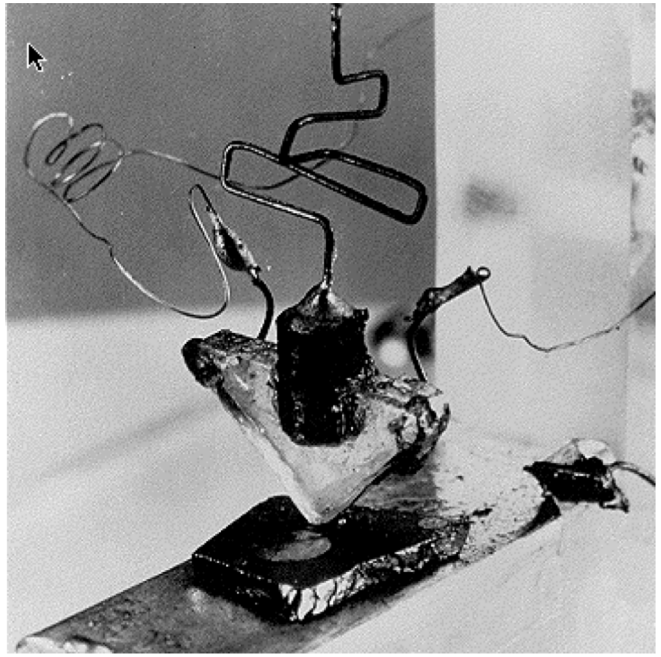
Lieven Vandersypen

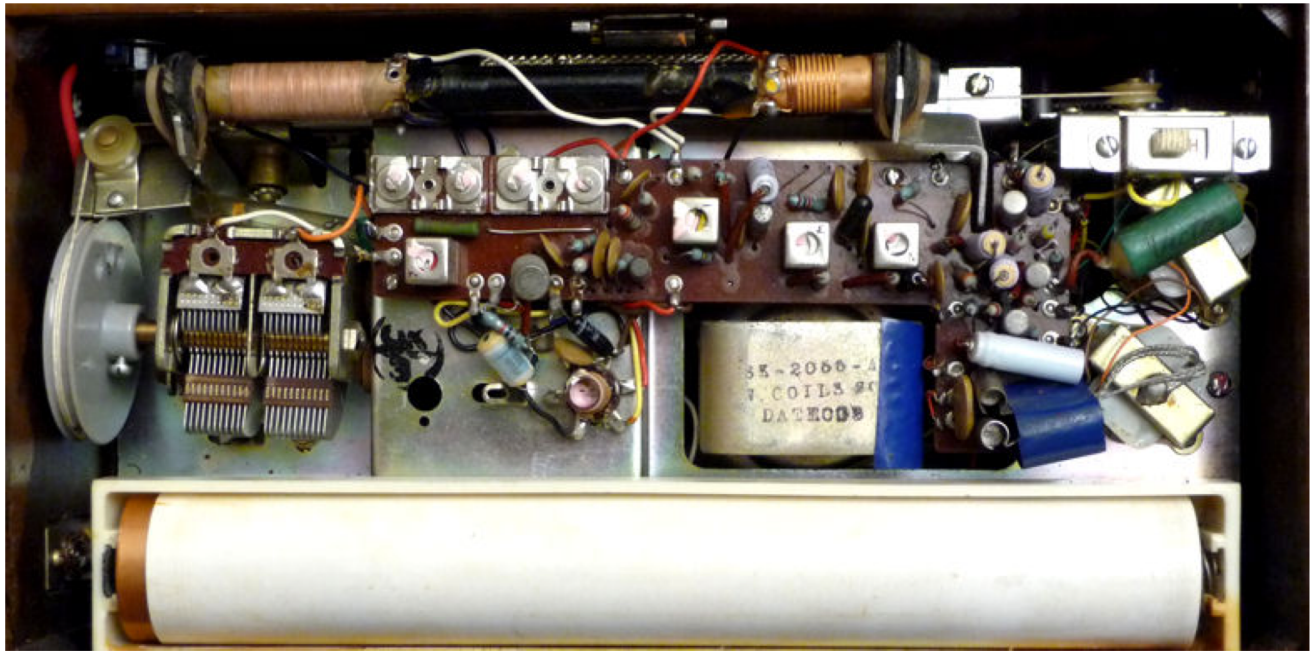
Spin Qubit

From transistors to quantum dots

1947 First transistor

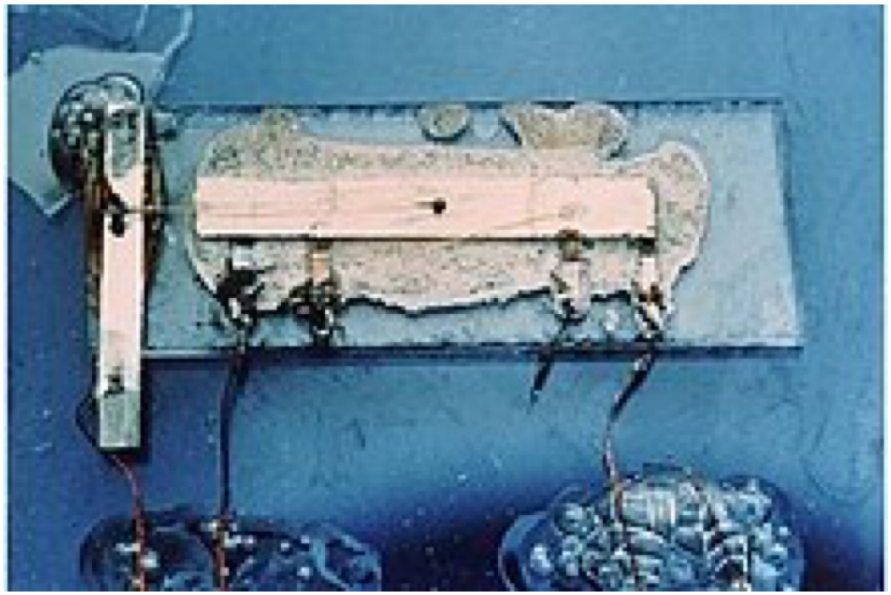


1954 First transistor radio’s

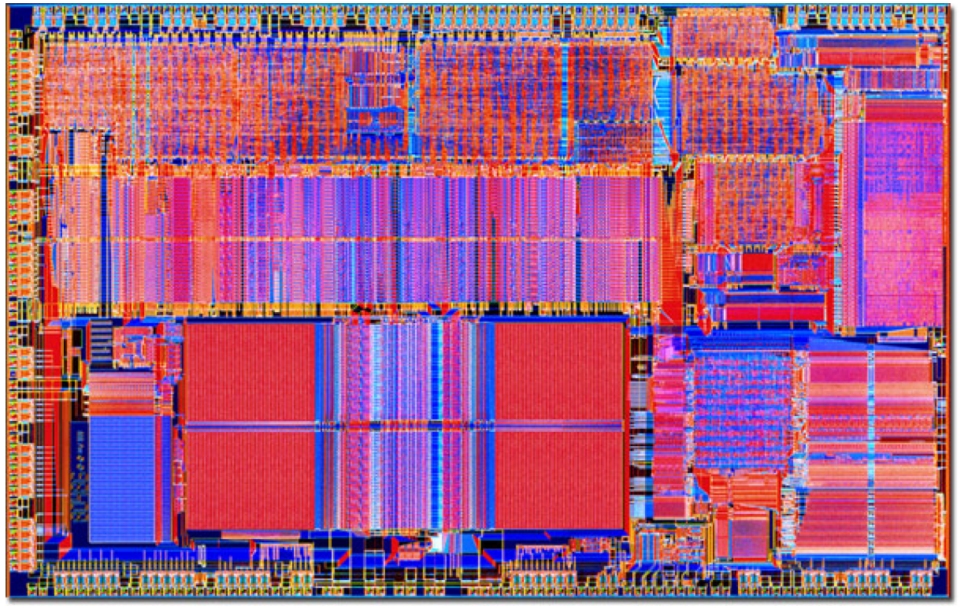


From transistors to quantum dots

1958 First integrated circuit



