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SAND2016-6592C

Few-Hole Double Quantum Dots

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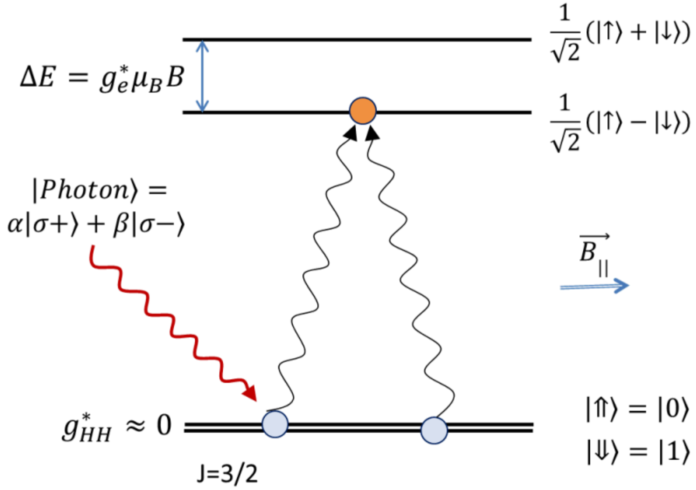
Motivation

- *Holes in GaAs have reduced hyperfine interaction compared to electrons => longer spin coherence times*
- *GaAs features direct band gap (unlike Silicon - requirement for hybridization with photons)*
- *Heavy hole g*-factor can be tuned in-situ (required for hybridization protocols)*



Quantum information transfer from a flying qubit to hole spin qubit

First proposal for electrons with g*≈0:
E. Yablonovitch, et. al, *"Optoelectronic quantum telecommunications based on spins in semiconductors," Proc. IEEE, v. 91, 761-780 (2003).*

P- Double Quantum Dot Device

Silicon Dots:
R. Li, F. E. Hudson, A. S. Dzurak, and A. R. Hamilton, Nano Letters **15,** 7314 (2015)
B.Voison,…. S.De Franceschi et al. Nano Letters 16 (2016) 88
R.Maurand et al. arXiv1605.07599

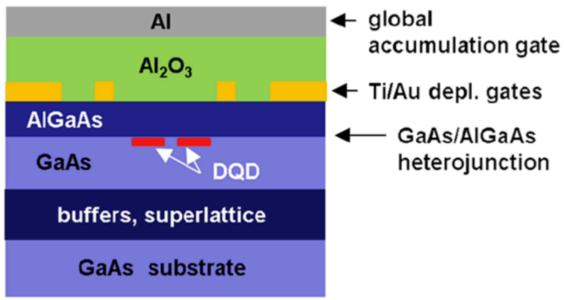
InSb Nanowires:
V.S. Pribiag, S,Nadj-Perge, S.M.Frolov,…L.Kouwenhoven Nature Nano. 8 (2013) 170

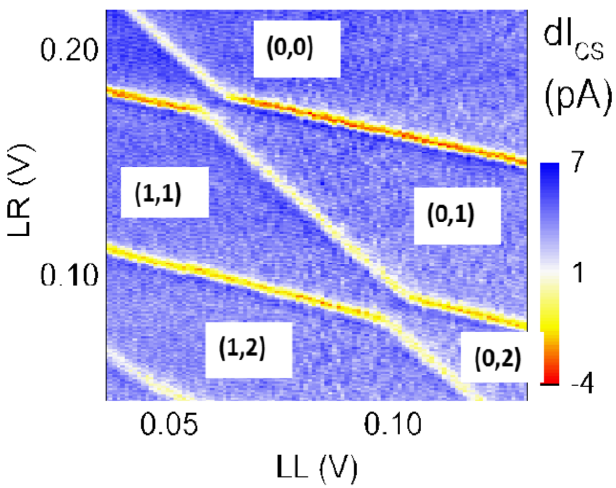
GaAs Dots:
D.Q Wang et al. Nanotechnolgy 27 (2016) 334001

