On photon emission processes from site-controlled quantum dots.

Eoin Murray
Epitaxy and physics of Nanostructure's group, Tyndall National Institute.

Project objectives:

- New photon counting cards - higher resolution and lower power measurements.
- Time resolved entanglement - theoretical/experimental.
- Hot Trion states - theoretical/experimental.

Emanuele Pelucchi
Gediminas Juska
Valeria Dimastrodonato
Tung-Hsun Chung
Agnieszka Gocalinski
Marina Manganaro

- Introduction to quantum dots and entangled photons.

- Time resolved entanglement.

- Hot trion states.

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University College Cork, Ireland

Tyndall
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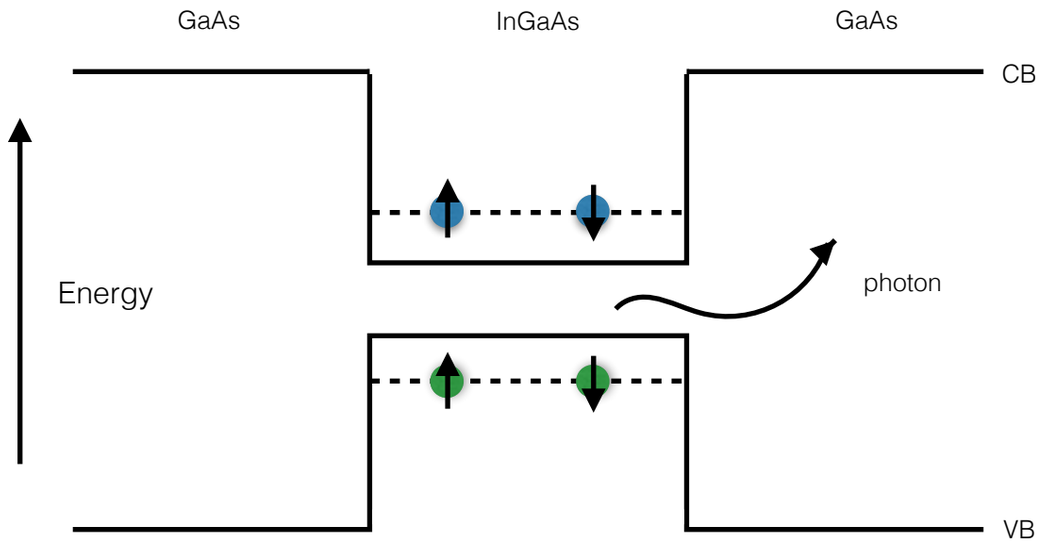
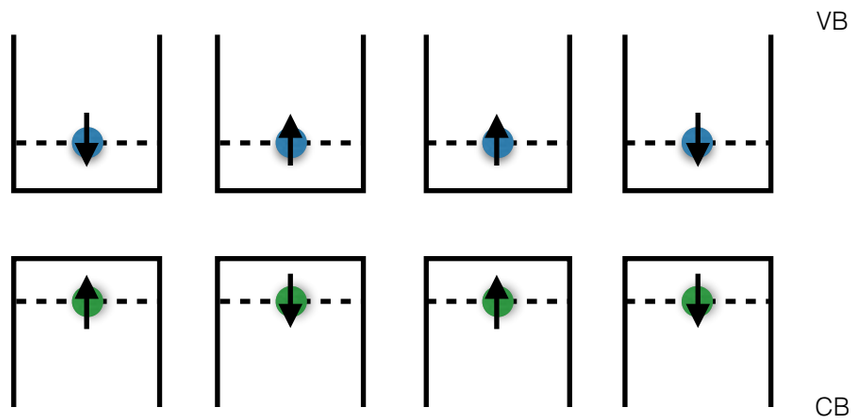
Quantum dot

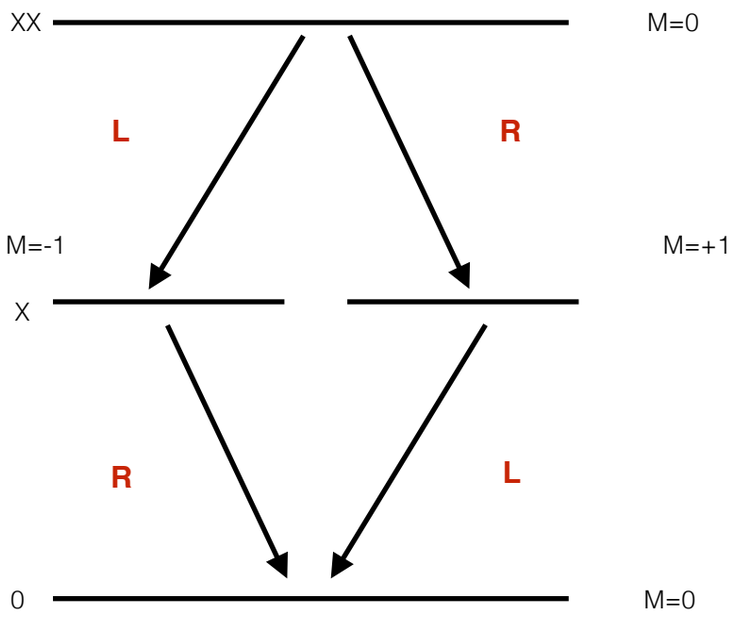


XX- Biexciton

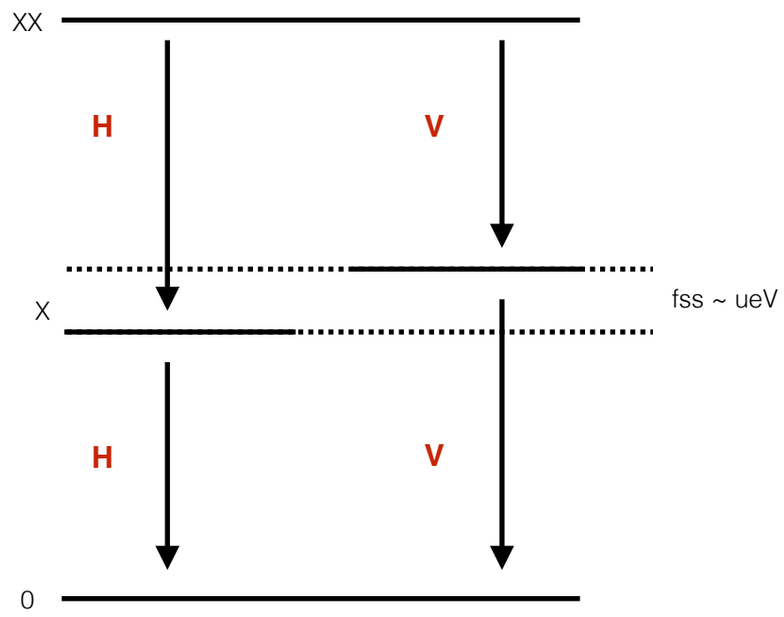


X - Exciton states

Photon emission - no FSS.

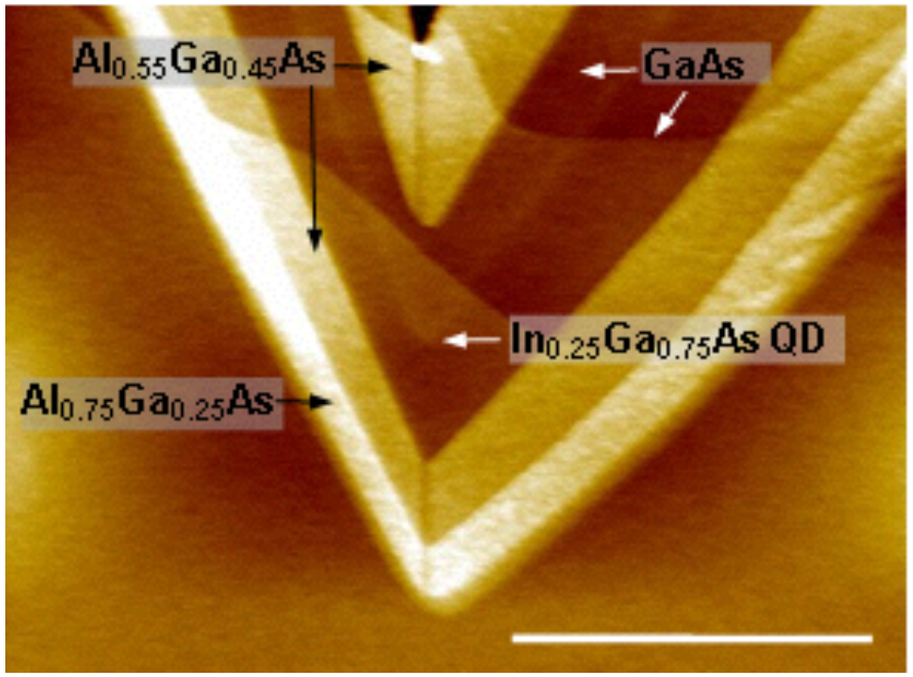


Photon emission - FSS ~ ueV.

