

Valley-spin qubit in a carbon nanotube

Fei Pei



Dr. Edward Laird



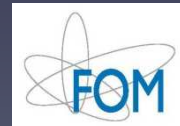
Ass. Prof. Gary Steele



Prof. Leo Kouwenhoven

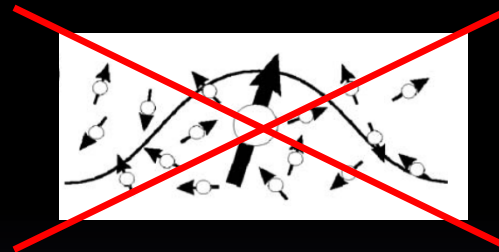


Supported by



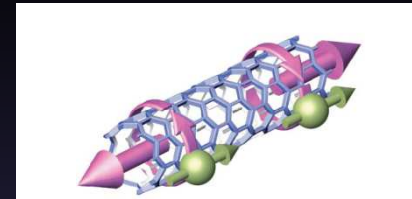
Why qubits in carbon nanotubes?

- zero-spin nuclei



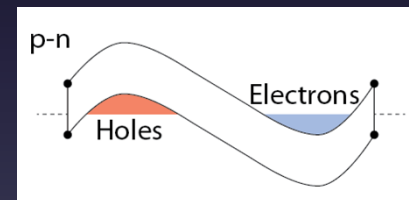
Hanson *et al.*
RMP (2007)

- spin-orbit coupling unique



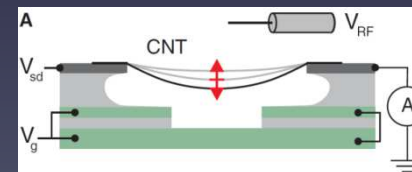
Kuemmeth *et al.*
Nature (2008)

- large level spacing



Pei *et al.*
Nature Nano. (2012)

- nanomechanical aspect



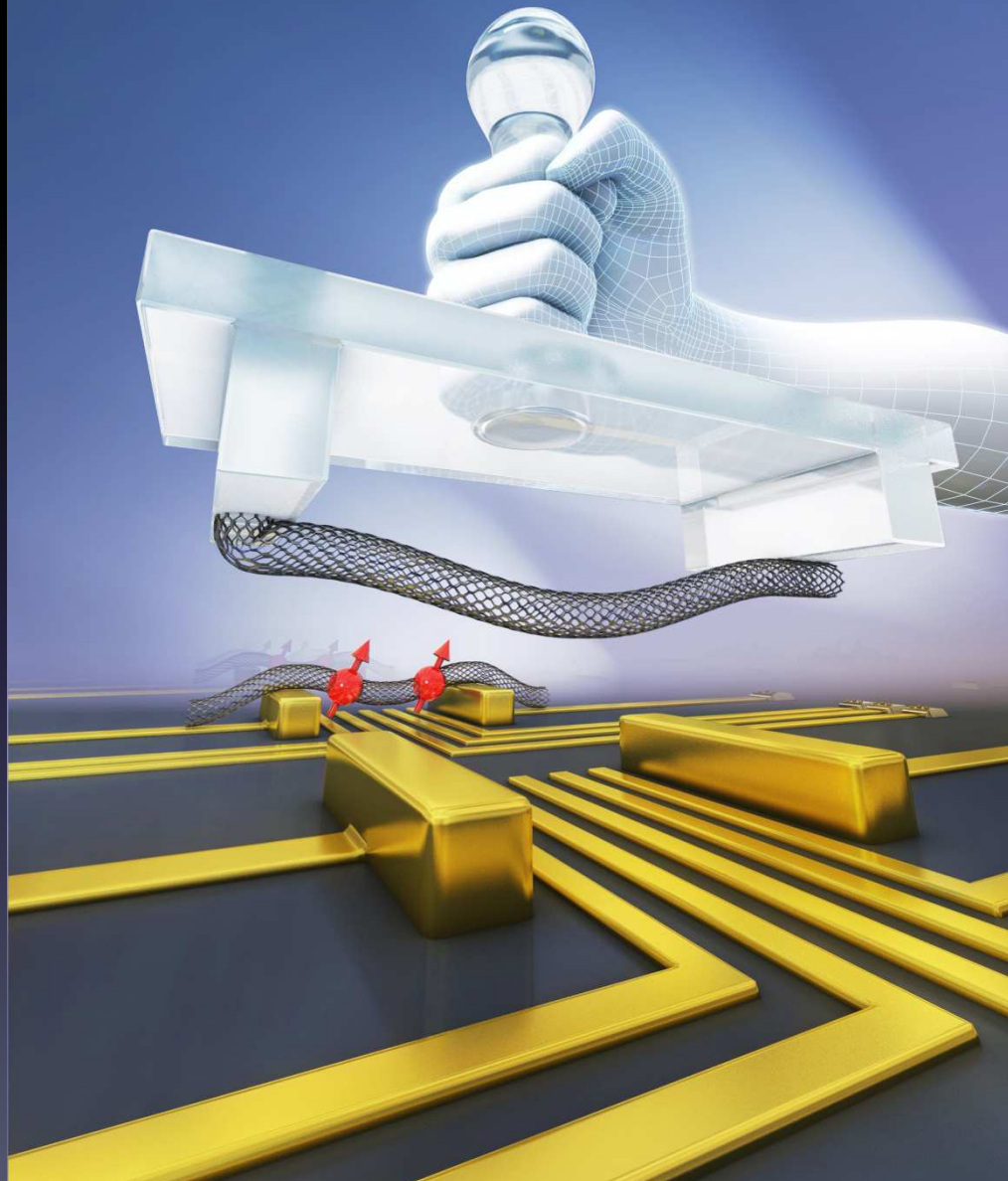
Steele *et al.*
Science (2009)