1989 Intel 486 processor



Low temperature operation

Single electron charging energy

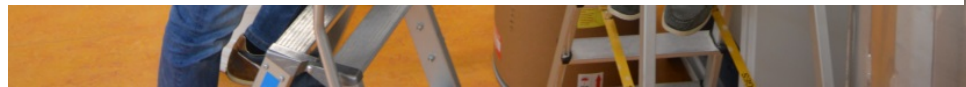
$E_C = e^2/C$, ($C=8e_re_oR$, disk)
R = 10 nm E_C = 30 meV
R = 100 nm E_C = 3 meV

Thermal energy

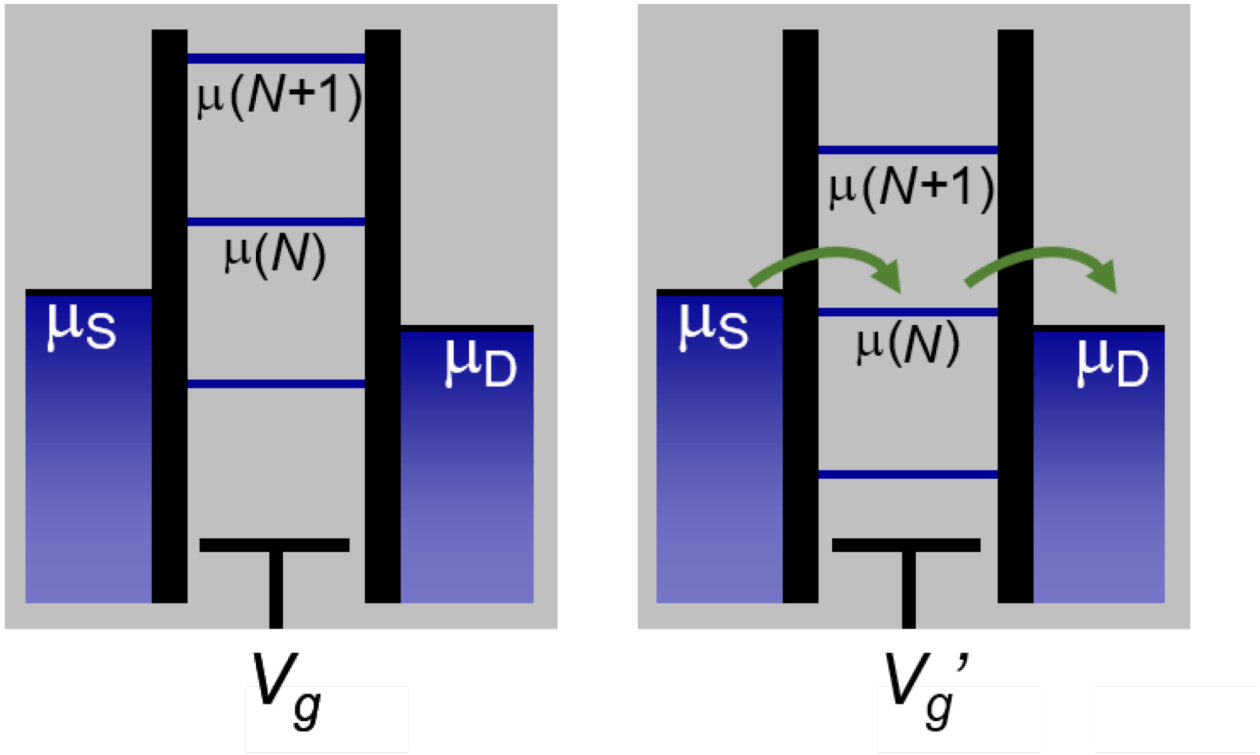
T = 300 K $k_BT \sim 26$ meV
T = 4.2 K $k_BT \sim 0.35$ meV
T = 30 mK $k_BT \sim 2.6$ ueV