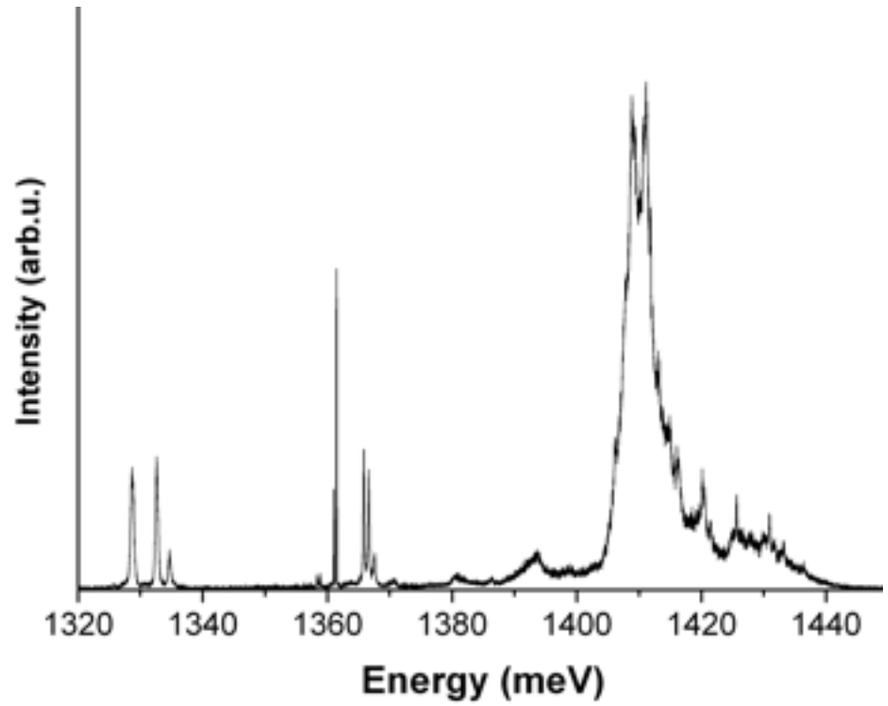


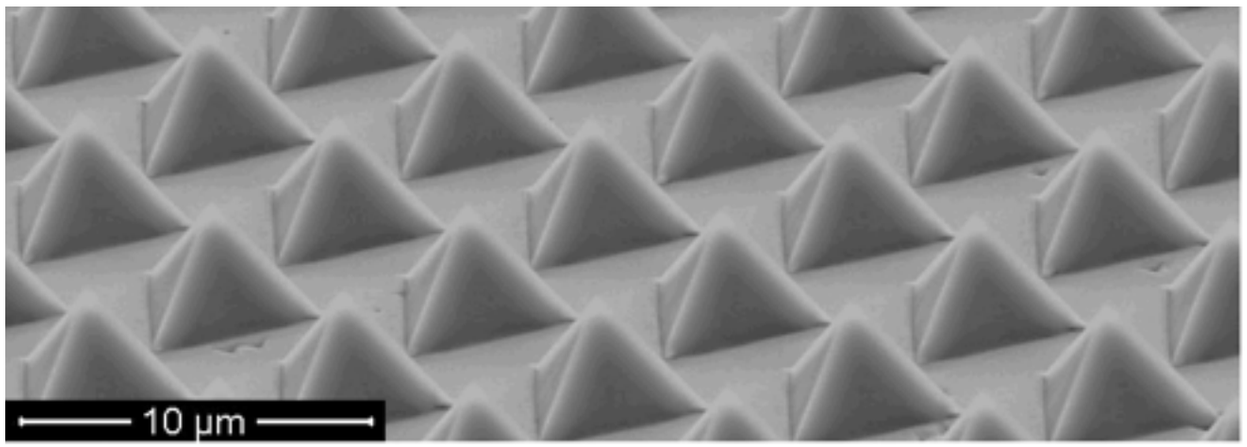
$$|\psi\rangle = \frac{1}{\sqrt{2}}\left(|H_{xx}H_x\rangle + \frac{-iS\tau}{\hbar}|V_{xx}V_x\rangle\right)$$

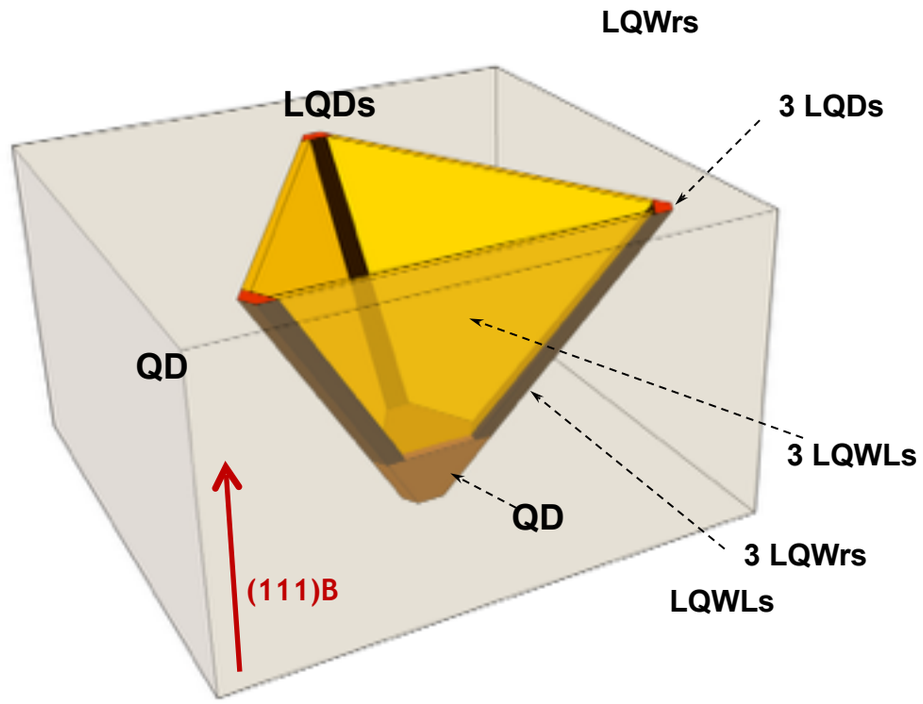
MOVPE site controlled system.



Epitaxially grown layers - lattice matched.







