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Towards a Quantum Non-Demolition Measurement for Photonic Qubits

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Many applications of quantum information processing benefit from, or even require, the possibility to detect the number of photons in a given signal pulse without destroying the photons nor the encoded quantum state. We propose and show first steps towards the implementation of such a Quantum Non-Demolition (QND) measurement for time-bin qubits. To implement this measurement, we first store a 'probe' pulse in a cryogenically cooled Tm:LiNbO₃ waveguide using an Atomic Frequency Comb (AFC) quantum memory protocol [1]. We then send a 'signal' pulse comprised of two temporal modes off-resonantly with the AFC through a previously prepared transparency window. The off-resonant interaction between the propagating signal and the thulium ions, onto which the probe pulse was mapped, results in the atomic state acquiring a phase-shift. This phase shift is imprinted onto the recalled probe pulse and can be determined using an interferometric measurement. The magnitude of this phase-shift depends on the signal pulse's energy, and detuning w.r.t to the probe pulse. Hence, knowing the phase-shift, we can determine the intensity or the number of photons in the signal pulse.

[1] E. Saglamyurek et al, ... Nature 2011

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