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Microwave Photonics and Quantum Applications

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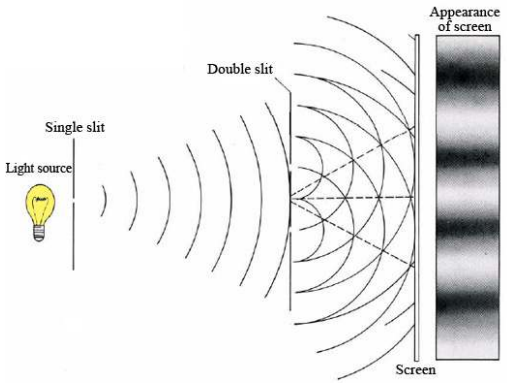
Outline

- What is “Quantum” in Quantum Technology
- MWP and its relation to Quantum Technology
- MWP Assisted Quantum
- Quantum Assisted MWP
- Examples and Future Directions

"Quantum" in Quantum Technology

- Photons, atoms, molecules and elementary particles are all quantum objects. But what sets quantum technology apart from a source of photons, for example, is the use of fundamentally "quantum" processes:
  - Non-locality
  - Quantum Superposition
  - Quantum Correlation and entanglement



What is Quantum Technology

- Quantum Computers
  - Bits -> qubits
- Quantum Sensors
  - Beyond the classical schemes
- Quantum Communication --- Cryptology and Security
- Quantum Networks

MWP and its Relation to Quantum Technology

- There is a reciprocal relationship between MWP and Quantum Technology:
  - Microwave Photonics applied to Quantum Technology
  - Quantum Technology applied to Microwave Photonics

MWP and its Relation to Quantum Technology

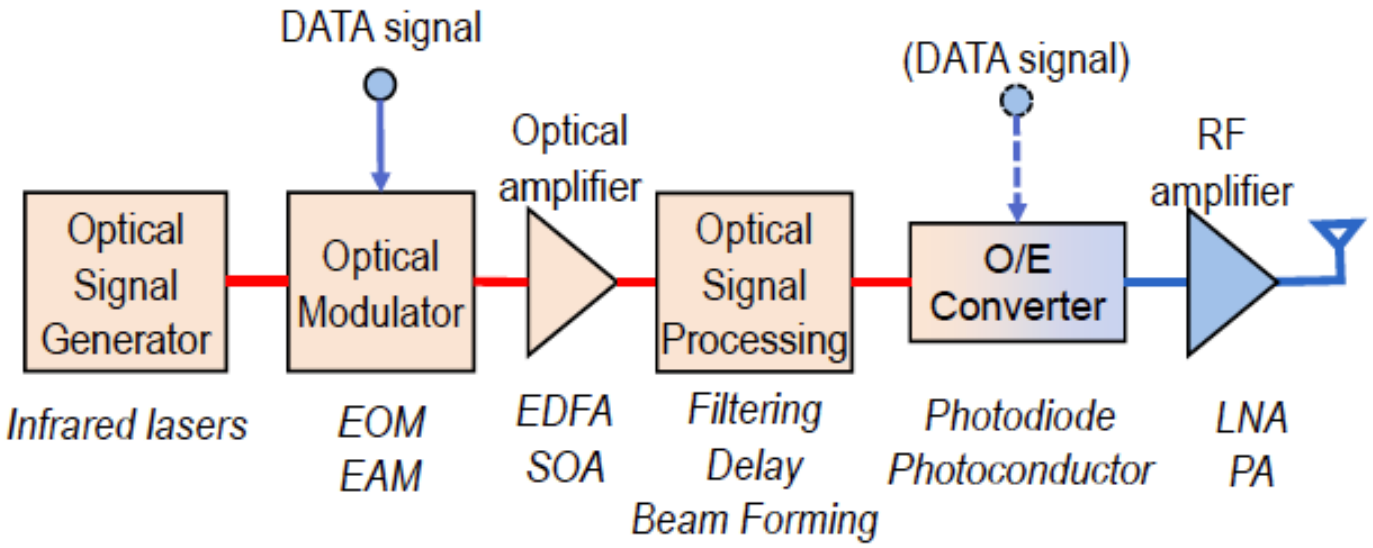
- There are similarities in the needs of the two technologies
  - High efficiency, low noise sources and detectors
  - Low loss links
- There are differences in the needs of the two technologies
  - MWP requires wide bandwidth and large dynamic range
  - Quantum Technologies require narrow bandwidth and small dynamic range