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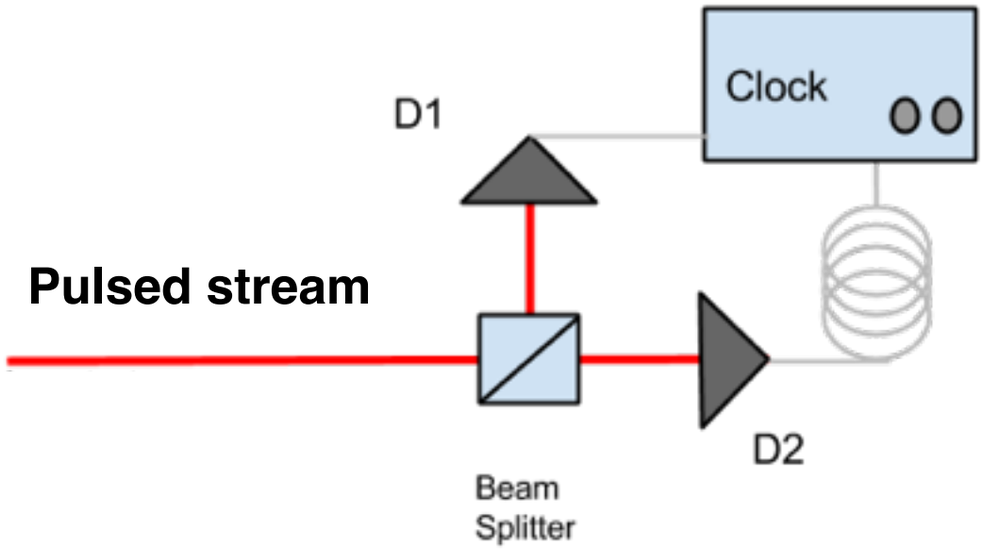
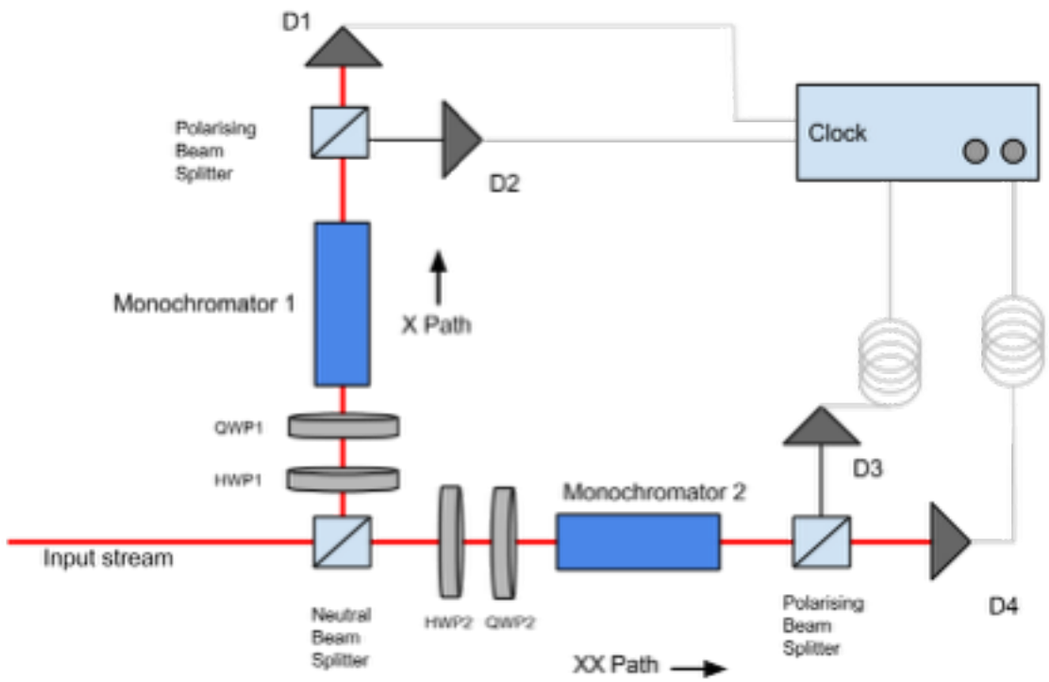
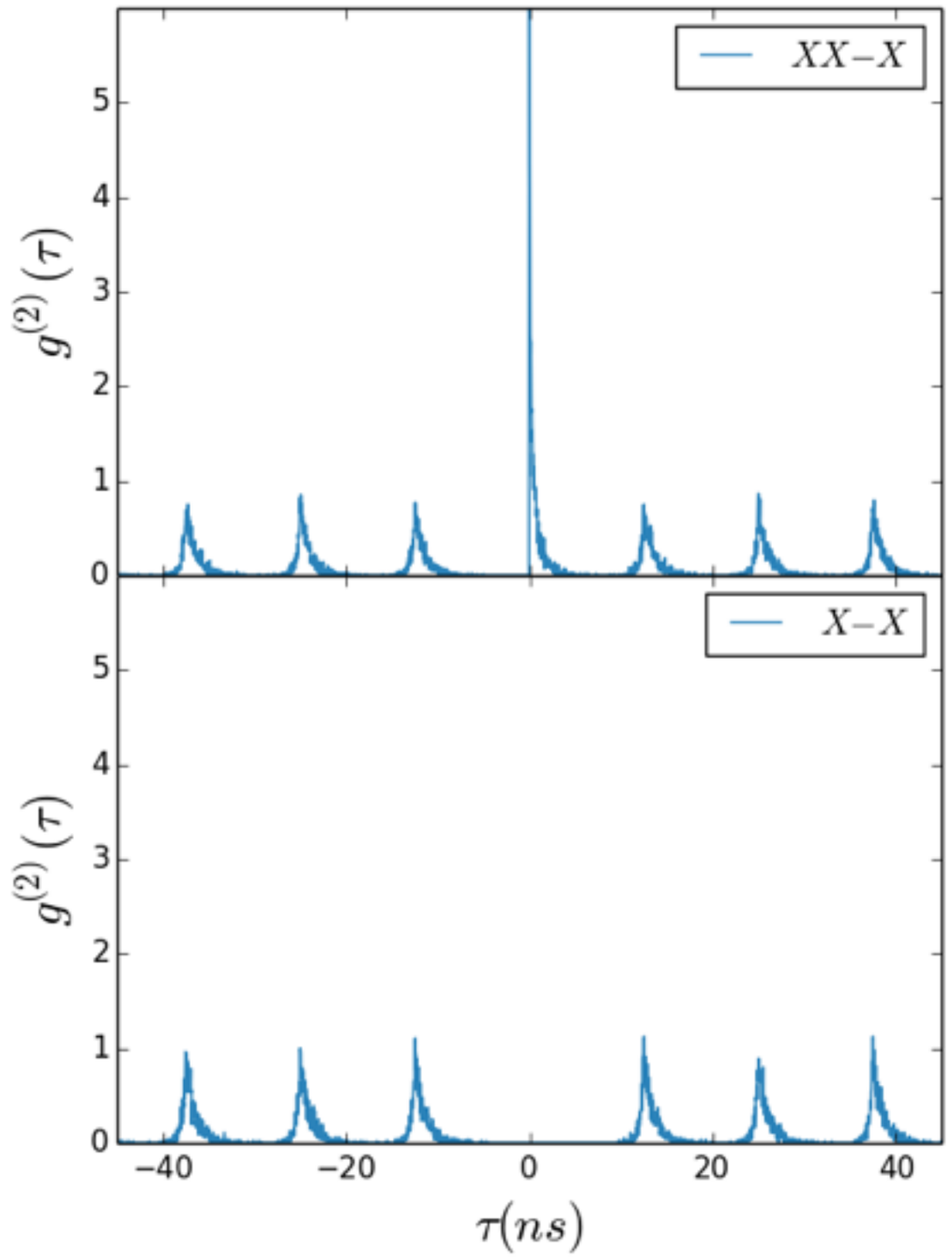
Second order correlation function

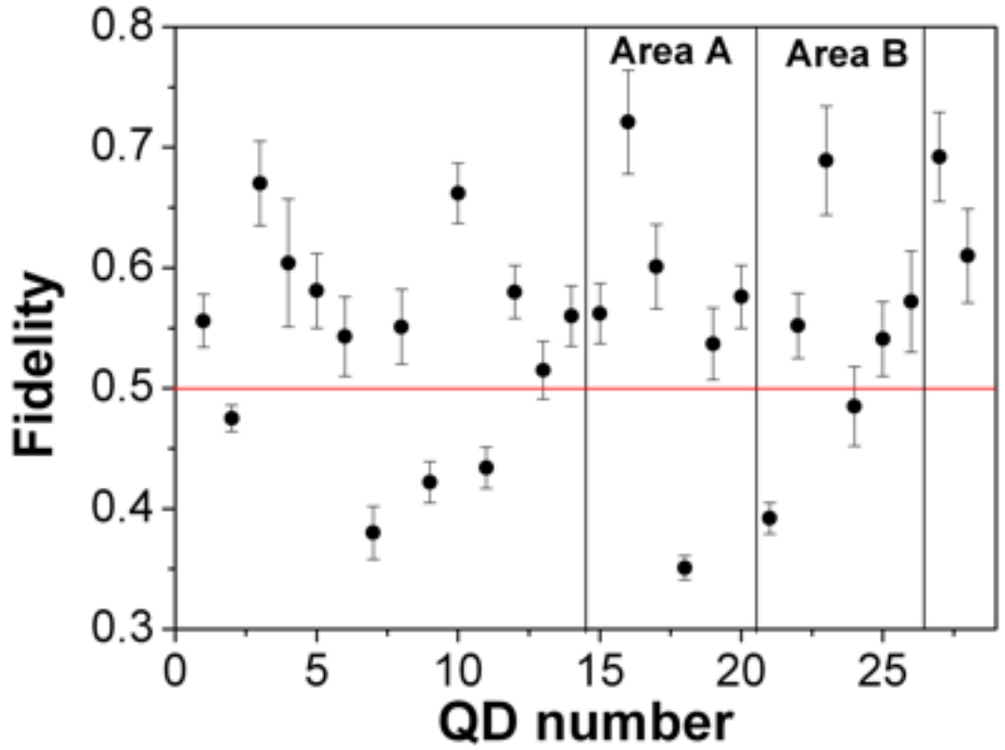
$$g^{(2)}_{i,j}(\tau) = \frac{\langle I_i(t) I_j(t+\tau) \rangle}{\langle I_i(t) \rangle \langle I_j(t) \rangle}$$

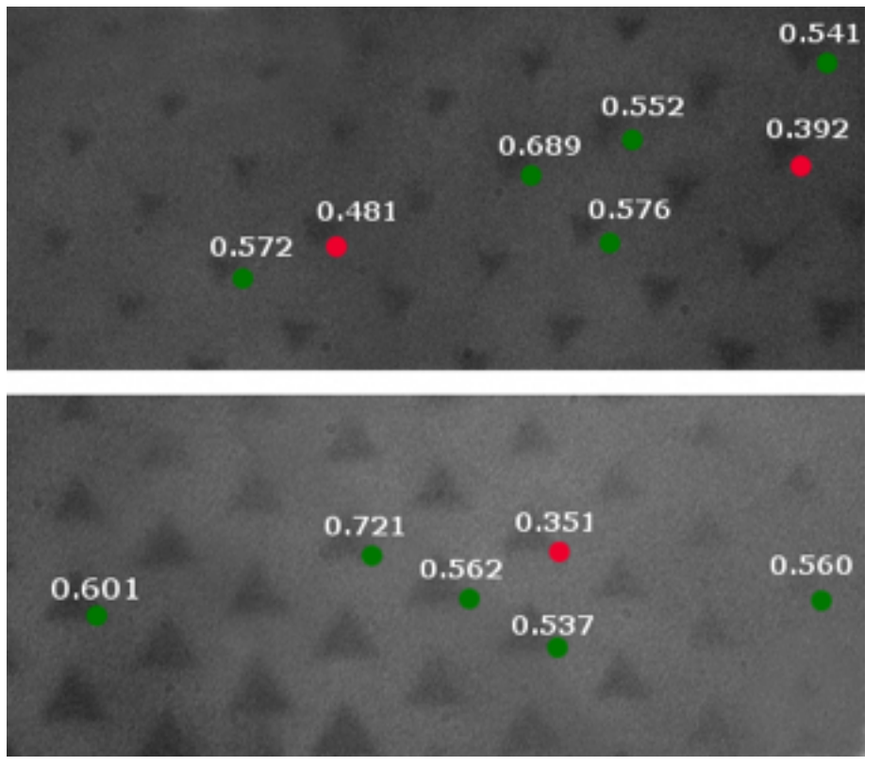


HBT Correlator - same but for entanglement.