New fabrication technique:

STAMPING

the nanotube

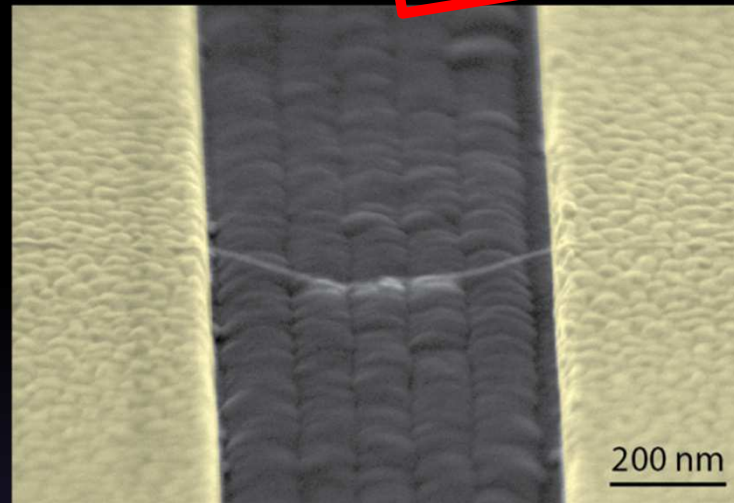
Inspired by Wu *et al.*
Nano lett. (2010)



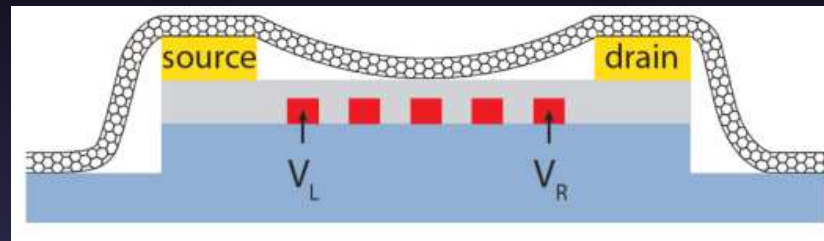
New fabrication technique:

STAMPING

the nanotube

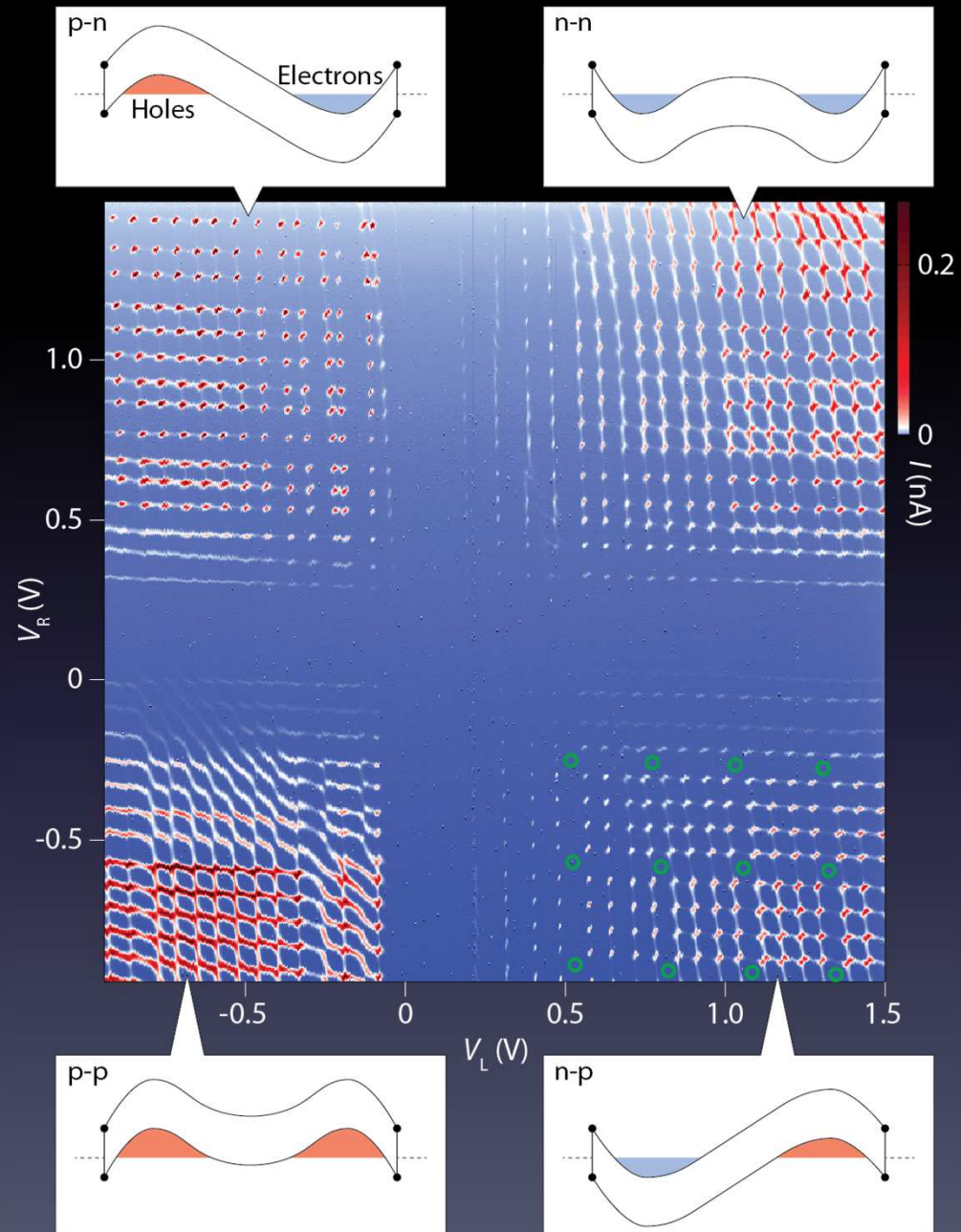


Pei *et al.*
Nature Nano. (2012)



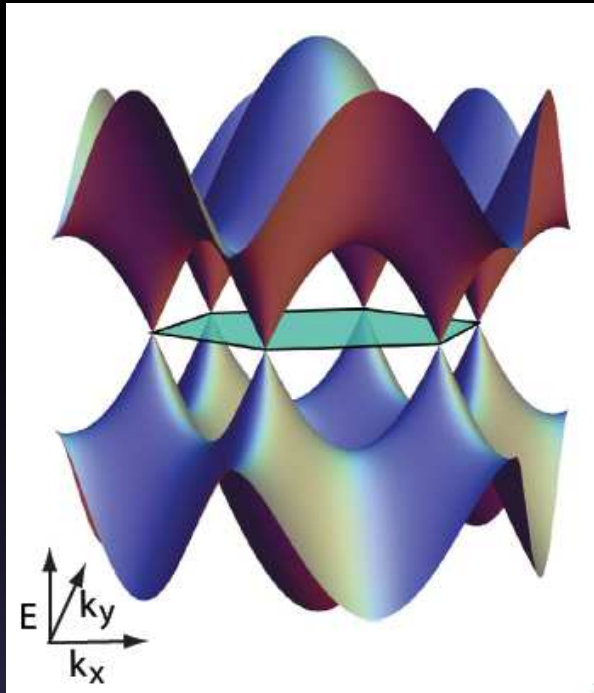
- + clean nanotube
- + narrow gates
- + bent nanotube