Sandia

L. A. Tracy, et al. *"Few-hole double quantum dot in an undoped GaAs/AlGaAs heterostructure," APL, v. 104, 123101 (2014).*

SANDIA REPORT SAND2015-8132 (October 2015)





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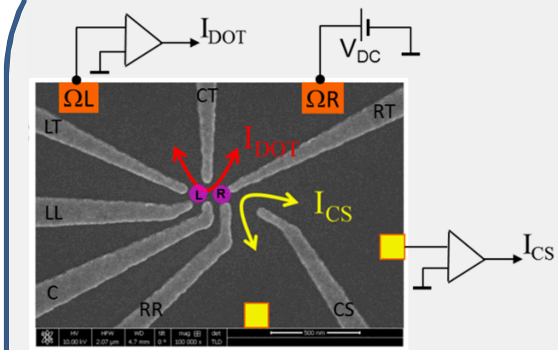
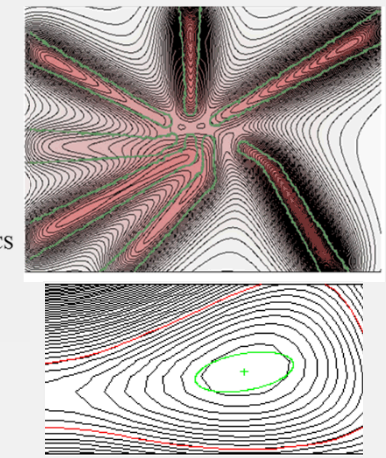
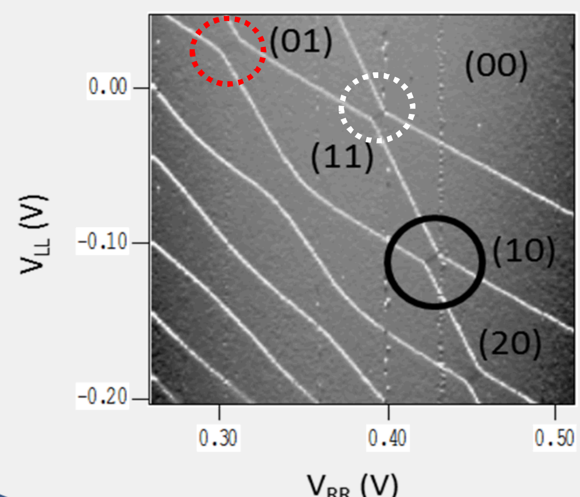
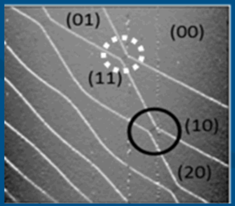
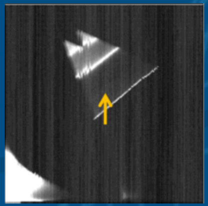






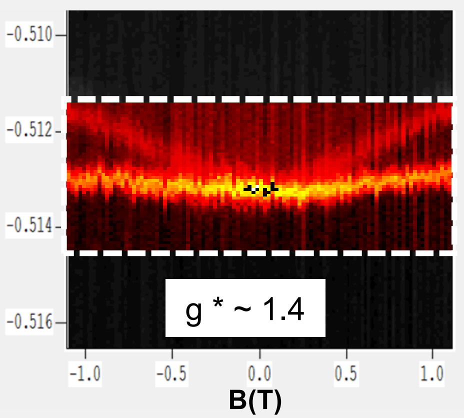
Spin non-conserving tunnelling transitions

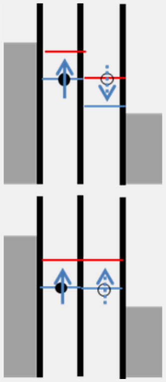


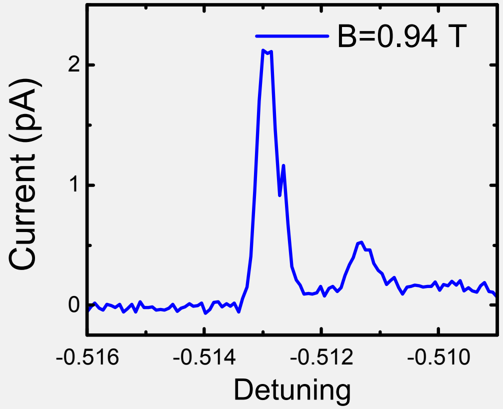


1 Hole

"nb. current not derivative"

