Ultra-Low-Noise All-Fiber Photon Pair Source

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Photon pair sources have many uses as entangled photon pair sources or as heralded sources of single photons, for applications such as linear optical quantum computing and entanglement-based quantum key distribution [1-2]. Generating photon pairs directly in optical fiber has the key advantage of compatibility with existing fiber telecom networks. It has previously been demonstrated that the strong Raman scattering in fiber can be reduced by cooling the fiber in liquid nitrogen to 77 K [1-2]. Here we achieved almost complete suppression of Raman scattering by cooling the fiber to 4 K in a dewar of liquid helium. Also, we optimized pair production efficiency, and we characterized and reduced all background photons to demonstrate a record coincidence-to-accidental ratio (CAR) of 1300.

We generated photon pairs through spontaneous four wave mixing (FWM) in dispersion shifted fiber (DSF). A simplified diagram of the photon pair generation system is shown in Fig. 1. The pump was a femtosecond fiber laser with a repetition frequency of 36 MHz, which was filtered with 1 nm linewidth bandpass filters at a wavelength of 1546.1 nm. After spontaneous FWM in the DSF, we used a cascaded set of 1 nm linewidth bandpass filters at the signal and idler wavelengths of 1550.9 and 1541.3 nm to separate the signal and idler photons from the pump photons. A time interval analyzer (TIA) created histograms of the relative delay between the two superconducting single photon detectors (SSPDs) each time a click was registered on both of the detectors.

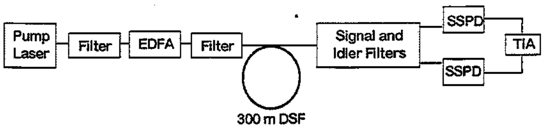

Fig. 1 Simplified diagram of the all-fiber photon pair source. DSF = dispersion shifted fiber. EDFA = erbium doped fiber amplifier. SSPD = superconducting single photon detectors. TIA = time interval analyzer.

We determined the CAR from the histograms recorded by the TIA. Comparisons of measured CAR with theoretical predictions based on [3] are shown in Fig. 2 as functions of pump power. We obtained a maximum measured CAR of 1300 ± 70 at a temperature of 4 K, compared with a maximum of 90 ± 15 at a temperature of 77 K and a maximum of 10 ± 2 at room temperature.

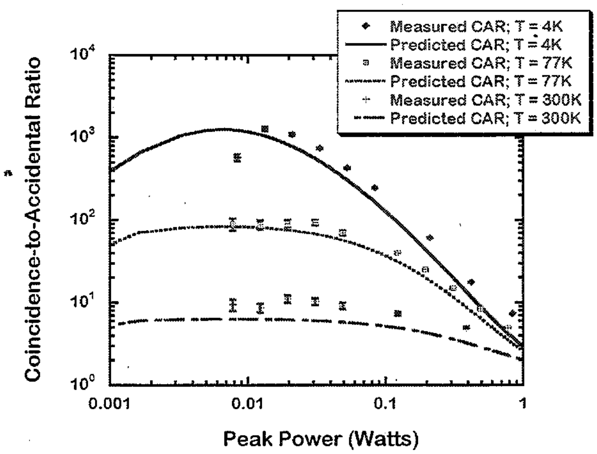

Fig. 2. Comparison of measured and predicted coincidence-to-accidental ratios. Error bars show the statistical uncertainty resulting from the practical limits to the integration time.

In summary, achieving a CAR of 1300 required careful characterization and minimization of all background photons. We also optimized the pair generation efficiency using results from a stimulated FWM measurement to determine the optimal pump wavelength. This high efficiency, low-noise photon pair source, which is compatible with existing fiber telecom networks and components, could enable many novel quantum information demonstrations.

[1] C. Liang, K. F. Lee, M. Medic, P. Kumar, R. H. Hadfield, and S. W. Nam, "Characterization of fiber-generated entangled photon pairs with superconducting single-photon detectors," Opt. Express **15**, 1322-1327 (2007).

[2] H. Takesue and K. Inoue, "1.5-μm band quantum-correlated photon pair generation in dispersion-shifted fiber: suppression of noise photons by cooling fiber," Opt. Express **13**, 7832-7839 (2005).

[3] Q. Lin, F. Yaman, and G. P. Agrawal, "Photon-pair generation in optical fibers through four-wave mixing: role of Raman scattering and pump polarization," Phys. Rev. A **75**, 023803 (2007).