

Non classical light generation and storage using cold atomic ensembles

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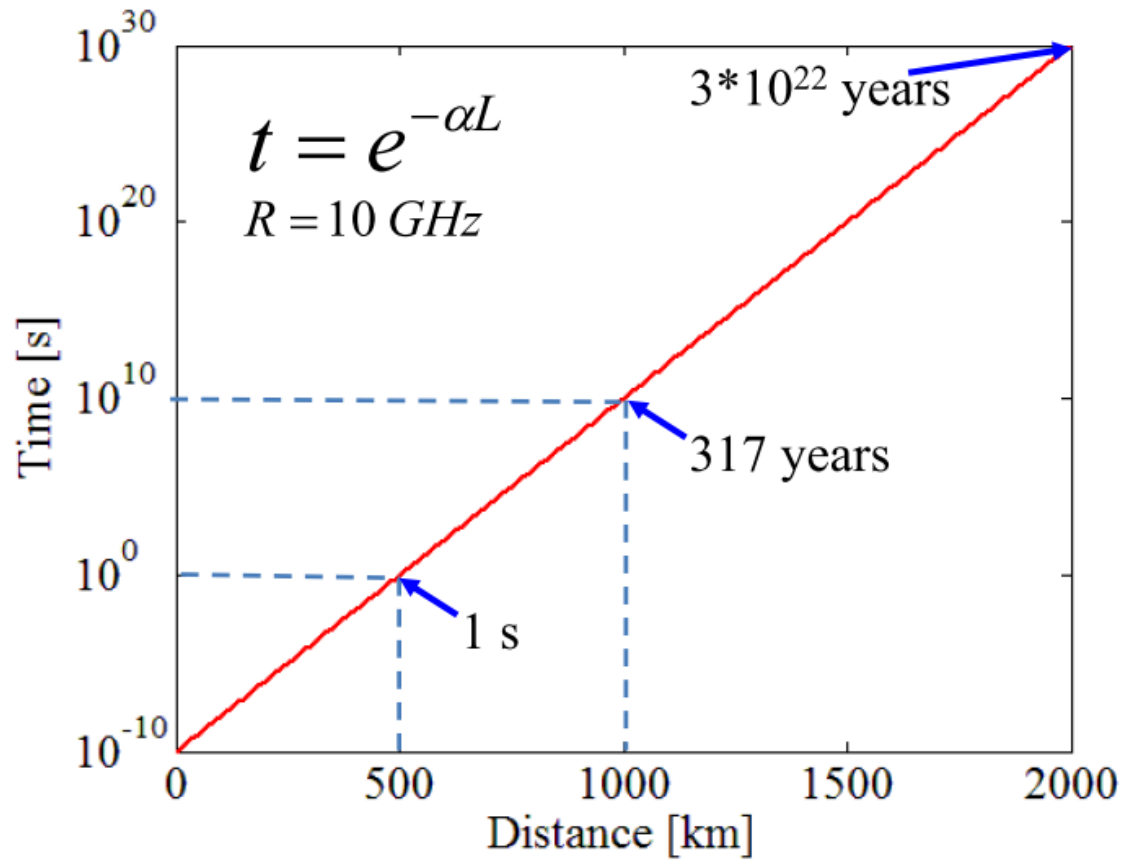
Prof. Chih-Sung Chuu's group.

