Recent progress on electron transport through single phosphorus donors in silicon

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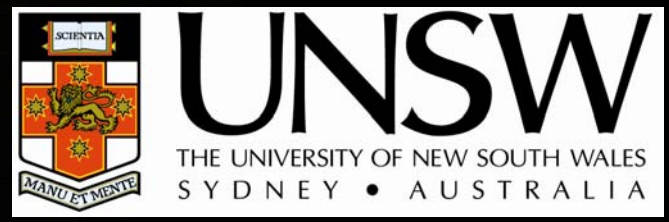

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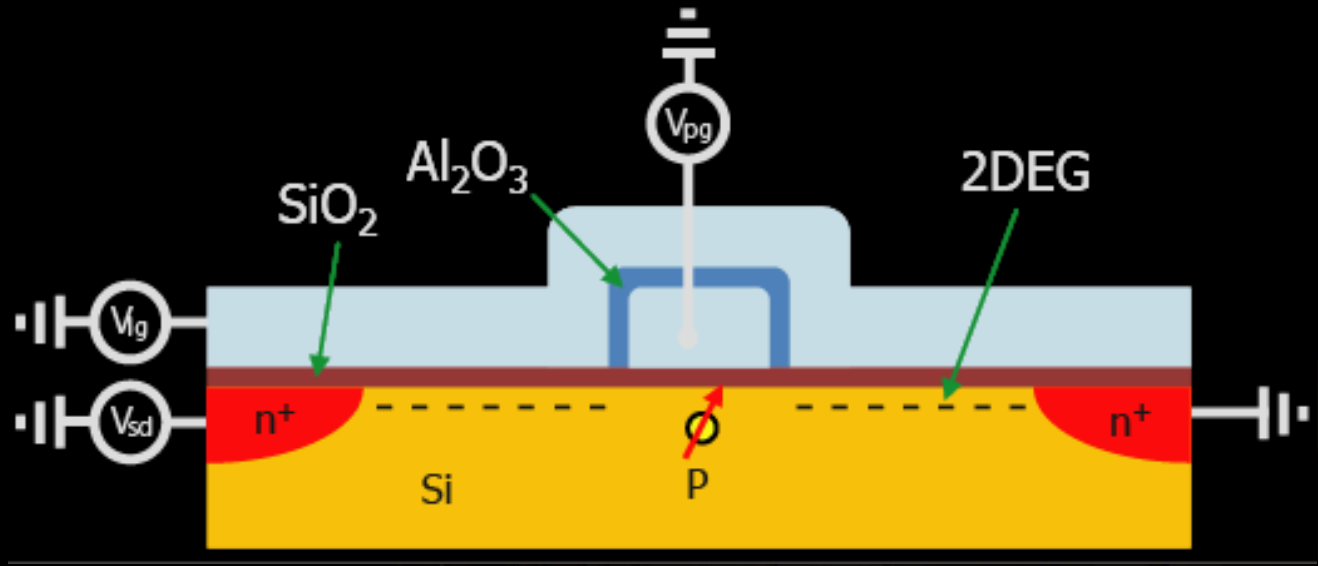
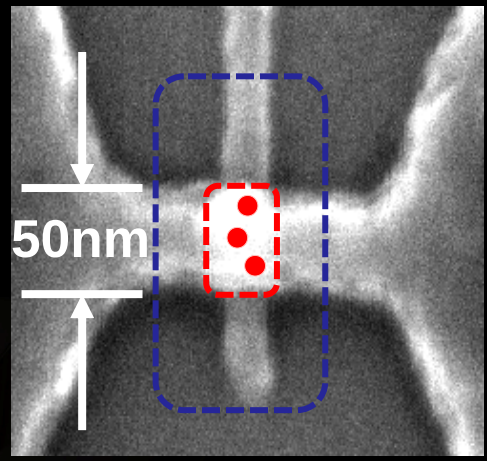
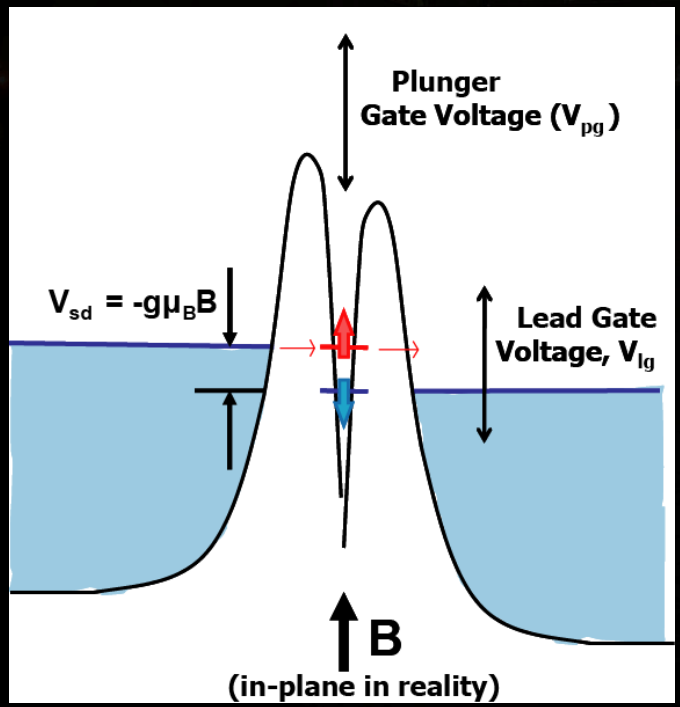
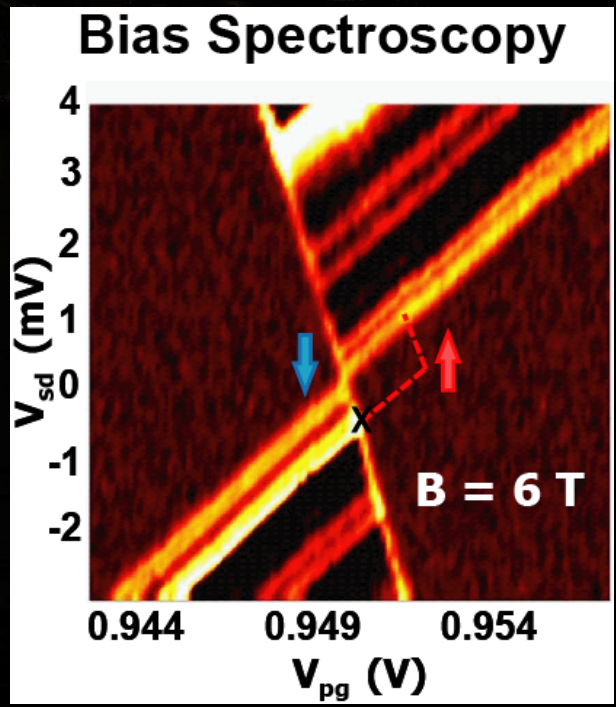
Motivation