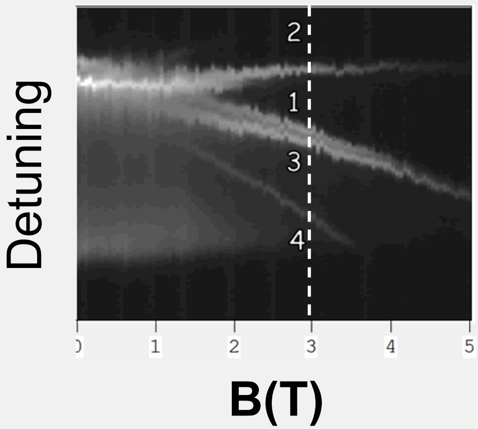




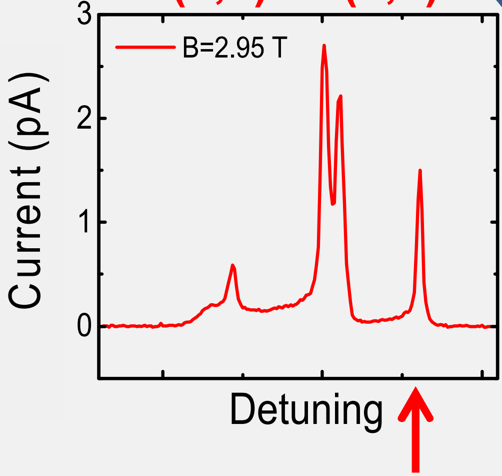


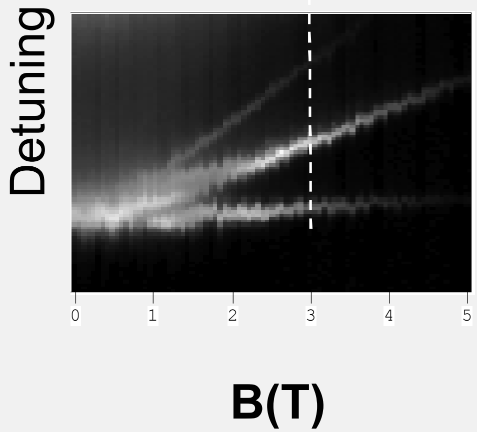
2 Holes

"nb. current not derivative"

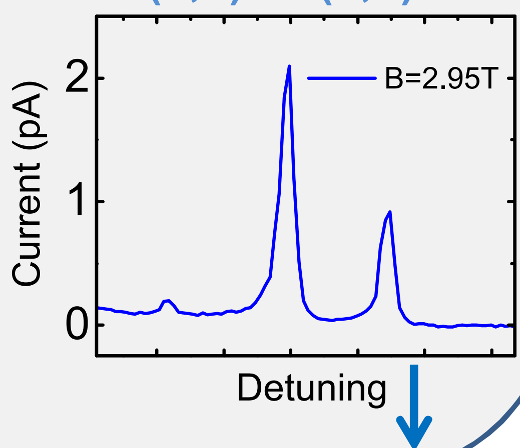


(1,1) to (2,0)





(2,0) to (1,1)