Quantum Photonics Laboratory

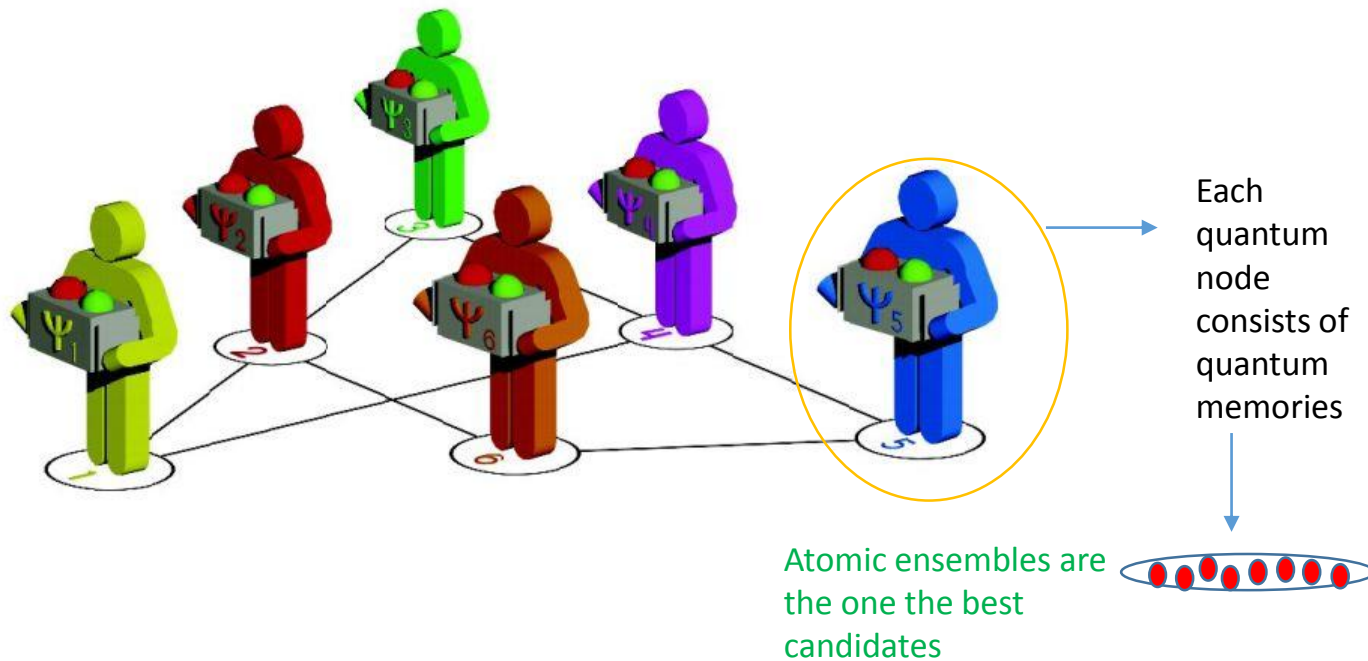
National Tsing Hua University

AMO summer school 2018

Long Distance Quantum Communication

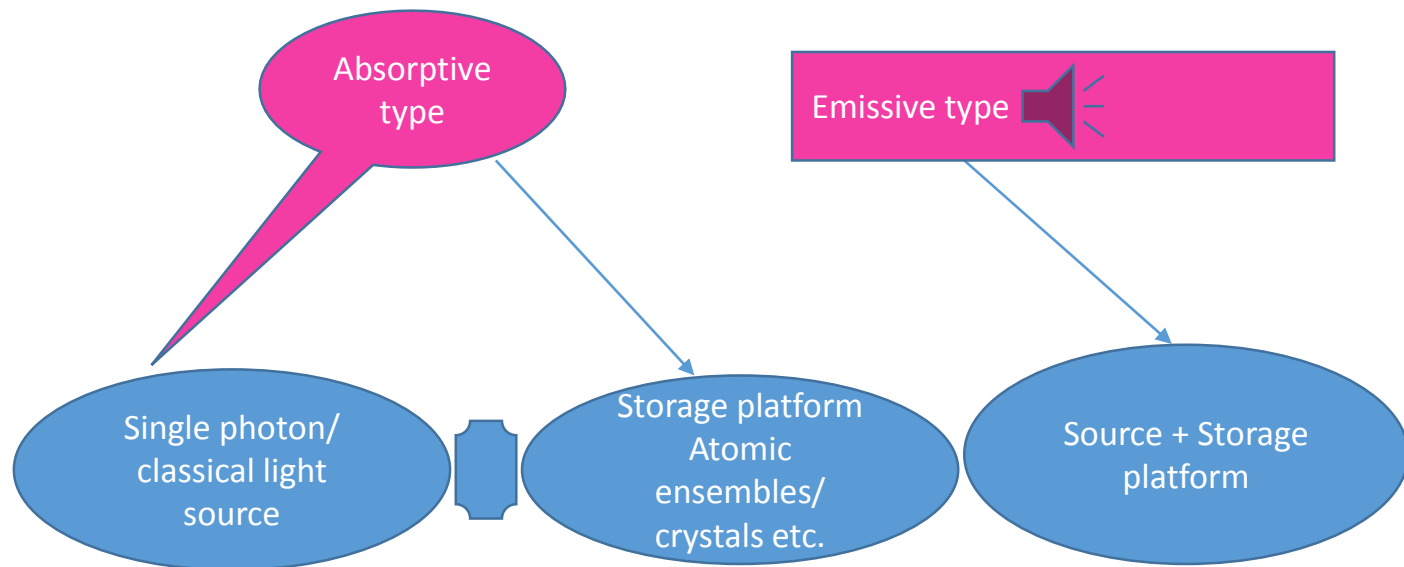


Quantum Network

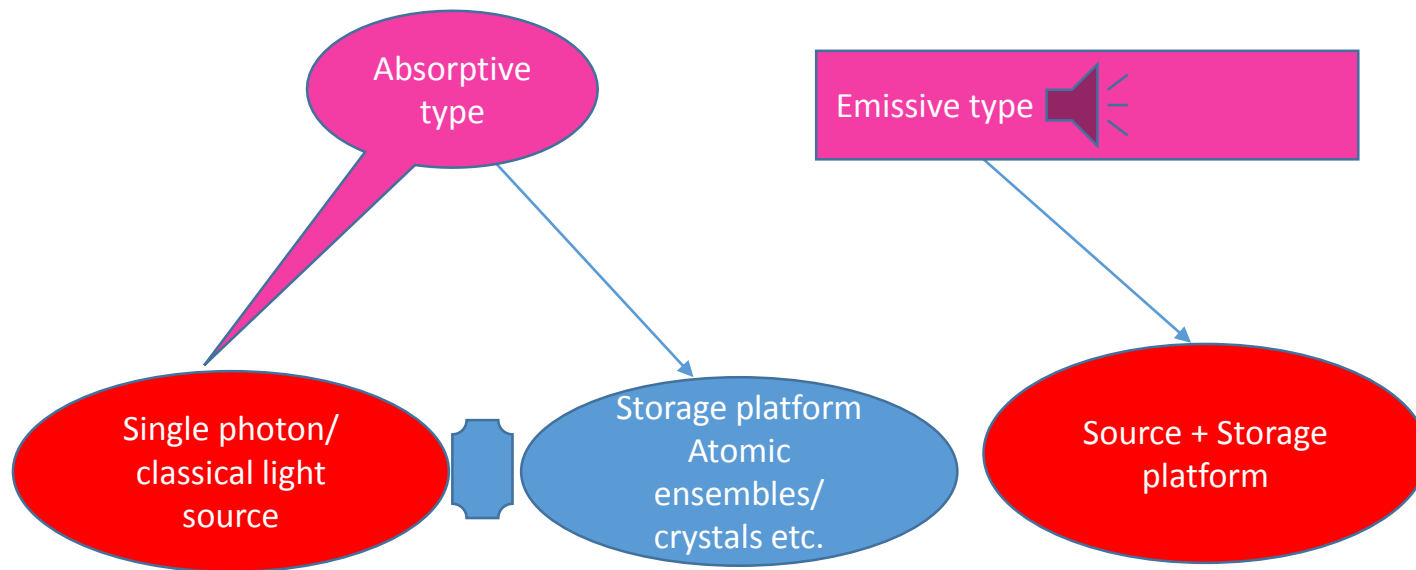


L.M.Duan et al., Nature 414, 413-418(2001)

