Superconducting Nanowires for Digital and Quantum Logic

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ASTRONAUT SCHOLARSHIP FOUNDATION

Agenda

1. Intro to Superconducting Nanowires
2. Three Key Results
3. Summary

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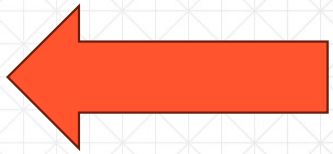
1. **Intro to Superconducting Nanowires**
2. Three Key Results
3. Summary



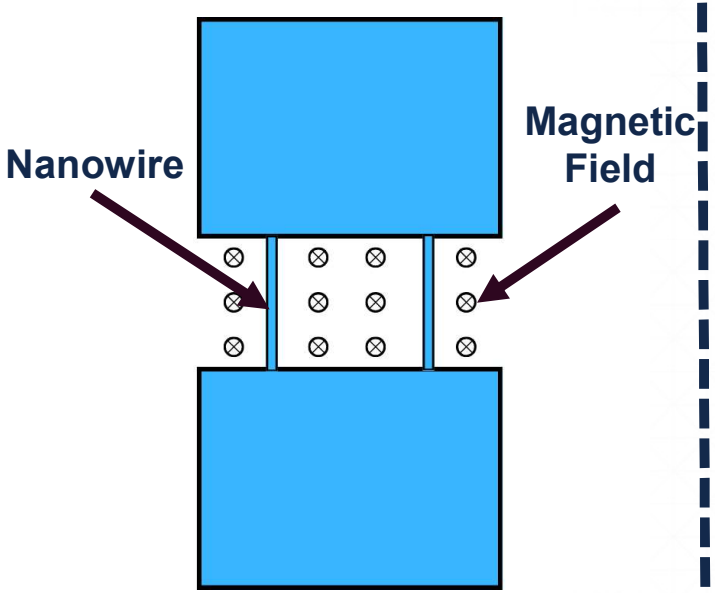
Superconductors for Computing

Superconductors have zero resistance → **Zero Power Dissipation** → **Perfectly Efficient Superconducting Computers**

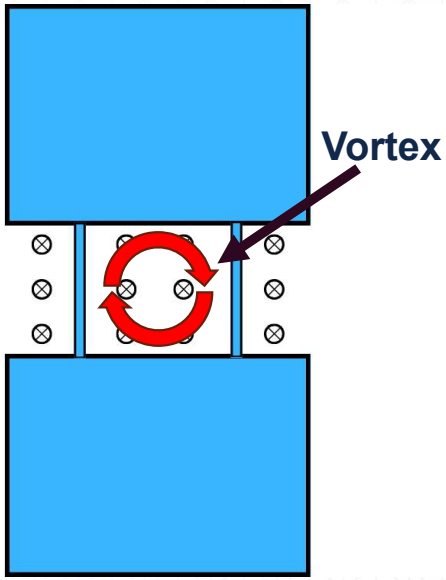
Problem: Current superconducting logic is too big and fragile

(!) Logic with superconducting nanowires → 1000x smaller and more robust (!)