For comparison with electron case see
T.Fujita et al. arXiv:1603.04861

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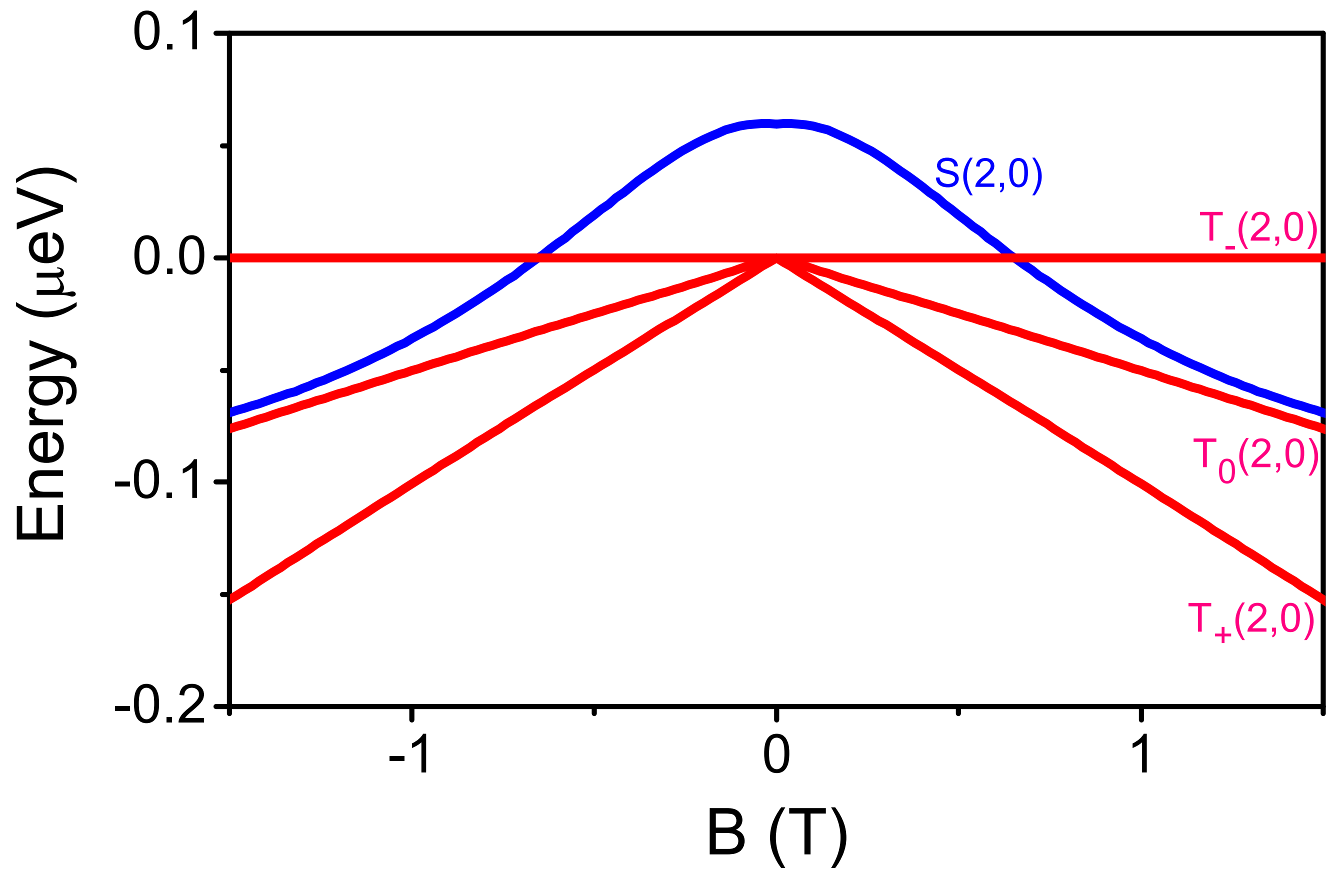