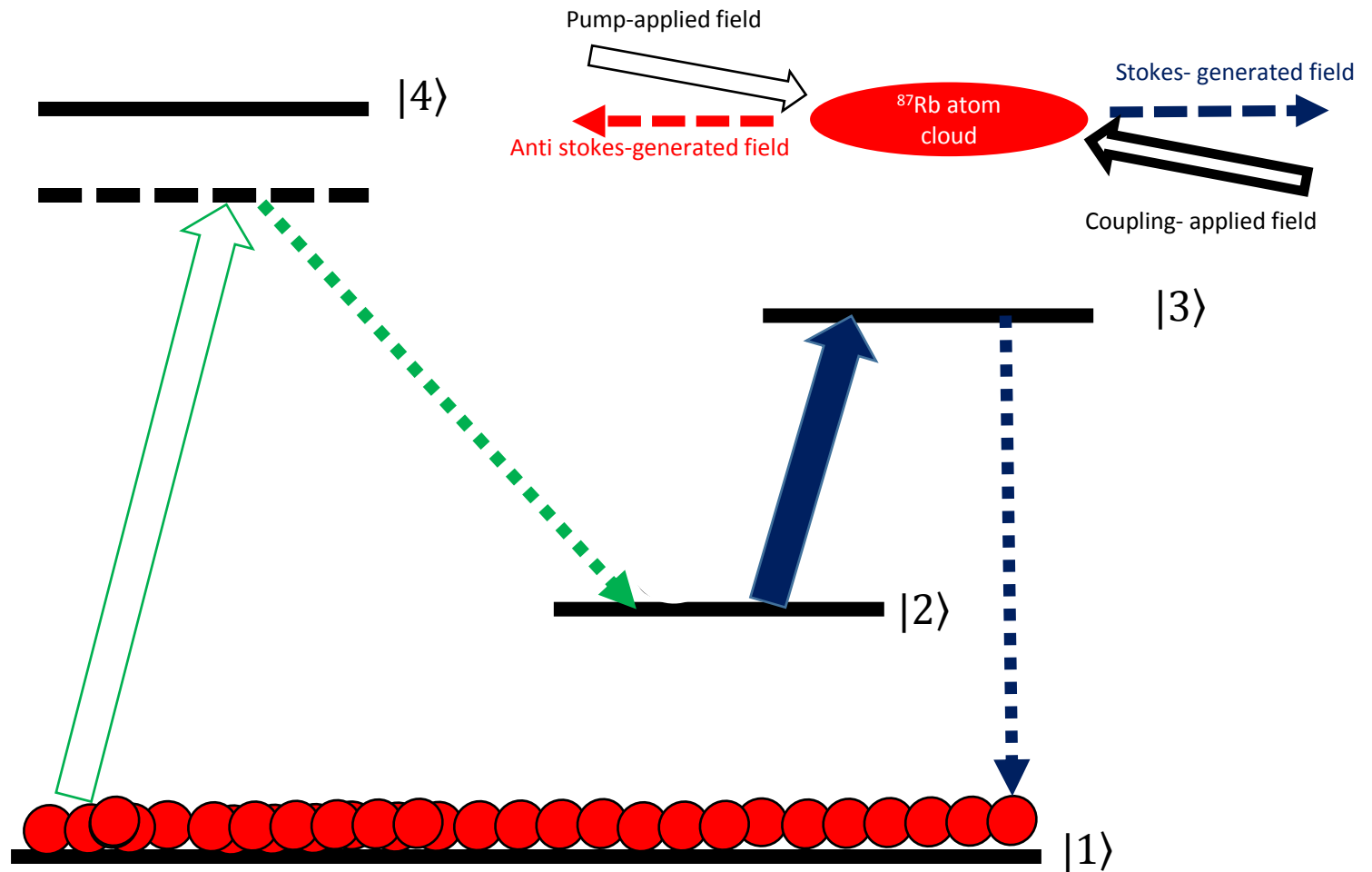
Different types of Quantum memories

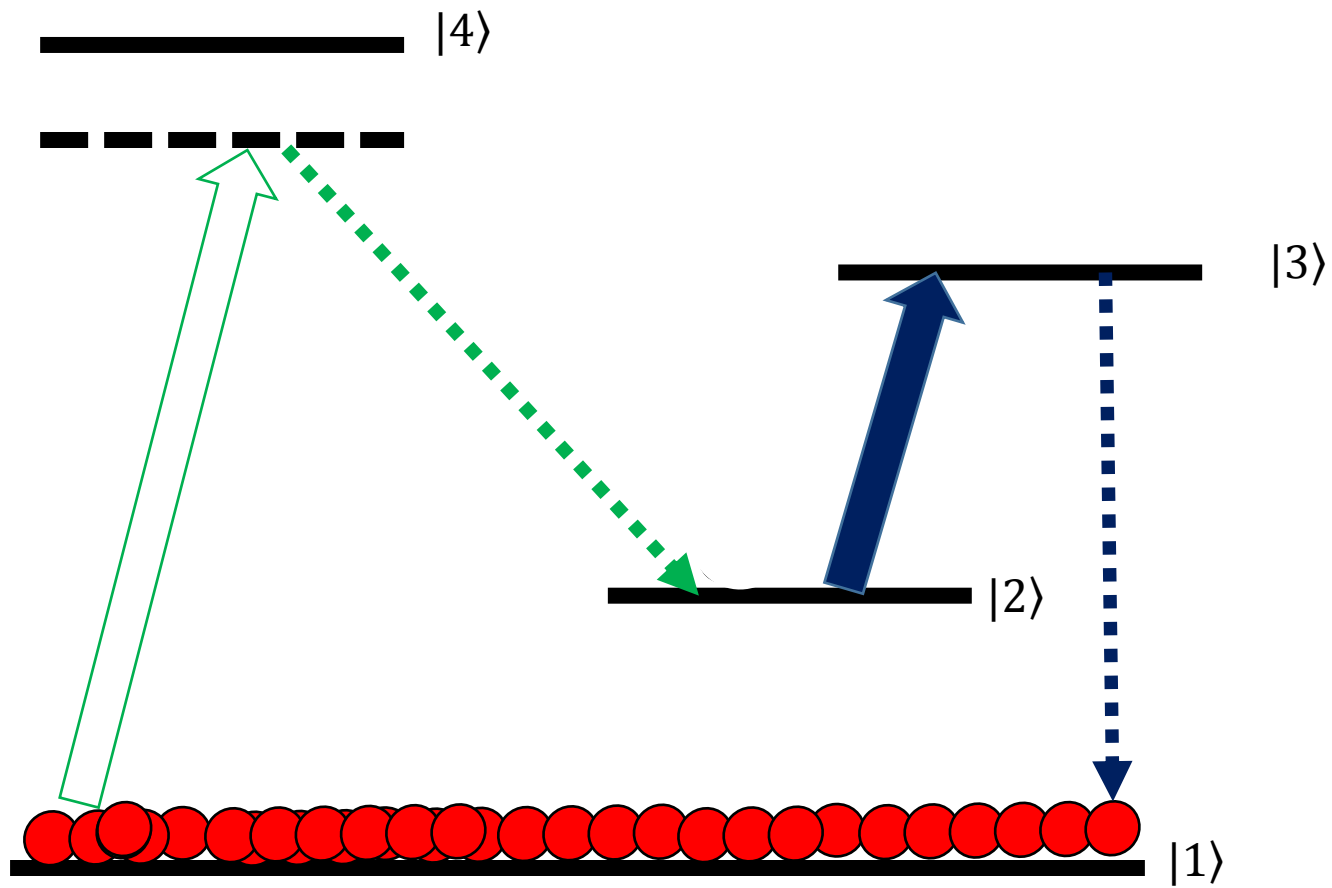


Different types of Quantum memories



Biphoton generation- Spontaneous Four wave mixing





Narrow band biphotons

Biphoton generation



Rabi oscillation regime (Third order nonlinear susceptibility Dominating)

