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BOSONIC QUANTUM SENSING

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QUANTUM SENSING

Quantum sensing is a big umbrella name: quantum strategies able to outperform classical techniques in tasks of detection, estimation, resolution, etc.

Two basic approaches with bosonic systems:

- Estimation of phase
- Estimation/discrimination of loss (e.g., optical absorbance)

Protocols are "quantum" because they beat "classical" benchmarks

Quantum illumination is "quantum" because it beats classical strategies (coherent states) in detecting a remote reflecting target

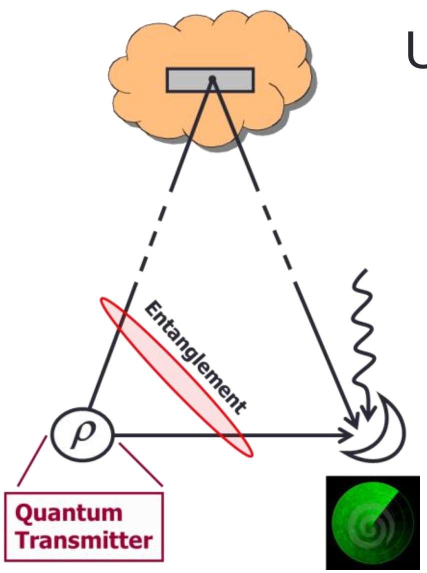
Quantum parameter estimation is "quantum" because it beats the standard quantum limit (performance of coherent states)

Quantum optical resolution is "quantum" because it beats the Rayleigh diffraction limit etc.

It is important:

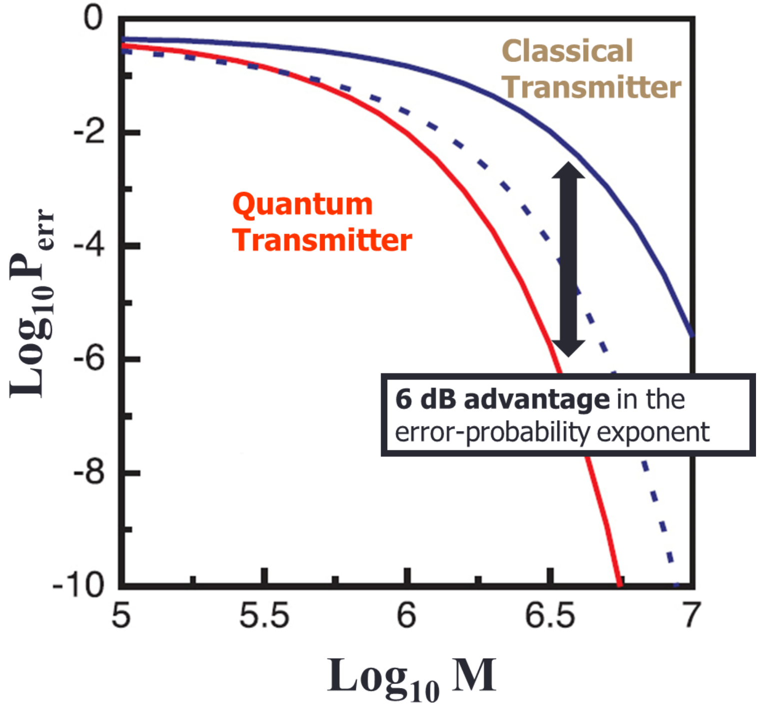
1) Clear identification of the **classical benchmark (theory)**
2) Proof that we can do better with a **quantum setup (theory)**
3) Proof that the quantum advantage is **robust & practical (theory/exp)**

Quantum LIDAR/RADAR



Use of entanglement to better detect an object in bright thermal noise

Entanglement robust to noise
6dB advantage over CS for large number of probes.



Tan et al. PRL 101, 253601 (2008)

Challenges:

- Need to store the idler modes
- Need joint multimode receivers
- Need many modes

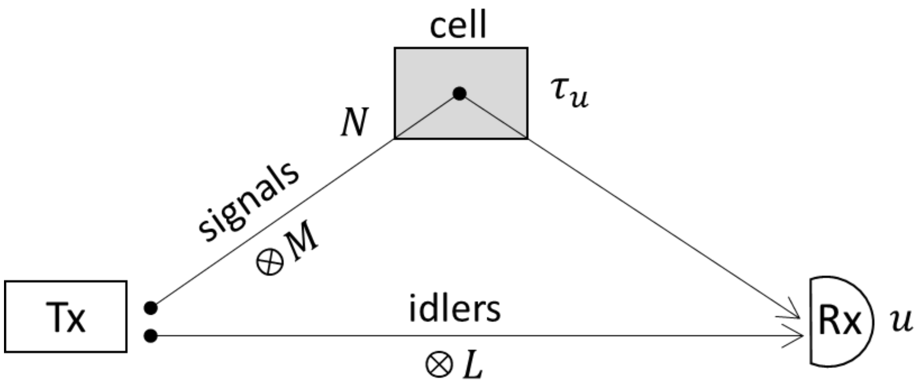
Restrictions:

- Not robust to loss (limited to short-range)
- Not developed beyond yes/no detection
- Need phase information from target

Applications: proximity sensors in bright backgrounds, short-range surveillance

Quantum readers/scanners

Use of a quantum source (e.g., entanglement) and a quantum receiver to boost the retrieval of information/data stored in the reflectivity/transmissivity of a physical system.



