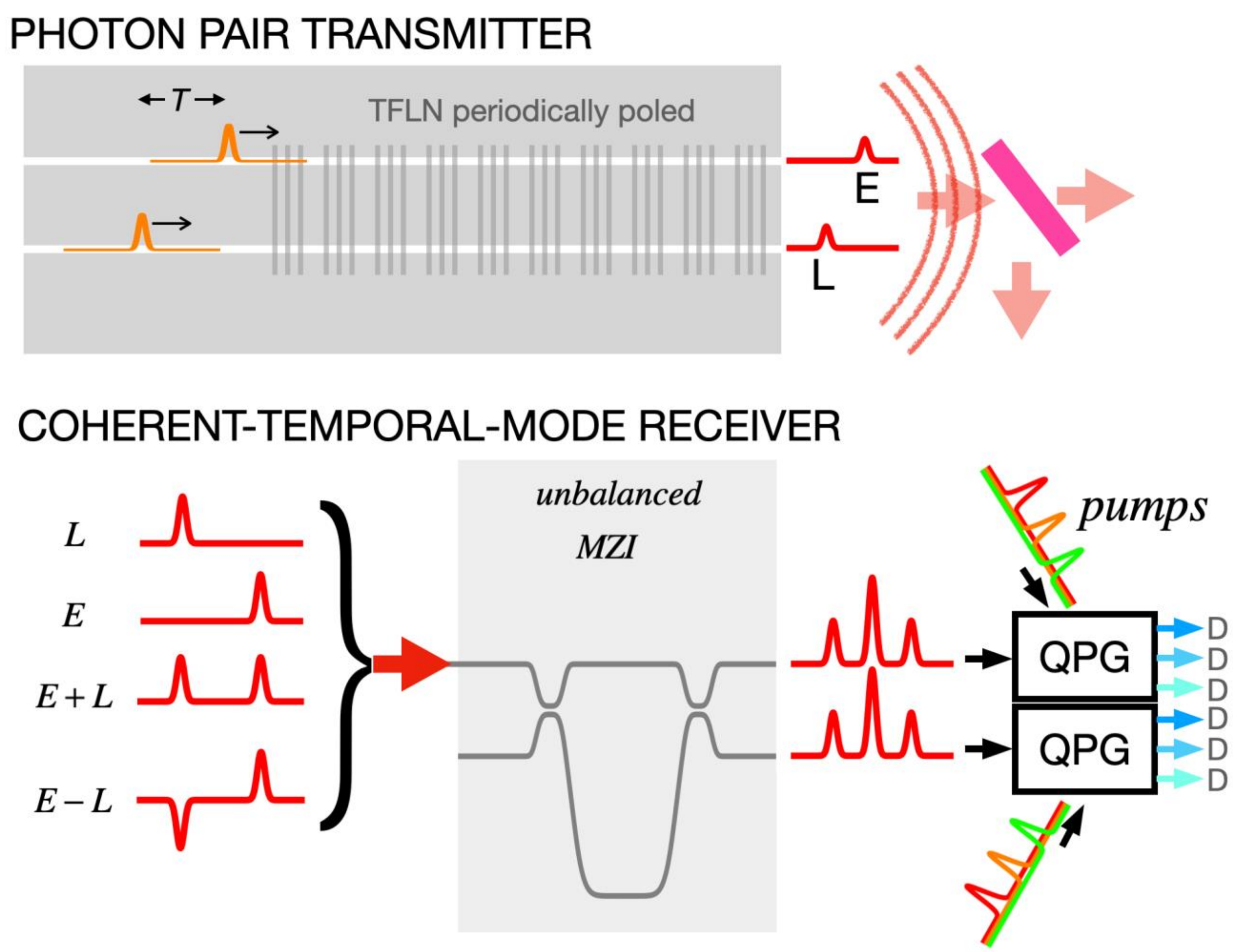
Quantum Communication Links using Coherent-Filter-Based Transmitter-Receiver Pairs

PI: Brian J Smith - University of Oregon
Co-PIs: Michael G. Raymer - University of Oregon
Marko Loncar - Harvard University
Neil Sinclair - Harvard University

Research Objectives

- Demonstrate a concrete path to achieve matched source and coherent temporal-mode receiver link demonstrating 80 MHz rate of distributed entanglement with less than 10^{-3} double pair probability and state fidelity greater than 0.99
- Increased entanglement distribution rate across noisy channels by at least an order of magnitude by coherent temporal-mode filtering
- Significant reduction in background noise using quantum pulse gate (QPG)
- Novel source-receiver design enabled by engineered phase-matching through quasi-phase matching in thin-film lithium niobate (TFLN)
- Starting TRL 2 and ending at TRL 4: current state is TRL2. QPG has been demonstrated. TFLN sources have been implemented.



Time-bin entangled-photon pair source based on spontaneous parametric down conversion (SPDC) (top) generated in two periodically-poled TFLN waveguides. Signal and idler photons are produced at non-degenerate wavelengths and separated using a dichroic mirror (or wavelength division multiplexing on chip). The spatial modes are coherently combined through free-space propagation to the receiver where they are not spatially resolved.

Coherent time-bin qubit receiver (bottom). Photons from the source can occupy early (E) or late (L) time bins, which can be probabilistically interfered in an unbalanced Mach-Zehnder interferometer (MZI). A quantum pulse gate (QPG), pumped by three spectrally-distinct pump pulses that temporally overlap with the three time-bins emerging from the unbalanced MZI, coherently converts each pulse to a unique output through sum-frequency generation (blue shades). These are detected or sent for further optical processing.

Approach

- Apply coherent filtering based on QPG to decrease noise and increase space communication rates by at least an order of magnitude
- Design and fabricate time-bin and frequency multiplexed entanglement source on a TFLN chip, with availability to further multiplex by an order of magnitude
- Design and fabricate segmented periodic poling to generate pure photon pairs in 8 frequency modes on a TFLN chip
- Develop fully integrated transmitter and receiver chips
- Develop theory for efficient device characterization and channel performance
- Optically test and characterize transmitter and receiver
- Demonstrate proof-of-concept communication link in laboratory setting

Potential Impacts

- Push entanglement distribution rates towards bandwidth limits, enabling understanding of practical limits to communication rates and device capabilities
- Temporal-mode based system enables synchronization by using shared reference pulses derived from SPDC pump
- Pairs could be used for remote quantum sensing applications
- Successful technology allows satellite and terrestrial based quantum communication and networks of scales and rates greater than the state of the art
- Benefits to optical communication (including deep-space optical comms), optical signal processing, quantum optics and computation, sensing and metrology, ultrafast optics