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Quantum entanglement for precision enhancement: advancing standardized quantum measurements

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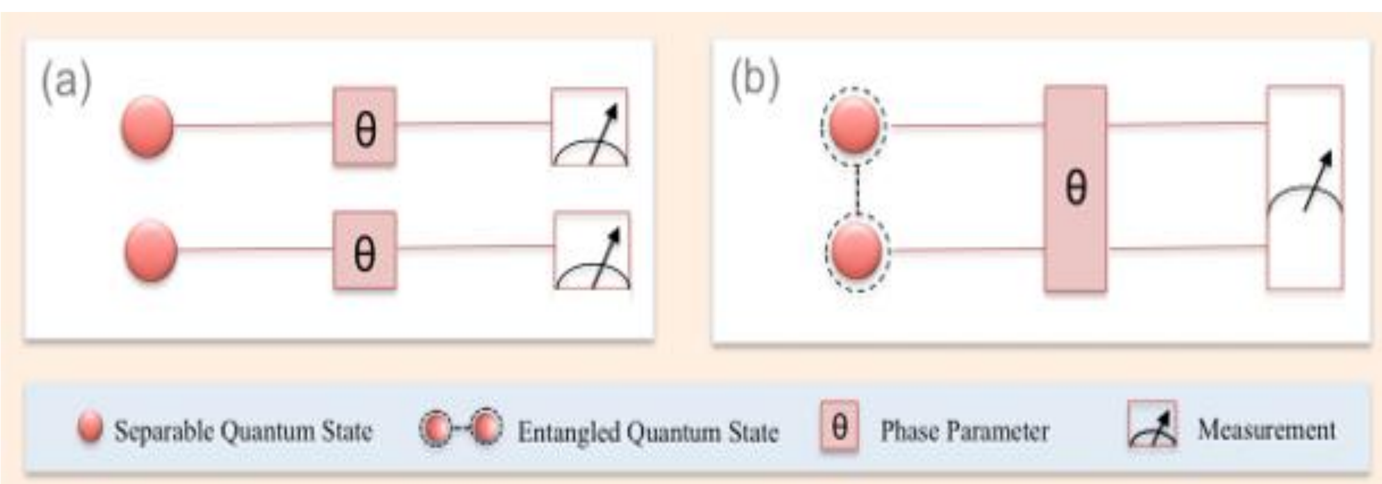
1. Introduction

1.1 Quantum-Enhanced Measurement Precision

Quantum theory predicts the ultimate limit of measurement precision. By leveraging quantum entanglement—correlations between particles of light or matter that cannot be explained in classical physics—one can surpass classical measurement limits. Specifically, entanglement enhances measurement precision by a factor of √N beyond what is achievable with classical resources (Figure 1) [1-3].



	(a) Poisson noise limit	(b) Heisenberg limit
Uncertainty	$1/\sqrt{2}$	$1/2$

Figure1. Comparison of measurement methodologies for single-parameter estimation. (a) Two separable probes independently interrogate the sensing target before independent detection. (b) A two-particle-entangled probe jointly interrogates the sensing target before joint detection.

1.2 Potential Impacts

Example application	Measurand
Clock synchronization [4]	Frequency
Baseline interferometry [5]	Optical phase
Sensor network [6]	Displacement
Cryptography [7]	Quantum state