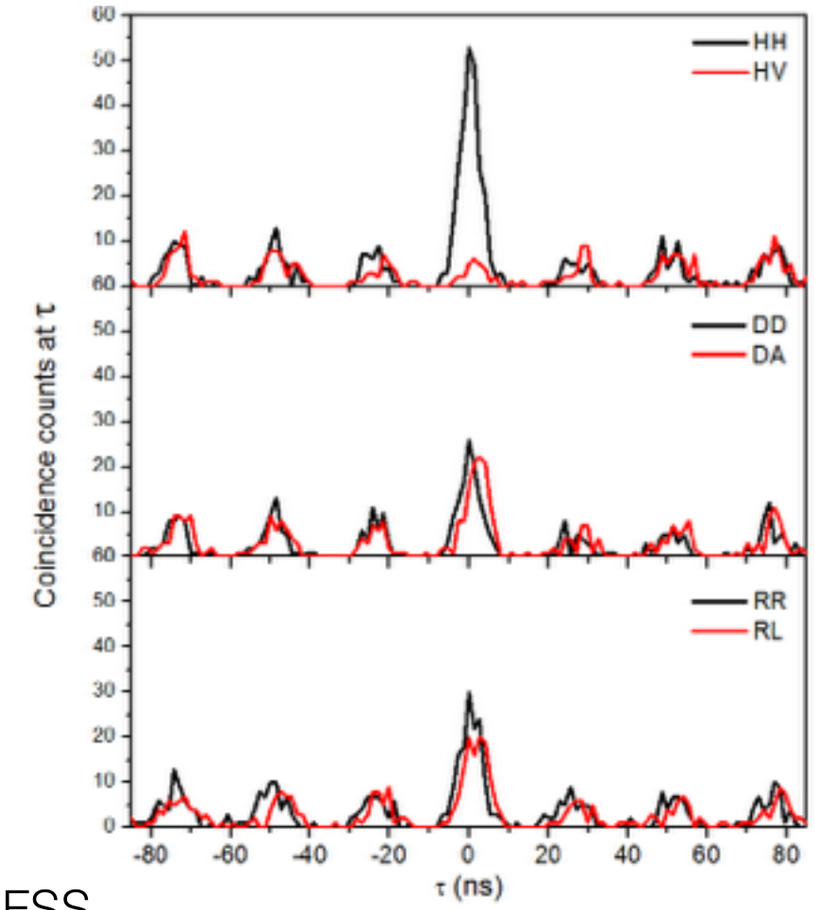




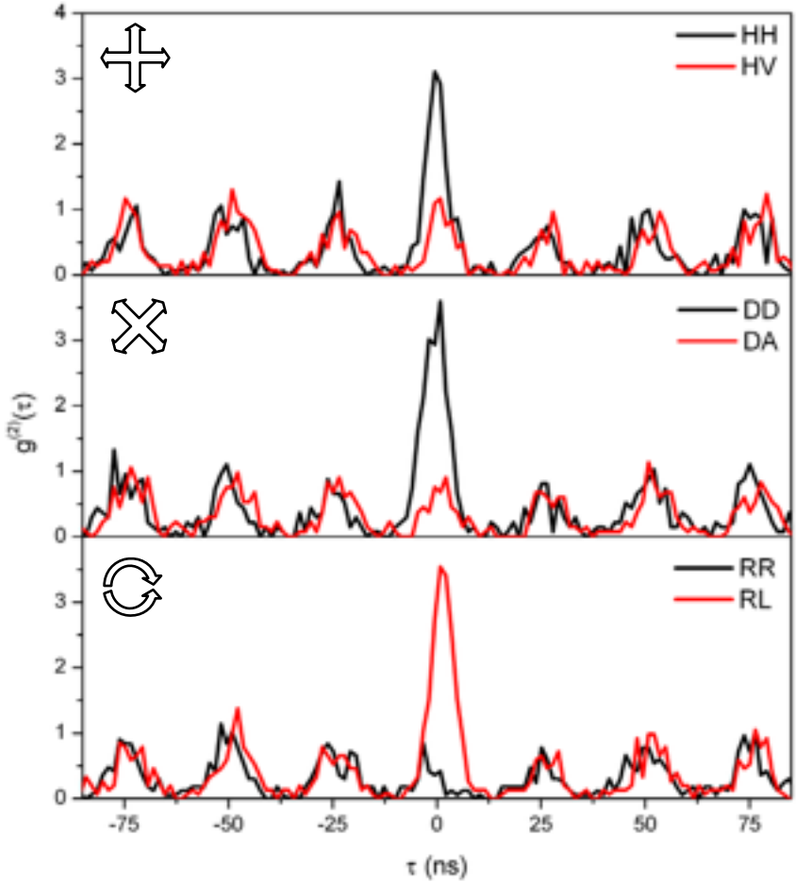


G, Juska et al, NATURE PHOTONICS, 7, 527 (2013).

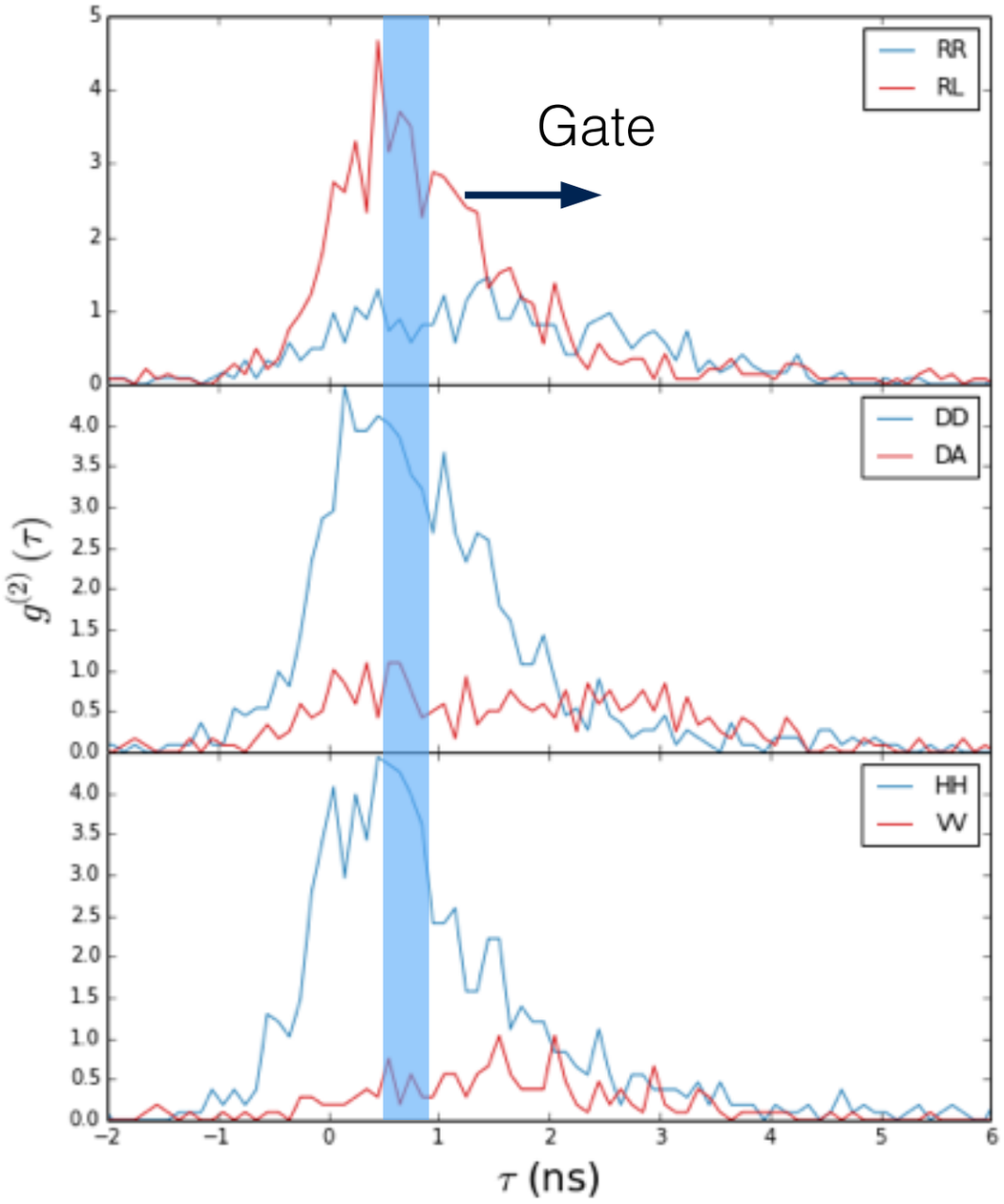
FSS ~ 3ueV



No FSS



Time tagging entanglement measurements.



$$|\psi\rangle = \frac{1}{\sqrt{2}}\left(|H_{xx}H_x\rangle + ^{\frac{-iS\tau}{\hbar}}\ |V_{xx}V_x\rangle\right)$$

Time gating:

- Move gate
- Change gate size

Individual QD we don't change FSS. Instead discriminate by lifetime.

Only recently able to measure with enough resolution.

