

# Repeated Error Correction for Quantum Metrology

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The objective of quantum metrology is to determine high precision estimates of unknown parameters. Because entanglement allows one to create non-classical correlations between the quantum probes, one is able to develop estimation strategies that achieve a quadratic gain in precision over the best classical strategies. However, in a realistic setting, quantum metrology is faced with many obstacles; one of the most difficult to overcome is noise. It becomes increasingly difficult to distinguish the effects of a signal versus the effects of noise [1]; significantly reducing the achievable precision.

One of the proposed solutions to counter the effects of noise is to incorporate quantum error correction techniques within the quantum metrology scheme. It was shown that if the noise and signal satisfy an orthogonality condition, then the Heisenberg limit may be recovered by repeatedly performing error correction [2, 3]. Unfortunately, the necessary conditions to recover the Heisenberg limit are unattainable with current quantum technologies. For example i) instantaneous error correction with an infinitesimal wait time between applications, ii) the availability of noiseless ancilla, and iii) error correction performed with perfect fidelity.

In our study we explore a model with discrete applications of error correction; illustrated in Figure 1. We keep current technological limitations in mind and focus on a specific error correction model: a parity check with an ancillary qubit. As expected, we show that the duration of time which the Heisenberg limit can be achieved is extended, but cannot not be achieved indefinitely. We discuss the limitations of general error correction strategies for quantum metrology. Lastly, we benchmark the factors of today's quantum technologies which need to be improved upon such that one can reliably achieve a Heisenberg limit level of precision.

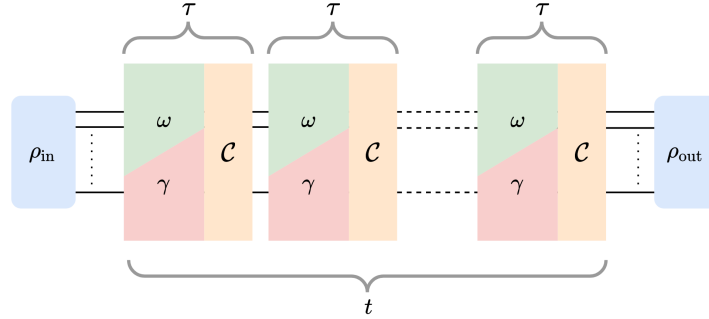


FIG. 1 : In a realistic quantum metrology scheme, error correction is not an instantaneous process, and that the wait time between error correction is not infinitesimally small. We account for this by setting a finite time  $\tau$  between applications of error correction; during which the evolution of the input state,  $\rho_{\text{in}}$ , is influenced by the signal  $\omega$  and the noise  $\gamma$ . This process is repeated  $t/\tau$  times. The final quantum state  $\rho_{\text{out}}$  is used for parameter estimation.

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