Operation is at low temperatures

Dilution refrigerators reach temperatures below 10mk



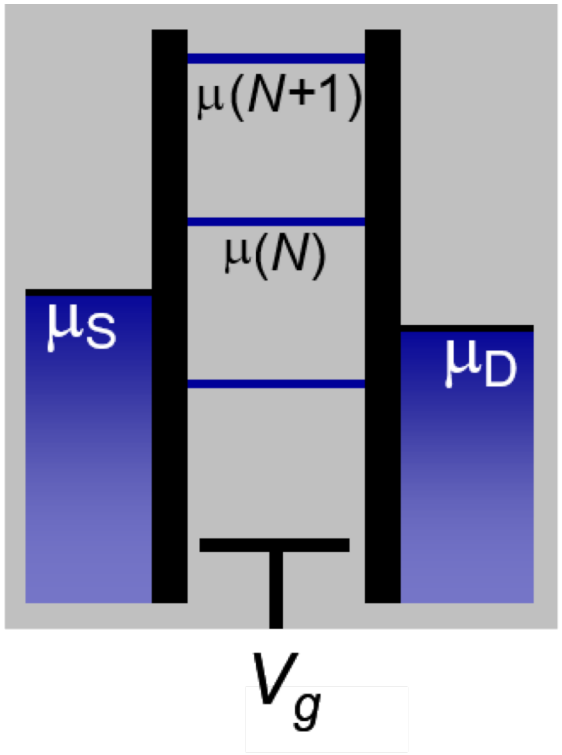
Quantum dots

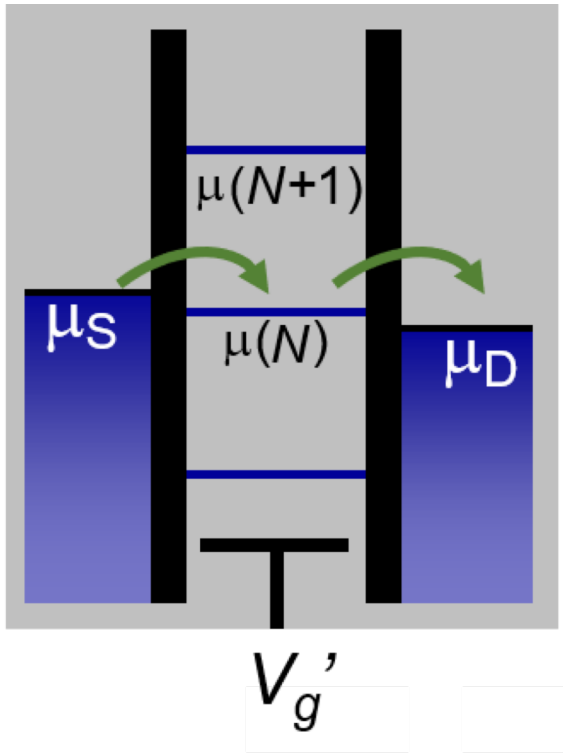


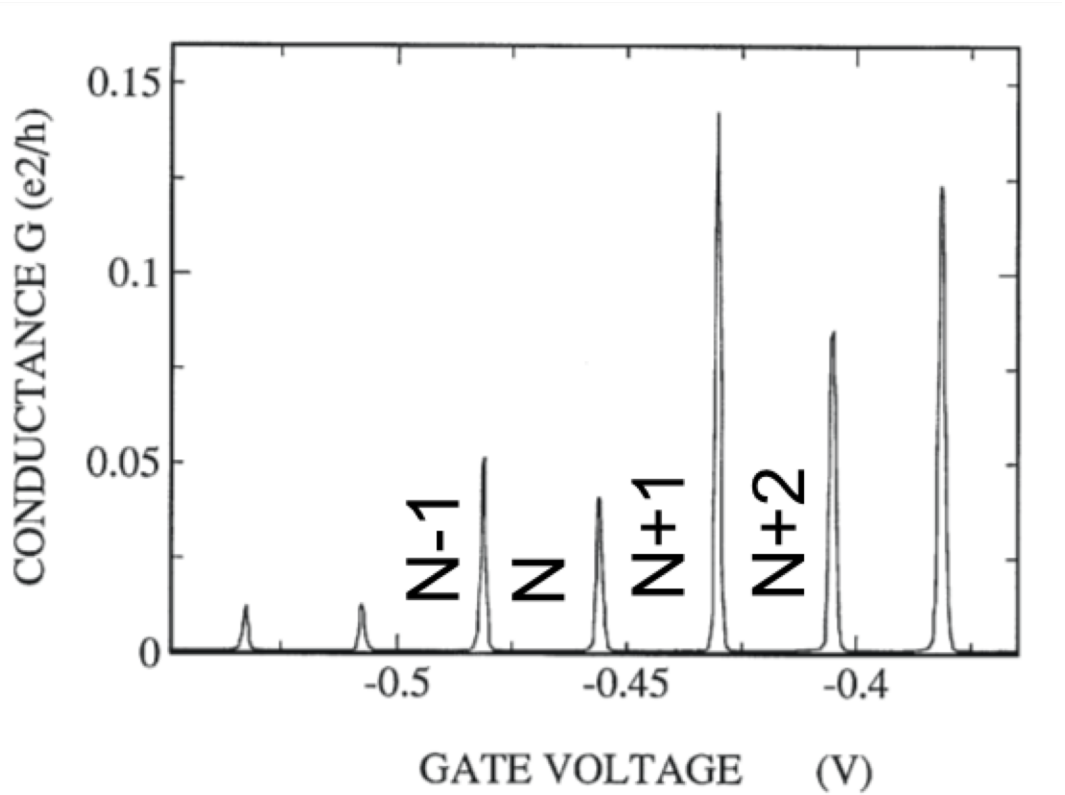
- Energy an electron needs to have in order to enter the dot.

