Abstract in English

The sensitivity of a probe to a parameter characterizing a system can be described within the single-parameter estimation framework. In the simplest treatment, the parameter is estimated under ideal conditions, neglecting imperfections from system–environment interactions. More advanced analyses consider estimation in the presence of known environmental noise. Although Heisenberg-limited sensitivity is lost, suitably engineered probes can still offer quantum enhancements. When the noise itself is unknown, the estimation problem becomes more complex, requiring a multiparameter approach.

Fundamental precision bounds for multiparameter estimation are well established, but their practical attainability remains elusive due to the challenge of constructing measurements with good multiparameter sensitivity. For a given probe, the incompatibility of optimal observables associated with different parameters poses an additional roadblock to achieving simultaneous optimal estimation. In practice, assessing the compatibility of separable measurements is essential, since very often collective strategies that are impractical are required to saturate the bound capturing fundamental incompatibility.

To this end, we consider the joint estimation of phase and phase diffusion, introducing quantifiers for information extraction and availability. We find that double homodyne measurement on states generated by the interference of N photons injected into one beamsplitter port yields the highest sensitivity. With respect to measurement compatibility, we study the joint estimation of phase and photon loss, and of phase and phase diffusion. Using the same multiphoton states, we compare double homodyne detection and photon counting against multiparameter precision benchmarks for collective and separable measurements. Among the cases considered, photon counting generally offers better performance for joint phase and loss estimation, while double homodyne still performs reasonably in some regimes for both estimation problems.