- Phosphorus donor forms a nearly ideal hydrogenic potential in silicon
- Reservoirs and gates are straigthforward to engineer with great tunability
- Transport experiments yield direct information on the spectrum and electric properties of donor electrons
- Single-donor devices hold great potential for scalable spin qubit registers and spintronics


V_{pg}
Al_2O_3
SiO_2
2DEG
V_{lg}
V_{sd}
n+
n+
Si
P

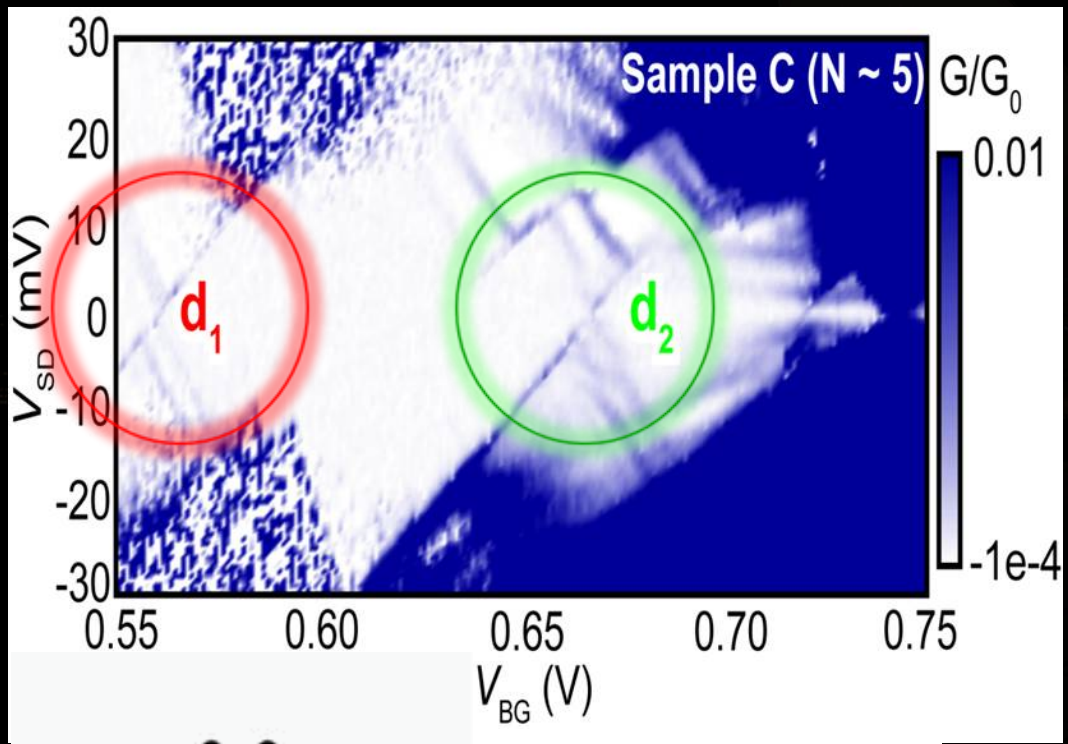

50nm

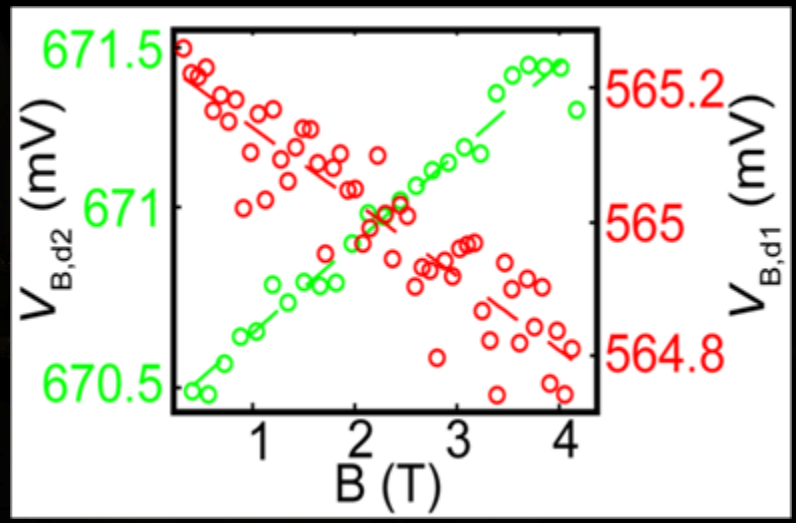

Plunger
Gate Voltage (V_{pg})
$V_{sd} = -g\mu_B B$
Lead Gate
Voltage, V_{lg}
B
(in-plane in reality)


Bias Spectroscopy
4
3
2
1
0
-1
-2
V_{sd} (mV)
B = 6 T
0.944
0.949
0.954
V_{pg} (V)

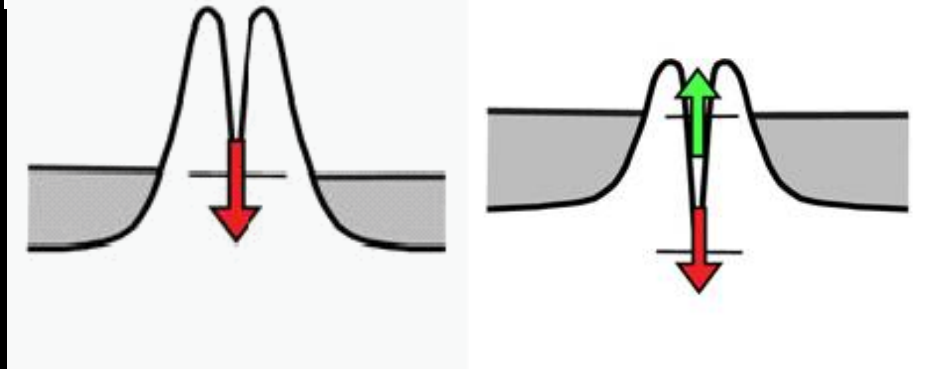
$D^+ \rightarrow D^0$ and $D^0 \rightarrow D^-$ transitions

