Single quantum dots as photon pair emitters

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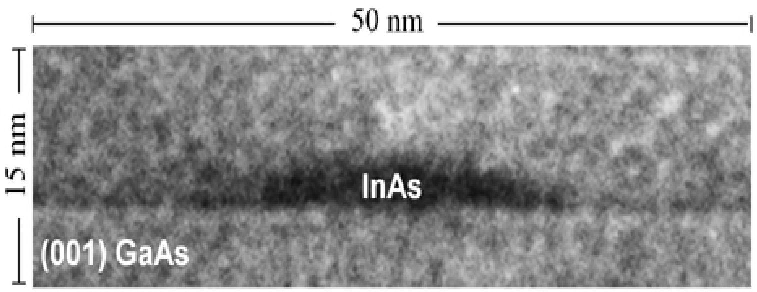
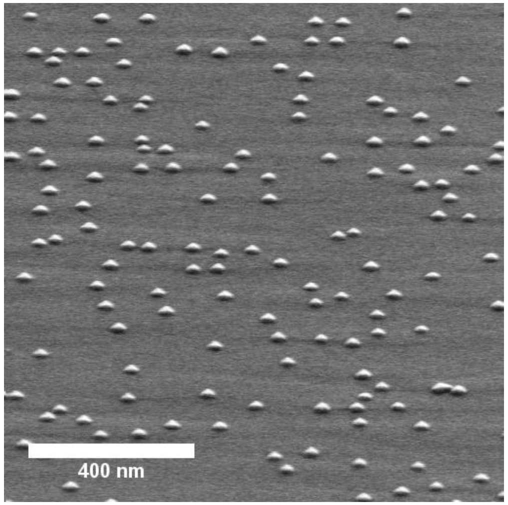
INVESTMENTS IN EDUCATION DEVELOPMENT

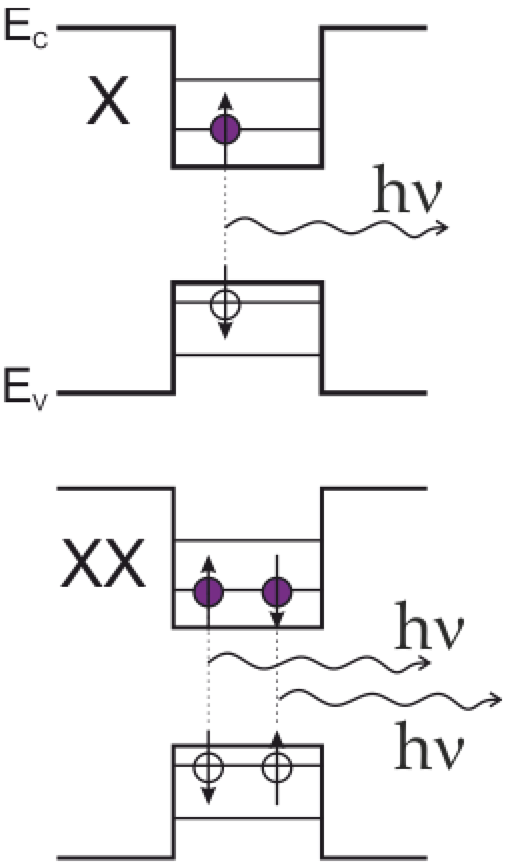
Quantum dots – artificial atoms



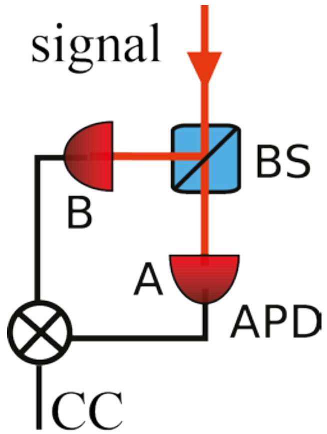
Property of Gilles Patriarche, Laboratoire de Photonique et Nanostructures, Marcoussis