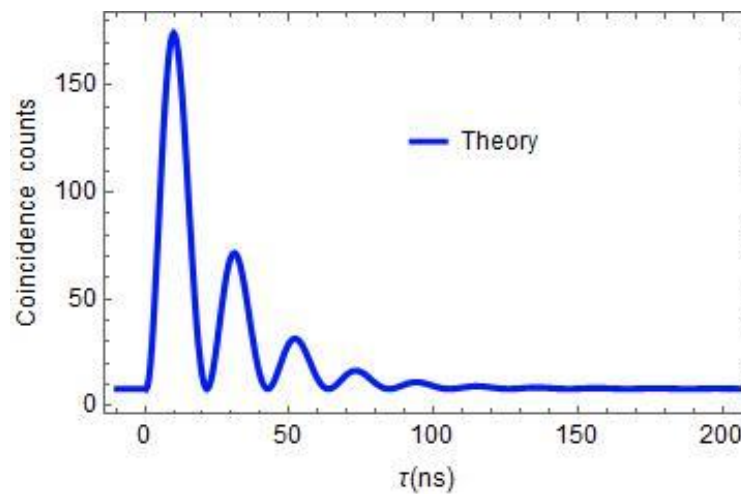
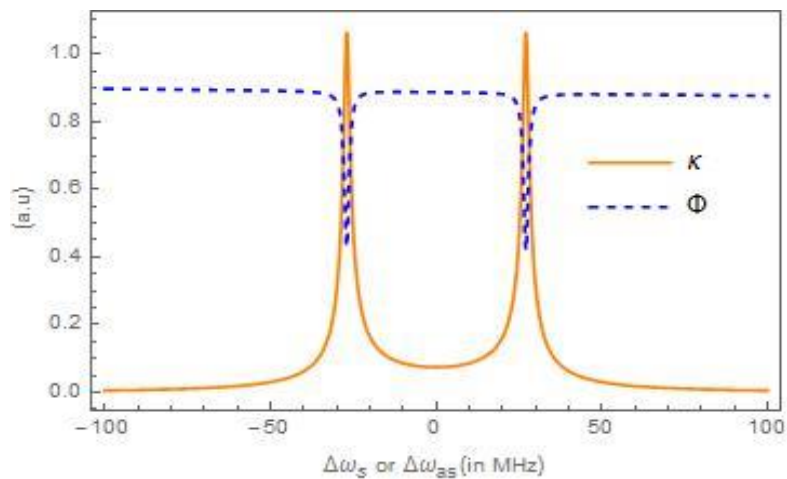
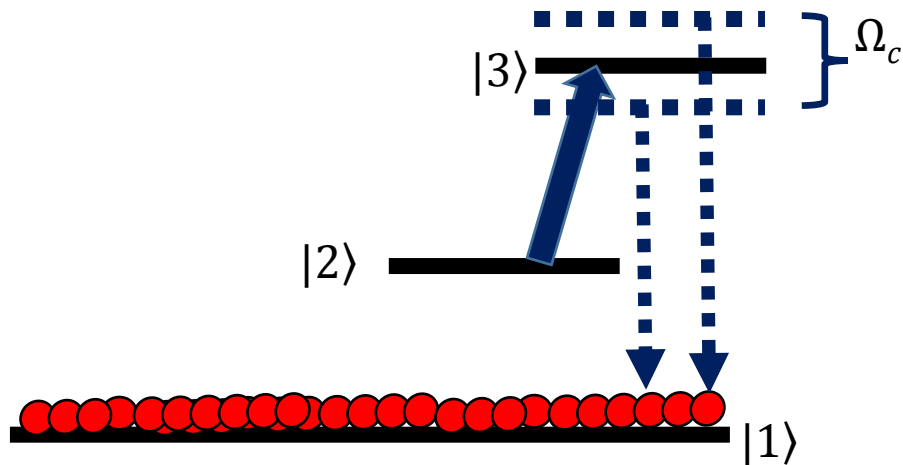
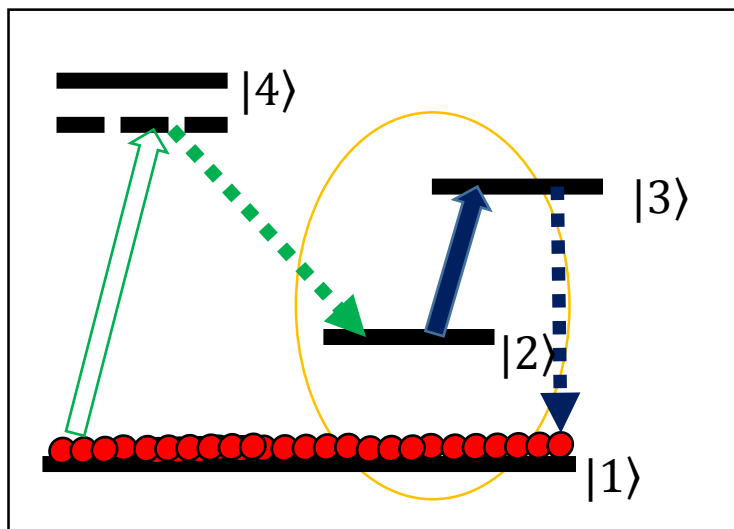
Group delay regime (Phase matching controlled)

$$\Psi(t_{as}, t_s) = \frac{L}{2\pi} \int d\omega_{as} \kappa(\omega_{as}) \phi(\omega_{as}) e^{-i(\omega_{as}t_{as} + \omega_s t_s)} = \psi(\tau) e^{-i[(\omega_p + \omega_c)t_s]}$$

