Efficient Electron Transport on Helium

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Introduction

Spins of electrons floating on the surface of superfluid helium are possible qubits for quantum information processing. Well-defined channels fabricated with standard silicon processing are filled with liquid helium (Fig.1). Voltages applied to underlying gates hold photoemitted electrons on the surface of the helium. The ability to clock electrons with gates from one region to the next without error would allow for moving the spin's quantum information, i.e. from storage to an interaction region, then to a detection region (Fig.2).

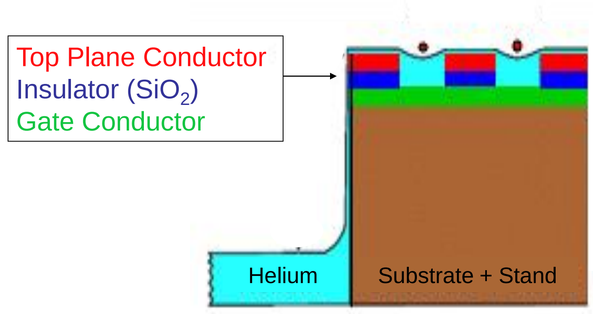


Figure 1

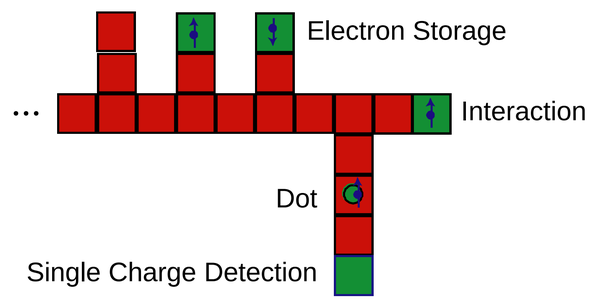
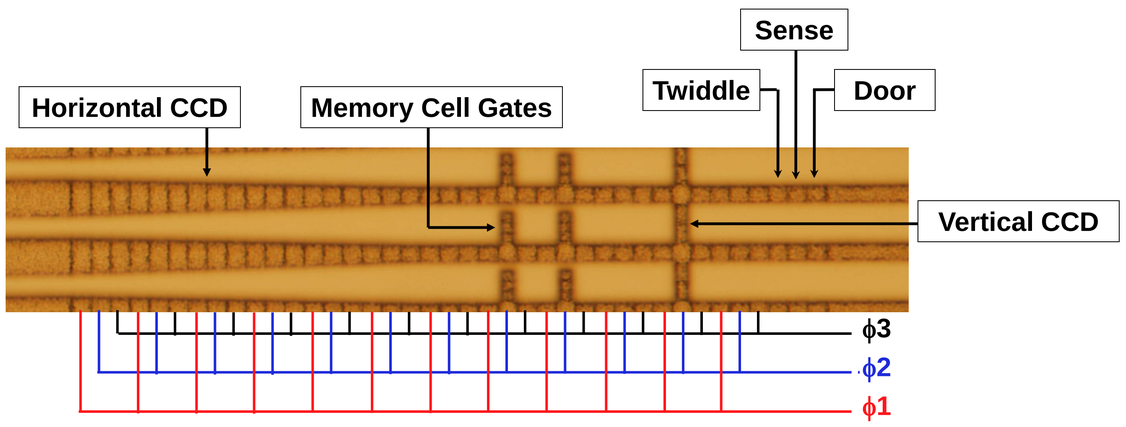


