Spatial Distribution of Electrons on a Superfluid Helium Charge-Coupled Device

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Background

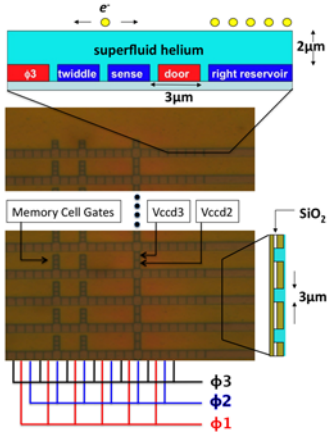
Spins of electrons floating on the surface of superfluid helium are possible qubits for quantum information processing. Well-defined channels fabricated with standard silicon processing are filled with liquid helium. We have demonstrated that transferring electrons from pixel to another over one billion pixels on a superfluid charge-coupled device is possible without any detectable transfer failure. The ability to clock electrons with gates from one region to the next without error would allow for moving the spin's quantum information. One channel perpendicular to the other 120 gives us means to measure the spatial distribution of electrons.

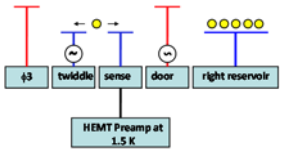
CMOS Process at Sandia National Laboratory

120 parallel channels
3μm wide
2μm deep

3μm period gates

3-phase CCD
Horizontal
ϕ1, ϕ2, and ϕ3
Vertical
ϕ2, Vccd2, and Vccd3



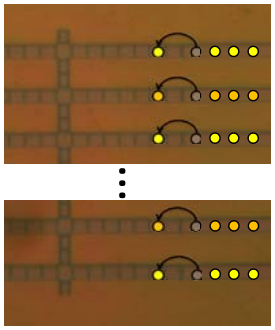


Detection gates:
'twiddle' and 'sense'

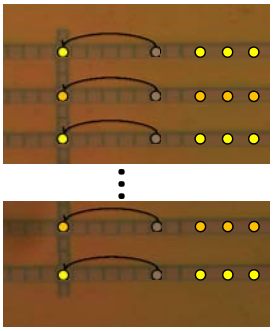
Modulate twiddle to push electrons on and off the sense gate

Electron Distribution

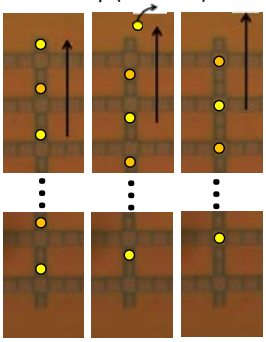
Step 1:
Load Electrons into pixels



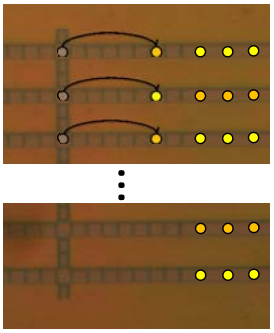
Step 2:
Clock to vertical CCD



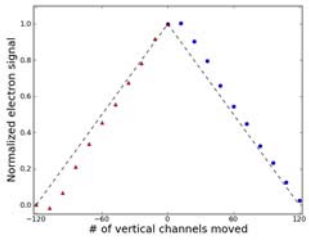
Step 3:
Clock up (12 times)



Step 4:
Measure



Step 5:
Repeat 'Step 3' and 'Step 4'



Signal normalized to the initial loading
Blue: Clocked up
Red: Clocked down
Dashed black line: Linear depopulation

C-Pattern Experiment and Results

1. Empty top 60 channels
2. C-pattern
   60-pixels up
   1-pixel right
   1-pixel left
   60-pixels down
   1-pixel right
   1-pixel left
3. Measure (Fig.1)
   Two different loadings
4. Clock up 10-pixels and measure (Fig.2)
   Repeat 12 times

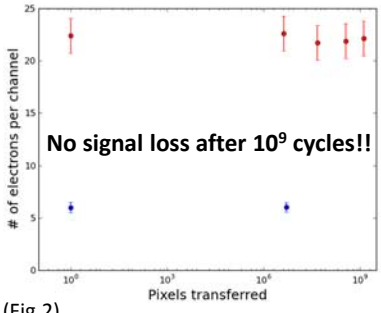


Figure 1

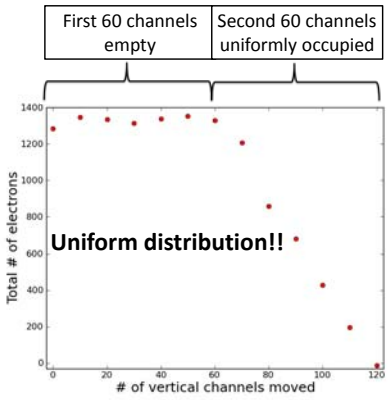


Figure 2

- **Extremely efficient electron transfer efficiency**
- **5-clock lines for full 2-D control**
- **Vertical channel utilized to check spatial distribution of electrons**
- **Uniform occupancy achievable with well-filled right reservoir by photoemission**