Time-frequency quantum metrology

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Abstract

Hong-Ou-Mandel interferometry takes advantage of the quantum nature of two-photon interference to increase the resolution of precision measurements of time delays. Relying on few-photon probe states, this approach is applicable also in cases of extremely sensible samples and it achieves attosecond-scale resolution, which is relevant to cell biology and two-dimensional materials. Here, we theoretically analyze how the precision of Hong-Ou-Mandel interferometers can be significantly improved by engineering the spectral distribution of two-photon probe states. In particular, we assess the metrological power of different classes of biphoton states with non-Gaussian time-frequency spectral distributions, considering the estimation of both time and frequency shifts. We find that grid states, characterized by a periodic structure of peaks in the chronocyclic Wigner function, can outperform standard biphoton states in sensing applications.
After discussing the spectral engineering of photon pairs, we will discuss the use of more general quantum states possessing a higher number of photons for estimating time shifts using the presented intrinsic multimode quantum metrology approach. We will show that the particle-number and time-frequency degree of freedom are intertwined for quantifying the ultimate precision achievable by quantum means. Increasing the number of photons of a large entangled EPR probe state actually increases the noise coming from the frequency continuous variable hence deteriorating the precision over the estimation of a time shift.

References

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2. Eloi Descamps, Nicolas Fabre, Arne Keller, and Pérola Milman, Phys. Rev. Lett. **131**, 030801 (2023)

Figures

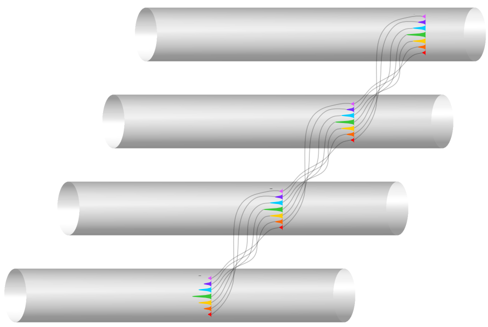

Figure 1: n-photon frequency entangled state in different spatial mode as a probe for estimating small temporal parameter.