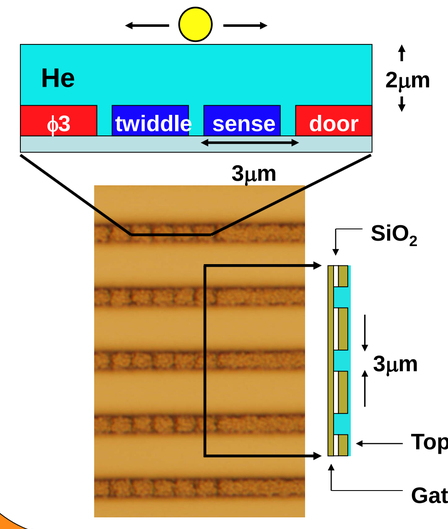
Figure 2

Device Structure



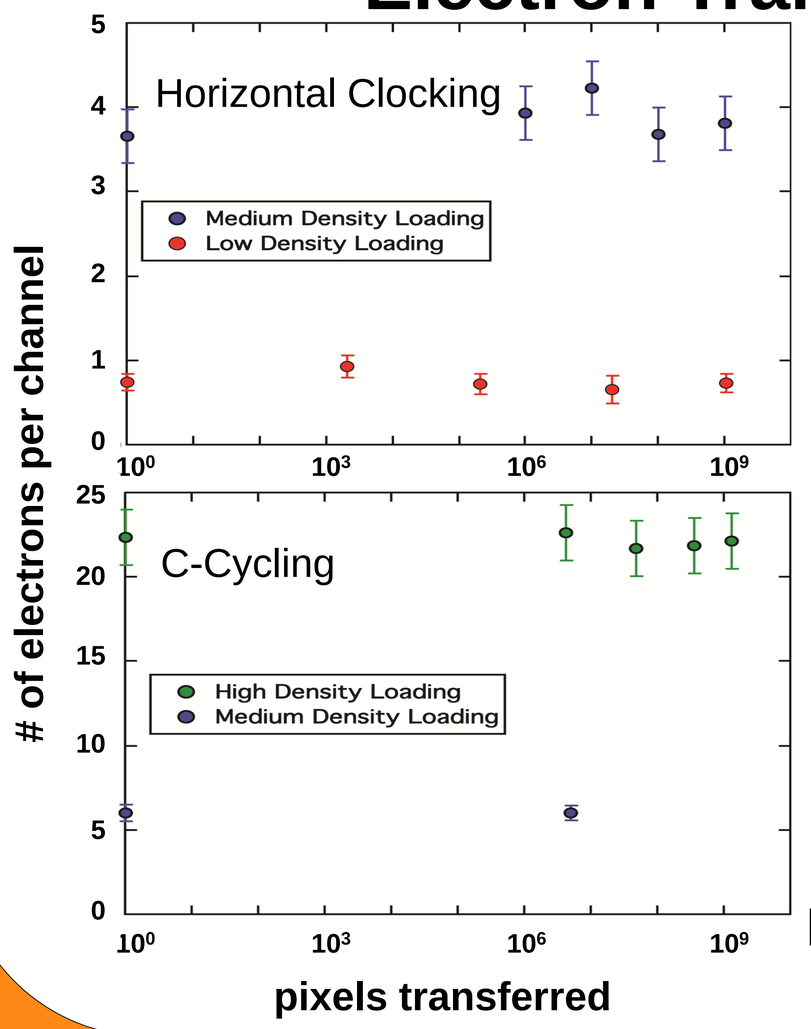
- 3-phase CCD array
  1-pixel = 3-gates
- Gates under 120 parallel channels
- Electrons are photoemitted onto large reservoir gates and then clocked to smaller gates

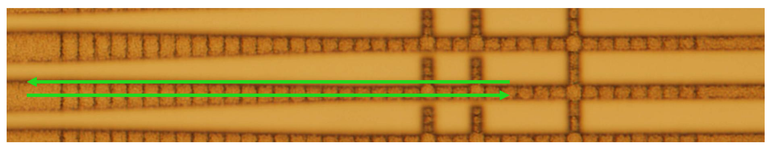
Measurement

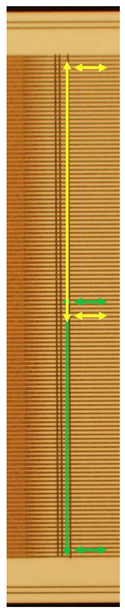


Modulate twiddle gate to push electrons on and off the sense gate

Electron Transfer Efficiency







Horizontal Clocking Sequence
Electrons in all 120 channels
10 pixels to the left
10 pixels back to the right

C-Cycling Sequence
Electrons in 60 channels
1 pixel to the left
60 pixels up through vertical CCD
1 pixel to the right
1 pixel back to the left
60 pixels back down
1 pixel back to the right

No signal loss after 10^9 cycles!!

Result

- Unprecedented reliability of a Charge Coupled Device
  - Essentially perfect Electron Transfer Efficiency
  i.e. No electrons on wrong pixel after traveling > 9km!
- 5 clock lines for full control
  - 2D Scalability: Move anywhere in our ~5000 position gate & channel array
  i.e. Electrons can move horizontally and vertically, with no cornering error
- Standard Si-Processing
  - Possibilities for integrating with Si IC's
  i.e. Inherent scalability along with possibility of on-chip control circuitry and amplification