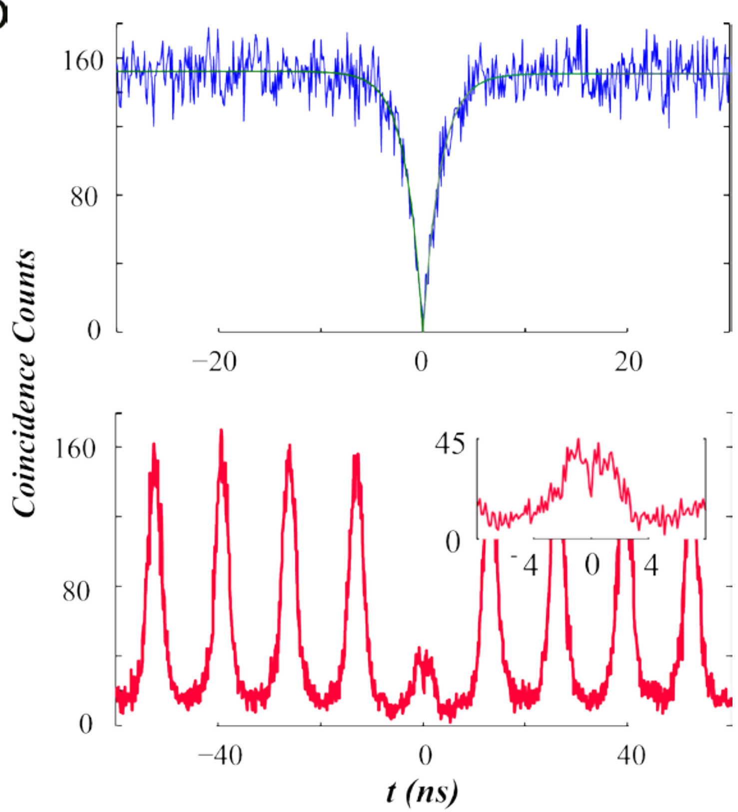


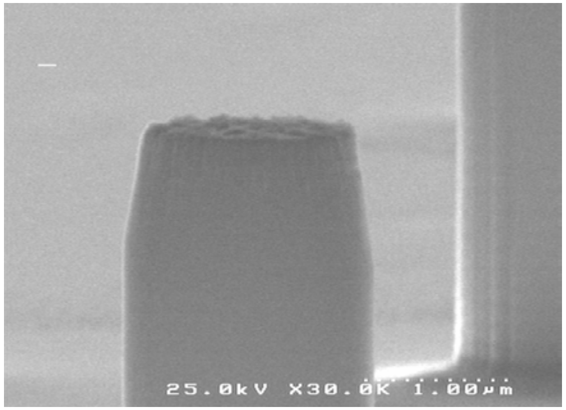
Courtesy of University Wuerzburg

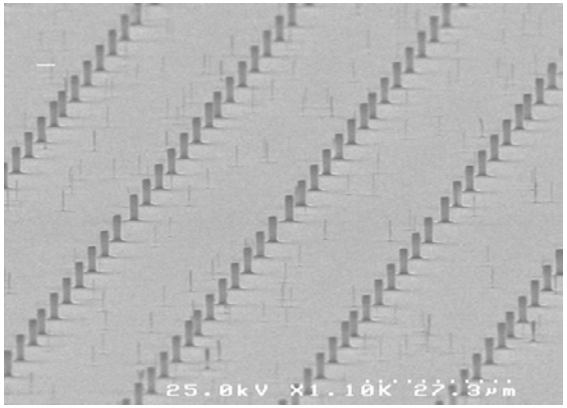


Application– producing single photons









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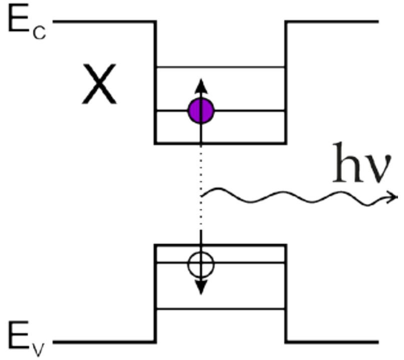
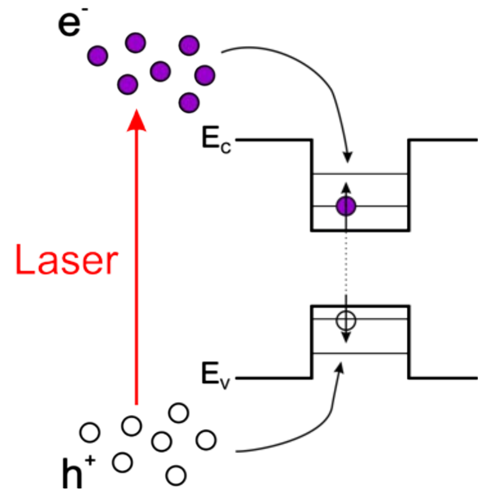
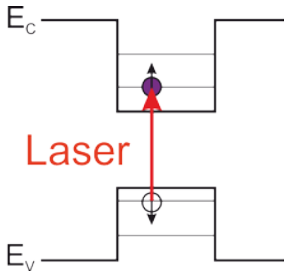
Quantum dots – benefits of resonant excitation





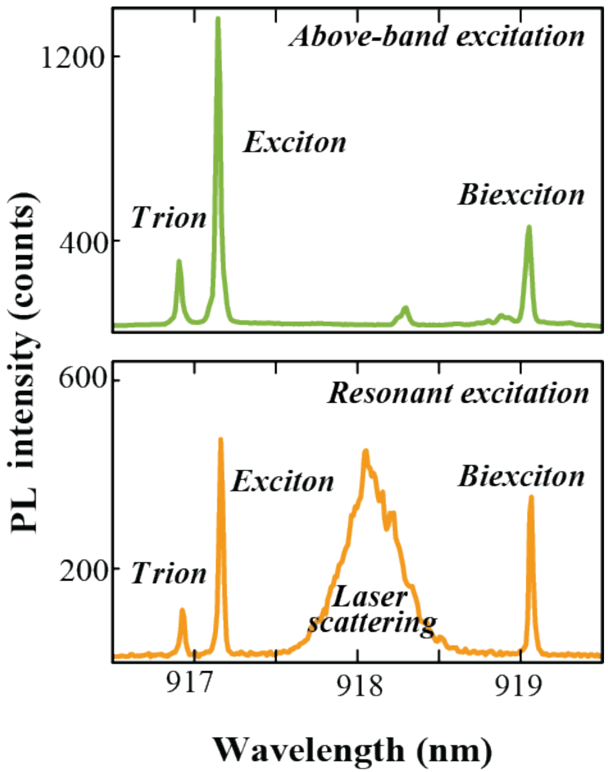


- control and coherent manipulation
- favourable photon statistics
- jitter-free wave packet

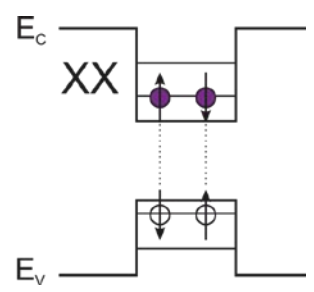
Overview

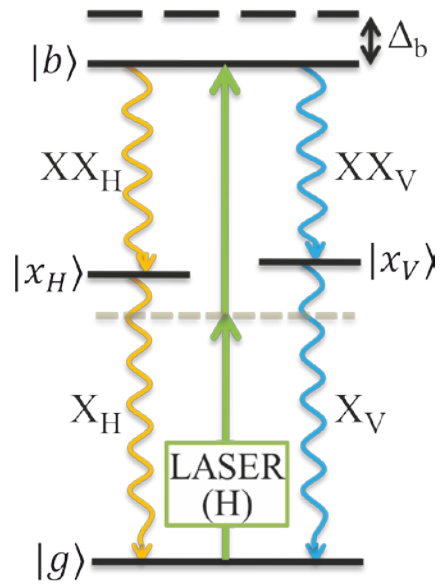
- resonant two – photon excitation
- characterization of the system
- experimental set-up
- time-bin entanglement