MWP and its relation to Quantum Technology

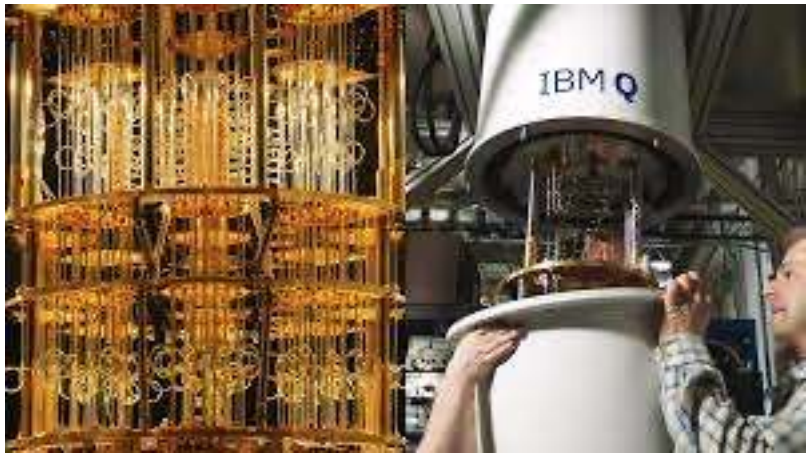
- Quantum Technology utilizes:
  - Low noise lasers
  - Entangled Photon sources
  - Single Photon detectors
  - Low loss links

