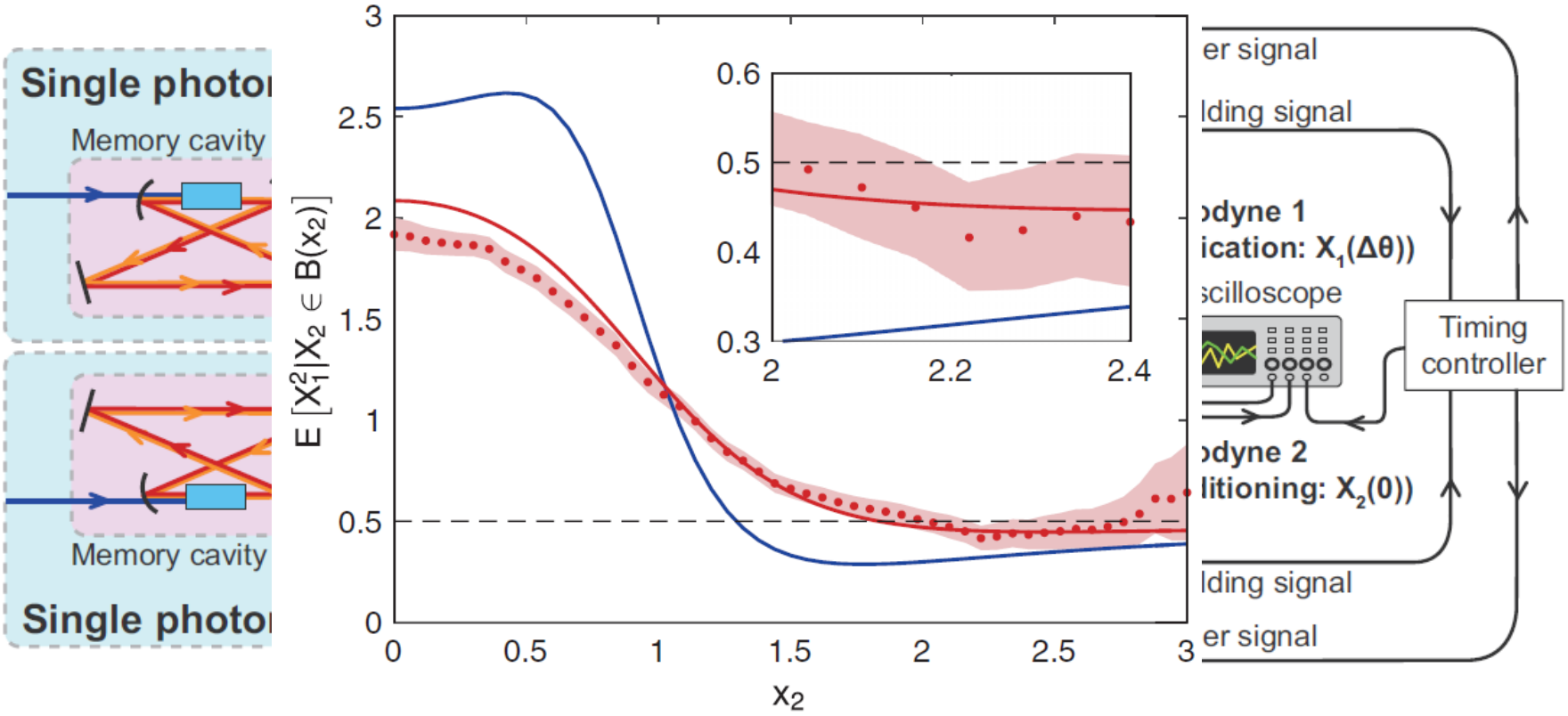
PRA 96, 033830 (2017)

Experimental test:



- Consistent with: $0.33|0\rangle\langle 0| + 0.65|1\rangle\langle 1| + 0.02|2\rangle\langle 2|$

$$V = 0.7$$

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PRA 96, 033830 (2017)

In summary:

- Homodyne detection can be used for HOM-like measurement
- Requires only a single set of measurements
- It can confirm
  - indistinguishability
  - single photon nature
  - phase stability of the interference

- More details in PRA 96, 033830 (2017)

Thank you for the attention!