$$m(n) = \mu(N) - \mu(N-1)$$

Quantum dots

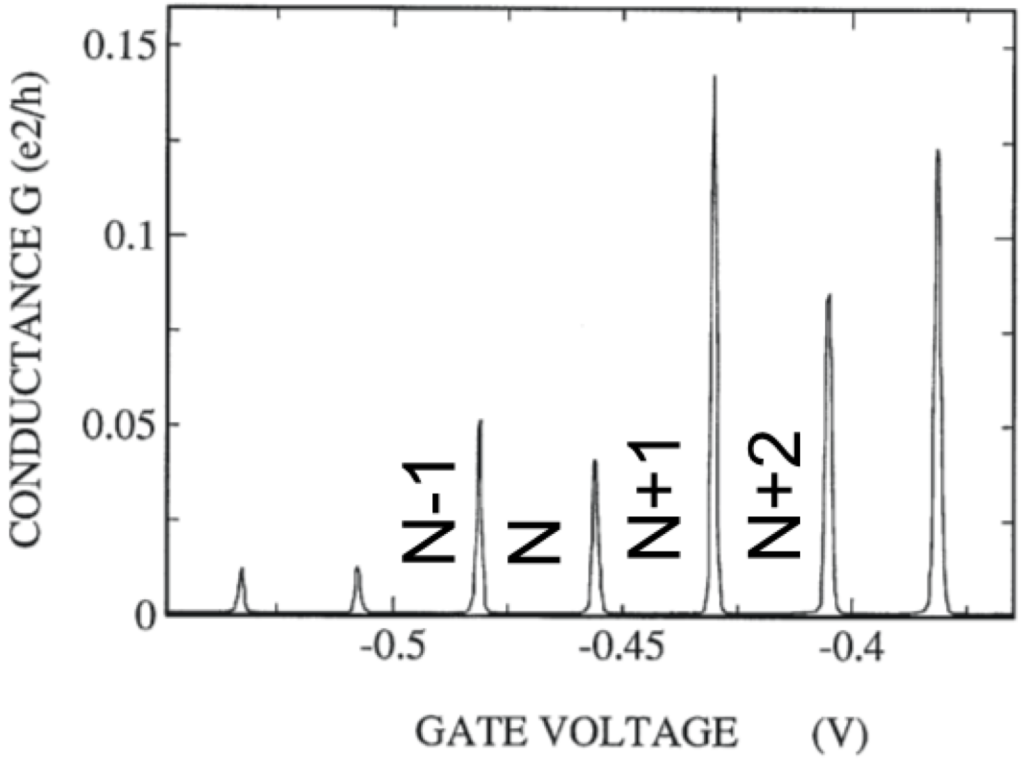




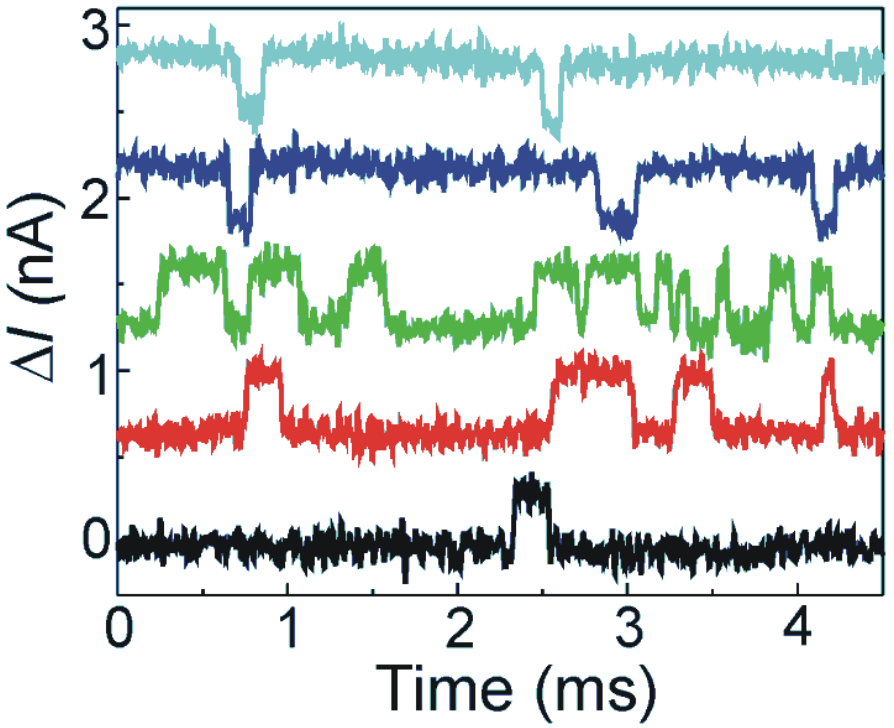


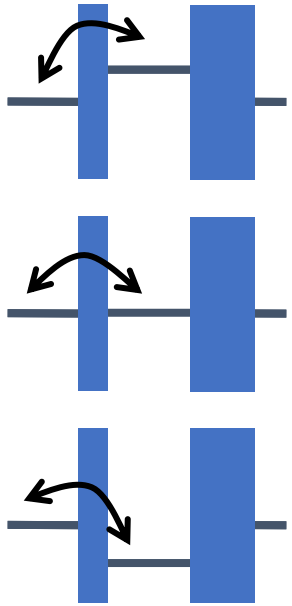
Charge sensing

- A quantum dot can also be a very sensitive electrometer.