Double quantum dot

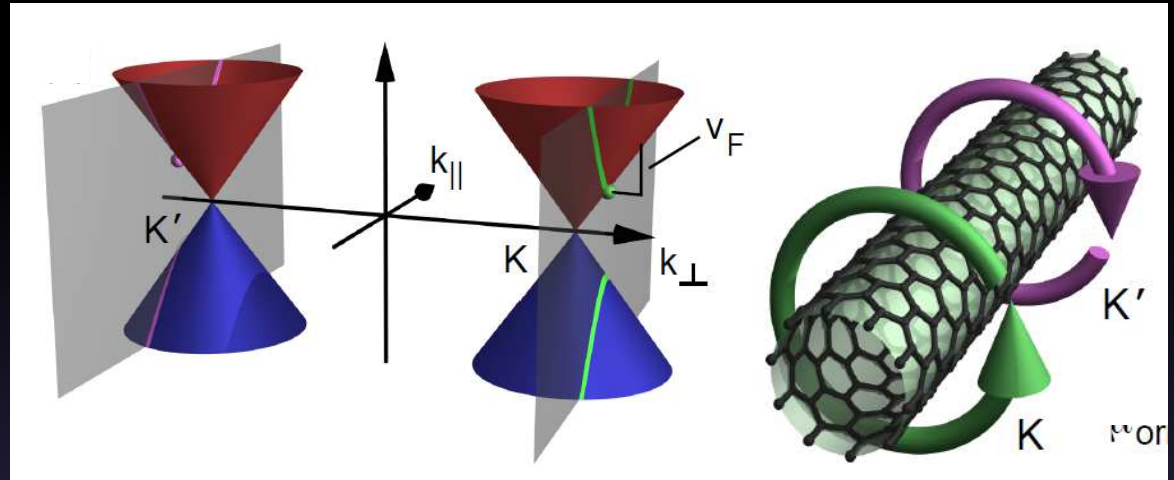


Valleys in carbon nanotube

Graphene