Property #1: Nanowires are 1-dimensional

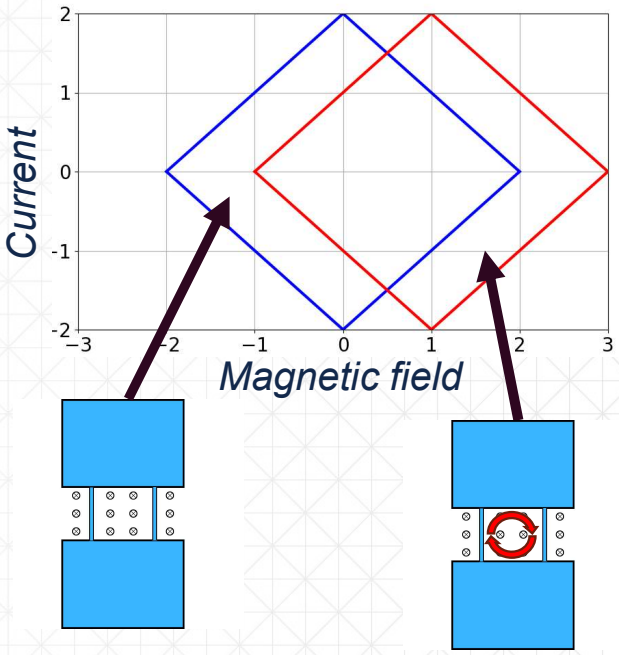


Property #2: Nanowires trap vortices*



*like tornado of current

Property #3: Vortices define device state



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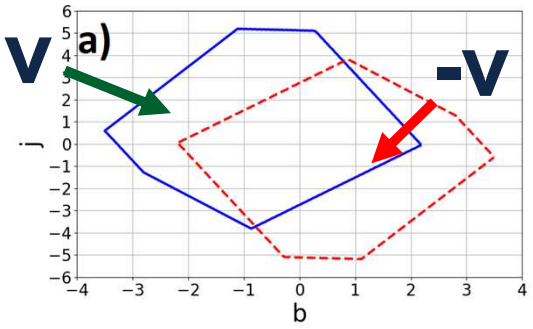
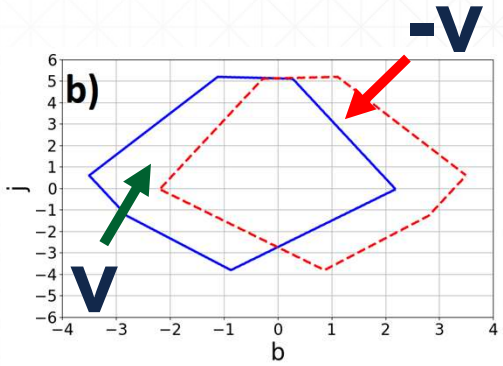
1. ~~Intro to Superconducting Nanowires~~
2. **Three Key Results**
3. Summary

Paper #1: Nanowire devices and particle physics share the *same* symmetry structure

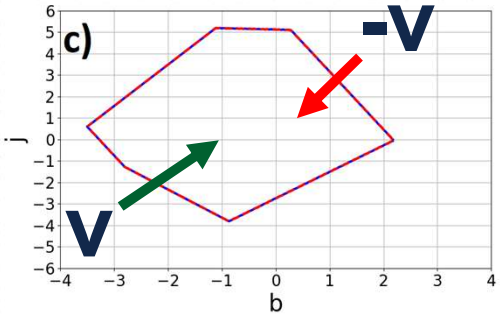
Paper #1: Sun et al. Nano Ex. 6 035014



Current (I) Inversion



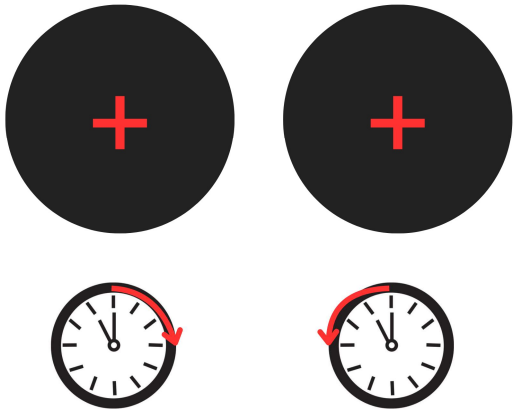
Magnetic Field (B) Inversion



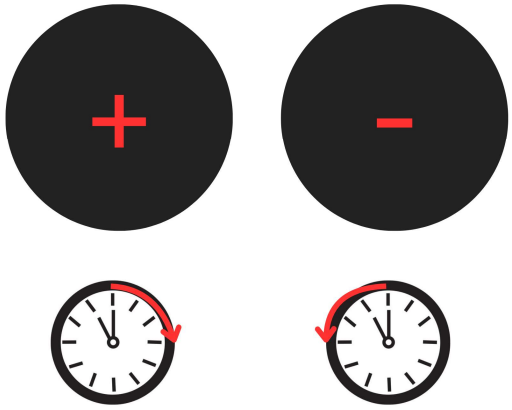
*Device A: **v** vorticity state*
*Device B: **-v** vorticity state*