These capabilities can enhance performance of MWP systems

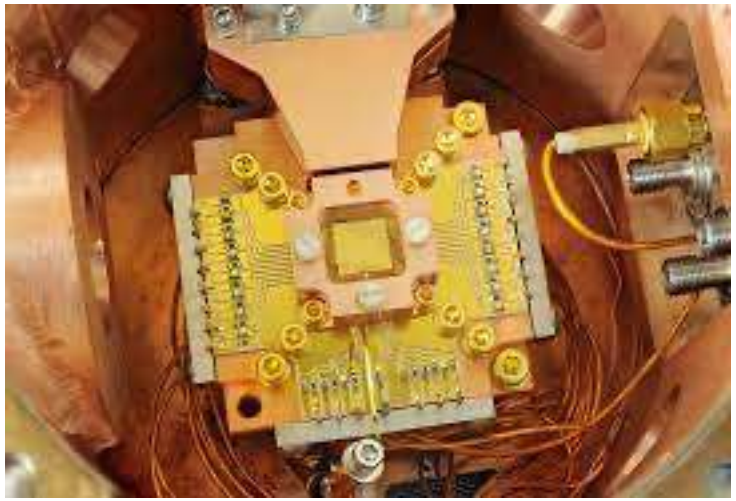
Block Diagram of a MWP Link



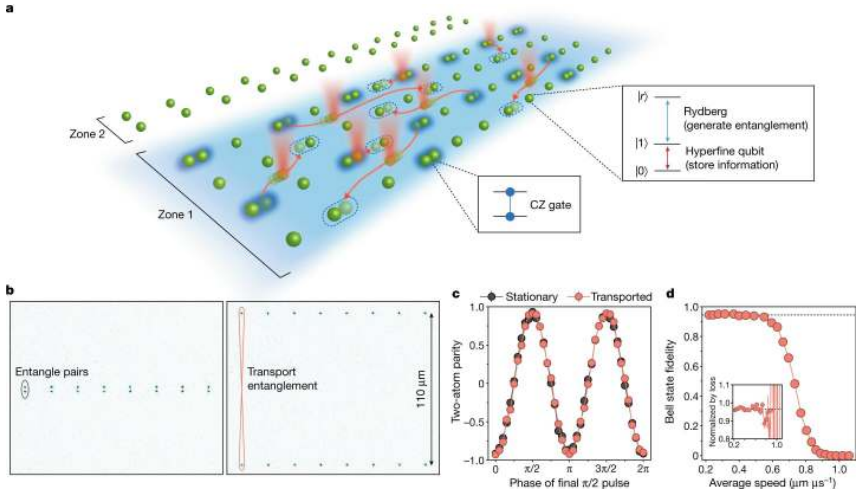
Quantum Computers



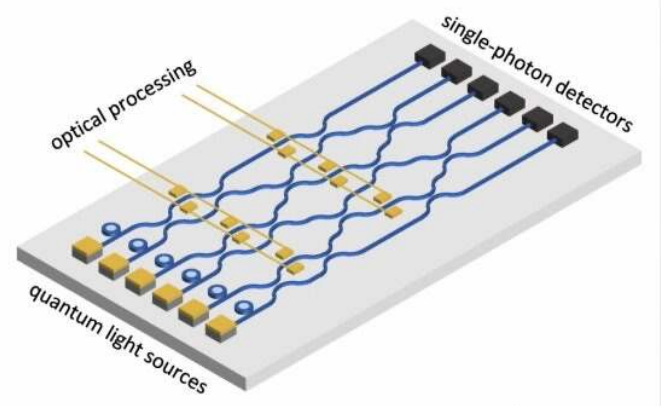
Superconducting Systems



Ion Trap Systems

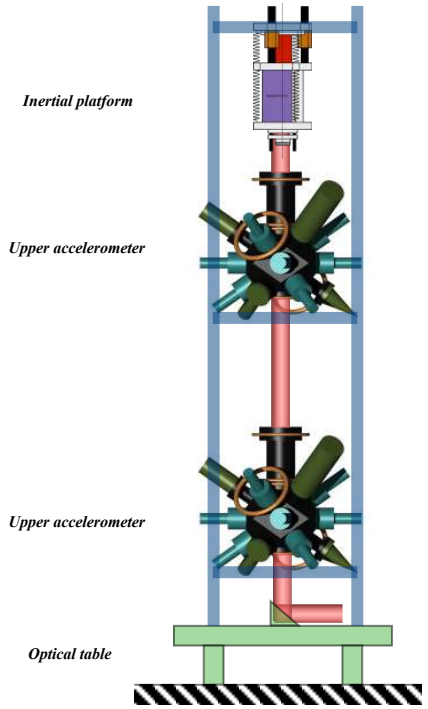


Neutral Atom Systems

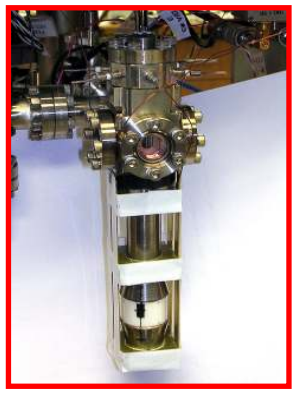


Photon Based Systems

