Photonic quantum correlations mediated by individual phonons

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We report on a new experimental scheme to perform heralded optical preparation of non-classical vibrational states, specifically the $n = 1$ Fock state, and its readout after a controllable time delay [1]. A single-phonon state is prepared probabilistically by spontaneous pulsed Raman scattering followed by single photon detection on the Stokes mode. Phonon readout is performed using anti-Stokes scattering and single photon detection (Fig. 1). Our technique relies on two-color pulsed excitation and spectral multiplexing to distinguish between the two events (preparation and readout), which occur much faster than the time jitter of our detectors would allow to resolve.

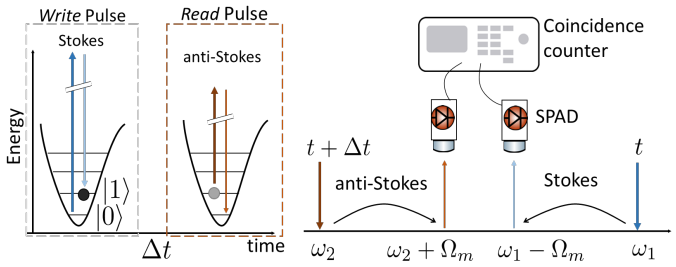

Figure 1: Conceptual representation of our measurement scheme.

The results of this experiment carried out on the 39.9 THz Raman-active phonon mode of a diamond crystal show a clear violation of the Cauchy-Schwartz inequality when measuring the Stokes – anti-Stokes cross-correlation function. It decays with an exponential time constant of 4 ps, corresponding to the single phonon lifetime (Fig. 2).

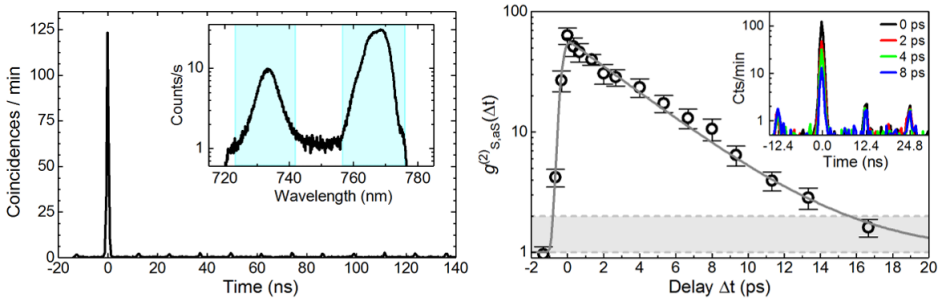

Figure 2: a) Coincidence histogram at zero delay, with the Raman spectrum from diamond as an inset. b) Second order correlation vs. time delay between pulses. Inset: raw correlation histograms at different delays.

We will discuss how our results and the versatility of our technique open new routes toward on-chip heralded non-classical vibrational state generation [2] and the realization of quantum cavity optomechanics with high frequency phonons in integrated photonic circuits and cavities.

References

[1] M. D. Anderson, S. Tarrago Velez, K. Seibold, H. Flayac, V. Savona, N. Sangouard, and C. Galland, "Two-Color Pump-Probe Measurement of Photonic Quantum Correlations Mediated by a Single Phonon", Phys. Rev. Lett. **120**, 233601 (2018).

[2] C. Galland, N. Sangouard, N. Piro, N. Gisin and T. J. Kippenberg, "Heralded Single Phonon Preparation, Storage and Readout in Cavity Optomechanics", Phys. Rev. Lett. **112**, 143602 (2014).