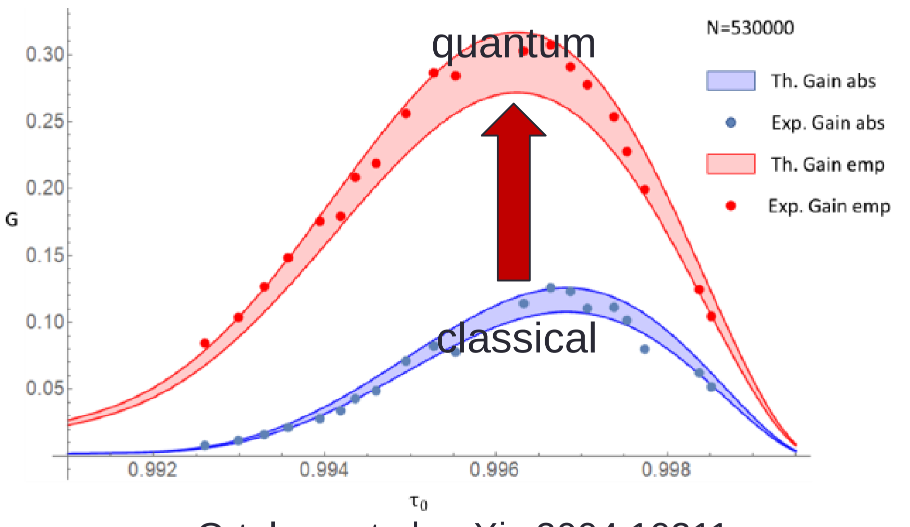
Pirandola, PRL 106, 090504 (2011)

Applications:

- Readout of optical/digital memories
- Barcode decoding
- Pattern recognition
- Digital image reconstruction

Regime:

- Mainly short-range (limited loss)
- Work in reflection or in transmission
- No need of large number of probes
- Less need for quantum memories (idler storage in delay lines)



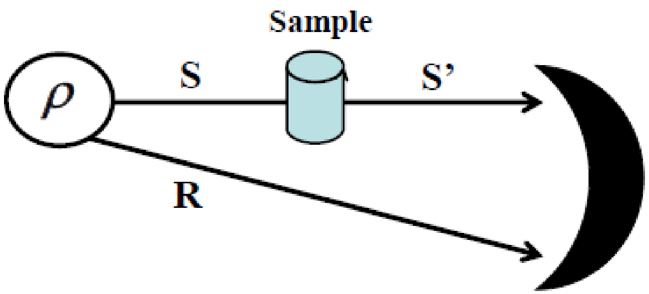
Ortolano et al. arXiv:2004.10211

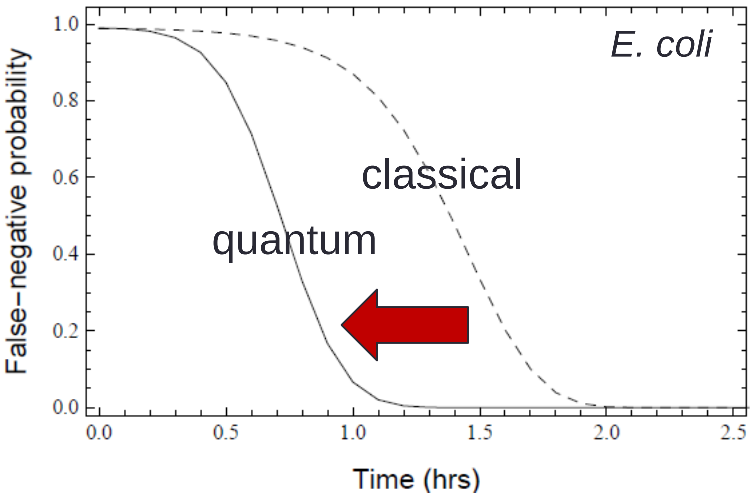
Status:

- A lot of theory already developed
- Only a few experiments

Quantum photometry/spectroscopy

- Development of quantum photometry
  - Improved measurements of concentrations (DNA/RNA etc.)
  - Faster identification of bacteria





In the frequency domain: bosonic loss associated with absorbance lines in spectra

Spedalieri et al., arXiv:2006.13250

- Development of quantum spectroscopy
  - More precise spectrum profiles
  - Low-energy: non-invasive, real-time monitoring
  - Optical but also lower frequencies (microwave):
    - Condensed matter physics (solid/atomic spins)
    - Rotational spectroscopy (organic molecules)

- Ideal developments: high-frequency applications (X-ray) - Low-dose CT scans