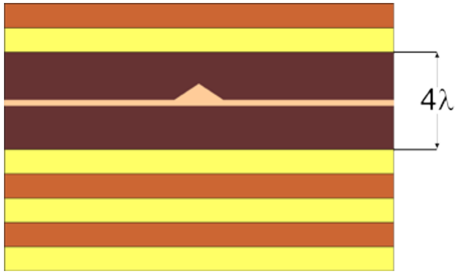
Two-photon resonant excitation

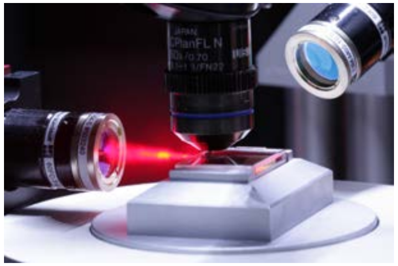


$$E_b = 2E_x - Exx$$









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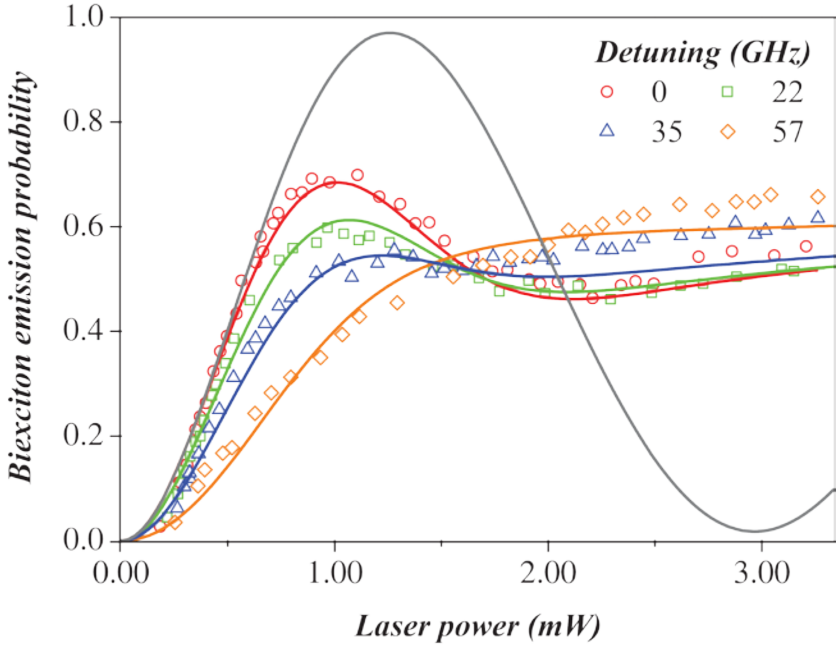
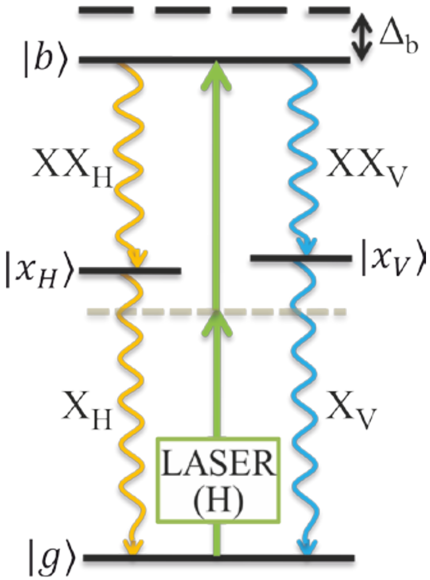
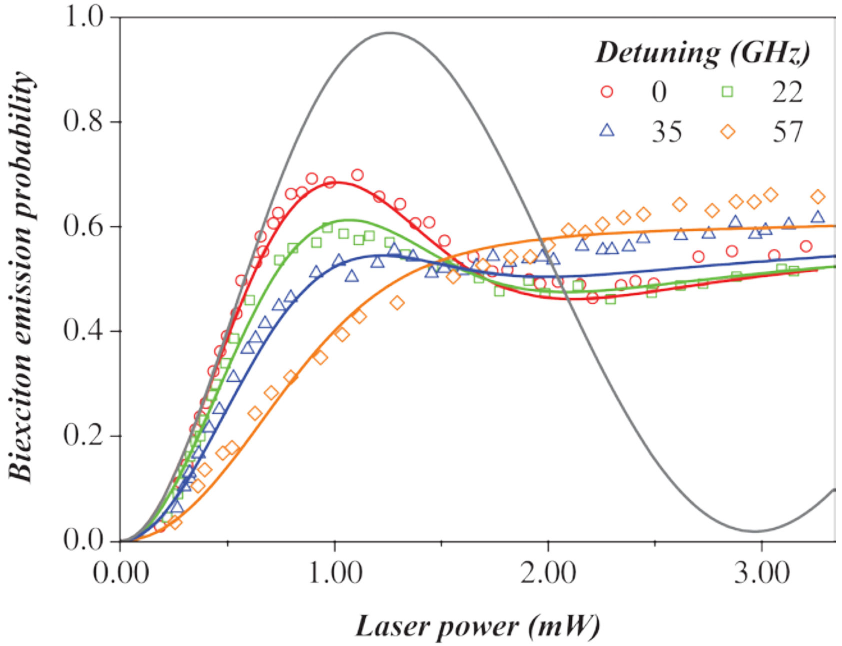
Resonant excitation allows for deterministic creation of population