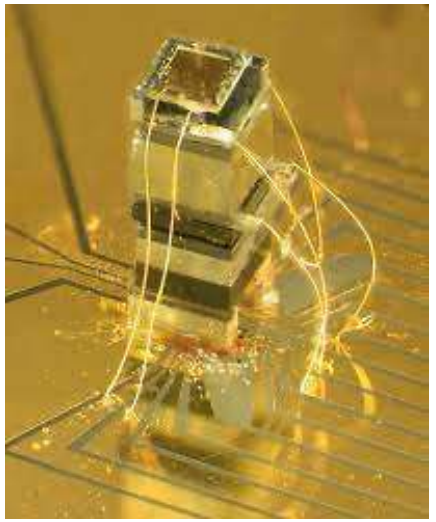
Quantum Sensors



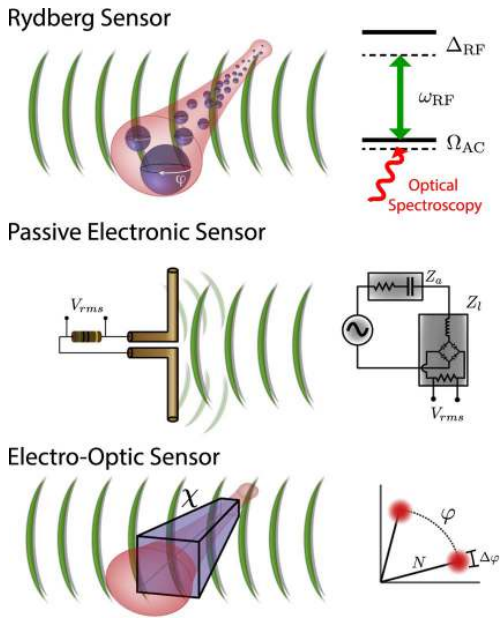
Quantum Gravity Gradiometer



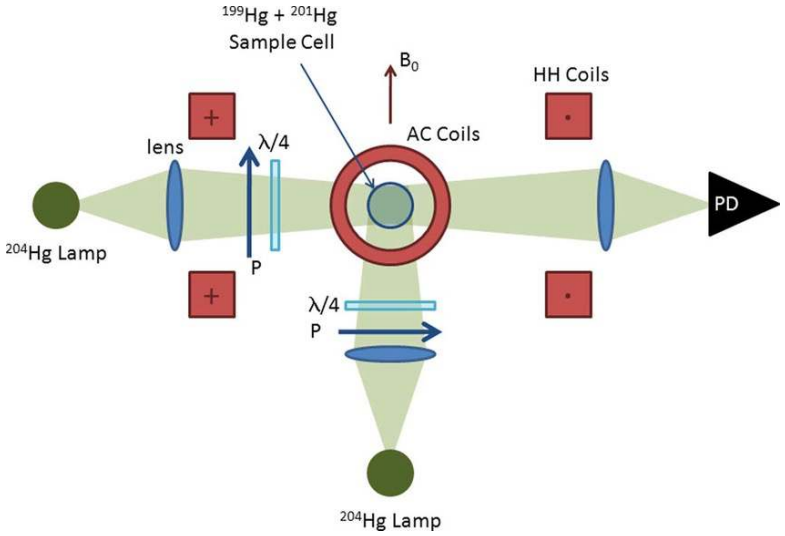
Atomic Clock



Magnetometer

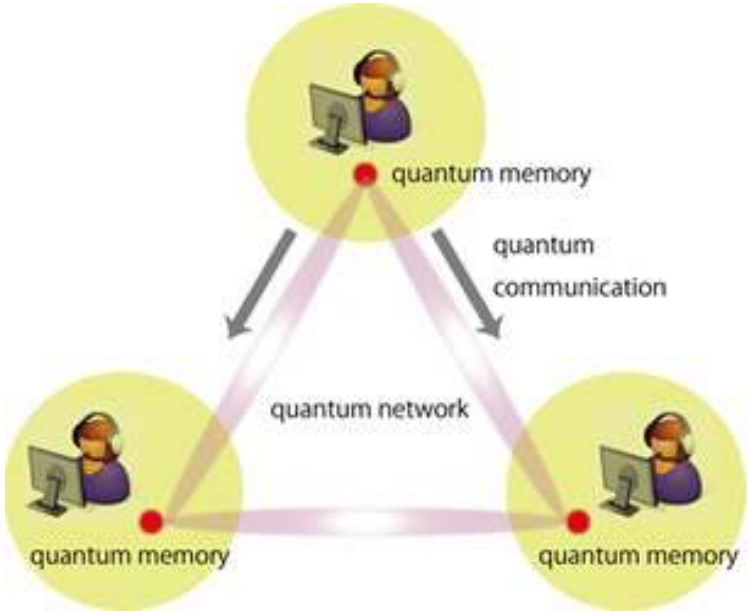


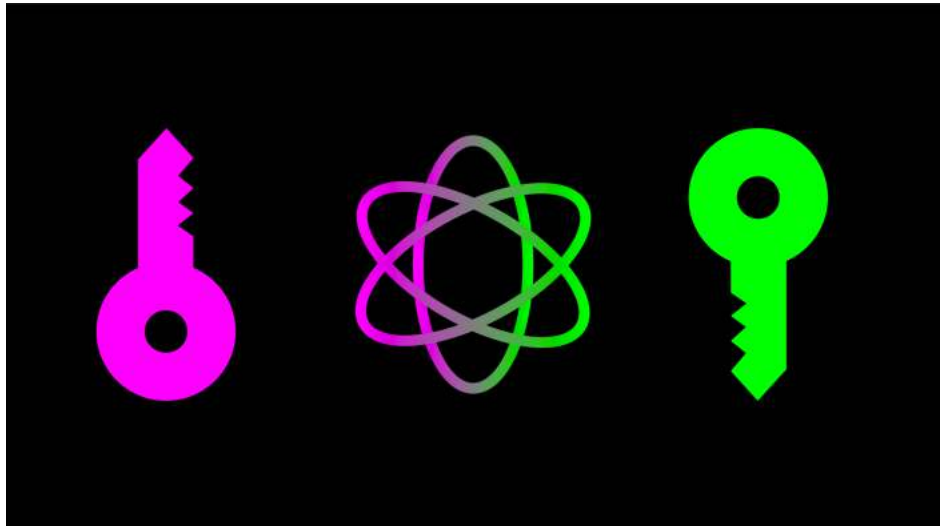
Field Sensors



Atomic Gyroscope

Quantum Communication

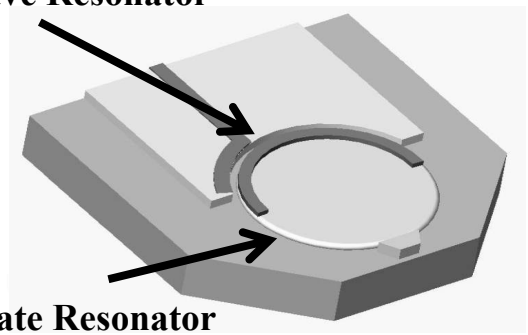




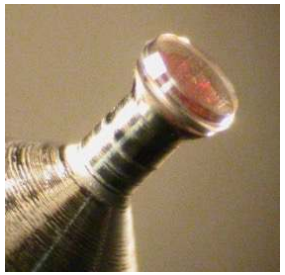