2. Current work at NRC Metrology

2.1 Quantum Network Testbed Development

1. Distributed entangled three photons
2. Entanglement certification and scalable generation

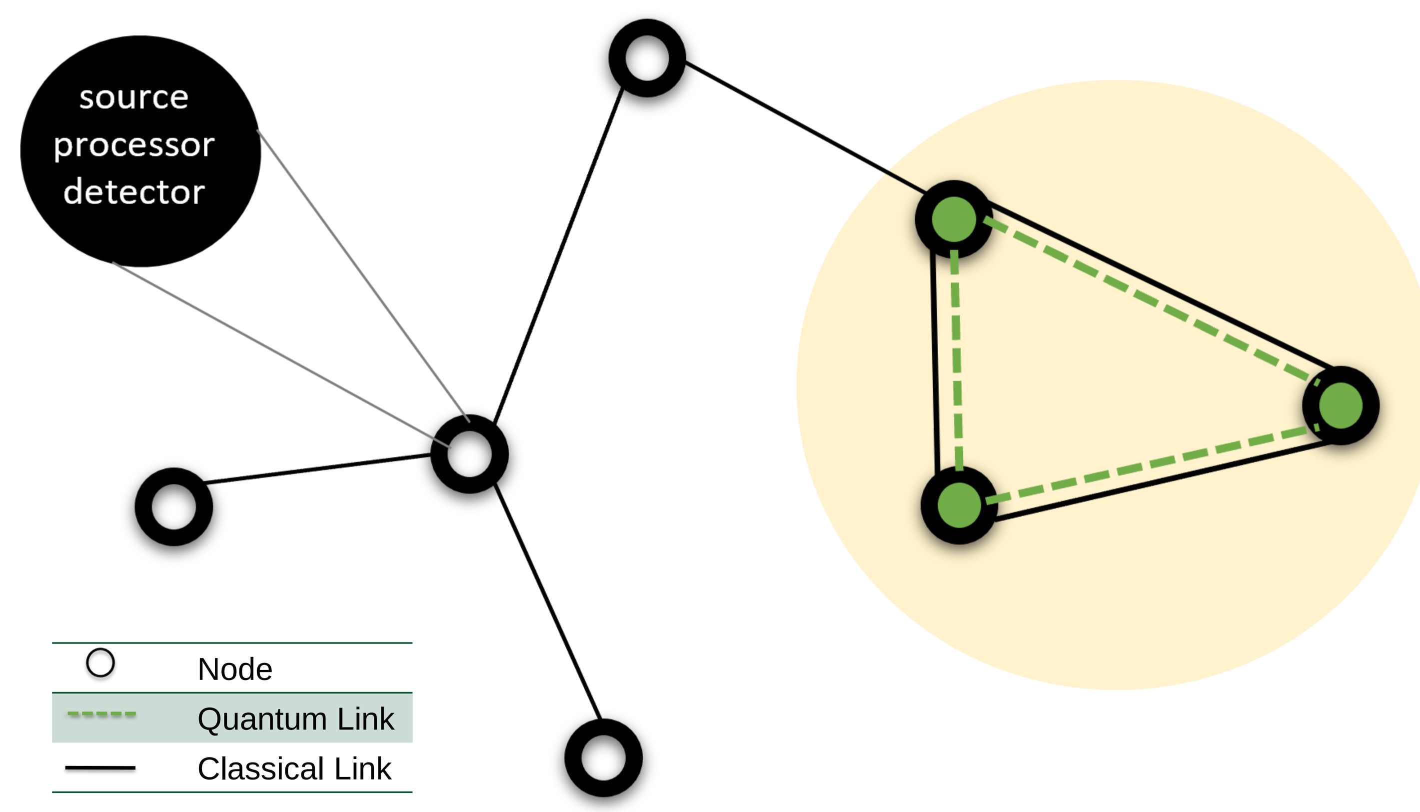
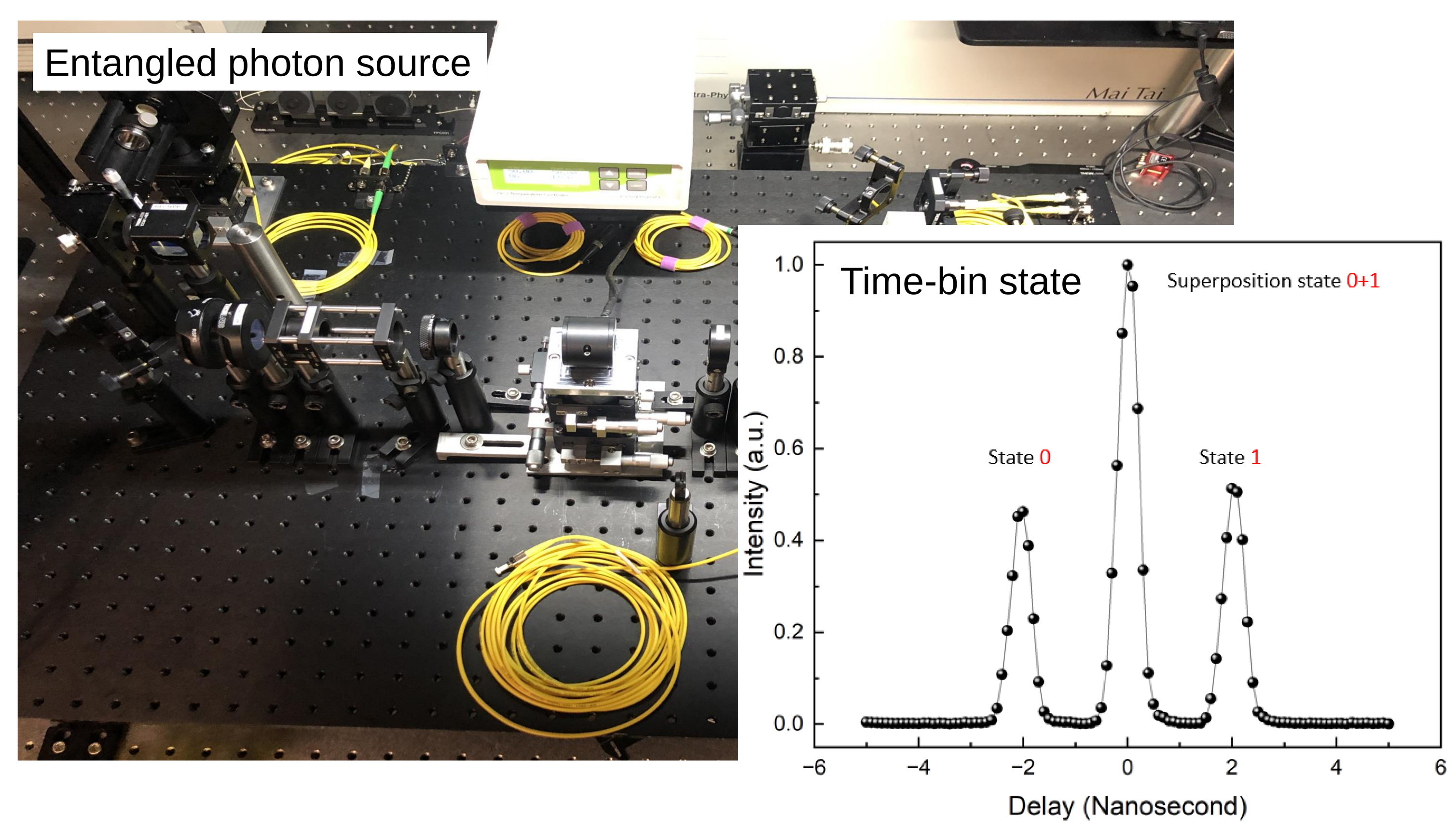


