Generation of Fiber-Coupled, Nondegenerate, Polarization-Entangled Photons for Quantum Communication

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Experimental quantum information science applies quantum mechanical resources, such as superposition and entanglement, to practical engineering applications in physical communication, computation, and metrology, often providing advantages unrealizable by their classical counterparts. A representative physical carrier for a quantum bit ('qubit') is the photon, which experiences only weak decoherence and interaction with its environment. The weak attenuation of photons through single-mode optical fibers allows the transfer of photonic qubits over long distances (e.g., kilometers), including the establishment of two-qubit entanglement for quantum key distribution (QKD). As such, the aim of this thesis project is to construct such a source of polarization-entangled photon pairs using spontaneous parametric downconversion (SPDC) in periodically-polled, MgO-doped lithium niobate (MgO:PPLN).

Two aspects of this construction are to be examined: first, SPDC in a given nonlinear crystal, and second, the arrangement of SPDC output for increased spectral brightness. SPDC in a nonlinear crystal spontaneously converts a single pump photon (**p**) into a pair of subharmonic photons (labelled signal **s** and idler **i**) while maintaining momentum and energy conservation such that $\omega_{\mathbf{p}} = \omega_{\mathbf{s}} + \omega_{\mathbf{i}}$. However, crystal choice and optical configurations pose varying difficulties. Momentum conservation of pump, signal, and idler photons (also known as phase matching) is temperature dependent, and for a given emission angle, restricts the creation of wavelength-degenerate photons to a particular temperature. Periodically-poling solves this problem by periodically inverting the crystal's effective nonlinearity with an alternating electric field during fabrication. This process eases the requirements for phase-matching angles and wavelengths that normally pose difficulties in bulk crystals, where angle and birefringence phase-matching were once the only methods prior to the discovery of quasi-phase matching.

I propose to apply previous[1] high-brightness technology using bidirectionally pumped type-II PPKTP in phase-stable, polarization Sagnac interferometers to type-I phase-matched MgO:PPLN. Our new source will use type-I downconversion of pump photons from a 532 nm continuous-wave (cw) laser into signal (798 nm) and idler photons (1608 nm). Type-I crystals pose several advantages over their type-II counterparts. Being nondegenerate, the downconverted signal and idler photons can be separated by a dichroic mirror and coupled into their respective single-mode optical fibers. The signal photon can be detected locally with a silicon avalanche photodiode (Si-APD), while the idler photon may be fiber-coupled and sent over longer distances with less attenuation. We will characterize the efficiency of our source by measuring its spectral brightness in terms of detected pairs/s/mW of pump power per nm of output photon bandwidth. Collinear photon emission cones from a type-I phase-matched crystal will increase spectral brightness relative to intersecting emission cones from a type-II downconversion. We will quantify the fidelity of the polarization-entangled singlet states created by measuring a quantum-interference visibility parameter using coincidence measurements.

[1]See Phys. Rev. A 73, 012316 (2006) and Rev. A 77, 032314 (2008) for initial construction of such sources, and Optics Express Vol. 15, No. 23, 15377 (2007) for wavelength-degenerate, type II, fiber-coupled sources.