E_c ~ 35 meV



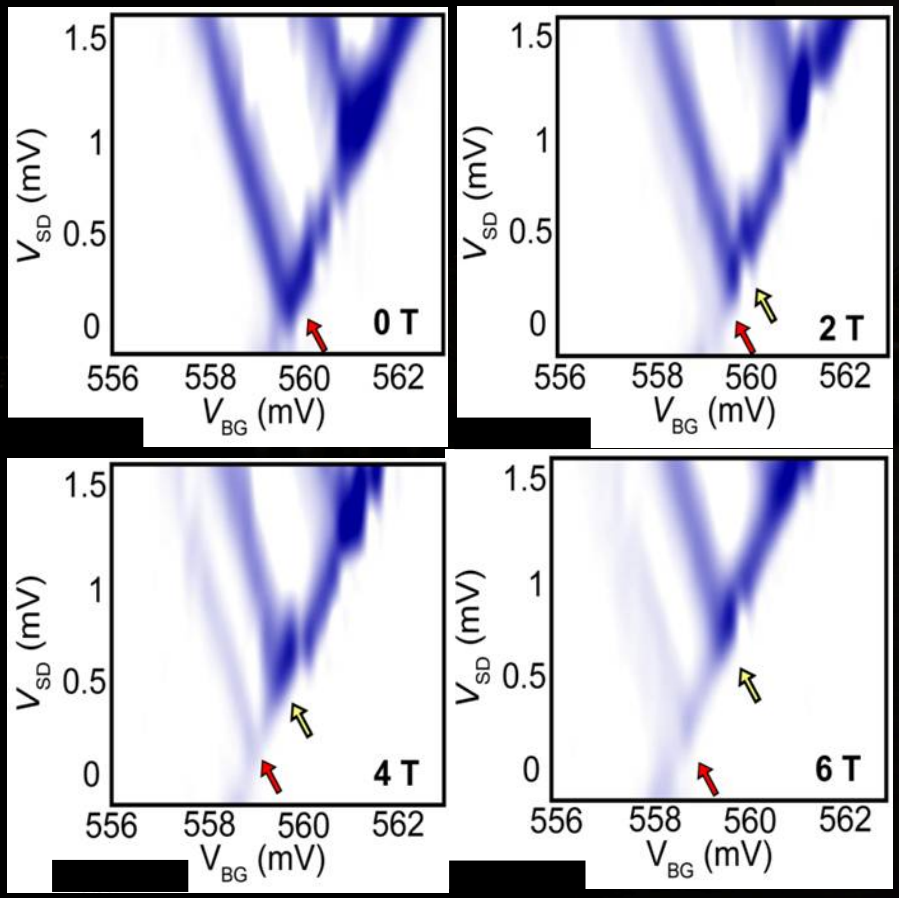


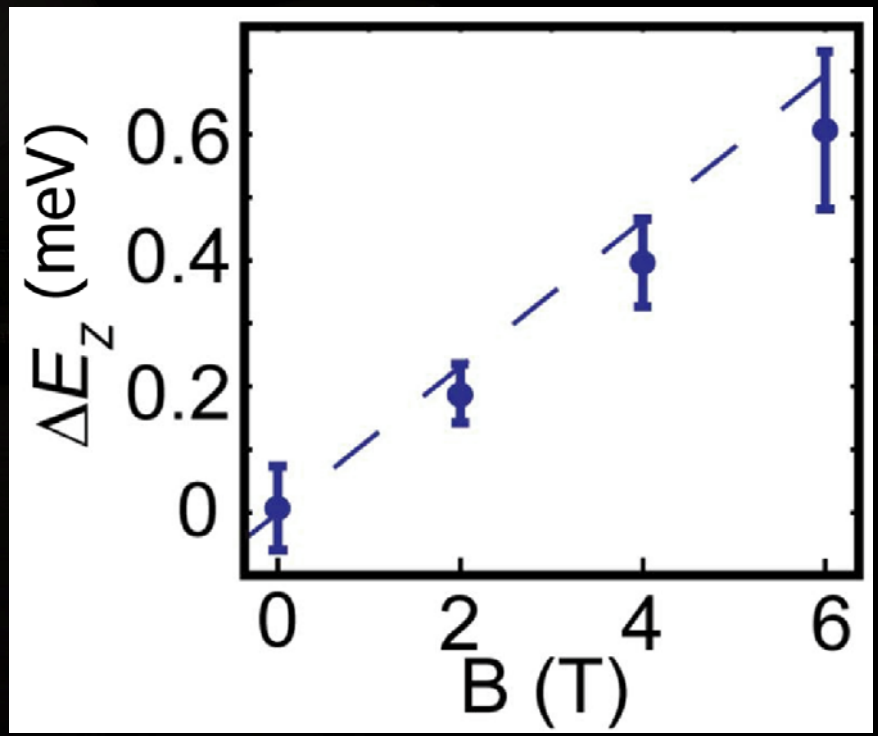
g factor ~ 2 (2.4 +- 0.5)



K.Y. Tan et al.,
arXiv:0905.4358 (2009)