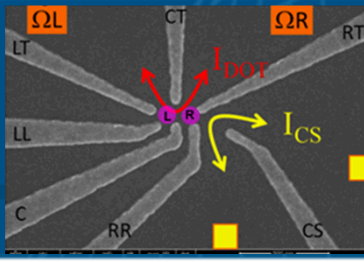
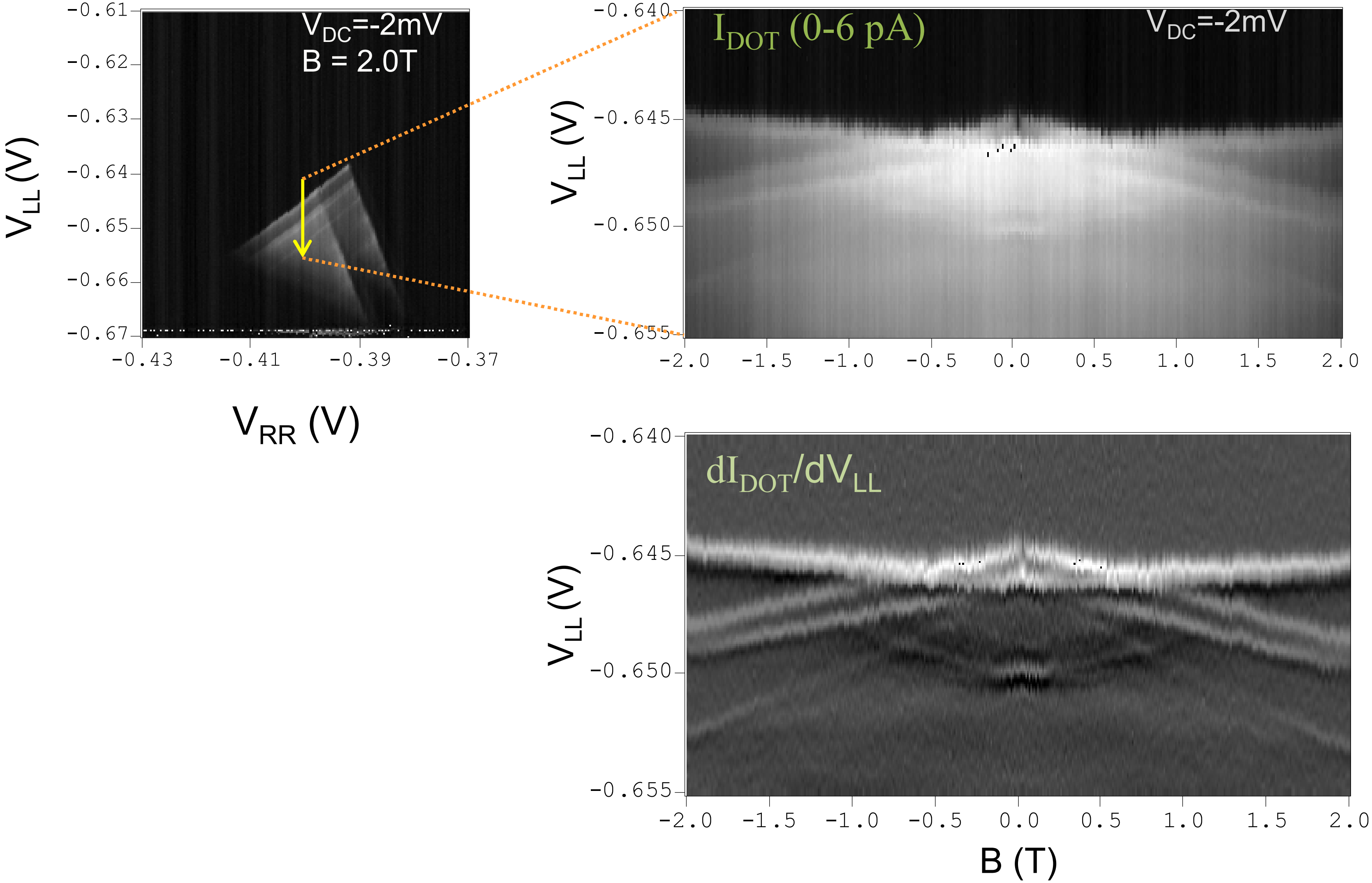
Predicted Spectrum of 2-hole single quantum dot.