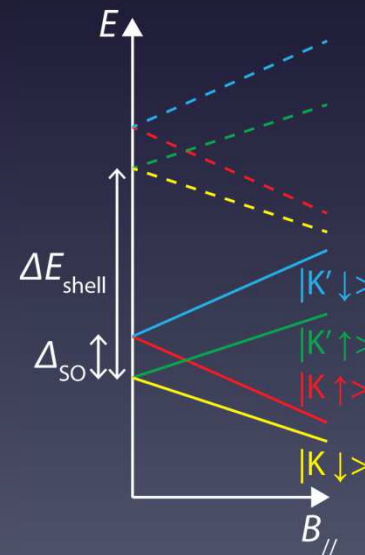


Nanotube

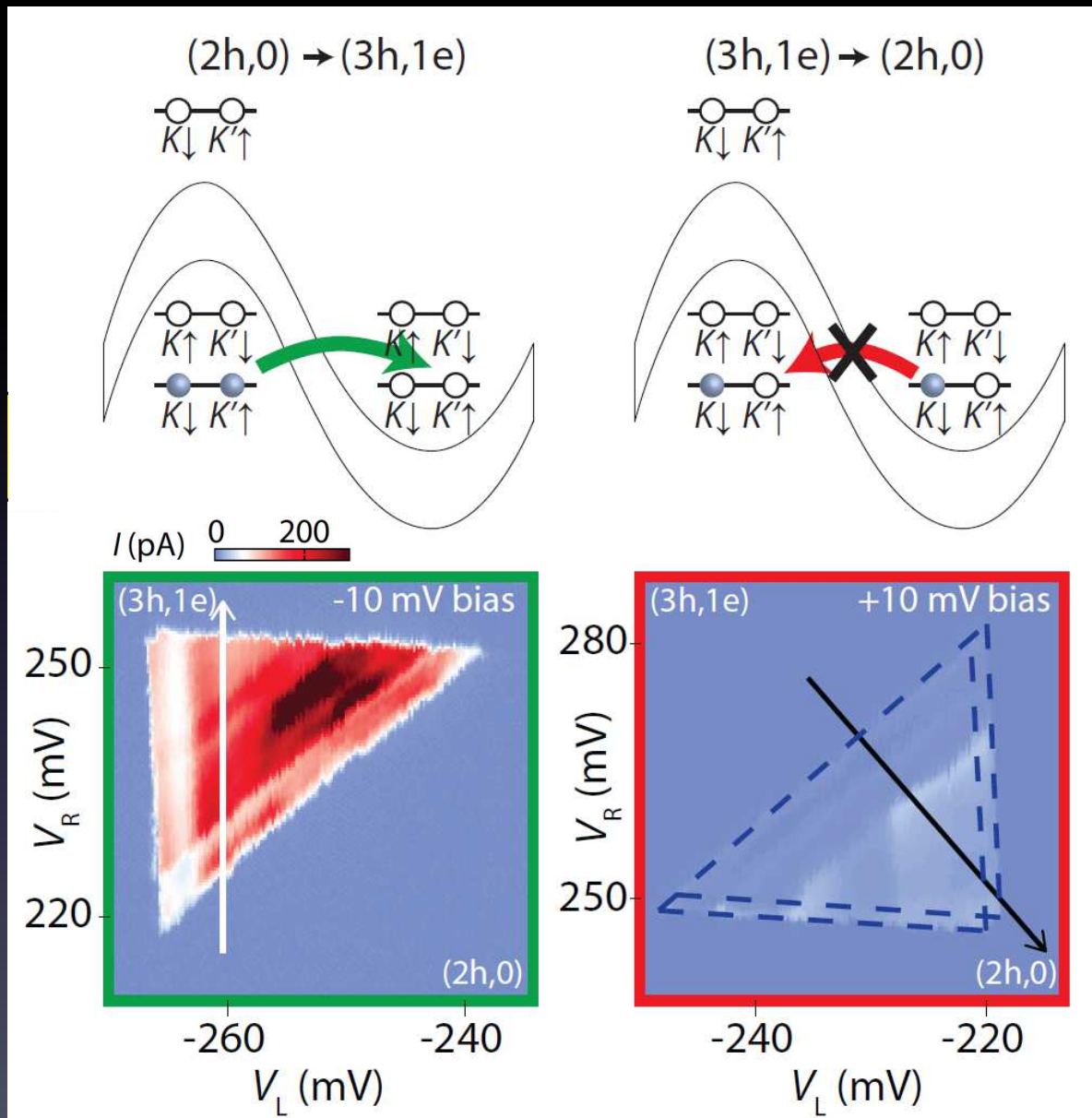


Churchil, 2012

