Quantum metrology: what about the measurements?

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The precision achievable by any measurement is ultimately limited by fundamental quantum mechanical bounds, but, well before that, the measurement strategy itself imposes other limitations. This is the case especially for multi-parameter scenarios for which the usual recipe of the Cramér-Rao bound does not provide strict bounds for the precision associated to each parameter [1, 2], and the problem is better cast in terms of a covariance matrix.

In this talk we will give a review on some recent results concerning bounds on precision arising from issue linked unavoidably to the measurement instruments, *rectius* to their associated POVMs. The cases we have investigated are:

The joint estimation of phase and phase diffusion with qubit-like systems. We find that, when coherent states, the attainable precisions on the mean value of a varying phase and its variance can not be estimated together at the quantum limit [2], and that quantum states commonly considered for quantum-enhanced precision, such as $N00N$ states, can not provide an advantage in this case. We also show that weak measurements are bound to obey the same bound, as we illustrated with a simple experimental example.

The estimation of detector efficiencies. While lossy optical detectors are commonly represented with a beamsplitter followed by an ideal device. When estimating the inefficiency of a detector, the POVM is fixed to that implemented by the ideal detector. This is fun- damentally different from the estimation of any other parameter, where one is free to choose the measurement [3]. We identify a crossover in the nature of the optimal probe state for estimating detector imperfections as a function of the loss parameter, as illustrated in Fig.1. We provide explicit results for on-off and homodyne detectors, the most widely used detectors in quantum photonics technologies.

Optimisation in the presence of imperfect measurements. Departures of measurement devices from the ideal behaviour are bound to affect the optimal precision which can be attained. However, these departures might not be known in advance and an exhaustive, and demanding, detector characterisation can be needed [4]. We have found that using the data fitting pattern technique [5] might alleviate the data processing needed to obtain the optimal probe state to be used with unknown devices. We discuss our progress in this direction.

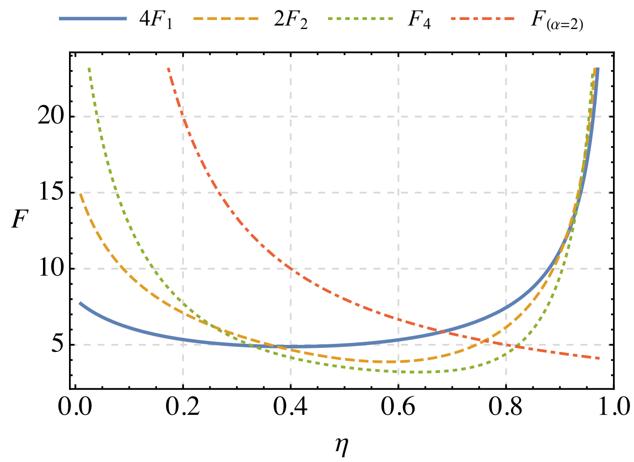

FIG. 1. Comparison of the Fisher information for the homodyne detector: n=1 Fock state (solid blue line), n=2 Fock state (dashed gold line), n=4 Fock state (dotted green line), and a coherent state with $|\alpha|^2$=4 (dot-dashed red line). The comparison is carried out for a given amount of energy, thus we allow for multiple copies of lower-energy probles.

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