Figure 2. A schematic diagram of a three-node quantum network (yellow circle) currently under development at NRC Metrology.

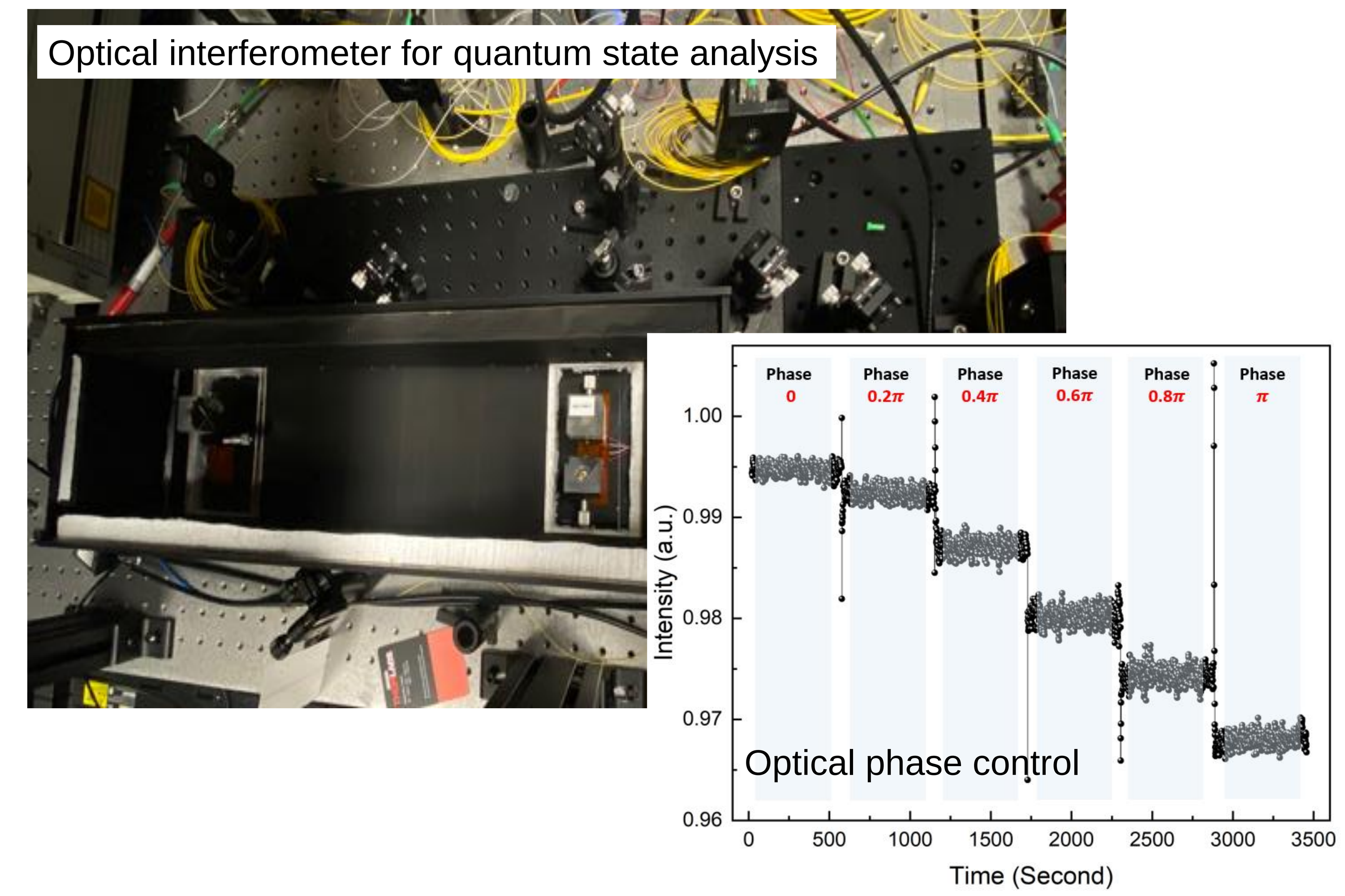
2.2 Entangled Sensors

1. Time-encoded photon states
2. Direct integration into telecommunication infrastructure



2.3 Entanglement Validation

Standards development for non-classical correlation



3. Future work

1. Real-time quantum channel stabilization
2. Utilization of the testbed for *in-situ* calibration of quantum hardware in collaboration with industry and academia
3. Support for quantum photonics standards

References

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