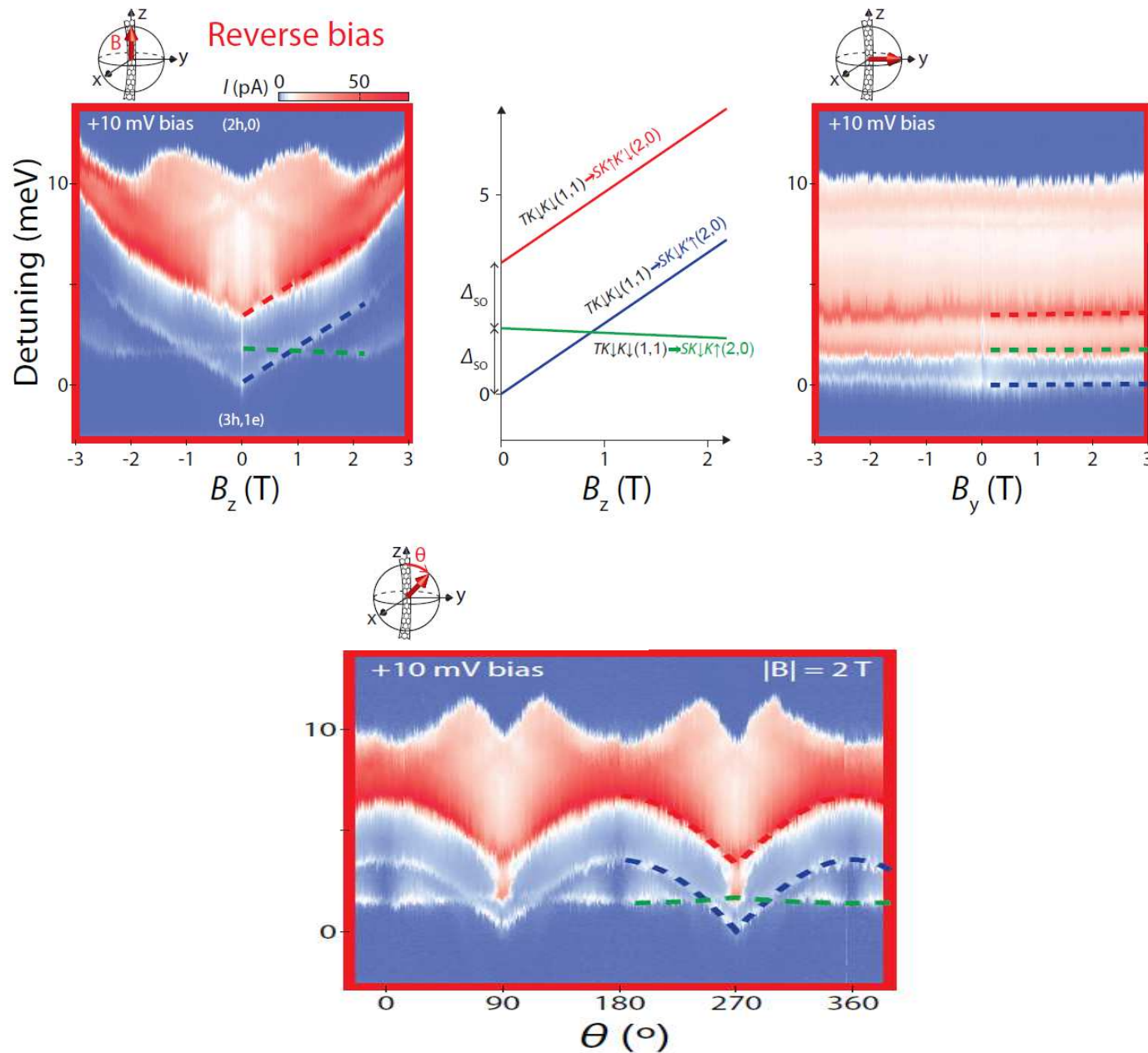
$$|K\uparrow\rangle, |K\downarrow\rangle, |K'\uparrow\rangle, |K'\downarrow\rangle$$