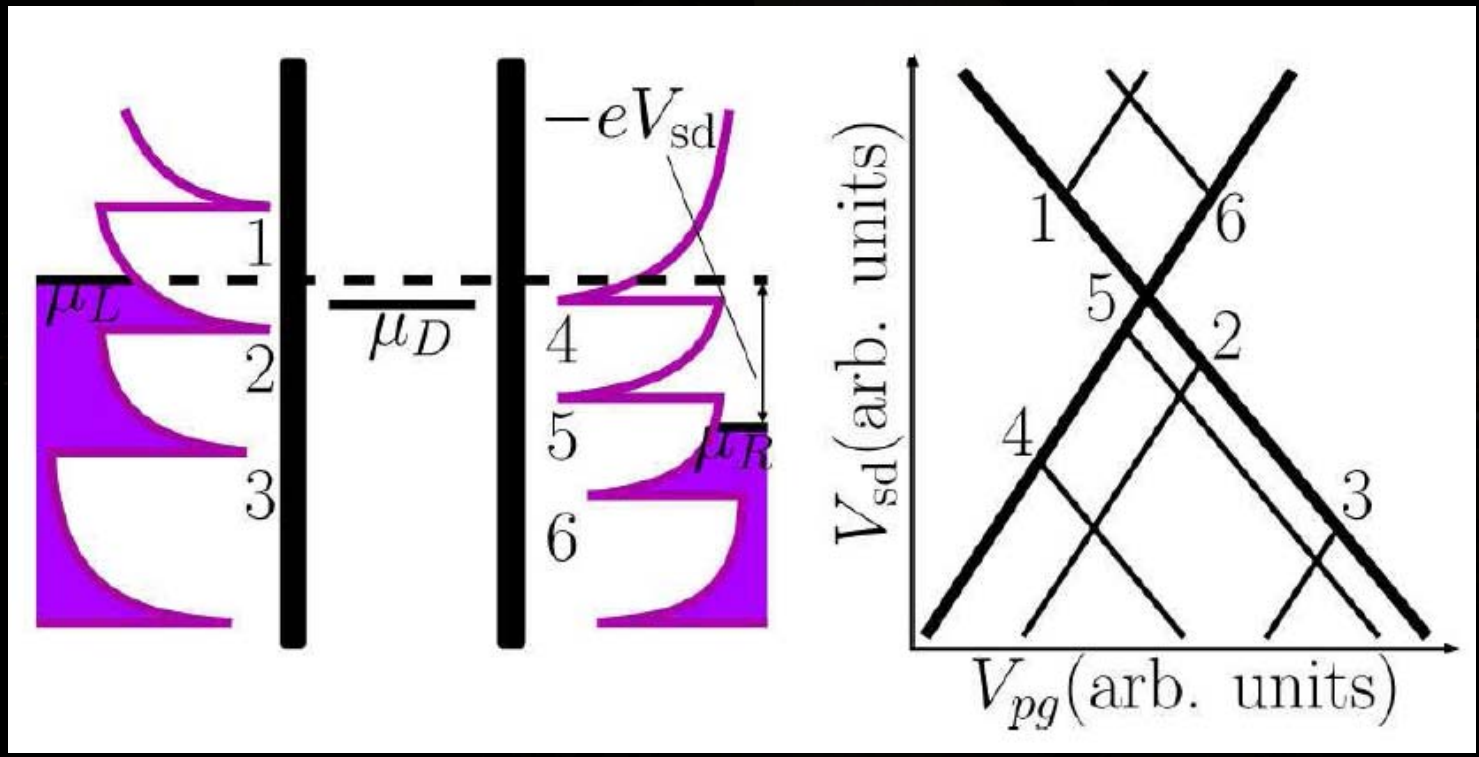
D^0 spin splitting in bias spectorcopy

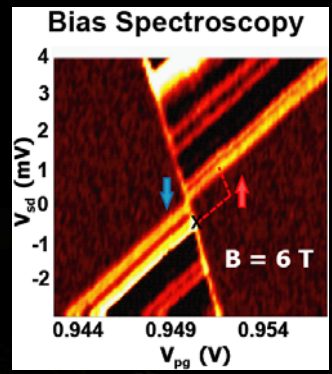


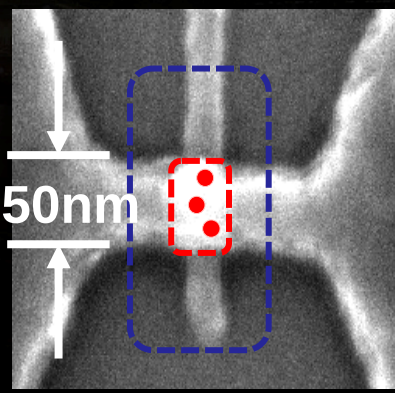


g factor ~ 2

Reservoir density of states (DOS)