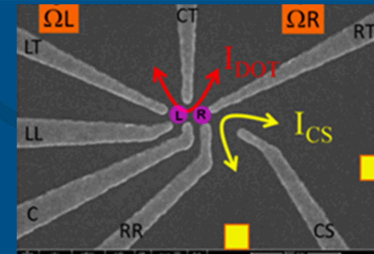


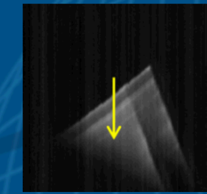
High-Bias 2 Hole Magneto-Transport Spectra
"dilution fridge measurements"





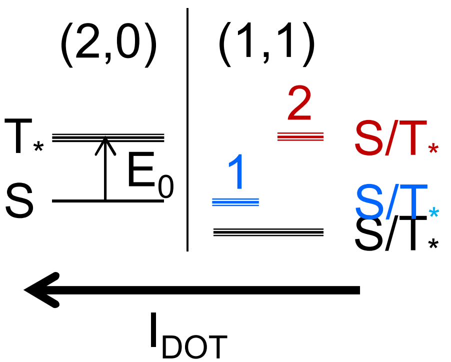
High-Bias 2 Hole Magneto-Transport Spectra





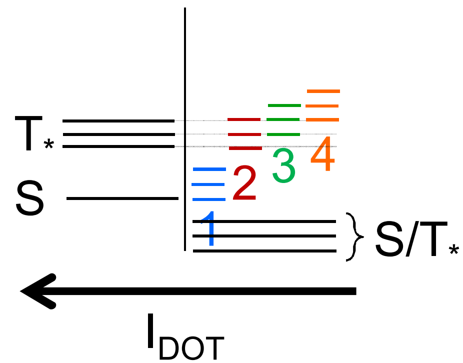
$E_Z = 0$

(2 Transport Conditions)



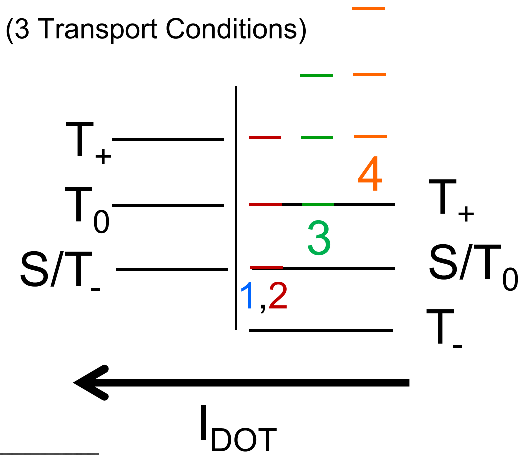
$E_Z > 0$

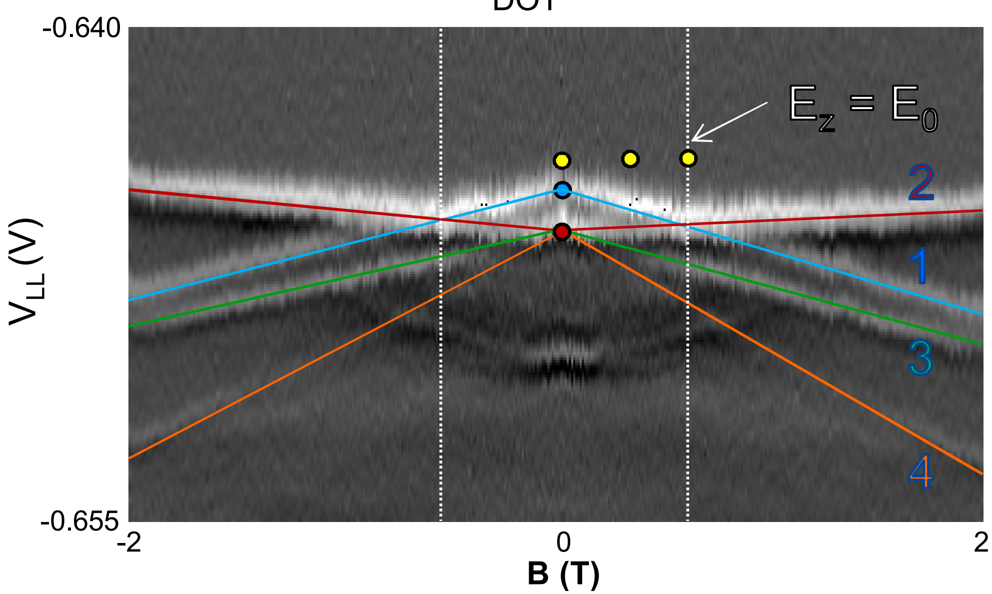
(4 Transport Conditions)