Valley-spin blockade

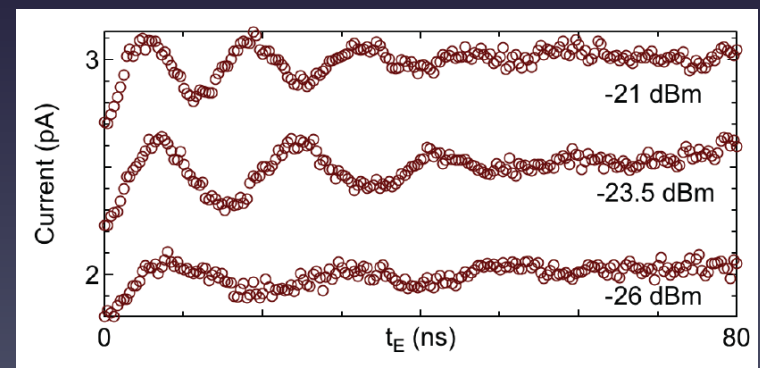
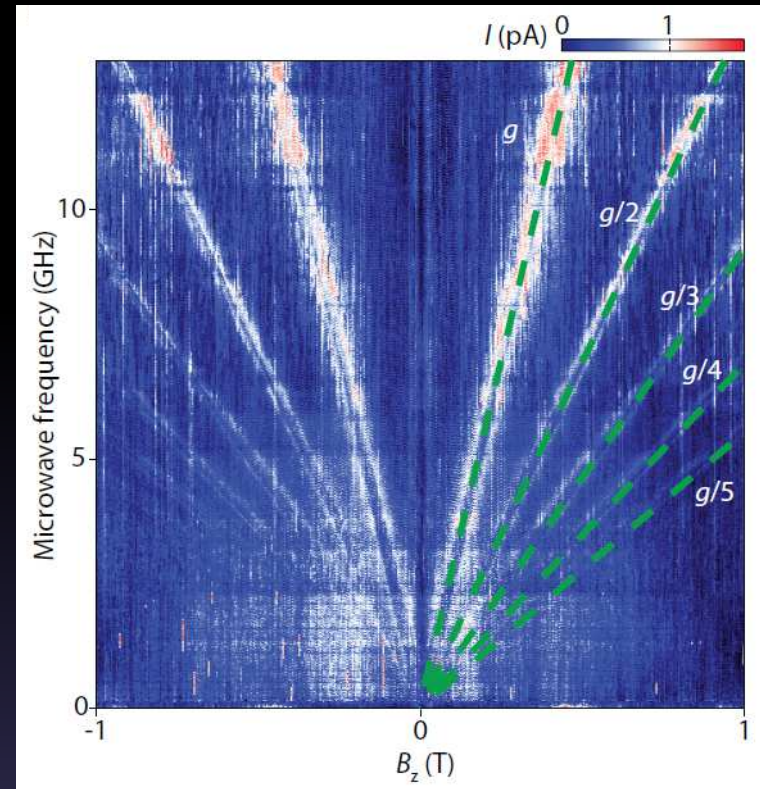
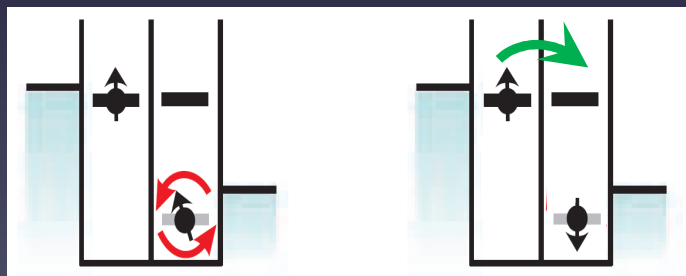
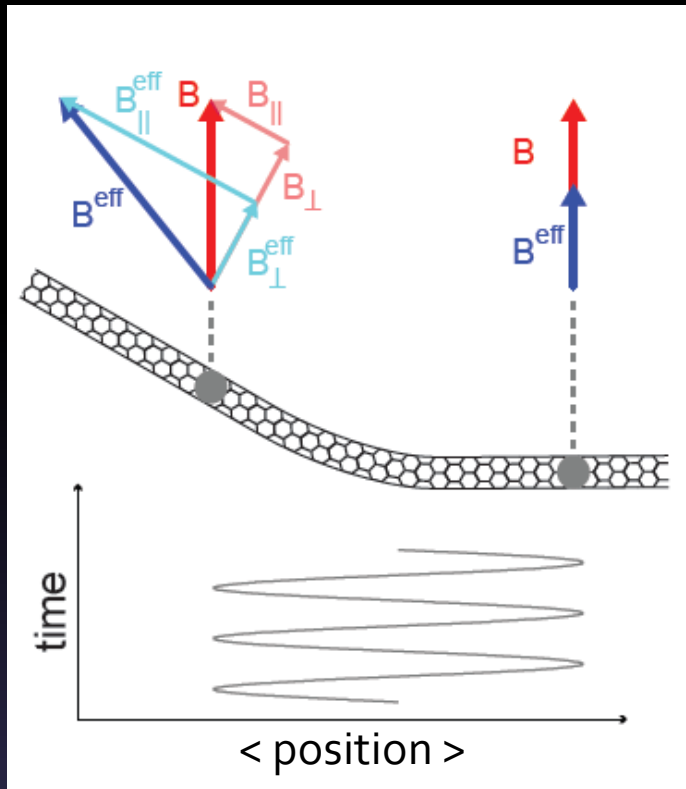