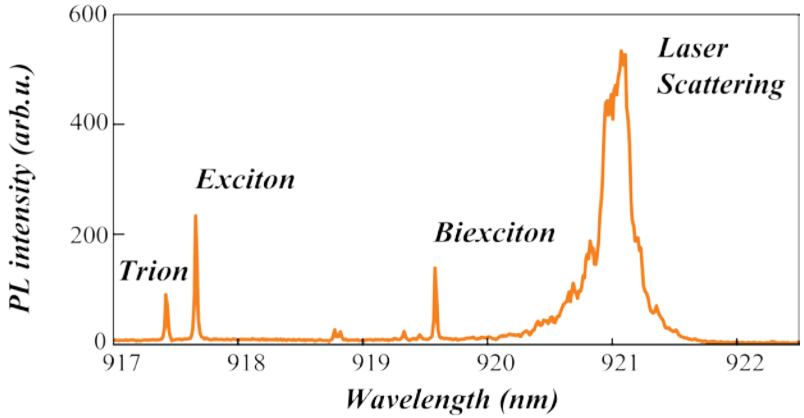




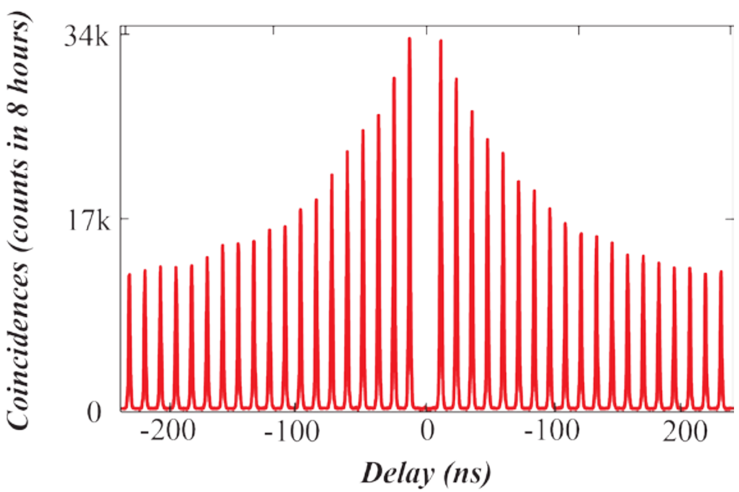
$$H = \hbar \begin{pmatrix} 0 & \frac{\Omega_1(t)}{2} & 0 \\ \frac{\Omega_1(t)}{2} & -\Delta_b + \Delta_e & \frac{\Omega_2(t)}{2} \\ 0 & \frac{\Omega_2(t)}{2} & -2\Delta_b \end{pmatrix}$$

Resonant excitation allows for deterministic creation of population

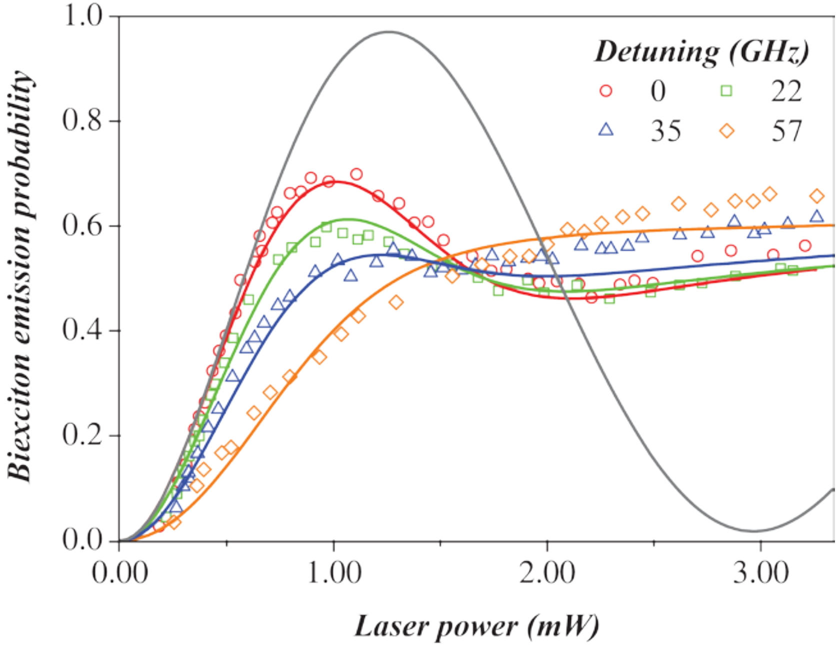


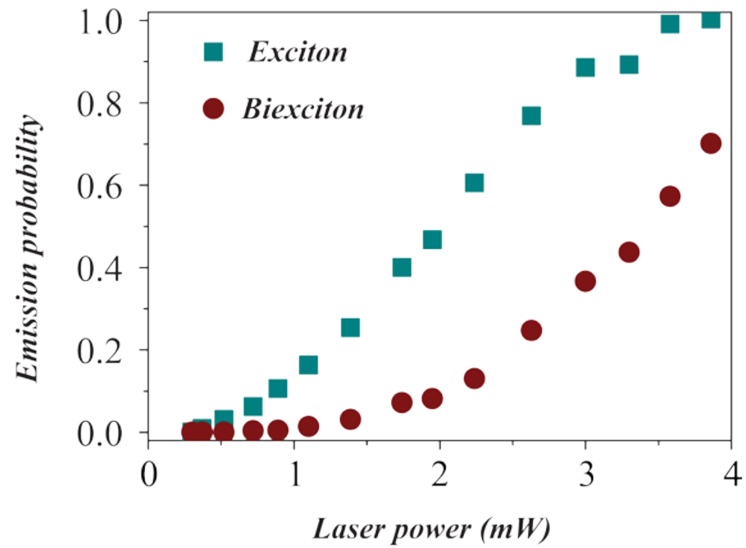


20 million excitations
quantum dot “blinking”

