

Direct observation of phase sensitive Hong-Ou-Mandel interference

Petr Marek¹, P. Zapletal¹, R. Filip¹, Y. Hashimoto², T. Toyama², J. Yoshikawa², K. Makino², and A. Furusawa²

¹ Department of Optics, Palacký University, 17. listopadu 1192/12, 77146 Olomouc, Czech Republic

² Department of Applied Physics and Quantum-Phase Electronics Center, School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan

Quantum interference of individual photons is one of the fundamental keystones of quantum technology. The ability to recognize whether photons from different sources can interfere is therefore an important one. The basic tests use photon correlation measurements to ascertain presence of individual photons and two-photon bunching to verify their interference. The experimental test of the bunching effect traditionally employs the Hong-Ou-Mandel interference [1], in which the two individual photons are mixed on a balanced beam splitter and the resulting two mode field is measured by a pair of photon counters. The bunching manifests as the lack of coincidence counts - if the coincidence probability is below one half, the interference effect is nonclassical, i. e. incompatible with description using a mixture of classical waves or classical particles.

For discrete variable quantum technology (DV) these features are sufficient. However, from the point of view of continuous variables (CV) and the more general framework of hybrid quantum technology [2], these experiments quantify only the particle nature of the interference and ignore the vacuum-related phase sensitive aspects of the photon bunched state. They also avoid the issues of coupling single photons with CV states, such as mode overlap with the local oscillator. The full picture of two-photon interference can be obtained by replacing the photon counters with homodyne detection and performing a full tomography [3, 4]. The reconstructed density matrix can then be analyzed in order to visualize and evaluate the interference caused by the indistinguishability. The drawback to this tomographic approach is that it requires a high number of individual measurements and that it can not be used as a direct witness.

To remedy this issue we introduce a direct witness which, for remotely prepared single photon states, summarily evaluates their single photon nature, indistinguishability, and compatibility with hybrid processing circuits [5]. The witness relies on observation of nonclassical quadrature correlations and thus requires only measuring a single two-quadrature joint probability distribution, which makes it significantly less demanding than quantum tomography. For explicit experimental demonstration we test the witness on a pair of photons individually prepared in timing synchronization cavities. See Fig. 1 for the experimental setup and Fig. 2 for the measured data.

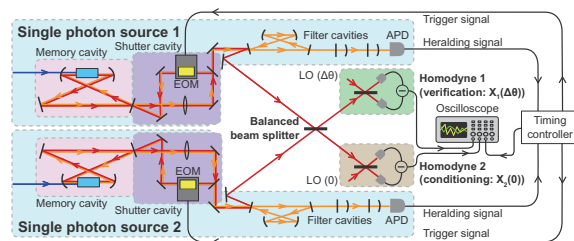


Figure 1: Experimental setup for the direct observation of the phase sensitive Hong-Ou-Mandel interference.

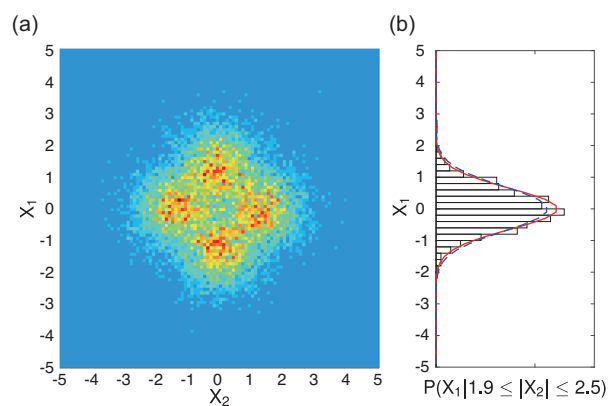


Figure 2: Experimental data. (a) the observed quadrature values. (b) the conditioned quadrature distribution.

- [4] M. Cooper, E. Slade, M. Karpiński, and B. J. Smith, *New J. Phys.* **17**, 033041 (2015).
- [5] P. Marek, P. Zapletal, R. Filip, Y. Hashimoto, T. Toyama, J. Yoshikawa, K. Makino, and A. Furusawa, *Phys. Rev. A* **96**, 033830 (2017).

[1] C. K. Hong, Z. Y. Ou, and L. Mandel, *Phys. Rev. Lett.* **59**, 2044 (1987).

[2] U. L. Andersen, J. S. Neergaard-Nielsen, P. van Loock, and A. Furusawa, *Nature Physics* **11**, 713 (2015).

[3] K. Makino, Y. Hashimoto, J. Yoshikawa, H. Ohdan, T. Toyama, P. van Loock, and A. Furusawa, *Science Advances* **2**, e1501772 (2016).