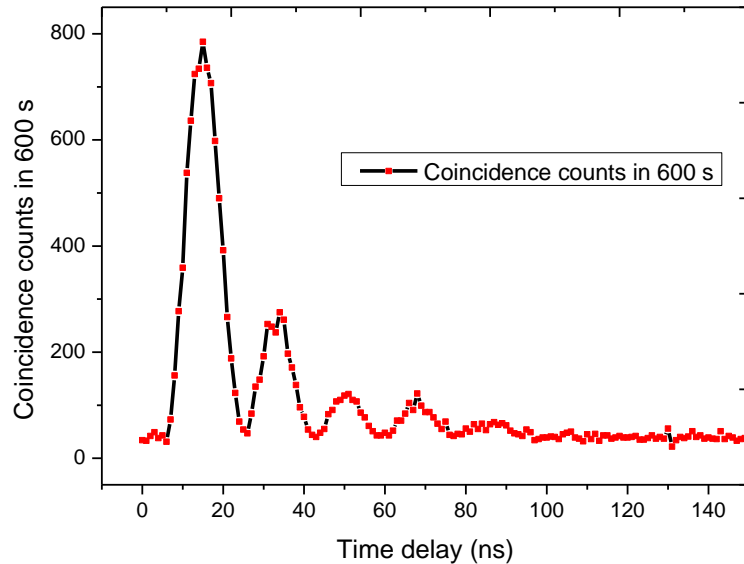
$$\phi(\omega_{as}) = \text{Sinc}\left(\frac{\Delta k L}{2}\right) e^{i[(k_s + k_{as})L/2]}$$

$$\kappa(\omega_s, \omega_{as}) = -\frac{i \sqrt{\omega_s \omega_{as}} \chi^{(3)}(\omega_s, \omega_{as}) E_p E_c}{2c}$$

Rabi oscillation regime



Rabi oscillation regime

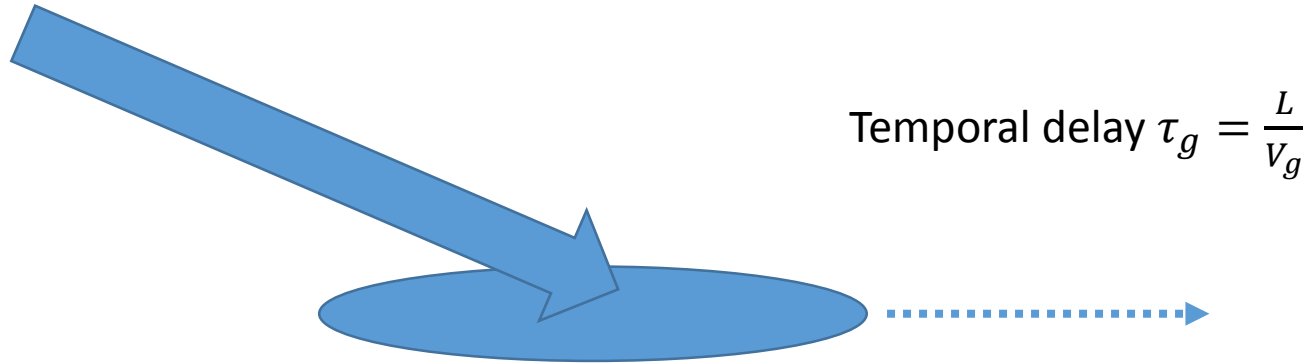


Band width \sim Natural linewidth
of the atoms

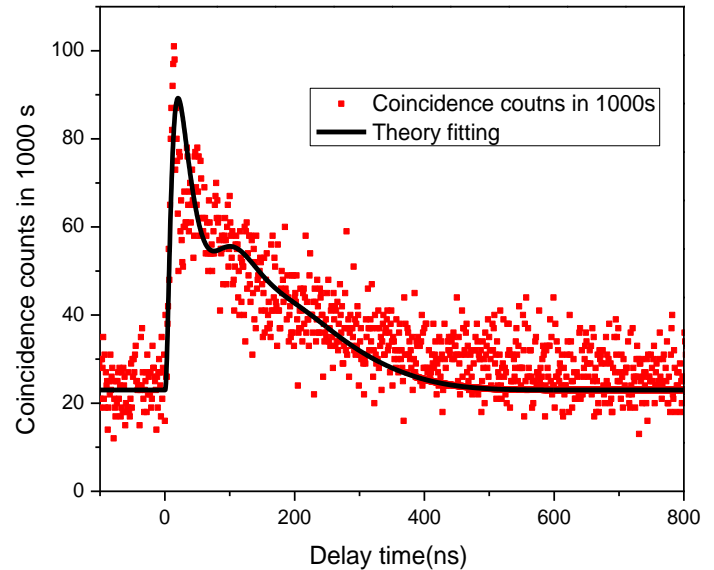
Temporal length \sim natural decay+ dephasing

Oscillation period is controlled by
Coupling strength

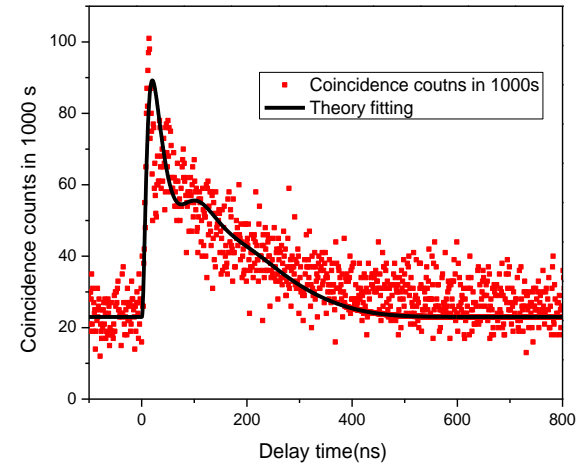
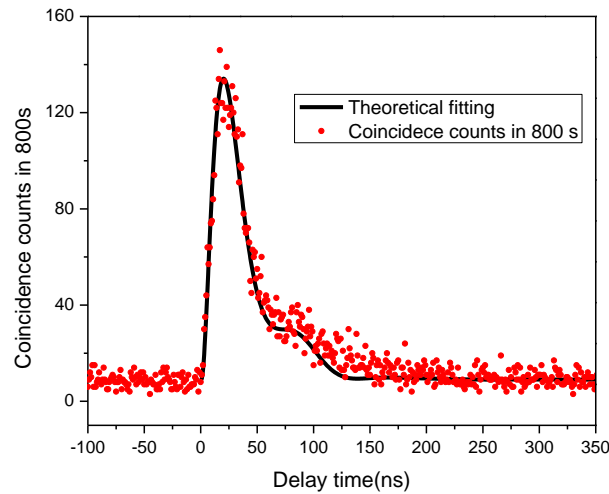
Group delay regime