"Device state obeys IBV Symmetry"

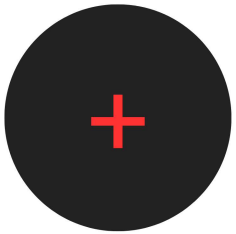
From particle physics:



Charge (C) Inversion



Parity* (P) Inversion



x2

**Or reflection*

*Particle A: Moving **forward** in time*
*Particle B: Moving **backwards** in time*

"Everything obeys CPT Symmetry"

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Paper #1: Sun et al. Nano Ex. 6 035014

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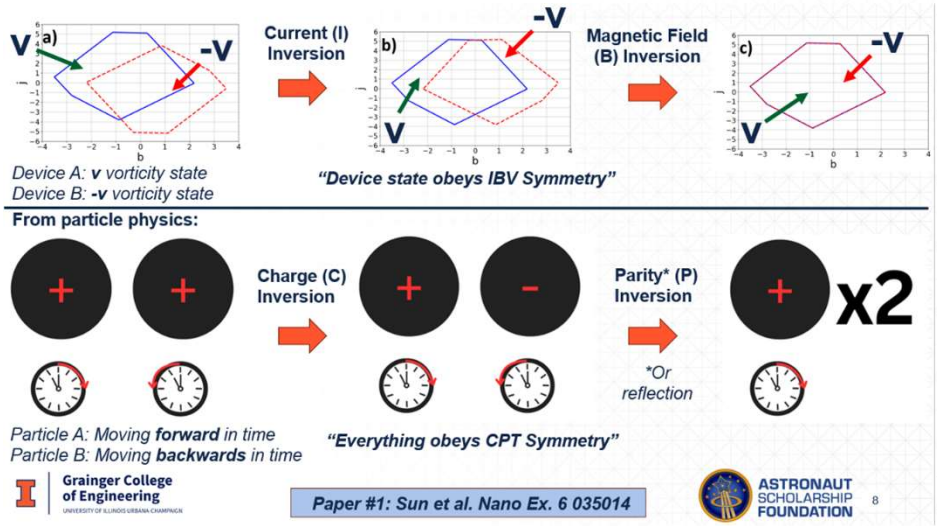


"Particle physics and nanowire devices have the same symmetry structure"

IMPORTANT:

Current inversion
~ Charge inversion

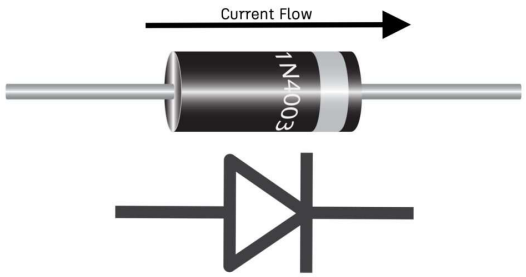
Magnetic Field inversion
~ Parity inversion

Vortex inversion
~ Time inversion

Paper #2: Breaking nanowire device symmetries creates diodes*

**Diodes can be used for digital logic*

Traditional Diode



Standardized Design

- ✓ **Created by breaking parity-time symmetry**
- ✓ **Sub-micron size ($< 1000nm$)**