$E_Z = E_0$

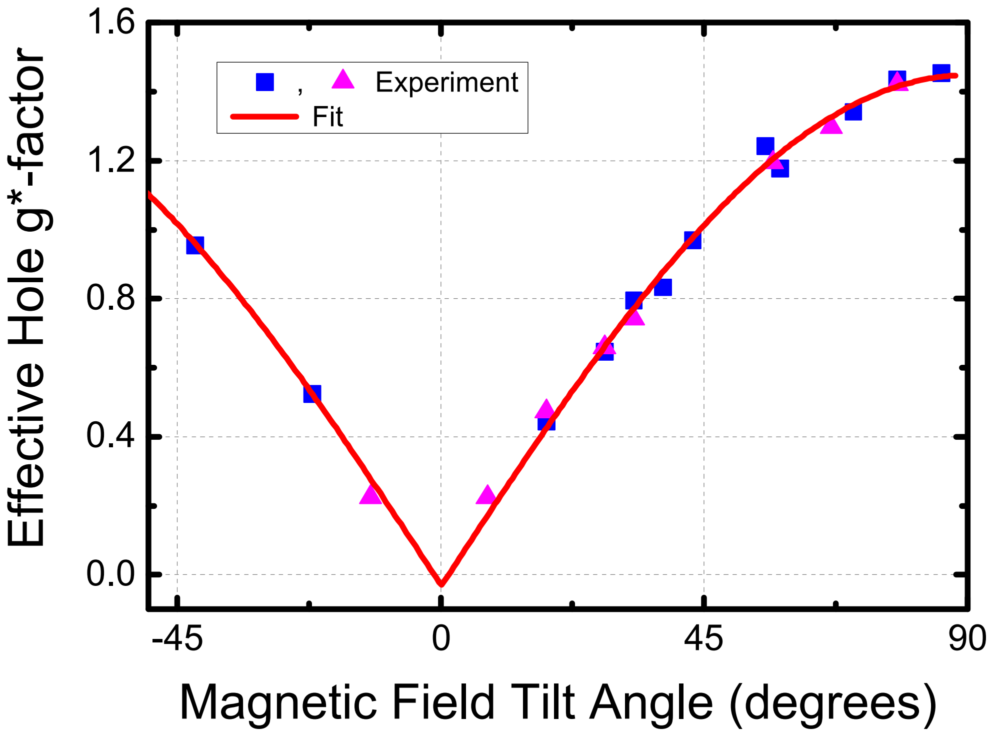
(3 Transport Conditions)





1 (single spin flip)	$\varepsilon = E_Z$
2 (no spin flip)	$\varepsilon = E_0$
3 (single spin flip)	$\varepsilon = E_0 + E_Z$
4 (two spin flips)	$\varepsilon = E_0 + 2E_Z$

Effective Heavy Hole g*-Factor in Tilted Magnetic Field



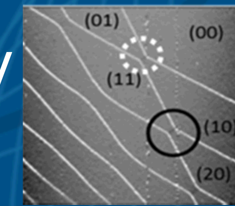
$$g^*(\theta) = g_0\,|\sin\theta| + g_{min}$$

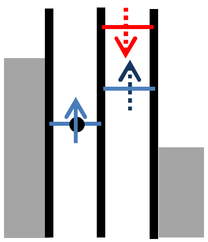
$g_0 = 1.45 \pm 0.1$
$g_{min} = -0.04 \pm 0.04$