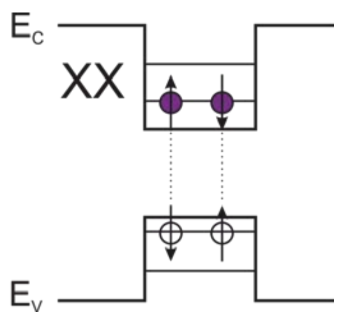


Resonant excitation allows for deterministic creation of population





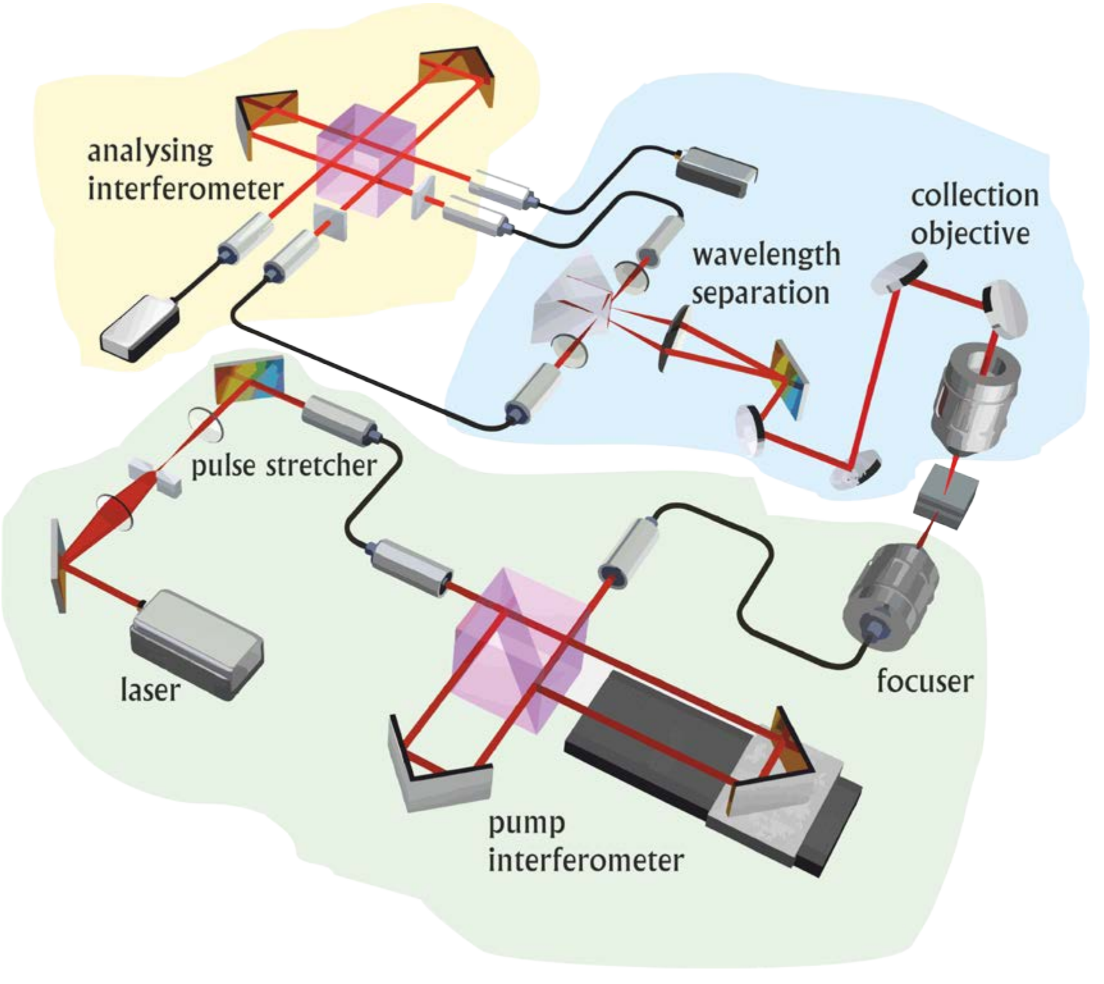
$$\dot{\rho} = -\frac{i}{\hbar}[H,\rho] + \sum_{i=1}^{4} \mathcal{L}_i(\rho)$$



$$\mathcal{L}_5(\rho) = \frac{\Omega_3^4}{2}\left(\sigma_{bx}^{\dagger}\sigma_{bx}\rho + \rho\sigma_{bx}^{\dagger}\sigma_{bx} - 2\sigma_{bx}\rho\sigma_{bx}^{\dagger}\right)$$

$$\mathcal{L}_6(\rho) = \frac{\Omega_3^4}{2}\left(\sigma_{gx}\sigma_{gx}^{\dagger}\rho + \rho\sigma_{gx}\sigma_{gx}^{\dagger} - 2\sigma_{gx}^{\dagger}\rho\sigma_{gx}\right)$$