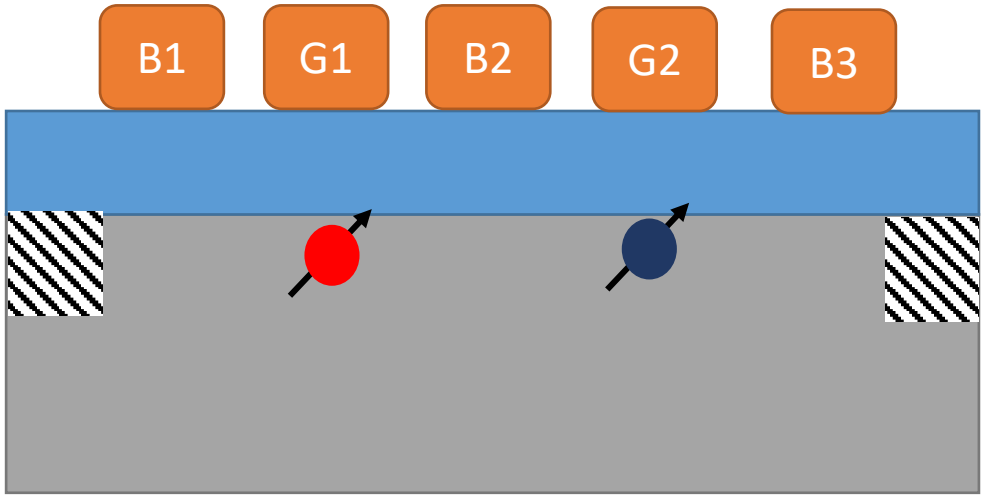


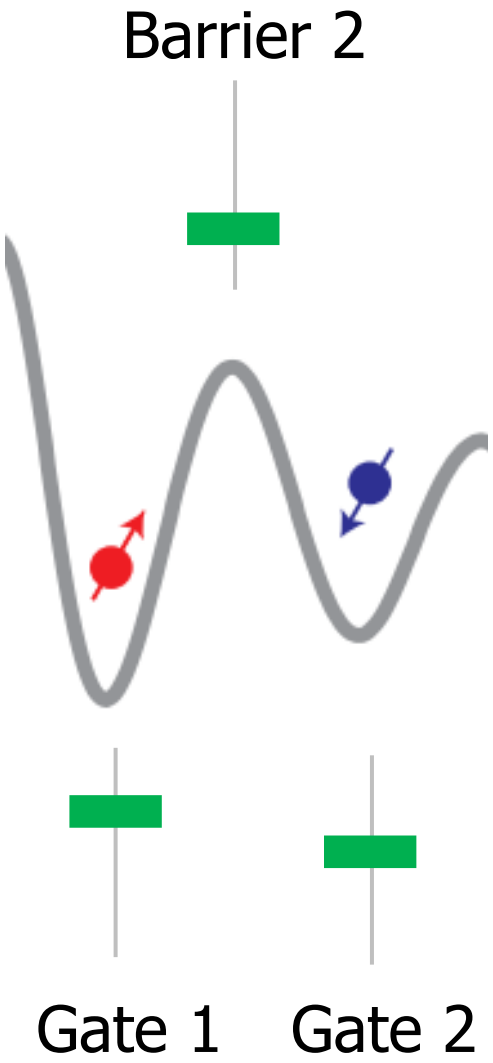
- See single electrons jump on/off in real time.