Need for Efficient Network Links

Efficient Single Sideband Modulator

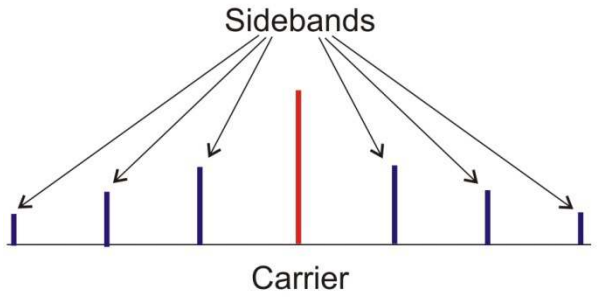
Microwave Resonator

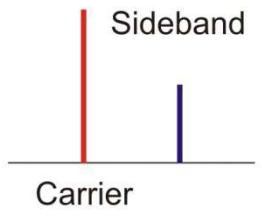


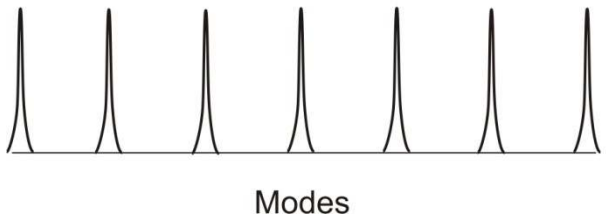
Lithium Niobate Resonator

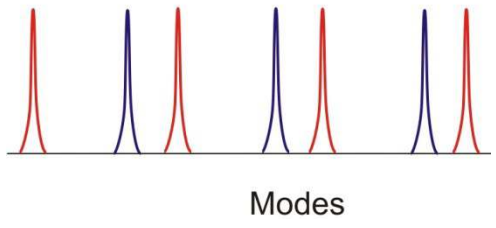


WGM Resonator

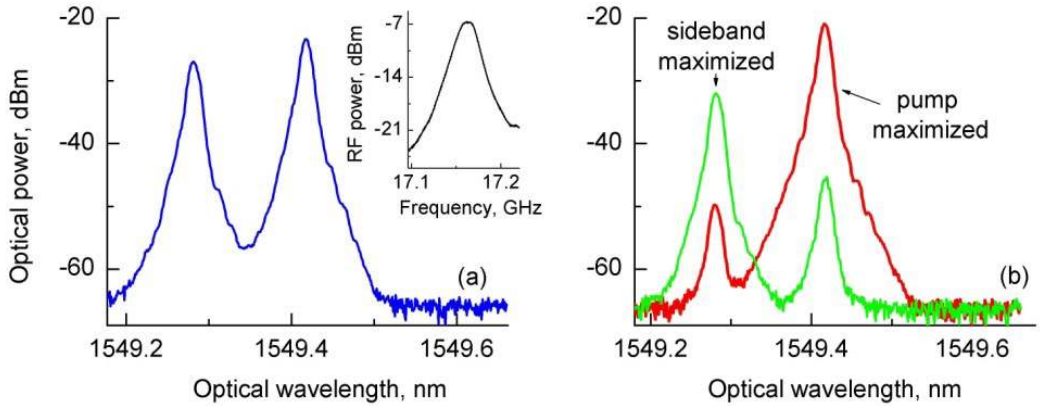


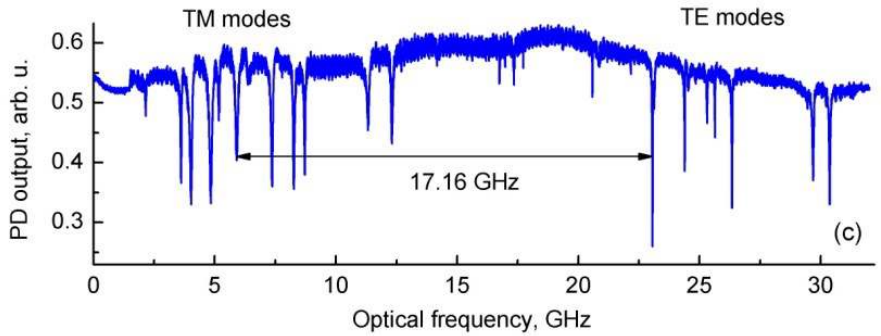






A. A. Savchenkov, et al.,Photonic E-field sensor.