R.M. Stevenson, PHYSICAL REVIEW LETTERS 101, 170501

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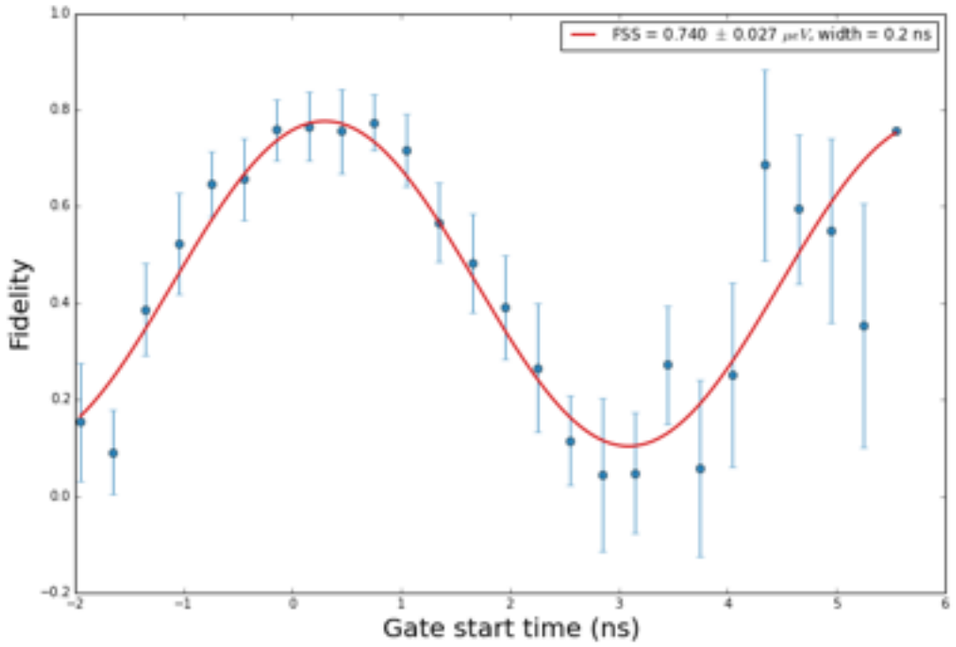
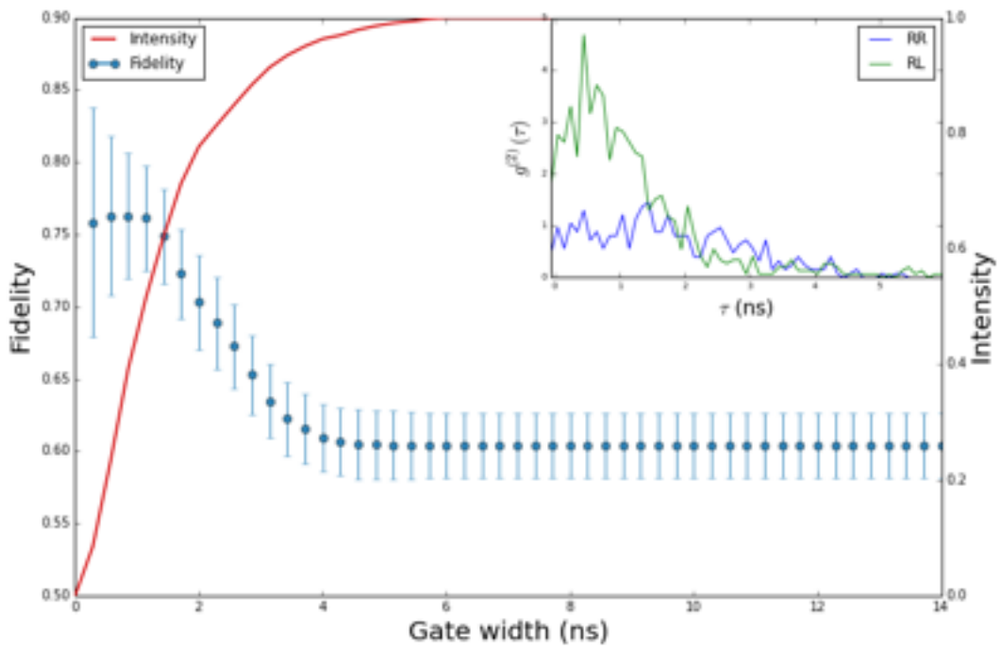
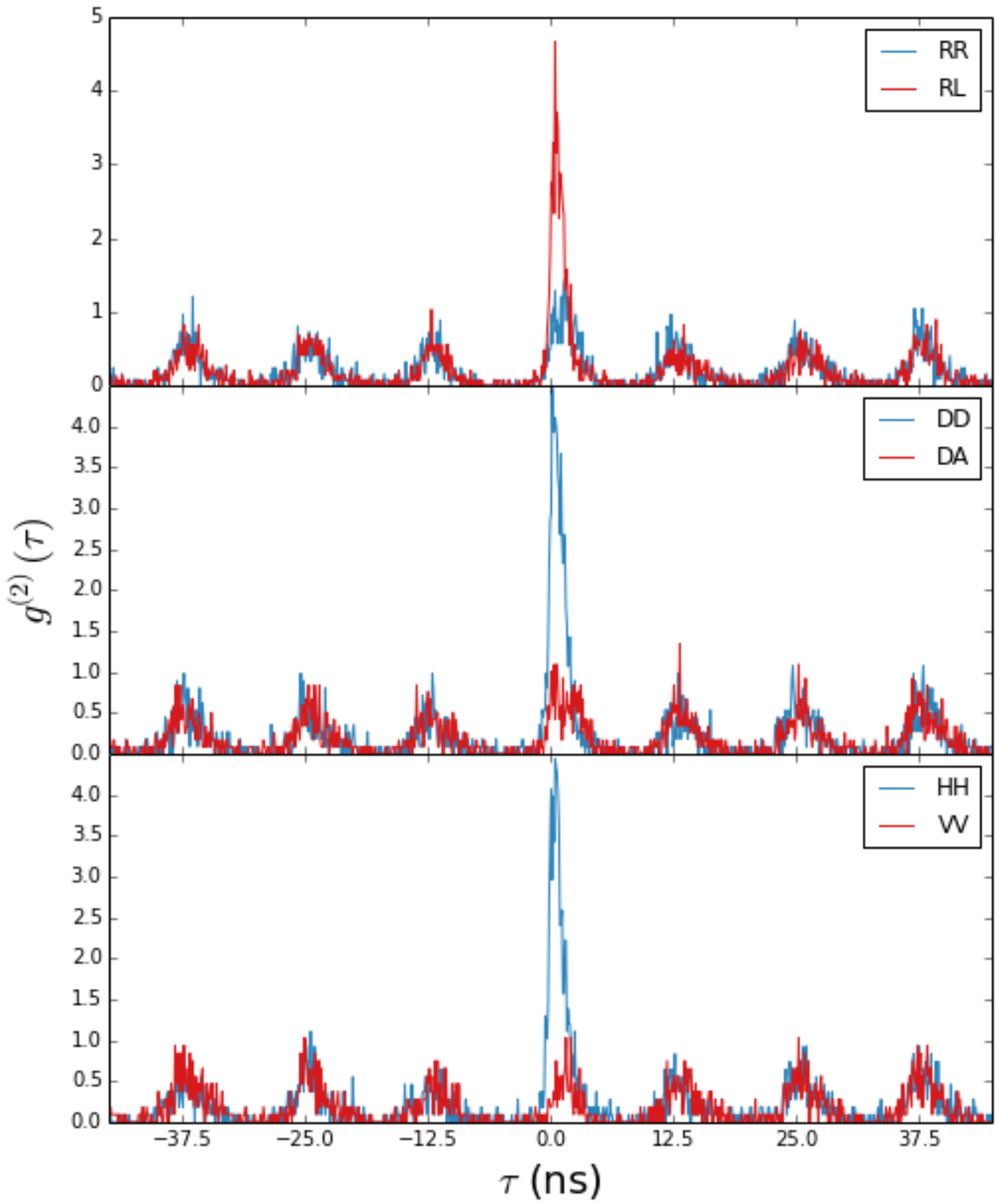
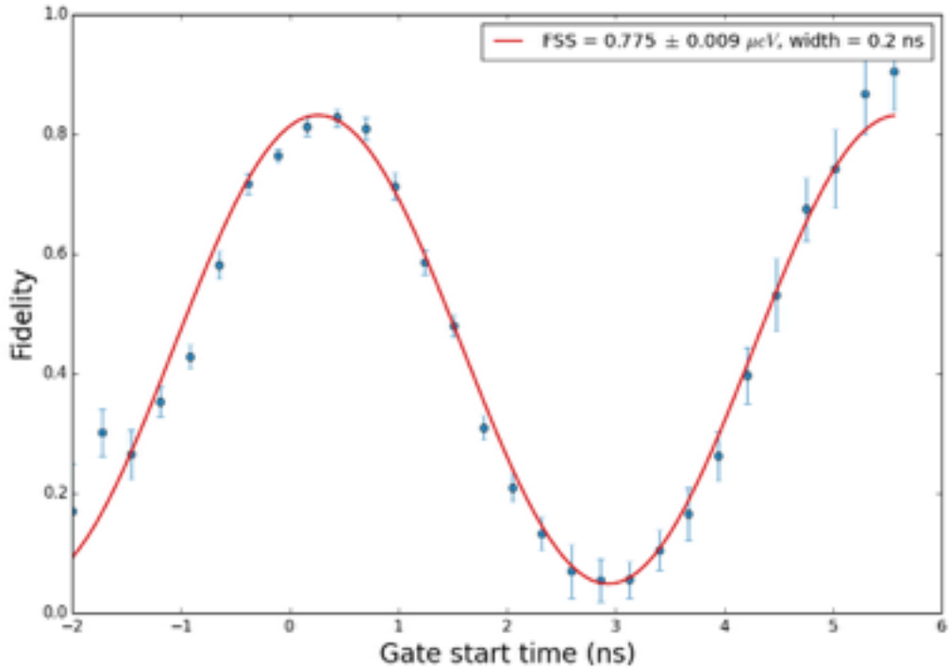
Data