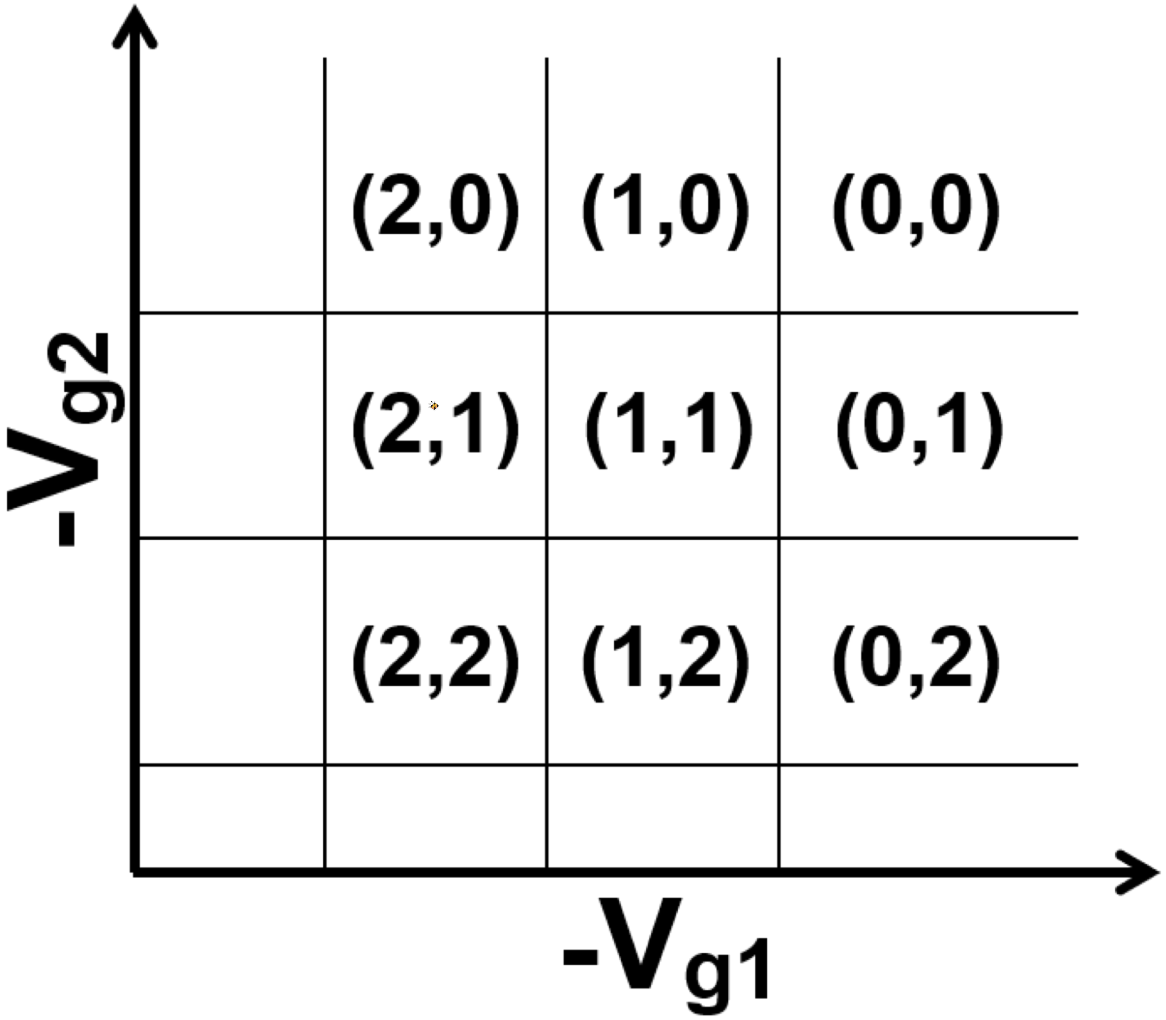


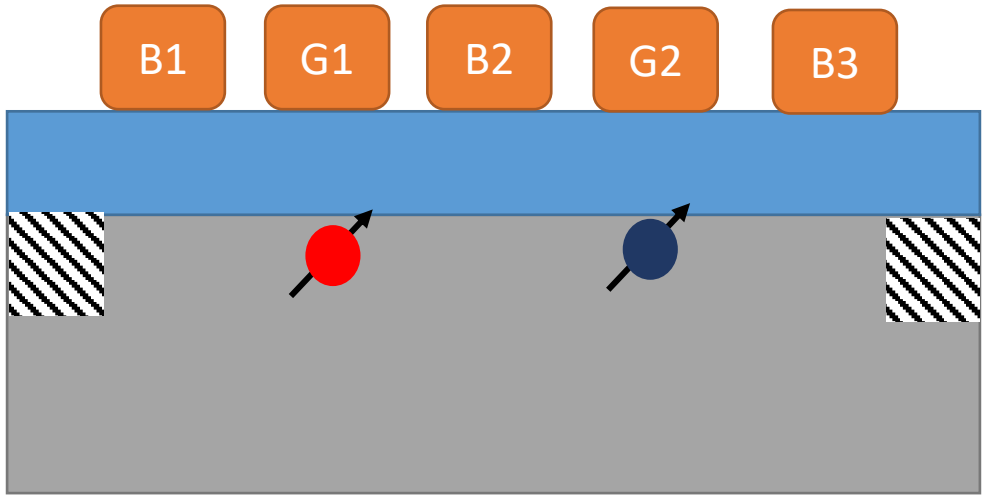
Quantum dot system



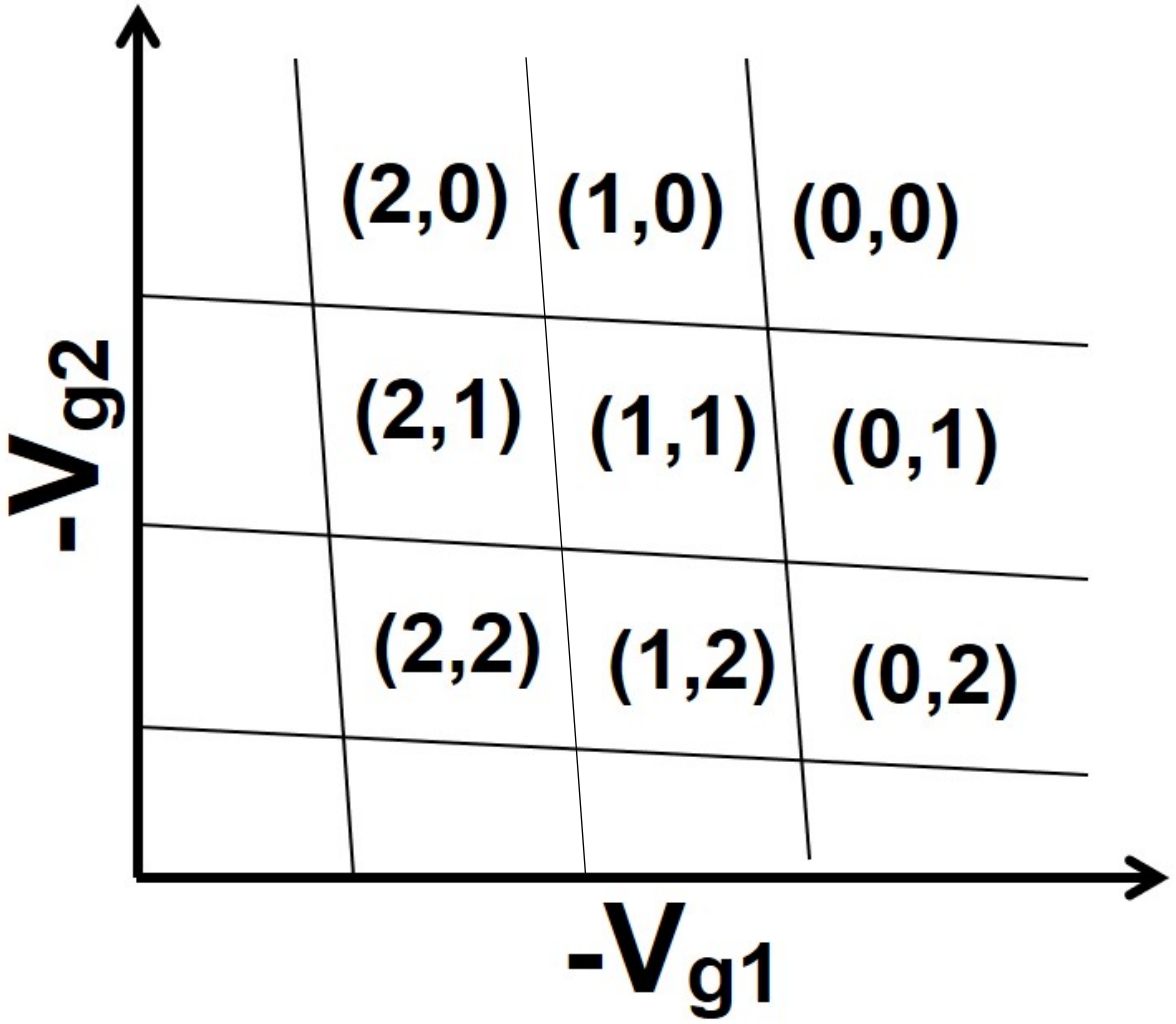


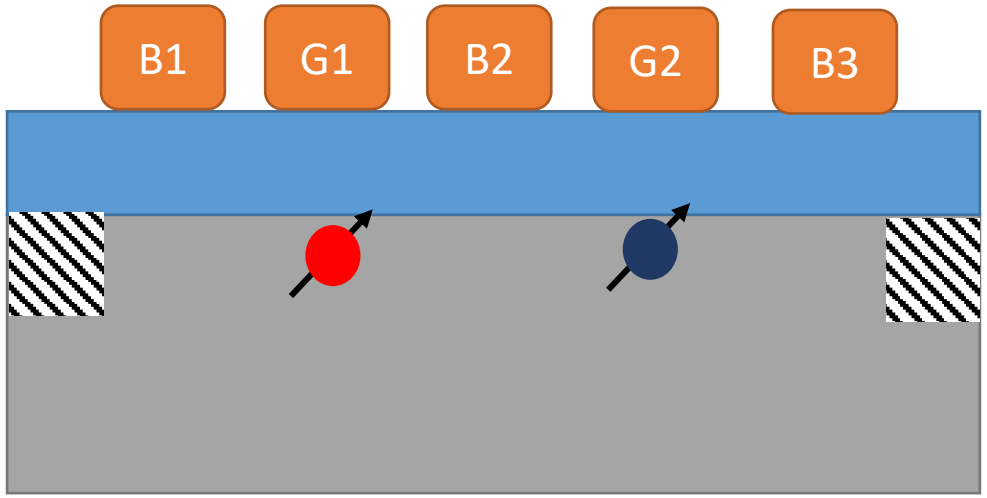