B. *AIP Advances* 1 December 2014; 4 (12): 122901.

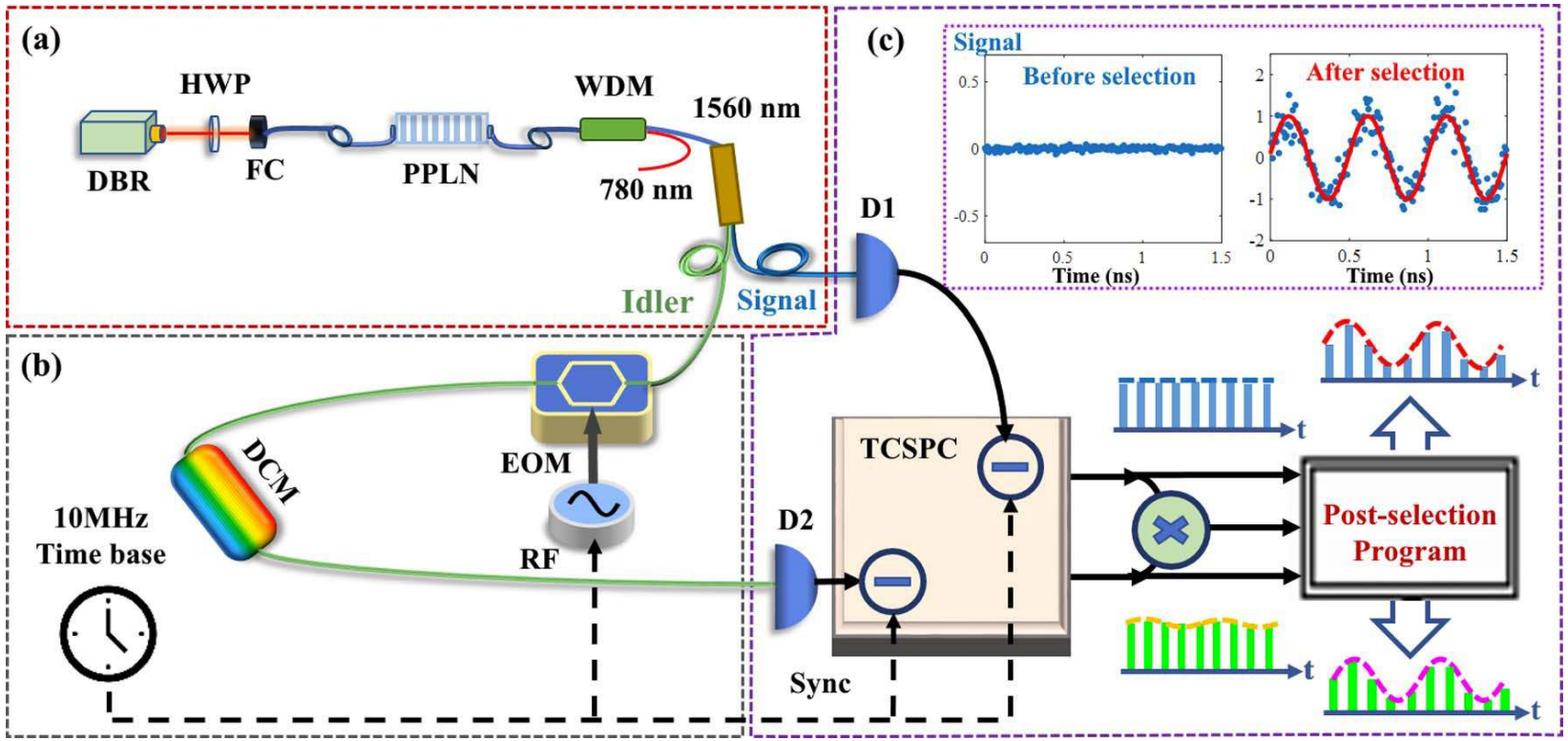




Q-MWP for Radio Over Fiber

- Q-MWP applied to Radio Over Fiber offers
  - Unprecedented non-local RF modulation
  - Strong resistance to dispersion
  - Improved spurious-free dynamic range enabled by nonlocal modulation and distilled RF signals
  - Potentially advances modern communications and networks

