# A novel integrated platform for quantum storage of heralded single photons

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The efficient and reversible mapping of quantum states of light into collective atomic excitation is a promising route towards the realization of quantum memories. Rare earth doped crystals offer long lived spin states and are naturally suitable for miniaturization and integration of several quantum memories onto a single substrate, e.g. in form of waveguides. The latter would greatly facilitate the scalability and, thanks to the tight confinement of light, would lead to a strong enhancement of the light matter interaction. $Pr^{3+}:Y_2SiO_5$ is currently one of the best systems for quantum memory. With this crystal very efficient storage of weak coherent states [1] has been demonstrated, as well as the longest storage time ever demonstrated in any system (in the regime of 1 minute for classical images) [2]. We recently proposed to create integrated quantum memories in $Pr^{3+}:Y_2SiO_5$ using femtosecond laser micromachining (FLM) [3]: a fs-pulsed laser is highly focused in the crystal to create pairs of parallel damage tracks. As a consequence of a positive change of refractive index between the two tracks, the light is guided (type II waveguide). In this approach, beside an improved light-matter interaction, the storage with on-demand retrieval was performed with bright light pulses, demonstrating the first implementation of an integrated on-demand optical memory [3].

Here [4], we propose a new platform for integrated optical memories, based again on FLM: we fabricate a single mode *type I* waveguide in $Pr^{3+}:Y_2SiO_5$ , by creating just one modified track along the crystal in which the positive change of refractive index coincides with the track itself. *Type I* waveguides provide stronger confinement than type II without increasing the losses, thus further increasing the light-ions interaction. Moreover they can be potentially connected with fibers and standard glass chips. We demonstrate that the coherence properties of the material are of the same order of magnitude as for the bulk, despite the invasive fabrication process. To prove that this platform is suitable for being used as a quantum memory, we perform storage of ultra-narrowband single visible photons (signals), using the partial atomic frequency comb protocol (AFC). The photons are generated by spontaneous parametric down conversion (SPDC) and with telecom heralding (idlers). We measure the second-order cross-correlation function $g^{(2)}_{AFC,i}$ between the idler and the stored and retrieved signal photons for different storage times $\tau$. For all the $\tau$ investigated, the measured $g^{(2)}_{AFC,i}$ is clearly above the classical bound, thus proving that laser written memories can operate in the quantum regime. Taking advantage of the large inhomogeneous broadening of the ions in $Pr^{3+}:Y_2SiO_5$ and of the strong light-matter interaction in the waveguide, we also demonstrated recently the storage of a frequency multiplexed photon. This device opens new perspectives for the implementation of miniaturized and integrated quantum memories, with possibilities to create memory enhanced photonic circuits in 3 dimensions.

## References

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