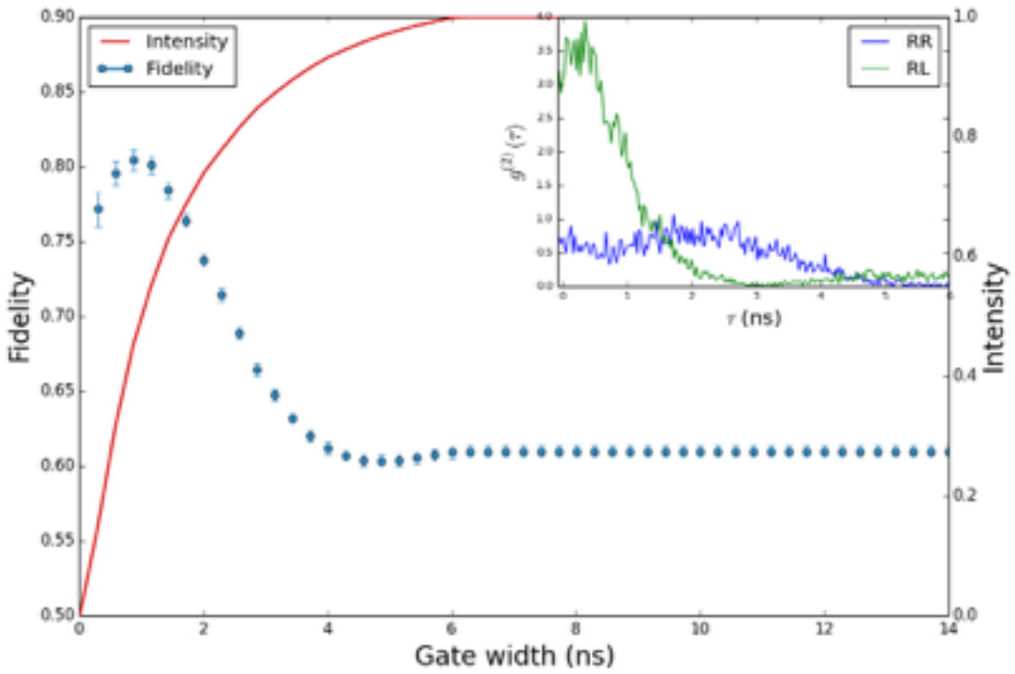

FSS = 0.740 ± 0.027 μeV, width = 0.2 ns
Fidelity
Gate start time (ns)

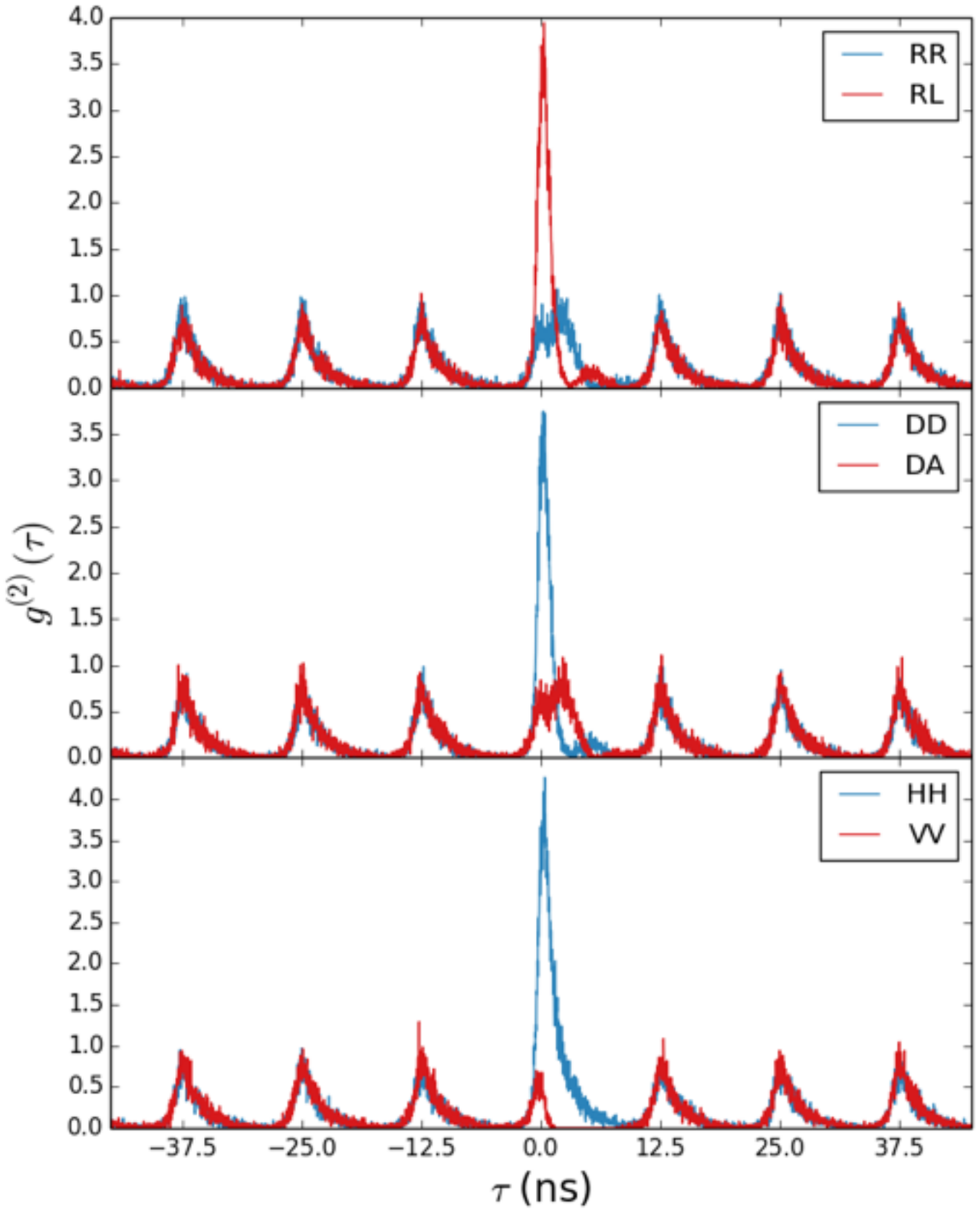

Intensity
Fidelity
RR
RL
$g^{(2)}(\tau)$
τ (ns)
Fidelity
Intensity
Gate width (ns)


RR
RL
DD
DA
HH
W
$g^{(2)}(\tau)$
τ (ns)

Simulation







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QD Monte carlo module.

1. Simulate lifetimes.
2. Simulate emission intensity.
3. Simulate phase and decoherence.

Lab bench Jones algebra module.

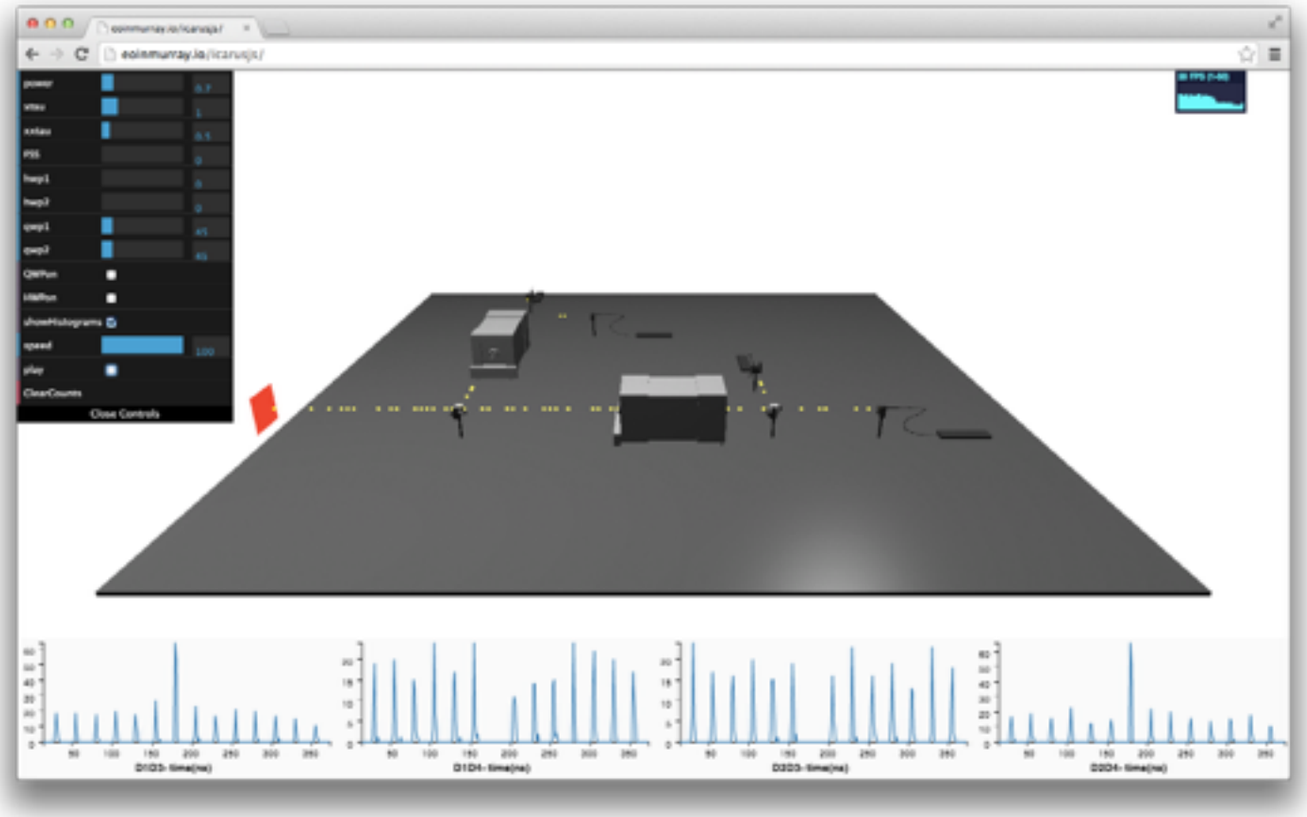
1. Build Jones matrix for every element.
2. Build biphoton state in lab basis (beam splitters, wave plates, monochromators, detectors).
3. Calculate probabilities as a function of QD state phase.