Q-MWP in Radio Over Fiber

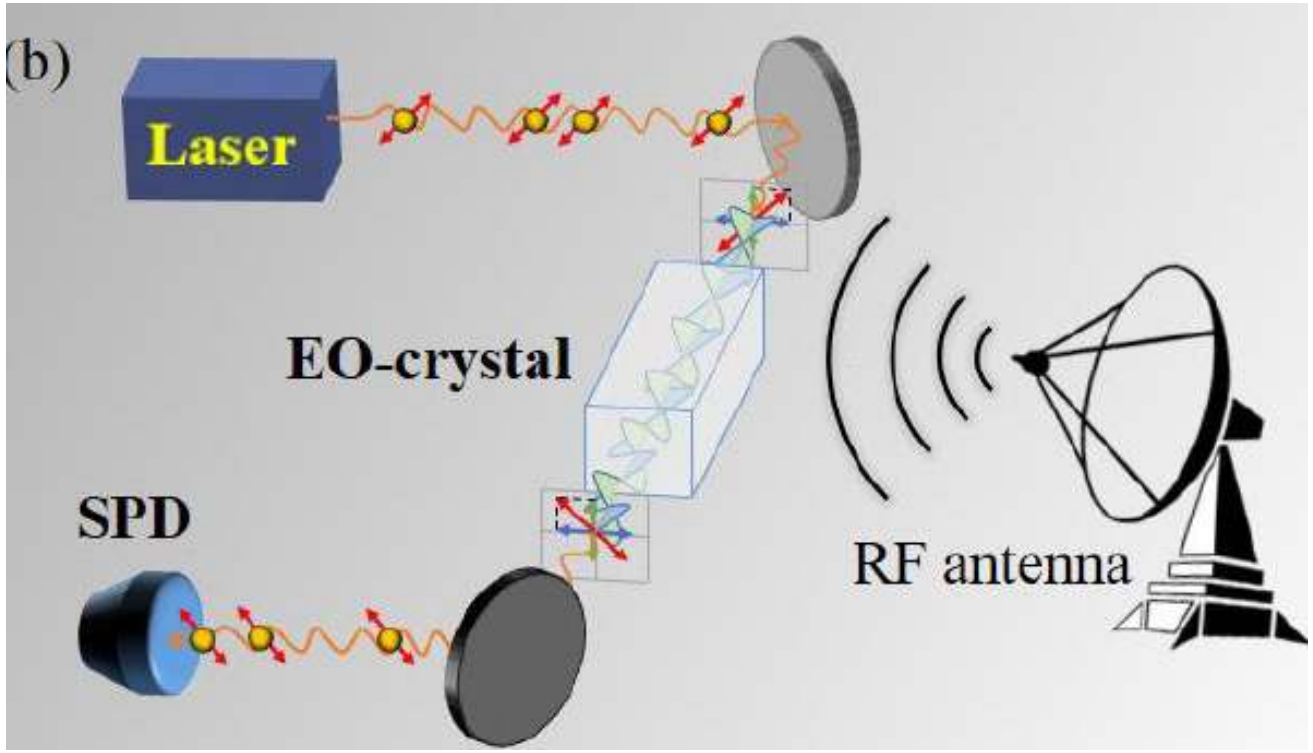


Yaqing Jin, et al., Photonics Research, Vol. 10, No. 7, July 2022

Quantum Compresses Sensing

- Fast and accurate detection and identification of unknown, wideband frequencies re crucial for radar warning, agile receivers; cognitive radio; wireless (5G-6G) communication, limited by ADC performance
- Compressed sensing is used to recover the sparse signal with the sampling rate far lower than the Nyquist sampling with energy efficiency
- Quantum mechanics and photonic compresses sensing can significantly improve real-time bandwidth analysis and compression ratio