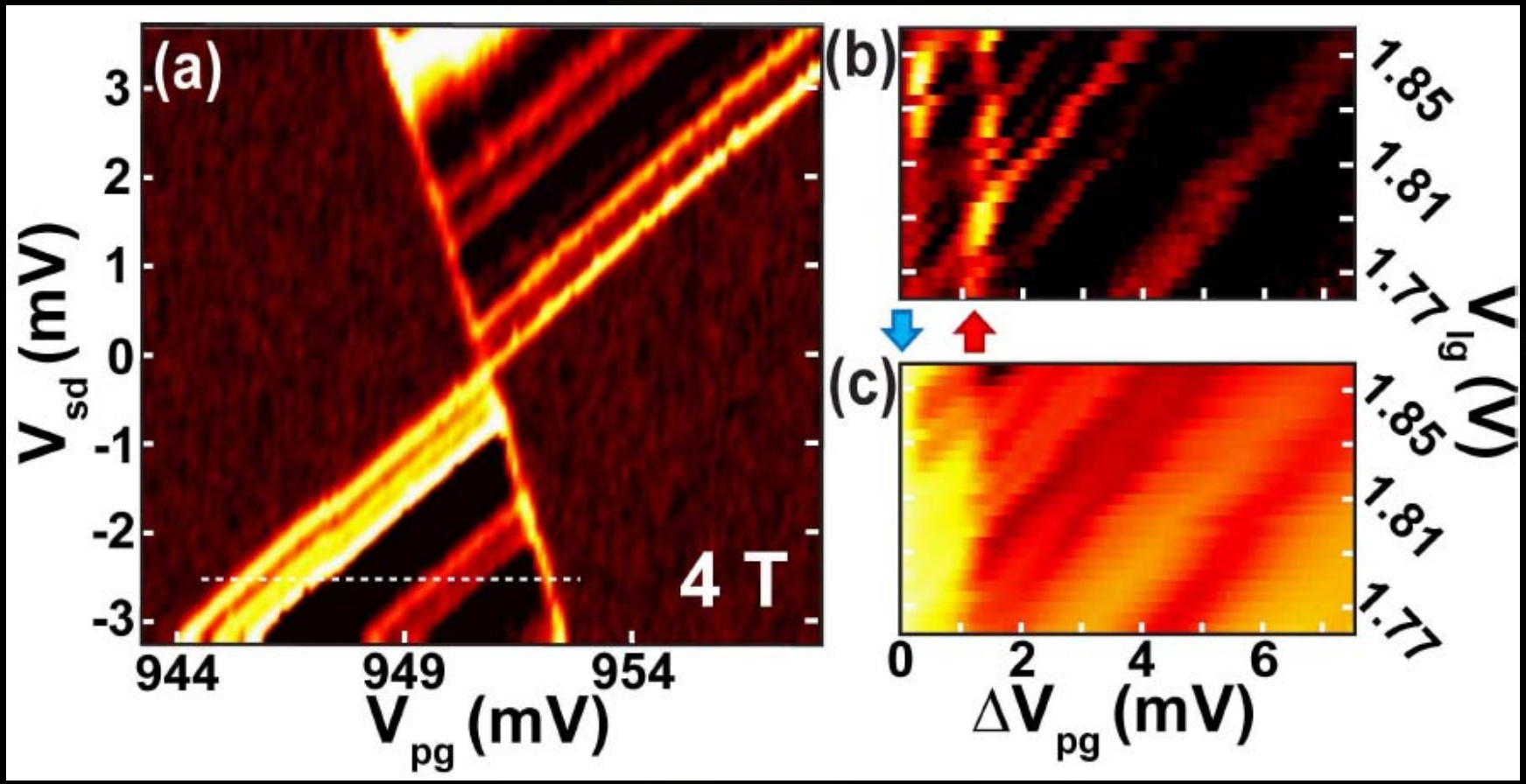




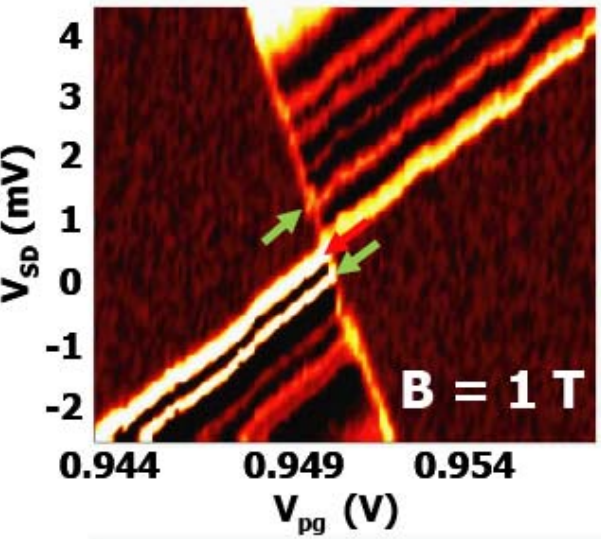


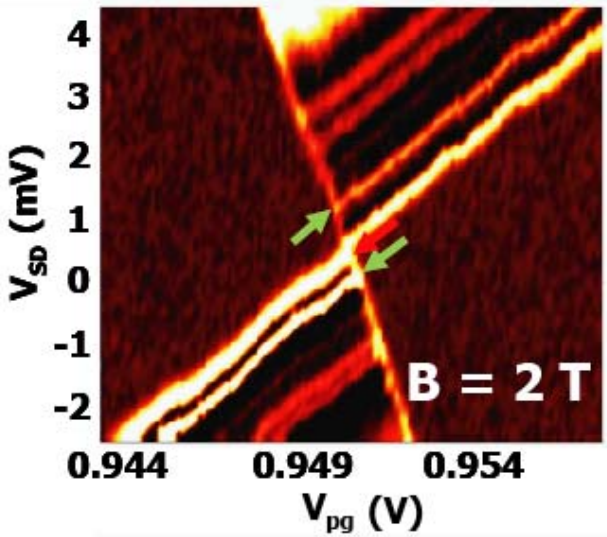
$$D(E) = \frac{\sqrt{2}}{\pi\hbar} \sum_{n_y,n_z,n_v} \frac{\sqrt{m_{x,n_v}}\Theta[E - E_{y,z}(n_y,n_z,n_v)]}{\sqrt{E - E_{y,z}(n_y,n_z,n_v)}}$$