Two coupled quantum dots





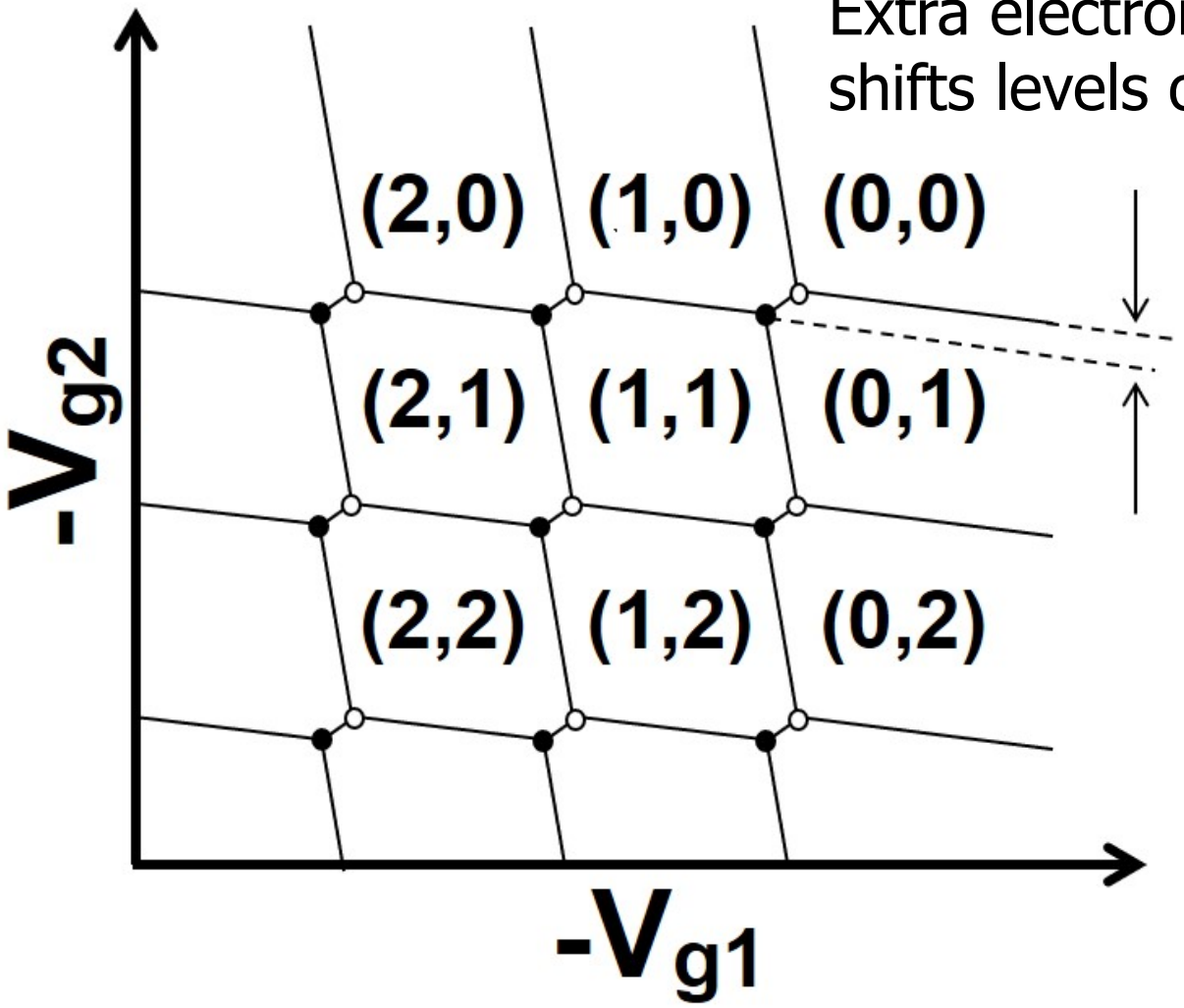
Two coupled quantum dots

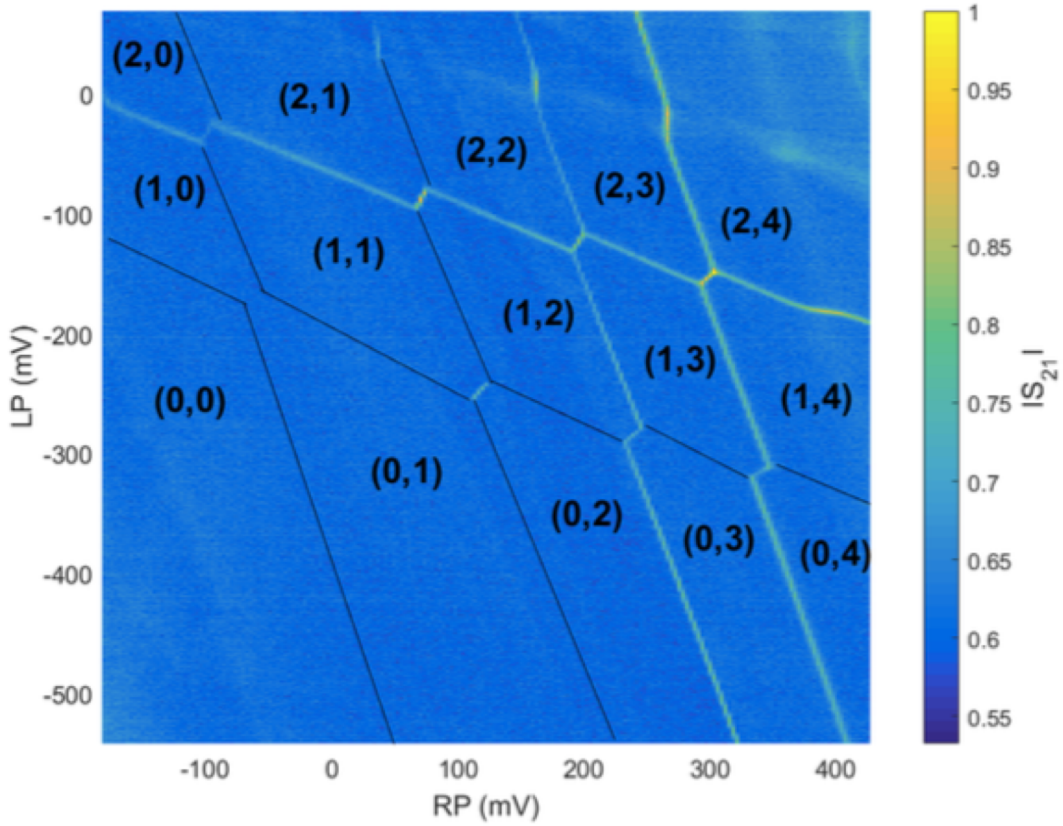




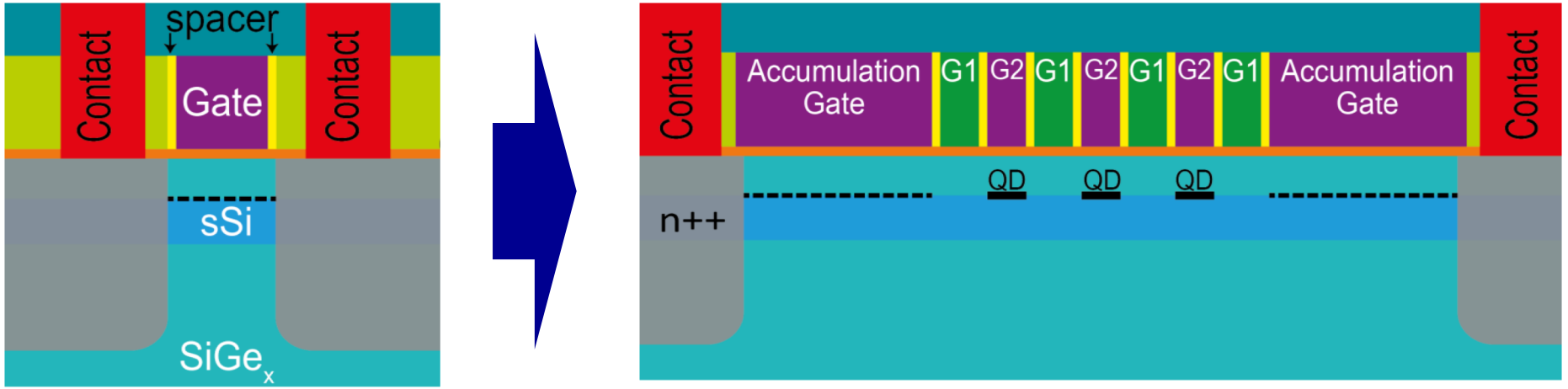
Two coupled quantum dots

