Hong-Ou-Mandel effect under partial time reversal : a destructive interference effect in the amplification of light

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In the usual, predictive approach of quantum mechanics, one deals with the preparation of a quantum system, followed by its time evolution and ultimately its measurement. In the retrodictive approach of quantum mechanics, one postselects the instances where a particular measurement outcome was observed and considers the probability of the preparation variable conditionally on this measurement outcome. This can be interpreted as if the actually measured state had propagated backwards in time to the preparer. Here, we present an intermediate picture, called partial time reversal, where a composite system is propagated partly forwards and partly backwards in time. As a striking application, we focus on the simplest two-mode linear-optical component, namely a beam splitter, and show that it transforms into a two-mode squeezer under partial time reversal [1]. More generally, by building on the generating function of the matrix elements of Gaussian unitaries in Fock basis, we prove that the multiphoton transition probabilities obey simple recurrence equations. This method applies to Gaussian unitaries effecting both passive and active linear coupling between two bosonic modes [2]. The recurrence includes an interferometric suppression term which generalizes the Hong-Ou-Mandel effect to more than two indistinguishable photons impinging on a beam splitter of transmittance 1/2. It also exhibits an unsuspected 2-photon suppression effect in an optical parametric amplifier of gain 2 originating from the indistinguishability between the input and output photon pairs which we coin “timelike" indistinguishability (it is the partial time-reversed version of the usual “spacelike" indistinguishability which is at work in the Hong-Ou-Mandel effect).

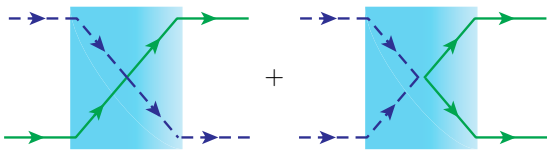

Figure 1. The optical parametric amplification of two single photons with gain 2 exhibits a destructive interference effect between both photons simply crossing the nonlinear medium, on the one hand, and the stimulated annihilation of the input photon pair accompanied with the stimulated emission of a distinct output pair, on the other hand. The “timelike" indistinguishability between the input and output photon pairs is responsible for the full suppression of the coincidence term (1,1) at the output.

[1] N. J. Cerf, *The optical beam splitter under partial time reversal*, Central European Workshop on Quantum Optics 2012, (Sinaia, Romania, 2012).

[2] M. G. Jabbour and N. J. Cerf, *Multiphoton interference effects in passive and active Gaussian transformations*, arXiv :1803.10734 [quant-ph] (2018).

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