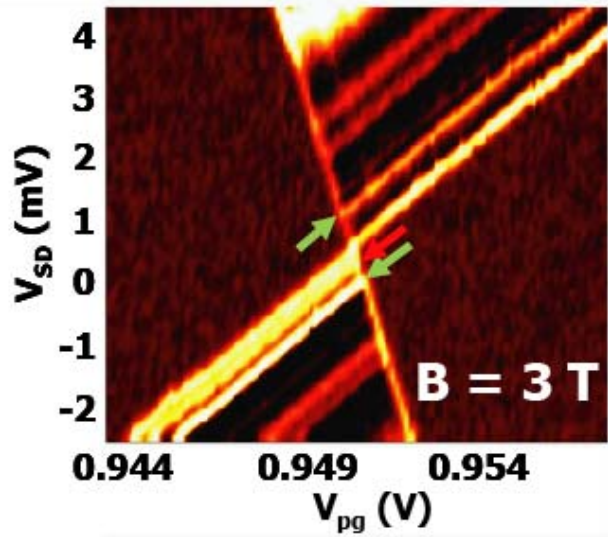
DOS experiments

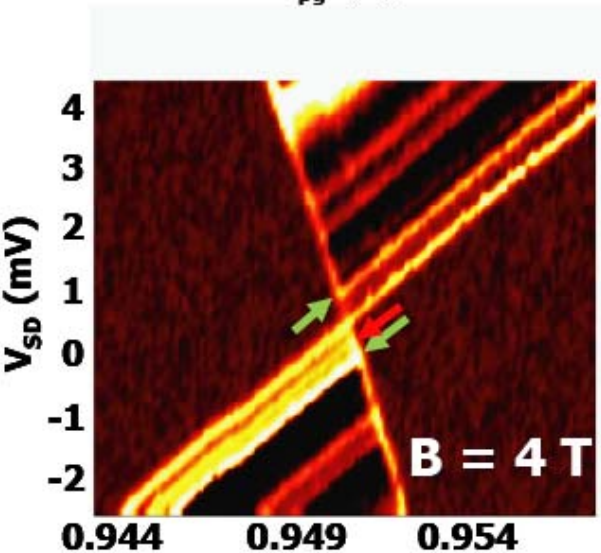


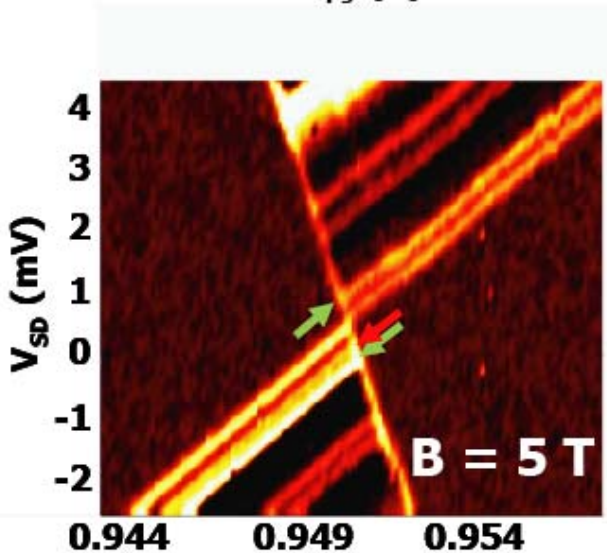
Scans in different magnetic fields

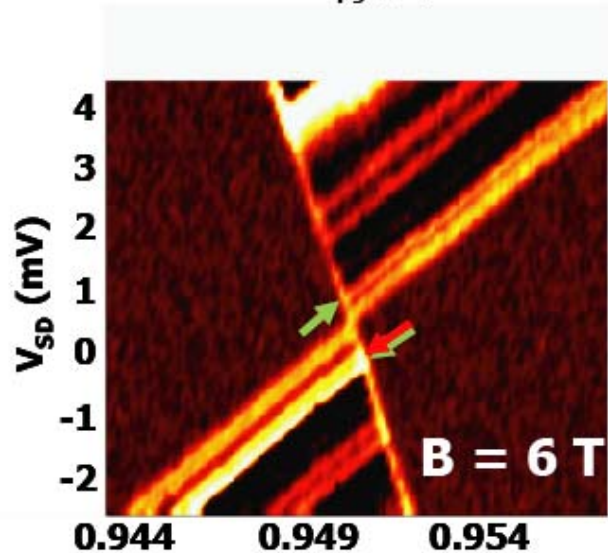




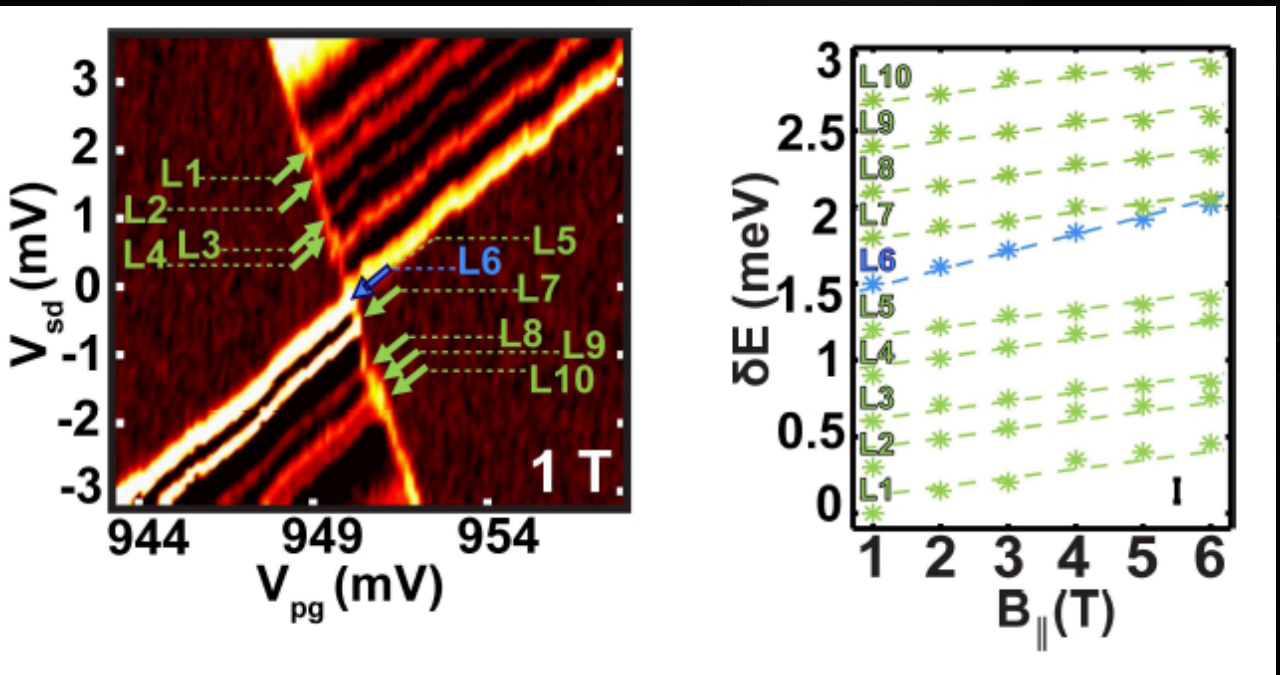


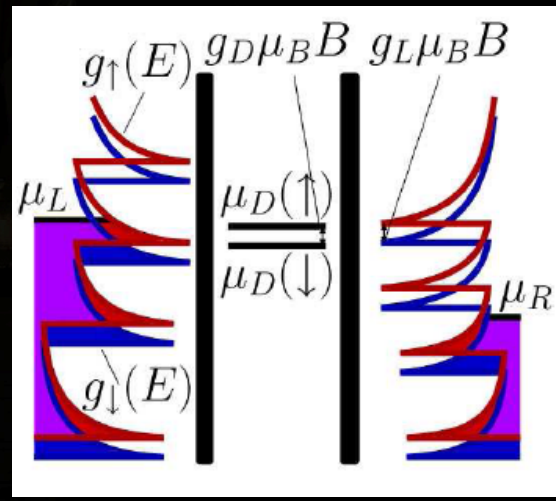






Conductance line shifts





Conclusions

- We introduced a nanoFET device to probe phosphorus in silicon:
  - Charging energy
  - $D^+ \rightarrow D^0$ and $D^0 \rightarrow D^-$ shifts in magnetic field
  - spin splitting of D^0 state
- We showed that anomalous lines in the stability diagrams are due to reservoir density of states