Towards a quantum memory in a fiber-cavity controlled by intra-cavity frequency translation
Supplemental Material

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I. PHOTON DETECTION EFFICIENCY AND THE SINGLE PHOTON LEVEL

When working with attenuated signal pulses, we set the single photon level by correcting for the total detection efficiency for signal photons at $\lambda_\mathrm{s} = 902.5\,\mathrm{nm}$ from inside the cavity. The total detection efficiency is $\eta_\mathrm{det} = 0.21(2)$, where $\eta_\mathrm{det} = \mathcal{T}_\mathrm{s}\eta_\mathrm{c}\eta_\mathrm{SPCM}$ for photons exiting the fibre. Here, $\mathcal{T}_\mathrm{s} = 0.74(5)$ is the end-facet-coating transmission at the output signal wavelength, $\eta_\mathrm{c} = 0.65(2)$ is the collection efficiency from the fiber-cavity exit facet to the SPCM, and $\eta_\mathrm{SPCM} = 0.44$ is the SPCM quantum efficiency quoted by the manufacturer. The quoted loss due to propagation in the fibre is $5\,\mathrm{dB/km}$; this is negligible during a single pass through the fibre.

II. POWER SCALING OF NOISE AND BRAGG-SCATTERING FOUR-WAVE MIXING

The input and output signal modes of Bragg-scattering four-wave mixing (BSFWM) in a birefringent fiber are related by a beam splitter formalism: the output signal pulse energy from the write interaction $W_\mathrm{s}^\mathrm{out}$ is expected to vary as

$$W_\mathrm{s}^\mathrm{out} = W_\mathrm{s}^\mathrm{in}\cos^2\left\{\xi_\mathrm{w}\sqrt{W_\mathrm{q}^\mathrm{w}W_\mathrm{p}^\mathrm{w}}\right\},$$

where ξ_w depends on the pulse shapes and fiber parameters [1], W_s^in is the input signal pulse energy, and $W_\mathrm{p,q}^\mathrm{w}$ are the write pulse energies in the fiber. Figure 1(a) is a plot of the signal (blue crosses), noise (yellow squares), noise-corrected signal (green circles), and a fit of $W_\mathrm{s}^\mathrm{out}$ (green, solid line) as a function of $\sqrt{W_\mathrm{q}^\mathrm{w}W_\mathrm{p}^\mathrm{w}}$. The fit to the noise corrected signal has good qualitative agreement and $R^2 = 0.996$. A weighted linear regression on the noise data gives a good fit with $R^2 > 0.98$. To gain further understanding of the noise process, we exchanged the EFC fiber for an uncoated fiber of similar length and measured the noise spectrum from the write control pulses. Figure 1(b) shows the broadband noise spectrum gradually decreasing with increasing wavelength. This spectrum and the linear power dependence of the noise are consistent with spontaneous Raman scattering from the control pulses as the dominant source of noise.

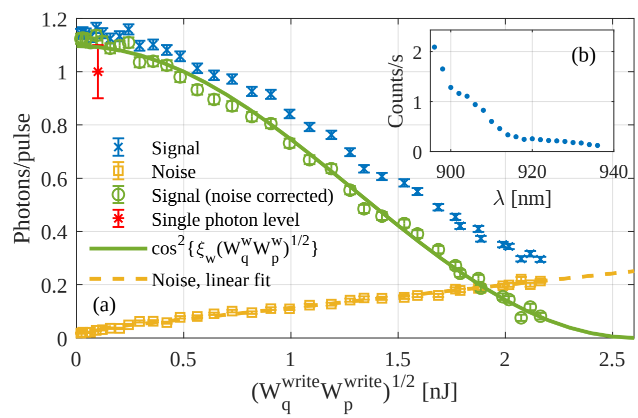

FIG. 1. (a) Signal (blue crosses), noise (yellow squares), and noise-corrected signal (green circles) as a function of control pulse energies for the write interaction. Fits to the noise-corrected signal (green, solid curve) and noise (yellow, dashed line) are plotted (see text). (b) Plot of the fast axis (Raman) noise spectrum in an uncoated HB800 PM fiber.

[1] J. B. Christensen, J. G. Koefoed, B. A. Bell, C. J. McKinstrie, and K. Rottwitt, Shape-preserving and unidirectional frequency conversion by four-wave mixing, Opt. Express **26**, 17145 (2018).

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