Experimental Apparatus consists of: Excitation, Collection and Analysis Part



Coherent Mira laser (76MHz) with pulse length of 2-4ps

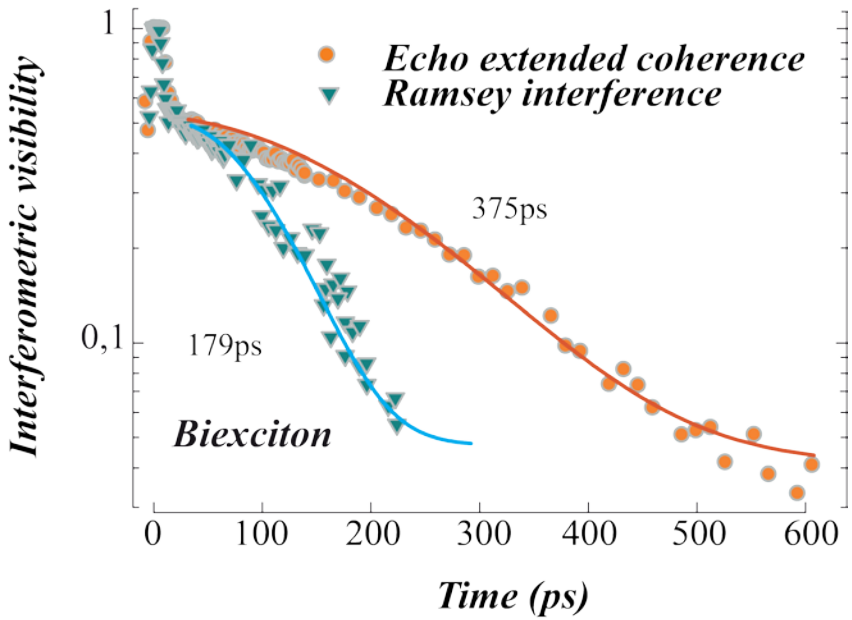
Pulse stretcher for pulse shaping

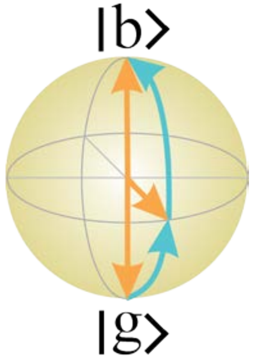
Pump interferometer of variable length for successive excitations

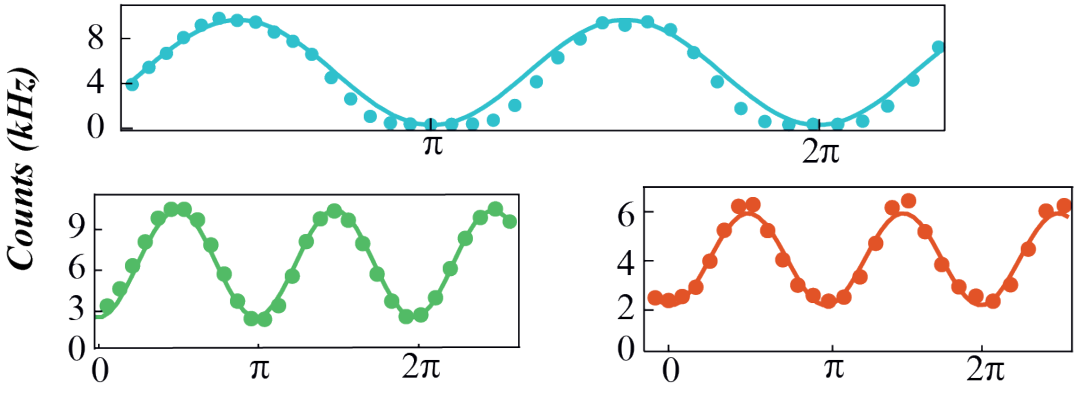
Spectrometer for line separation

Analyzing interferometer

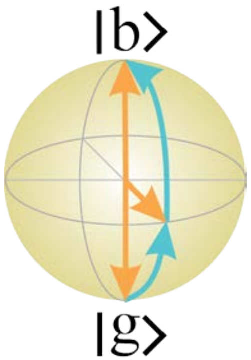
Coherent Spin-Echo Manipulation allows for Reversal of Low Frequency Noise