Superconducting Diode

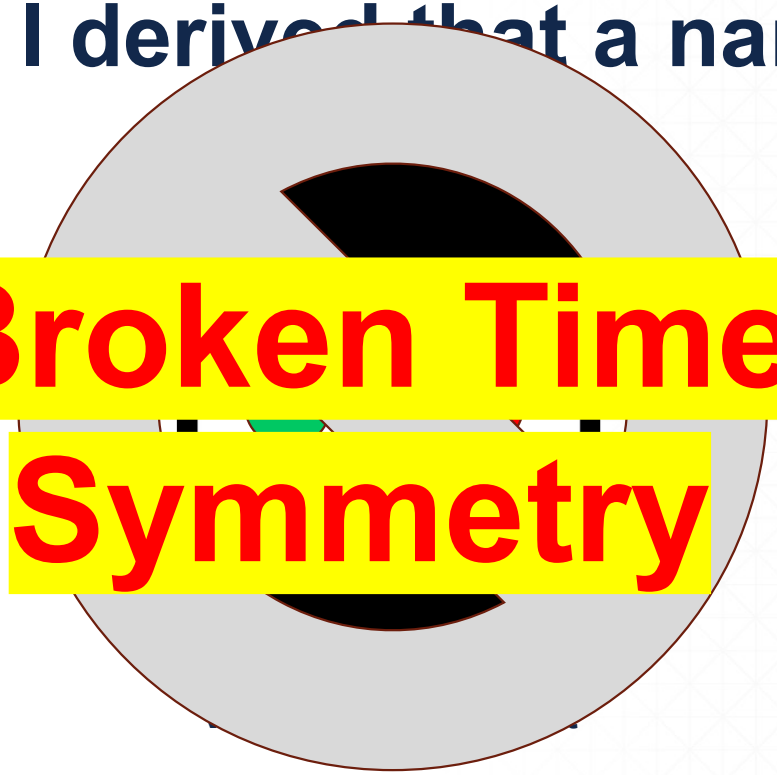
?

No Standardized Design

- ➢ **Cannot be reliably created**
- ➢ **Super-micron size ($> 1000nm$)**

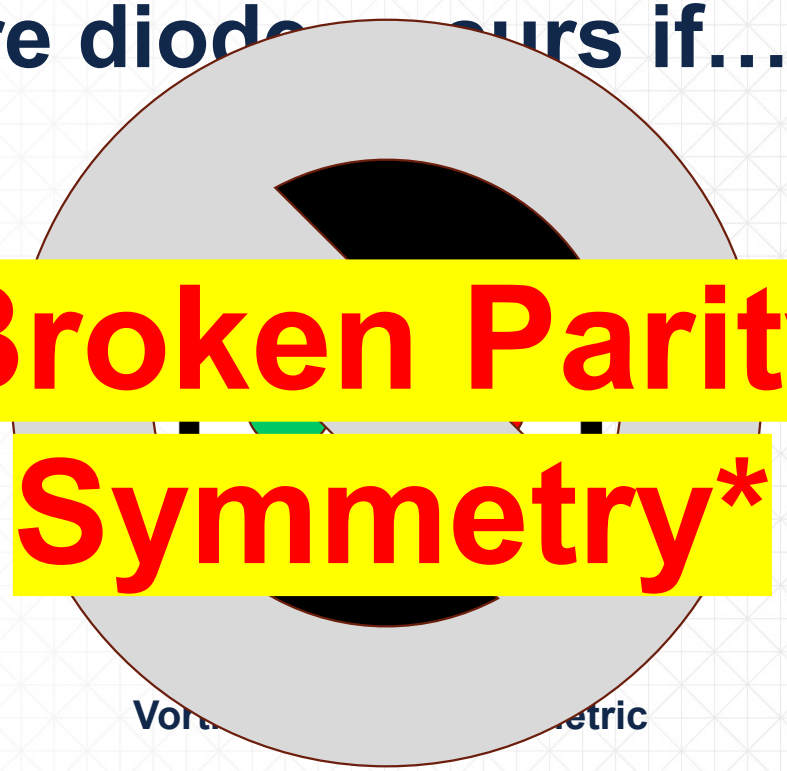
*Anti-symmetric vortices are equivalent to adding magnetic field

I derived that a nanowire diode occurs if…



Broken Time Symmetry

Vortex inversion
~ Time inversion



Broken Parity Symmetry*

Magnetic Field inversion
~ Parity inversion

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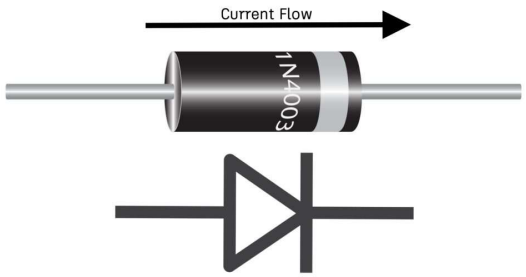