Use magnetic field to probe energy levels



A valley-spin qubit

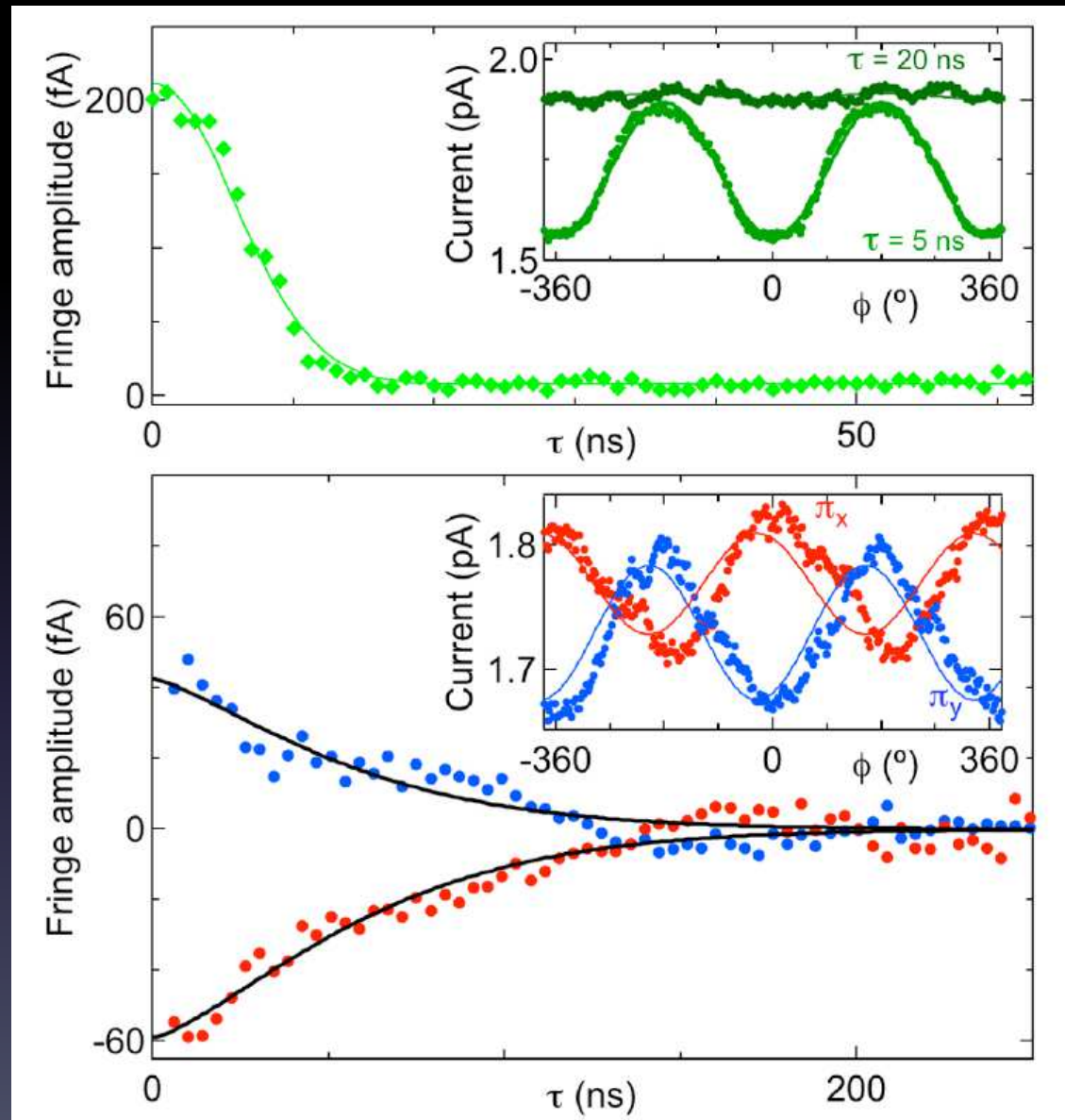
Laird *et al.* Nature Nano. In press
Arxiv 1210.3085



$$f_{\text{Rabi}} = 100 \text{ MHz}$$

Qubit coherence times

Laird *et al.* Nature Nano. In press
Arxiv 1210.3085

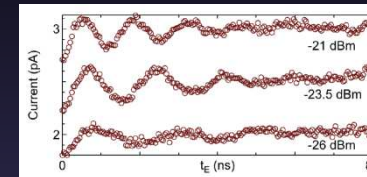
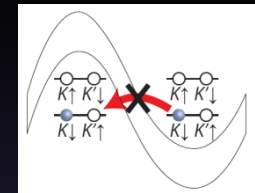


Ramsey sequence
 $T_2^* = 8$ ns

Echo sequence
 $T_2 = 70$ ns

Summary

- Stamping the nanotube
- Valley-spin blockade
- Valley-spin qubit



Pei *et al.* Nature Nanotechnology (2012)
Valley-spin blockade and spin resonance in carbon nanotubes

Laird *et al.* Nature Nanotechnology (2013, in press), Arxiv 1210.3085
A valley-spin qubit in a carbon nanotube

Steele *et al.* Nature Communications (2013)
Large spin-orbit coupling in carbon nanotubes