Extra electron in one dot
shifts levels of other dot

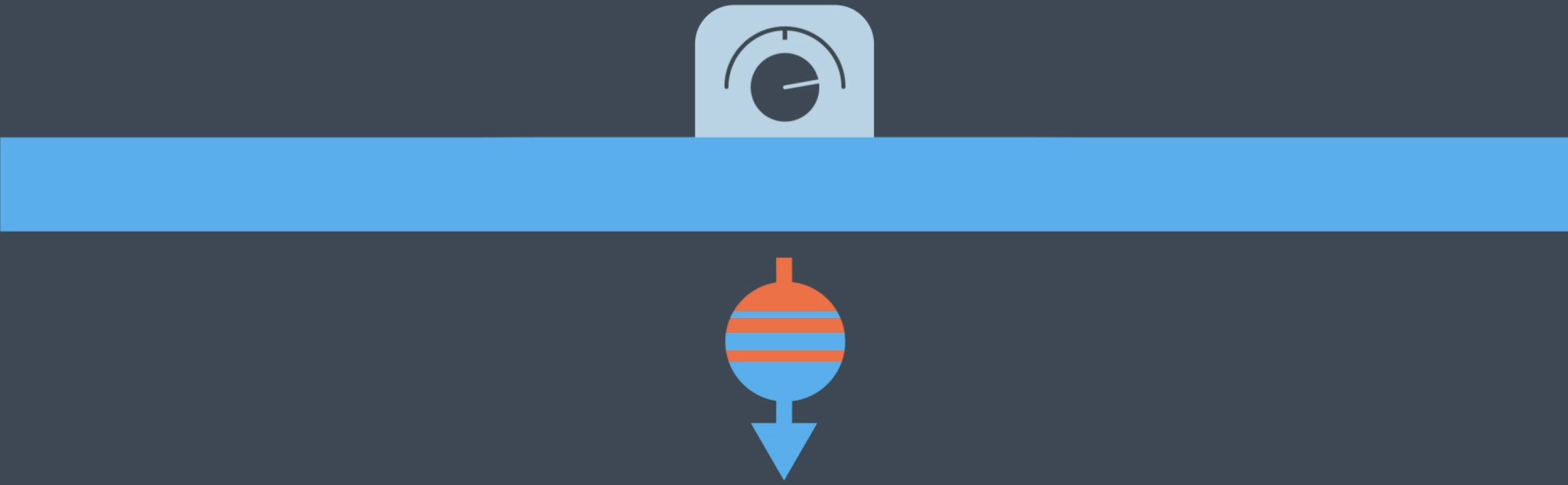




From transistors to many quantum dots



Industrial involvement



A quantum integrated circuit