Algorithm.

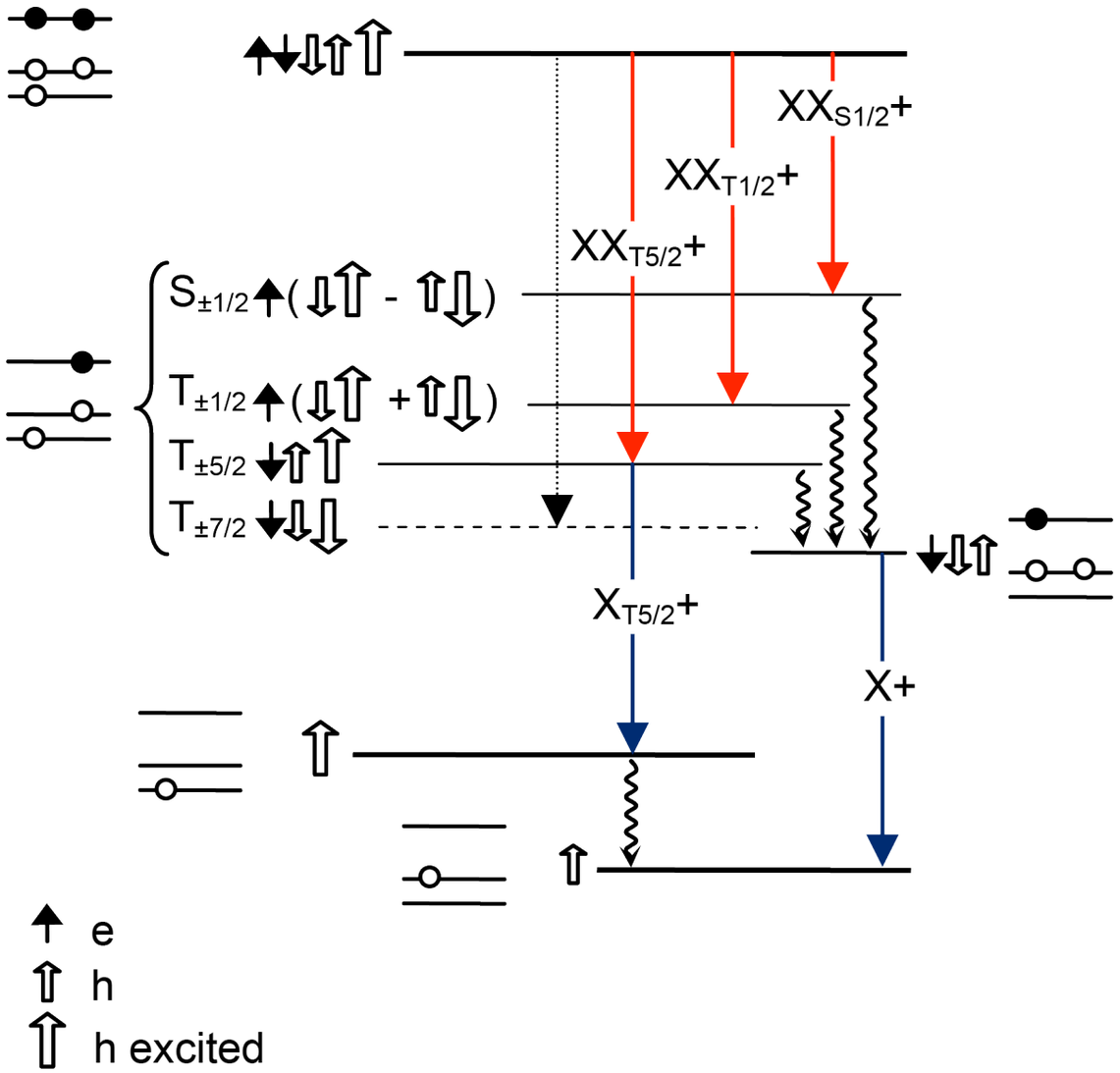
1. Create dot stats, phase, lifetime, intensity.
2. Propagate QD through system.
3. Hit each detector depending on probabilities.

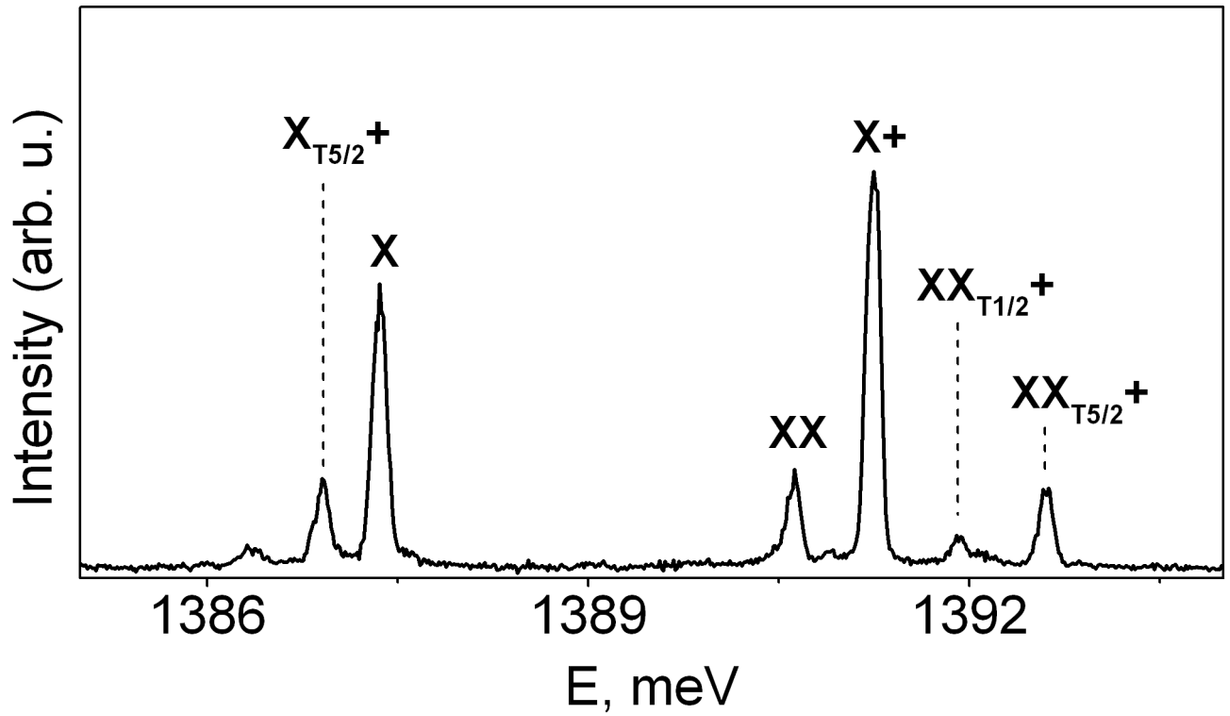
Process data.