Temporal length and the bandwidth can be controlled easily by just simply Tuning the Rabi frequency and Optical Depth

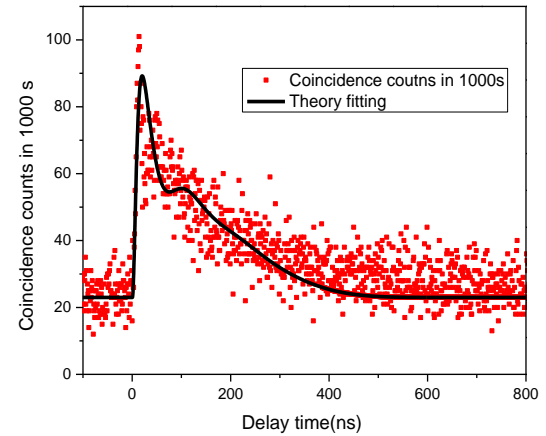
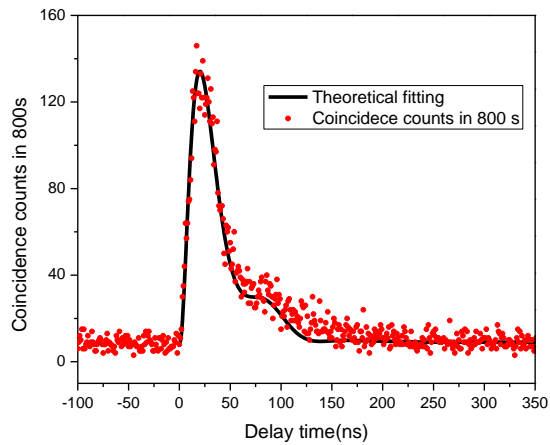
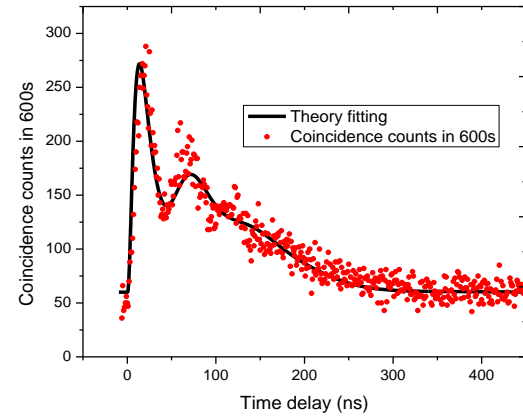
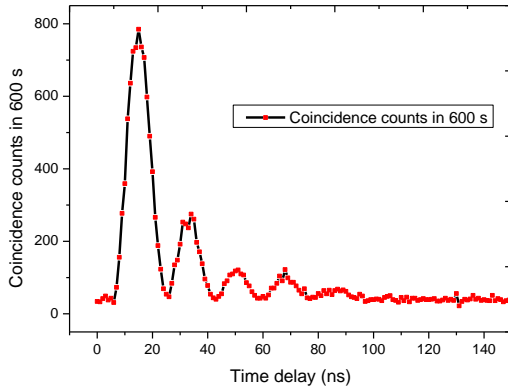


Non classical nature verification

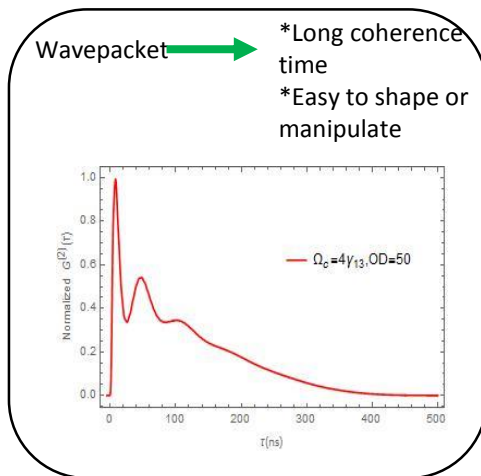
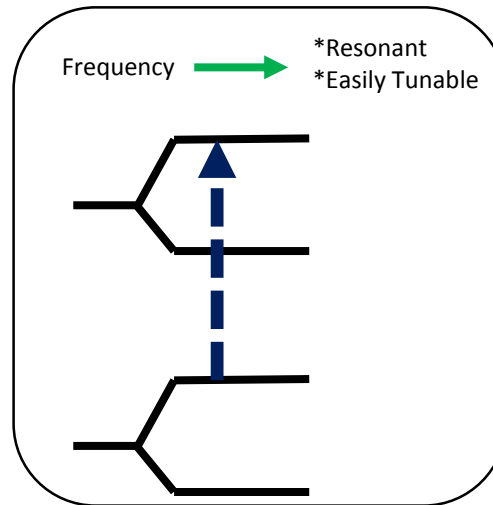
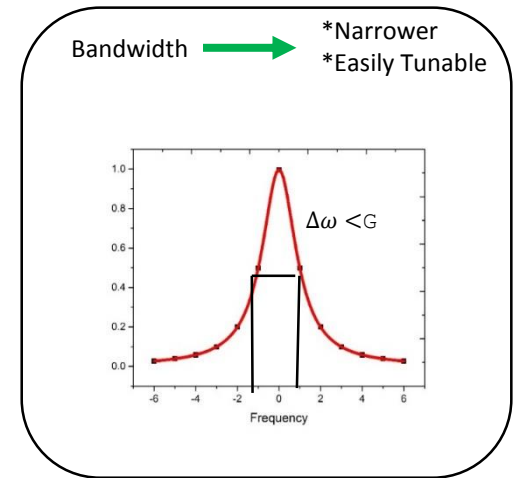


Pump Detuning γ_{13}	Ω_c γ_{13}	OD	CS violation factor	Estimated Bandwidth 2π (MHz)
13.3	5.5	15	65.7	16
16.7	2.6	20	4.4	2.80

