In this paper, we measure both the temporal coherence ($g^{(2)}(\mathrm{t})$) and the frequency spectrum of the photon pairs independently and show that the spectrum is near fourier transform limited. Direct measurements in this respect hasn't been performed with similar photon pair sources before. Such transform limited photons pairs are essential for efficient interaction with atomic systems. In addition we have demonstrated a highest level of non-classical bunching of the photons observerd yet from such sources. This is evident by the increase in the violation of a Cauchy-Schwartz inequality by almost three orders of magnitude compared to the previous reported values.

I. HERALDED AND UNHERALDED BANDWIDTHS

The photons in the idler mode is a statistical mixture of super-radiant (collective) decay and incoherent two step decay (non-collective). For a given optical density of the MOT, the bandwidth for the super-radiant decay is different from the bandwidth for the two step decay. This results in a narrow unheralded idler bandwidth. The figure shows the estimated bandwidth of the non-superradient photons by correcting for the various losses in signal mode. The losses include filtering (11%), optical elements (7%), Detector (60%), polarization selection (12%), and fiber coupling loss (30%).

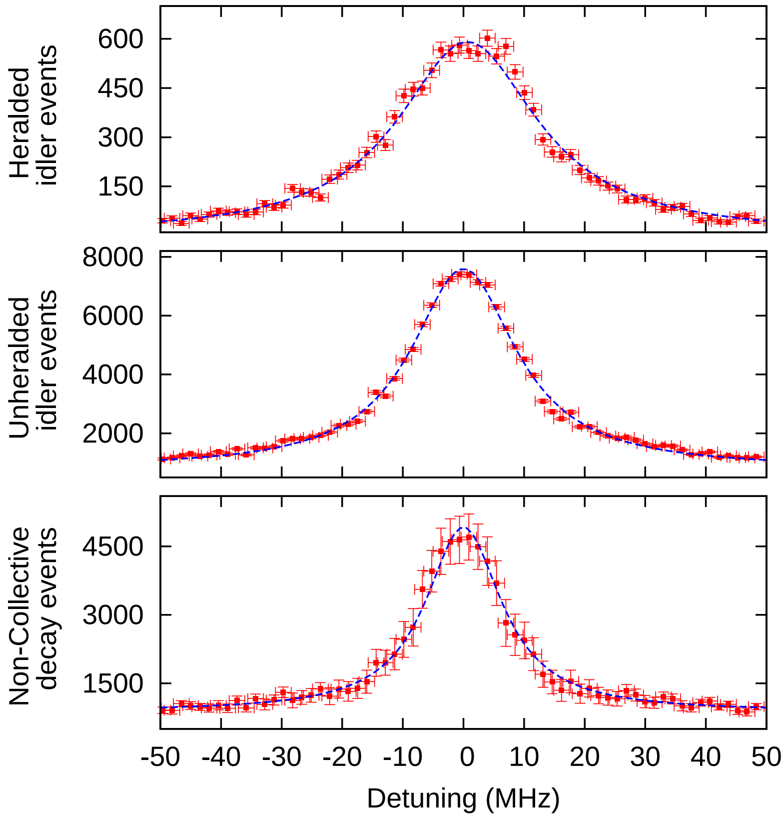

FIG. 1: (Top) Heralded Idler photon bandwidth. (Middle) Unheralded Idler bandwidth. (Bottom) Bandwidth of non-superradiant photons inferred from the above two plots by correcting for the losses.

The effective optical density of the MOT for the generated idler photons can be inferred from the bandwidth of the heralded idler photons from $od = (\gamma/\gamma_0 - 1)$ [1, 2]. The idler bandwidth of the incoherent two step decay at this optical density is consistant with the inferred bandwidth from the plot (Fig. 1(c))

II. GEOMETRY AND BANDWIDTH

The bandwidth resulting from the phase-matching and the waists of the pump and photon modes is much wider than the spectral width of the ^{87}Rb D1 line. Therefore, the bandwidth of the photons are limited by the atomic linewidths rather than the geometry of the phase-matching. The longitudinal phase mismatch for an atomic cloud of length $2\,mm$ is $\delta k \approx c \times 2\pi \times 200GHz$ which is much wider than the transition linewidth of the order of $10MHz$.

III. POLARIZATION

The polarization of the pumps (H for 780nm and V for 776 nm) and the photons (H for signal and V for idler) are chosen in order to obtain highest rates and efficiency. This can be seen by comparing the product of the clebsch-gordan coefficients for different pump and photon polarizations. [3] Our source also produces polarization entangelement by appropriate choice of pump polarizations and is an ongoing work. This manuscript is intended to discuss the temporal and spectral characteristics of the photon pairs.

[1] A. Walther, A. Amari, S. Kröll, and A. Kalachev, Phys. Rev. A **80**, 012317 (2009).

[2] H. H. Jen, Phys. Rev. A **85**, 013835 (2012).

[3] S. D. Jenkins, D. N. Matsukevich, T. Chanelière, S.-Y. Lan, T. A. B. Kennedy, and A. Kuzmich, J. Opt. Soc. Am. B **24**(2), 316 (2007).