1. Correlate detectors.
2. Time-gate.



Hot trion states



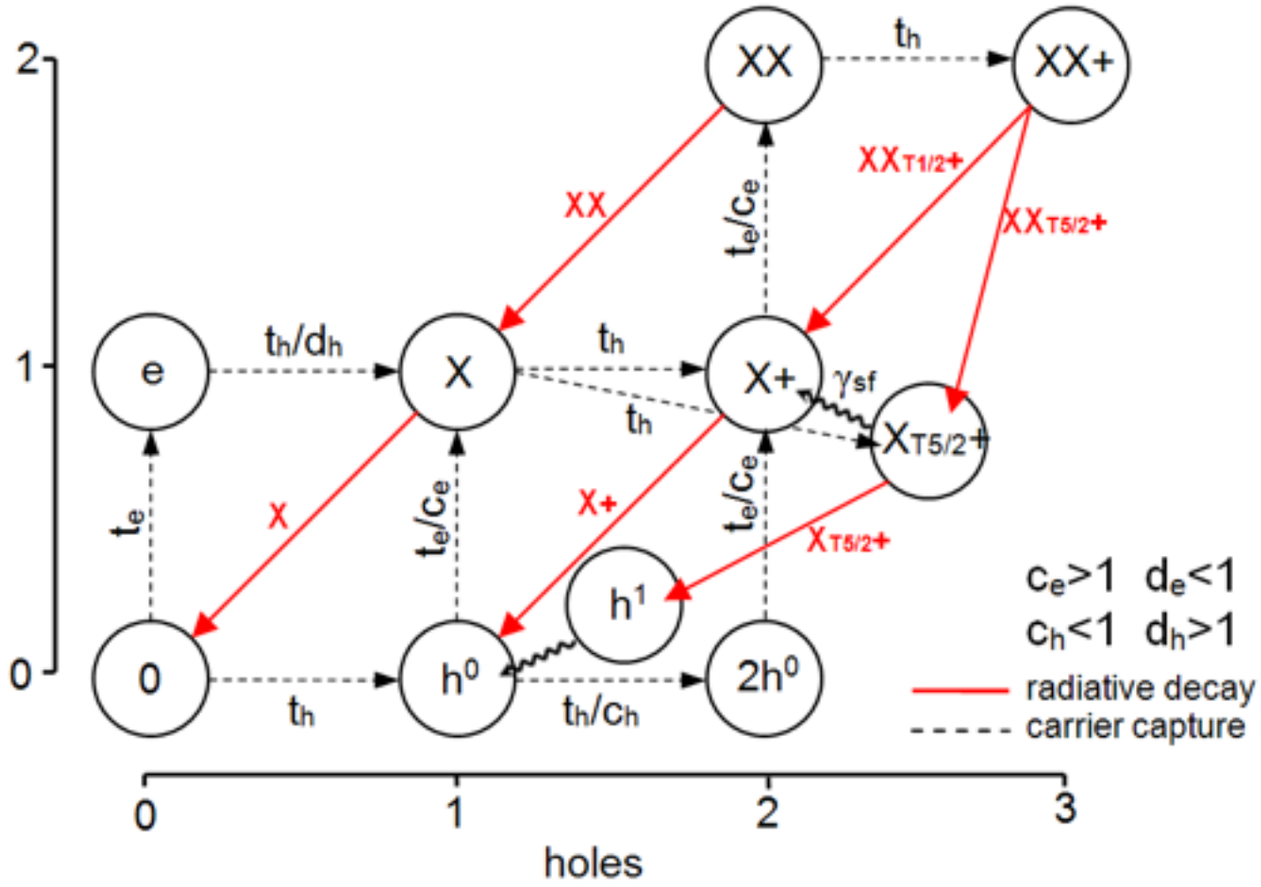


H. Kramer, PROC. AMST. ACAD 33 959 (1930)

T. Warming et al, PHYSICAL REVIEW B 79, 125316 2009

Y. Igarashi, et al. PHYSICAL REVIEW B 81, 245304 2010

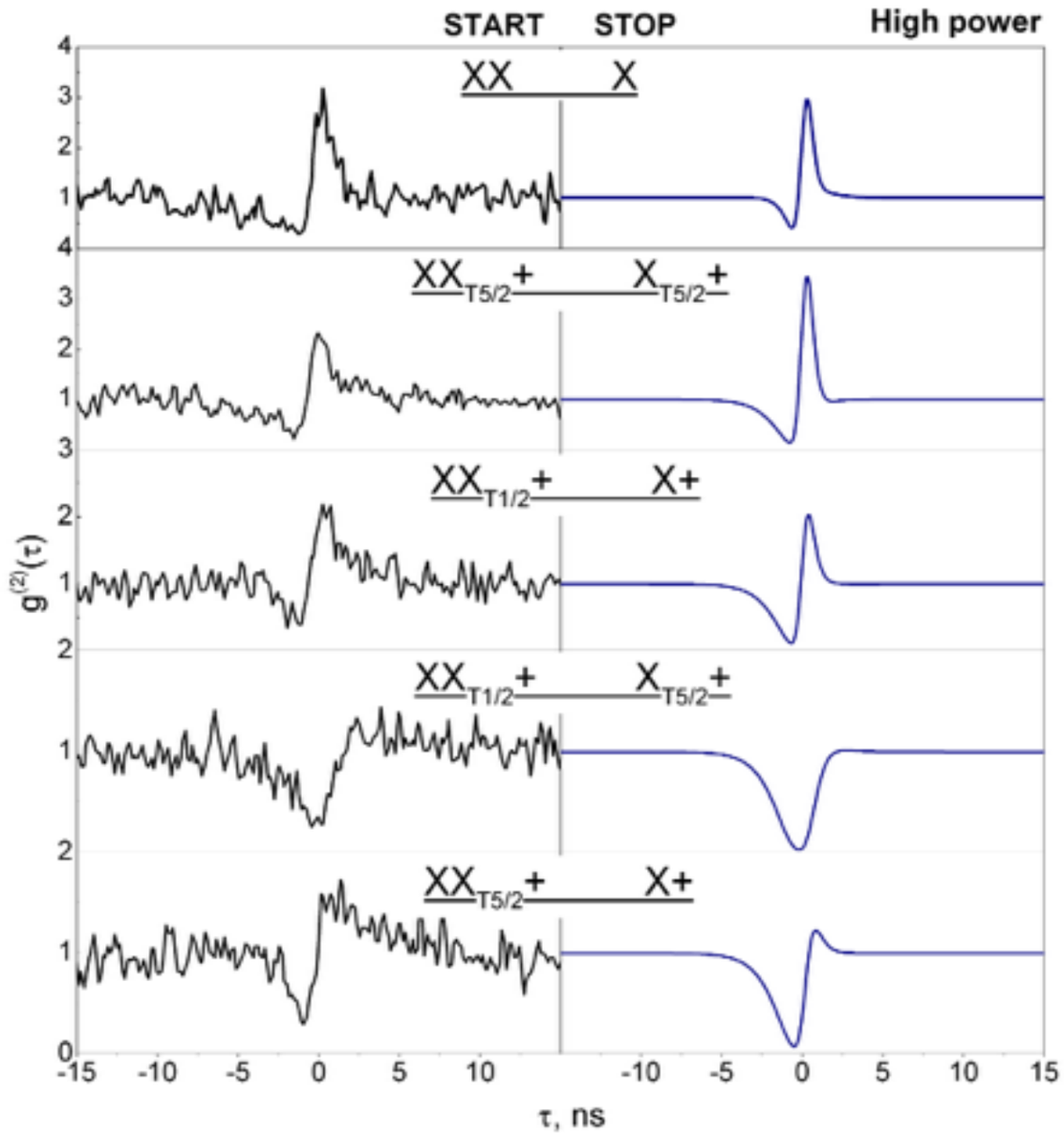
Modelling correlations

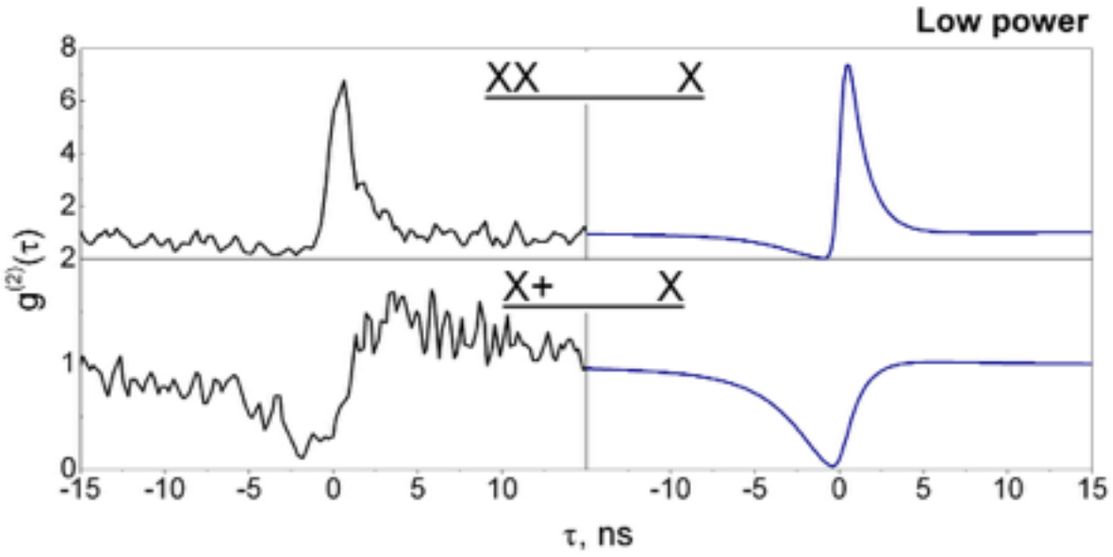


To be submitted to PRB.

M. H. Baier et al, PHYSICAL REVIEW B 73, 205321 2006

M. Grundmann and D. Bimberg, PHYSICAL REVIEW B 55, 9740 1997





Summary

- Site-controlled array of entangled photon emitters.
- Verified entanglement time-dependance.
- Observation of hot trion states.

Further work

- Tailor the growth for more neutral QDs.
- Tune emission wavelength and FSS.
- Simulation : Interferometry, Teleportation.

Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

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