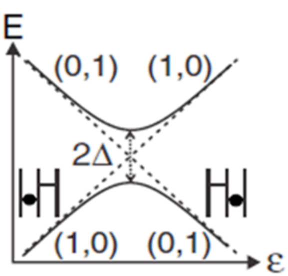
Minimal heavy/light-hole mixing

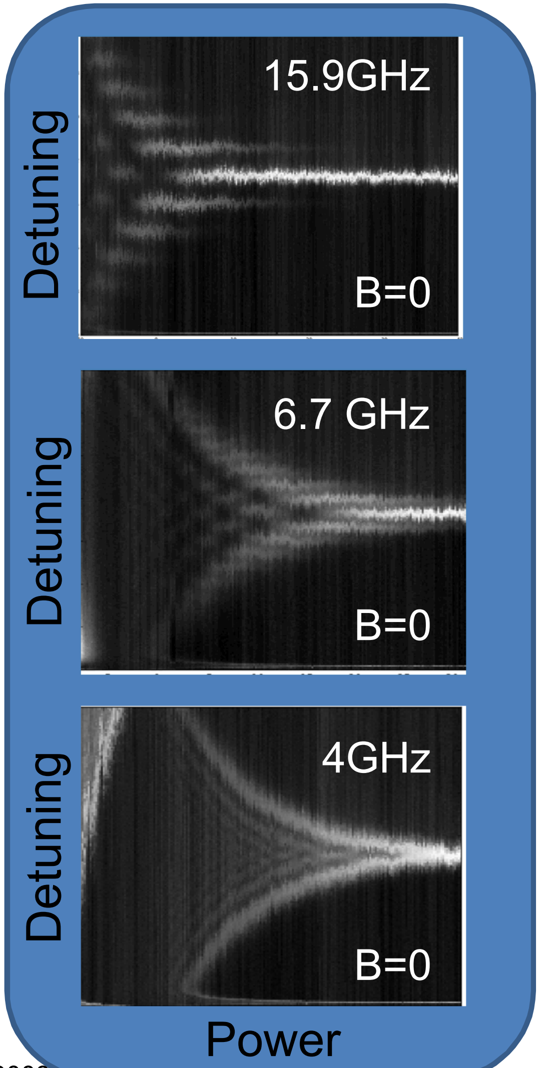
g-factor from Landau-Zener-Stückelberg Interferometry

utilizing non-spin conserving transitions

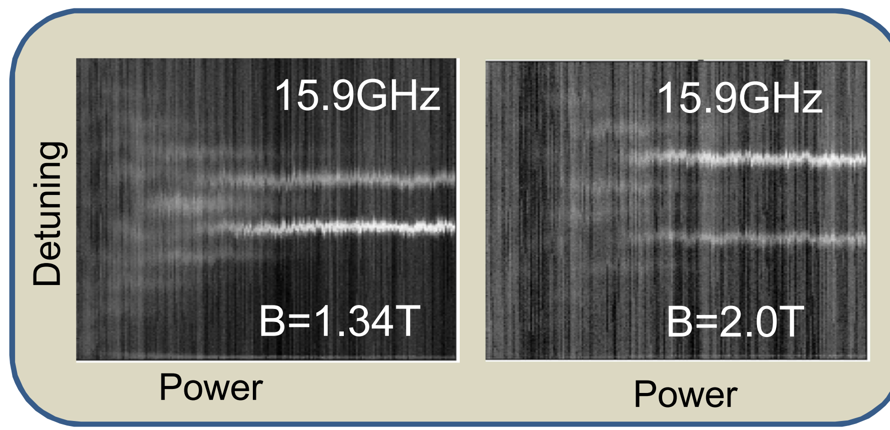








g* ~1.45



For related electron LZS see e.g.
- Forster et al. PRL 112 (2014) 116803
- Stehlik et al. PRB 86 121303(2012)1213003

For ‘electron’ spin-flip photon assisted rates
See Braakman et al. PRB89 (2014) 07417

Summary

- Magneto-transport spectroscopy for 1 and 2 hole systems
- Non-spin conserving tunneling in direct transport and LZS interferometry
- Anisotropic g-factor of the hole with g~0 for in plane field