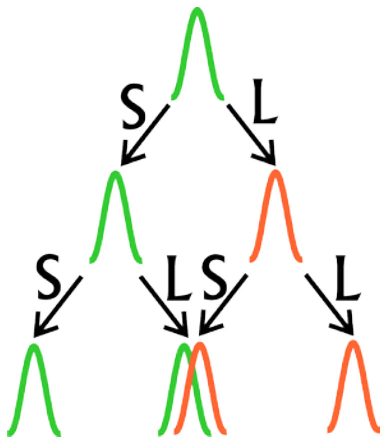


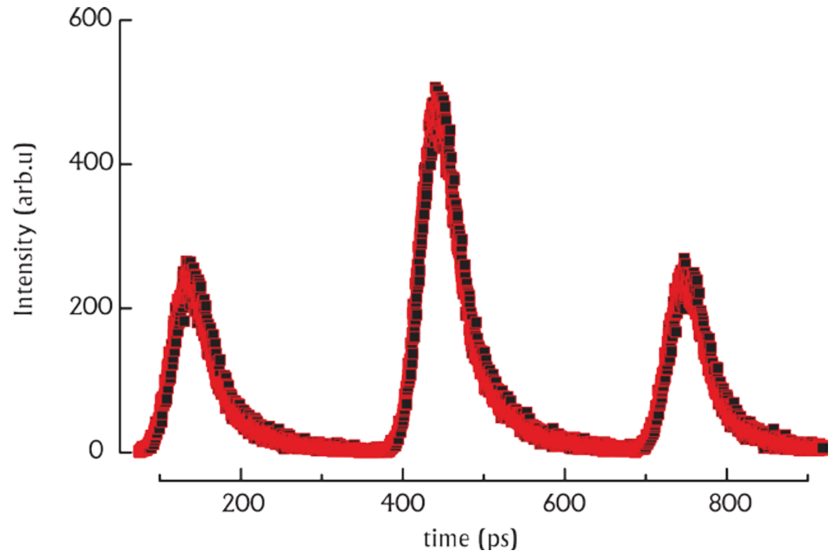


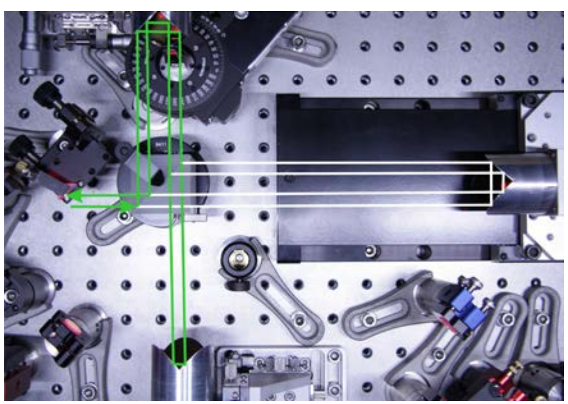


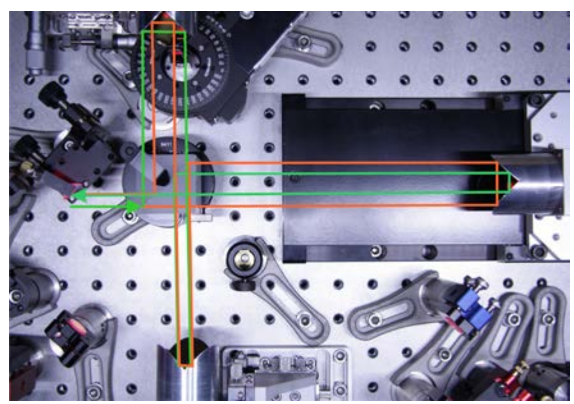
Coherent Spin-Echo Manipulation allows for Reversal of Low Frequency Noise

