2025.

We investigated the possibility of quantum metrological optimization with multiple copies of quantum states in a very general case [1]. Our method can be used in other areas of physics, e.g. for maximizing the quantities used to measure entanglement. In this way, we determined the maximum violation of the so-called Computable Cross Norm - Realignment criterion for a given system size. This was an important question in quantum information science. Our other result related to quantum metrology showed that the quantum metrological usefulness can be well estimated by the average entangled block size [2]. Before, it was thought that the maximum entangled block size should be used for the estimation. Our work simplifies many cold gas experiments.

We continued to work on the quantum Wasserstein distance in relation to quantum metrology. Concerning the classical Wasserstein distance, we identified an application in processing of EEG signals [6].

We also dealt with entanglement detection independently of quantum metrology. We developed procedures for entanglement detection around Dicke states in cold atoms, which were successfully applied experimentally [3]. We have developed methods for detecting entanglement in d-dimensional particle ensembles [4] and in qubit ensembles using measurements with random directions [5]

We presented an exact analytical solution of the Hu–Paz–Zhang master equation in a precise Markovian limit for a system of two harmonically coupled harmonic oscillators interacting with a common thermal bath of harmonic oscillators. The thermal bath was initially considered to be at arbitrary temperatures and was characterized by an Ohmic Lorentz–Drude spectral density. In the examined system, couplings between the two harmonic oscillators and the environment ensured a complete decoupling of the center-of-mass and relative degrees of freedom, resulting in undamped dynamics in the relative coordinate. The exact time evolution was used to analyze the system's entanglement dynamics, quantified through logarithmic negativity and quantum mutual information, while ensuring the positivity of the density operator to confirm the physical validity of the results. We demonstrated that, under certain parameter regimes and initial conditions, the asymptotic dynamics could give rise to periodic entanglement–disentanglement behavior. Furthermore, numerical simulations revealed that for negative values of the direct coupling between the oscillators, which were sufficiently close to a critical lower bound beyond which the system became unstable, the system could maintain entanglement across a broad temperature range and for arbitrarily long durations [7].

We developed a method for optimizing the structure of general binary-tree multiplexers realized with asymmetric photon routers aiming at improving the performance of spatially multiplexed single-photon sources. Our procedure systematically considered all possible binary-tree multiplexers that could be constructed using a certain number of photon routers. Using this method one can select the multiplexer structure that leads to the highest single-photon probability for a given set of loss parameters characterizing the system. We determined the optimal general binary-tree multiplexers for experimentally realizable values of the transmission coefficients of the photon routers and that of the detector efficiency. We showed that single-photon sources based on such optimal multiplexers yield higher single-photon probabilities than what can be achieved with single-photon sources based on any other spatial multiplexer considered in the literature. Our approach improveed the performance of multiplexed single-photon sources even for small system sizes which is the typical situation in current experiments [8].

The interplay between symmetry and dynamics is central to physics, as well as to other branches of science. An interesting situation arises in decision-making when you are offered several equally viable solutions and you are forced to select one. The ensuing delay is generally known as Buridan's paradox. We investigate a sketch of this situation in the context of optical multi-ports and comment on the role of symmetry and how physics deals with the dilemma of many options. It is noteworthy that in its simplest form, the evolution away from its initial state is sped up by quantum interference. However, more fully connected networks can display the frustration familiar from the classical paradox. The role of symmetry breaking is analysed for several cases and implications for the paradox were discussed. Our results have implications for quantum communications networks and other distributed quantum systems [9].

We presented a study of an open nondegenerate parametric oscillator below threshold in the undepleted pump regime with time-delayed coherent feedback. The figure of merit is the two-mode squeezing spectrum, measuring the strength of continuous-variable Einstein-Podolsky-Rosen-type entanglement between the down-converted modes in the output field as a function of frequency. Exploring different areas of the parameter space reveals the possibility of significantly enhanced entanglement with tunable characteristic frequency. This is a result of the emerging dynamical features that are only accessible due to delayed feedback. The system is very sensitive to phase matching, which can be adjusted by various parameters of the system and the feedback loop. In this way, sharp, resonancelike features are obtained that show a level of robustness against extraneous losses [10].

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