Quantum Compresses Sensing



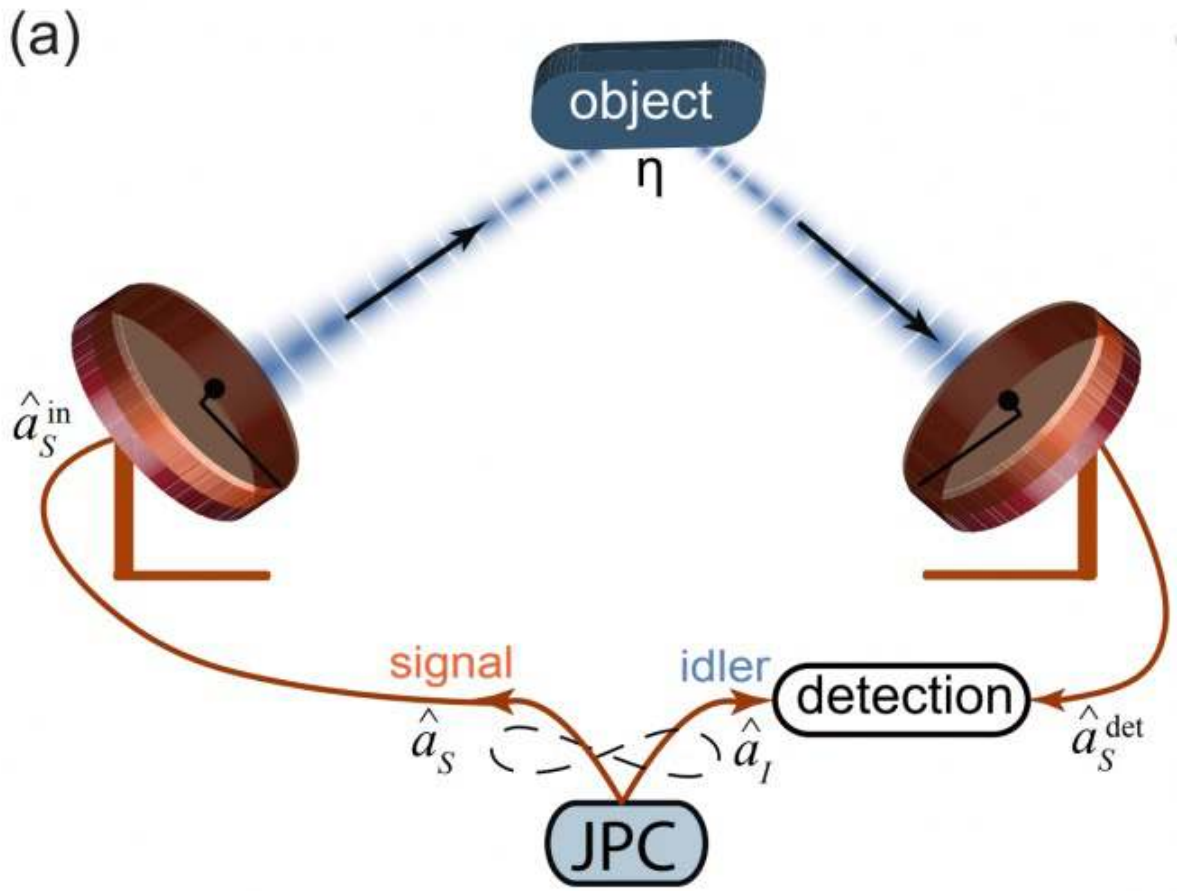
Jianyong Hu, et. al, arXiv:2106.13668

Quantum Radar

Microwave photons, optical photons, and quantum phenomena

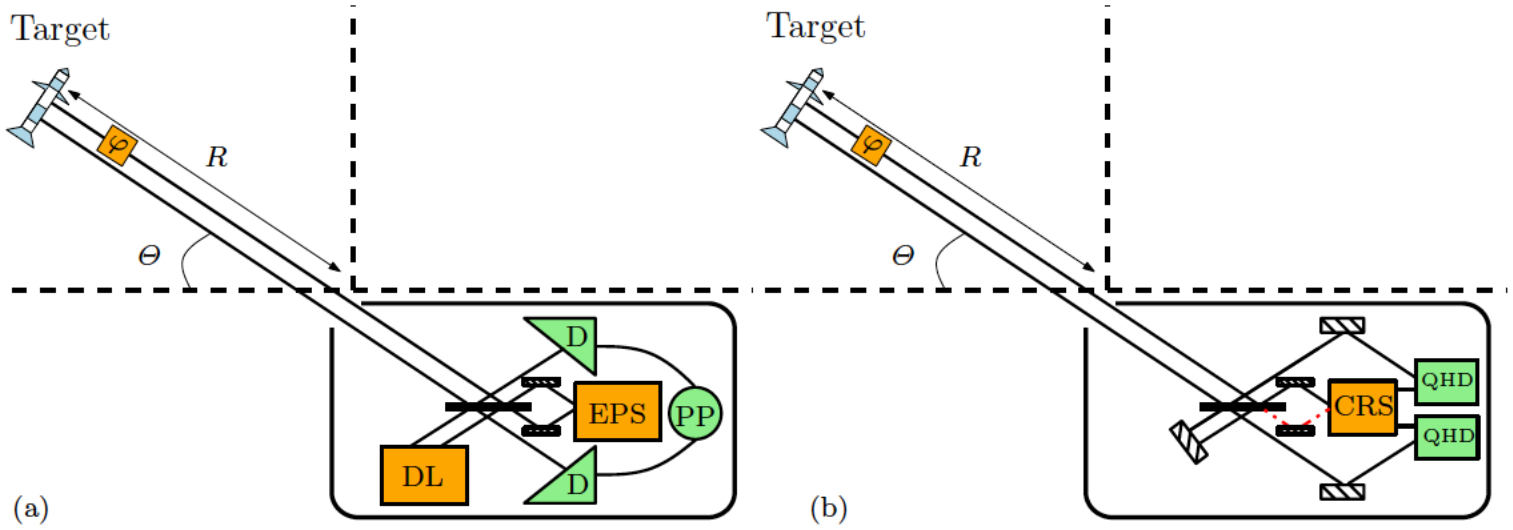
- Quantum Radar combines coherent radar radiation sources with quantum homodyne detection
- It can provide longitudinal, and angular, resolution below Rayleigh diffraction limit (super-resolution)
- It is still to be demonstrated fully, though progress has been made

Quantum Illumination



S. Barzanjeh, S. Pirandola, D. Vitali, J. M. Fink,
arXiv:1908.03058

Quantum Radar



Two Quantum Radar systems in Michelson Interferometer configuration

Kebei Jiang, Doctoral Dissertation, LSU 2014

Summary

- Q-MWP is an emerging field and offers combined capabilities of Quantum and MWP to advance both fields
  - Some of the requirements for the two fields are different and opposite; some of the requirements are the same
  - Many of the techniques and components that exist or emerging can benefit both fields
- New concepts in Q-MWP represent major and revolutionary advances in the field
- There are many opportunities to engage in the development of Q-MWP