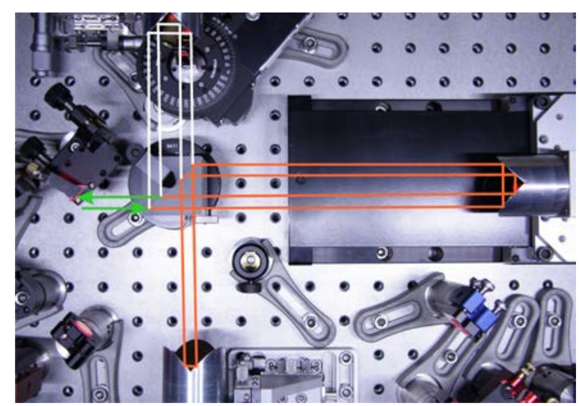




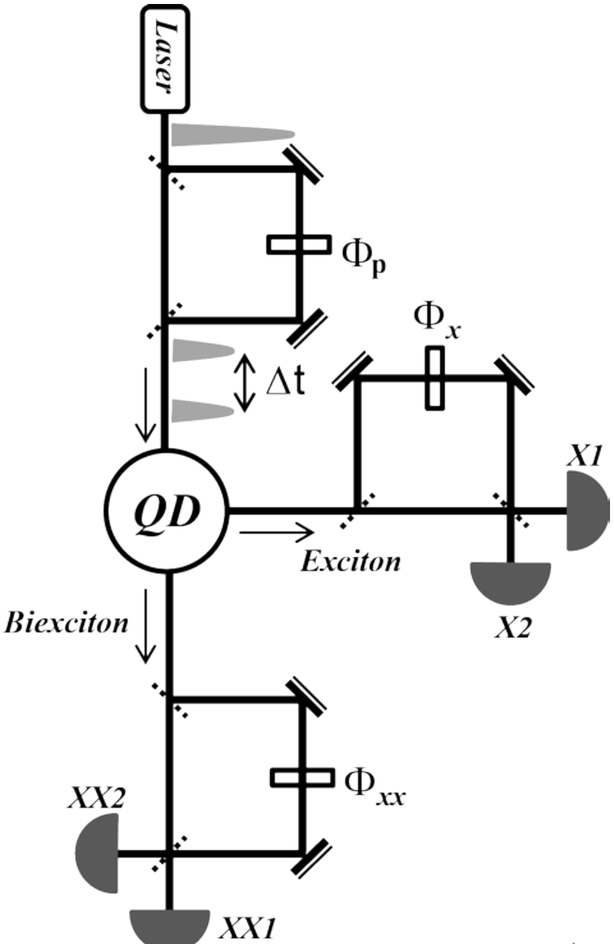




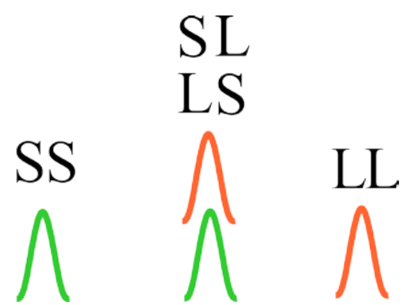




Time-bin entanglement

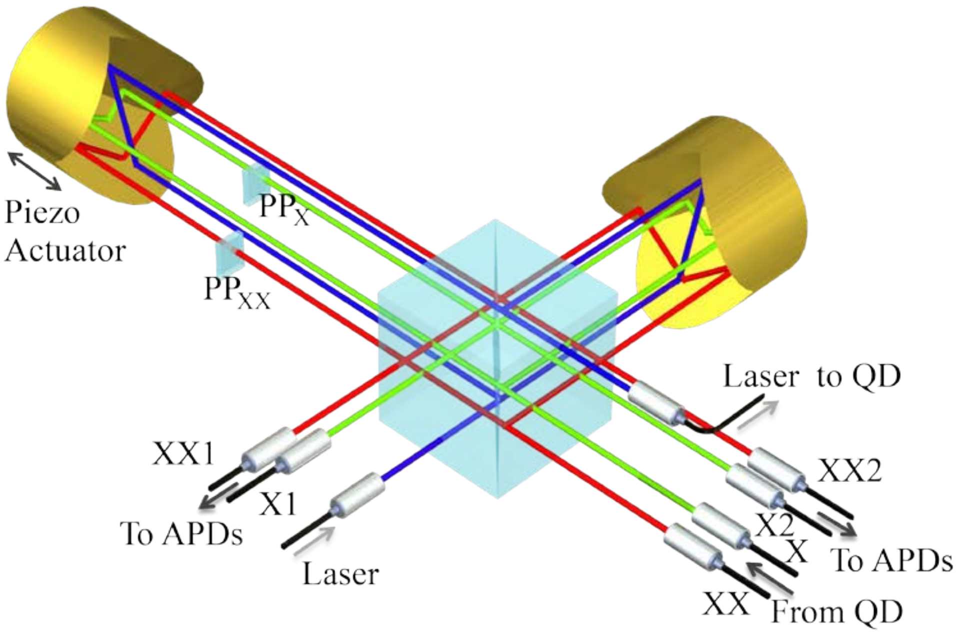


$$|\Phi\rangle_{pump} = \frac{1}{\sqrt{2}}(|early\rangle_p + e^{i\phi_p}|late\rangle_p)$$



$$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|early\rangle_X|early\rangle_{XX} + e^{i\phi_p}|late\rangle_X|late\rangle_{XX}$$

Entanglement analysis is phase-drift independent

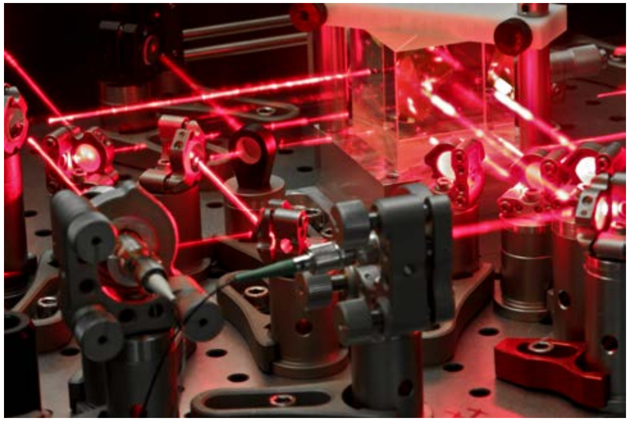


XX, X $|E\rangle + |L\rangle$

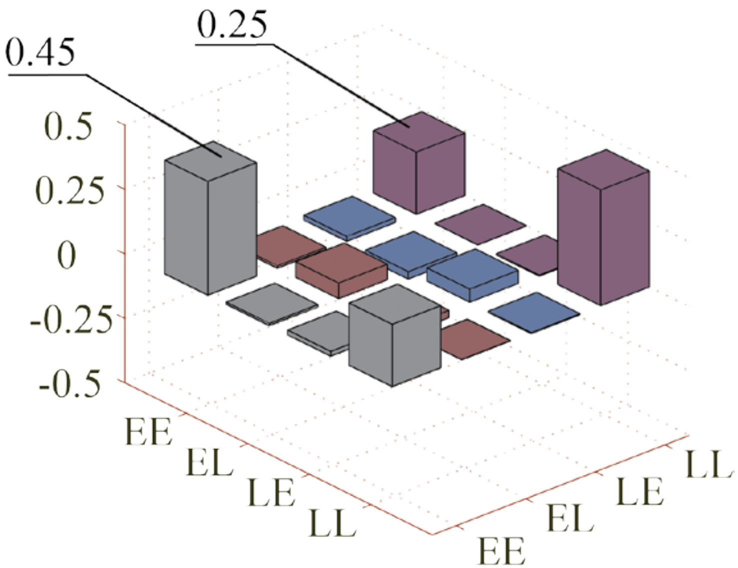
$|E\rangle + i|L\rangle$

4 measurements

1	0	0
2	0	$\pi/2$
3	$\pi/2$	0
4	$\pi/2$	$\pi/2$

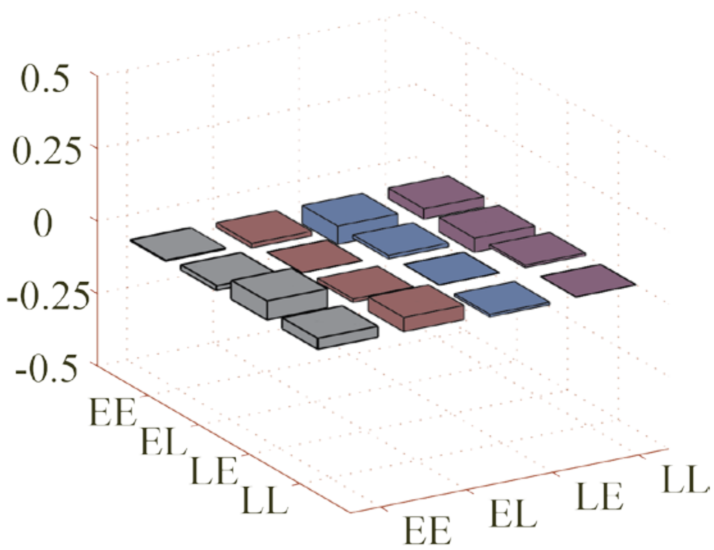


Tomography measurements show entanglement



Concurrence **0.41(6)**

Fidelity **0.69(3)**



Lifetime	***xx***	**405 ps**
	x	**711 ps**
Coherence length	***xx***	**214 ps**
	x	**111 ps**

We have…

demonstrated resonant excitation

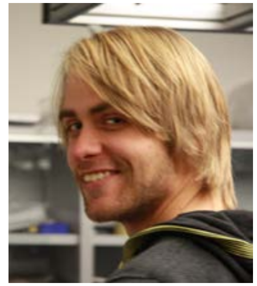
- Rabi oscillations
- Ramsey interference

measured a moderate level of time-bin entanglement

- higher collection efficiency
- Purcell-enhanced emission

arXiv:1305.2081 (2013)

Harishankar Jayakumar



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Gregor Weihs