Biphoton wavepackets



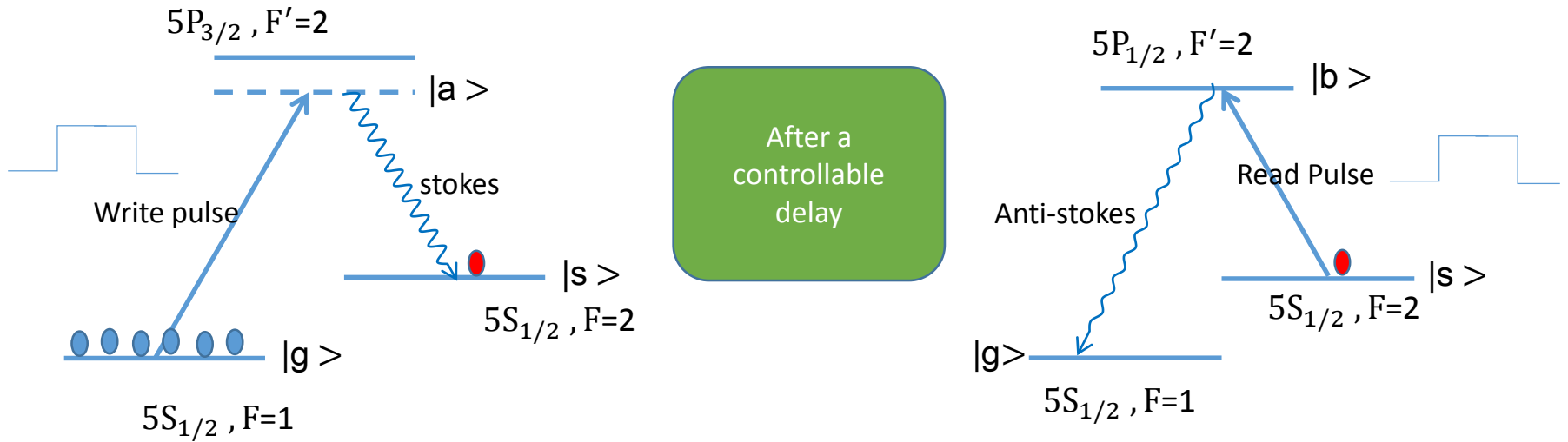
Part I- Conclusion & Work in progress



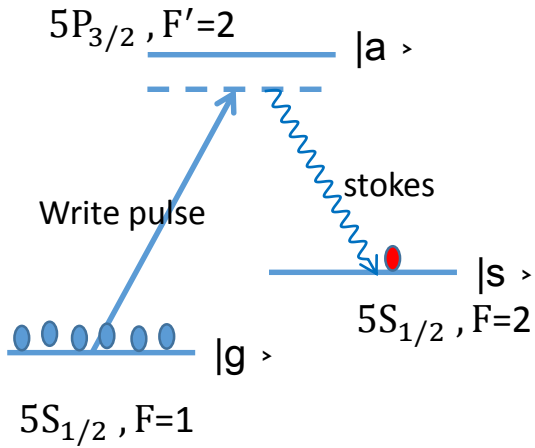
We are working on different
Types of modulation techniques
To arbitrarily shape the photons

Paired photon generation with
controllable delay / emission type
Quantum memory

DLCZ Scheme



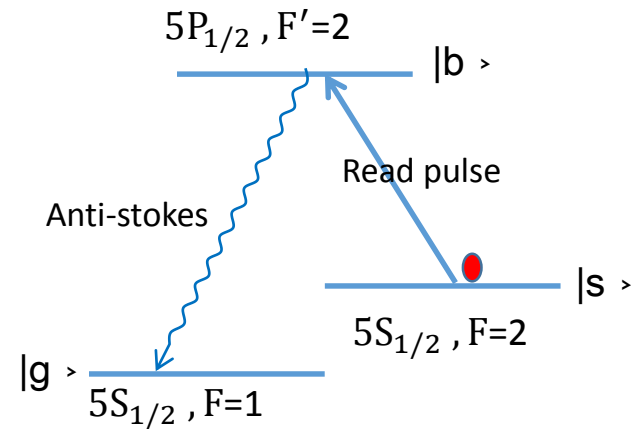
$$S = \frac{1}{\sqrt{N}} \sum_{j=1}^N e^{-i(\mathbf{k}_W - \mathbf{k}_w) \cdot \mathbf{r}_j} |g\rangle_j \langle s|$$



$$|\psi(t)\rangle = \frac{1}{\sqrt{N}} \sum_{j=1}^N e^{i(x_j + v_j t) \cdot (\mathbf{k}_W - \mathbf{k}_w) \cdot \mathbf{r}_j} |g_1 \dots s_j \dots g_N\rangle$$

$$\mathbf{k}_r = \mathbf{k}_W + \mathbf{k}_R - \mathbf{k}_w$$

$$\eta_{ret} \propto \left| \frac{1}{N} \sum_{j=1}^N e^{i v_j \cdot (\mathbf{k}_W - \mathbf{k}_w) t} \right|^2$$



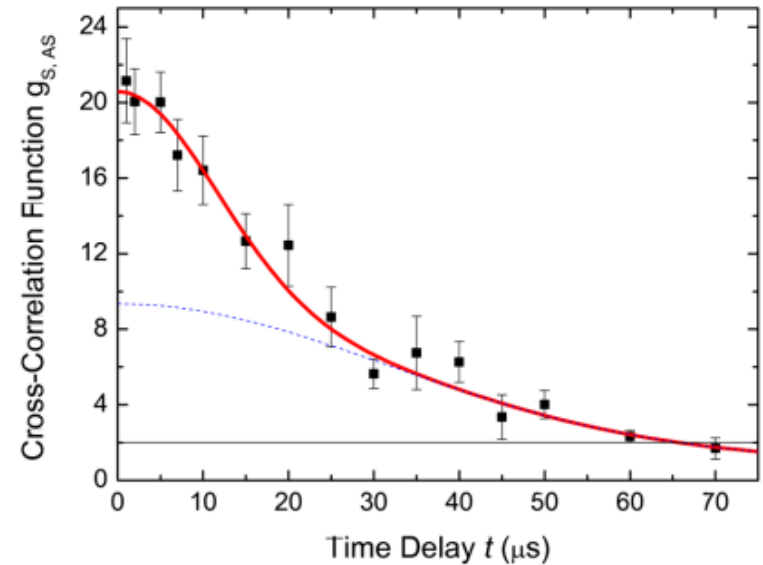
Quantum Memory with Optically Trapped Atoms

