Precision Timing via Energy-of-Light Chronometry

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Precise temporal metrology of single-photonic signals is limited by the intrinsic timing jitter of single-photon avalanche diodes [1] and superconducting nanowire single-photon detectors [2]. To overcome this limitation, we utilize Energy-of-Light Chronometry (ELC), whereby temporal information is mapped to the spectral domain in order to leverage high-resolution spectroscopy for precise readout. Signal photons at ~1560 nm are upconverted by sum-frequency generation in a nonlinear crystal via a chirped ~780-nm escort pulse to photons at ~520 nm. ELC is performed by mapping the measured central-wavelength shift of the upconverted light to the relative change in time-of-arrival of the signal with respect to the chirped escort pulse, as shown in Fig. 1.

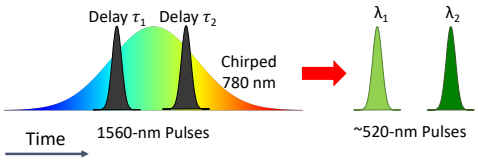

Fig. 1: *Delay mapped to upconverted spectra.*

In order to measure spectral shifts of the upconverted signal at the single-photon level, we employ a weak-value amplification (WVA) approach [3]. A reflective grating inside a slightly misaligned Sagnac interferometer maps spectral shifts of the input light to an amplified transverse deflection of the light leaking out of the interferometer's "dark" port. This deflection is measured by splitting the output light between two single-photon detectors and calculating the difference in detected events between them, as a function of signal-escort relative delay, as shown in Fig. 2.

Experiments with single-photon-level signals are currently underway. ELC can be extended to precise Light Detection and Ranging of infrared single-photon signals with non-infrared detectors.

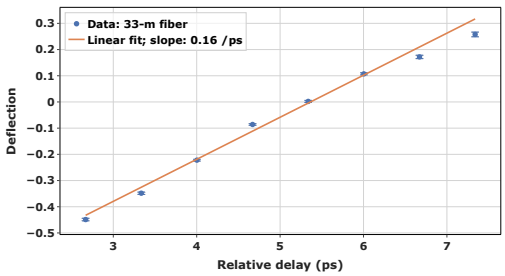

Fig. 2: *Mapping WVA deflections to set delays. The escort was chirped by propagating through ~33-m long fiber. This particular dataset corresponds to an average timing error of ~7 ps; this is smaller than the ~15-ps resolution of the detector.*

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References

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