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In the presence of Magnetic field

$$\Delta\omega(mF) = \frac{\Delta E(mF)}{\hbar} = \frac{\mu_B g_F m_F B}{\hbar}$$

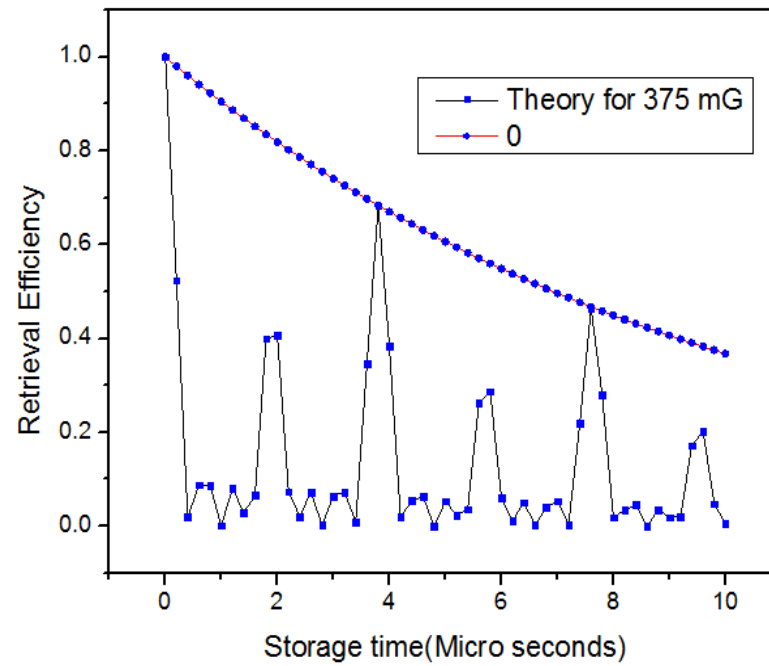
$$|\psi(t)\rangle = \frac{1}{\sqrt{N}} \sum_{\sigma_{mF}=-2}^2 \sum_{j=1}^{N_{\sigma_{mF}}} e^{i \int_0^t \Delta\omega_{\sigma_{mF}}(t') dt' + i x_j \cdot (\mathbf{k}_W - \mathbf{k}_w)} |g_1 \dots s_j \dots g_N\rangle$$

Periodic retrieval can be observed
Due to the temporal fluctuation of
phase

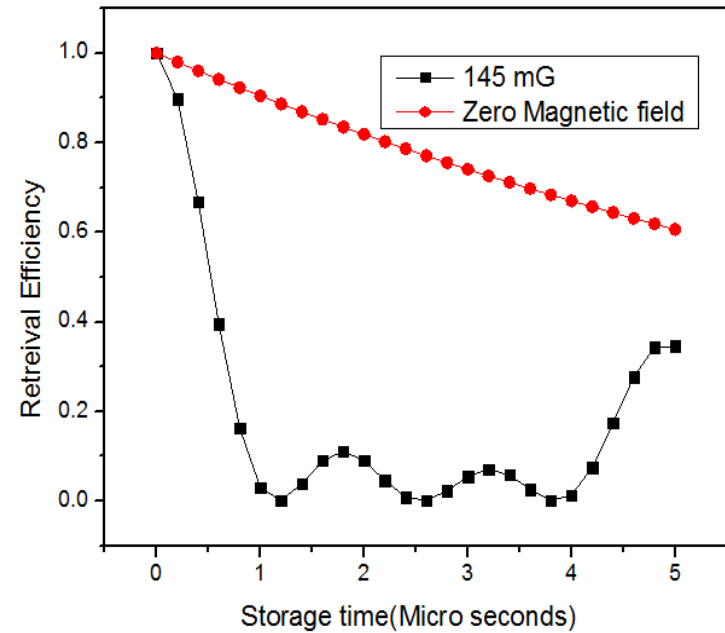
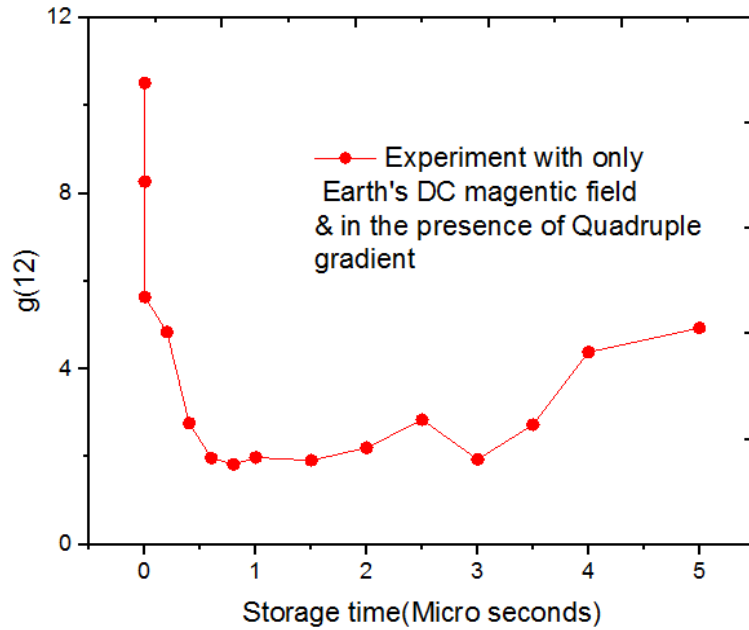
$$\eta_{ret} \propto \left| \sum_{\sigma_{mF}=-2}^2 C_{\sigma_{mF}} e^{i \frac{\mu_B |g_F| m_F B}{\hbar} t \sigma_{mF}} \right|$$

Good & Bad 😊

Results



Results



Conclusion & Outlook

- Our cigar shaped cold atomic system is a powerful platform for generating and storing photons without turning of the quadruple magnetic field gradient.
- We have generated heralded single photons to realize single photon absorptive type Quantum memory.
- Experimentally demonstrated in controlled(still need to be optimized) fashion of retrieval at different wavelengths

Thank you very much for your kind attention