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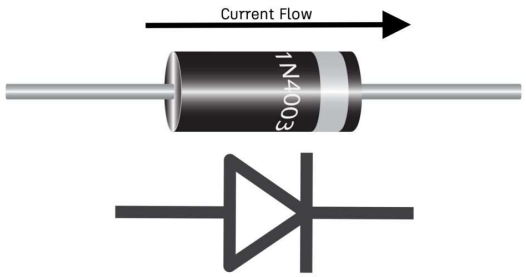

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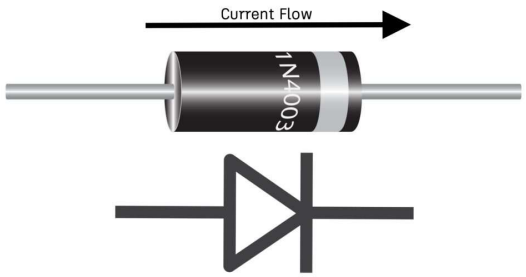

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- ✓ **Nanometer size ($\sim 1\mathrm{n}m$)**

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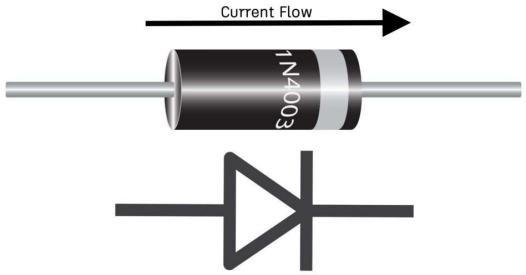

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- ✓ **Nanometer size ($\sim 1\mathrm{n}m$)**
- ✓ **Experimentally Verified!**

Paper #2: ***Sun et al. Phys. Lett. A. 563 131055***

Paper #3: Zhao, Z., Sun, C. *et al. arxiv 2606.14051*

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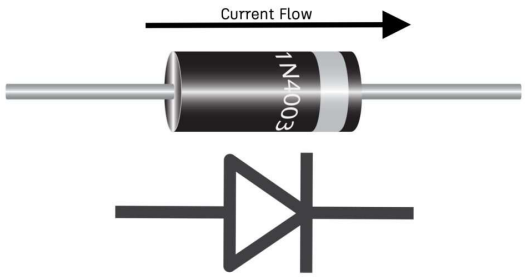
Traditional Diode



Standardized Design

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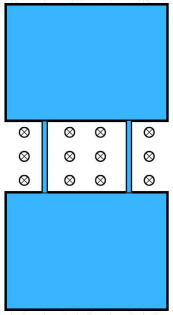
- ✓ Sub-micron size ($< 1000nm$)

Superconducting Diode



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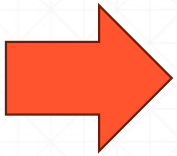
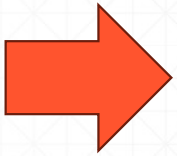
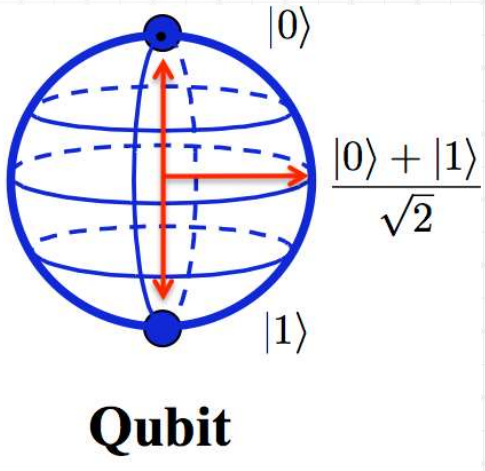
Paper #3: A new family of superconducting quantum bits

Paper #4: *Sun et al. Supercond. Sci. Technol.*

U.S. Patent Filed #64/072,143







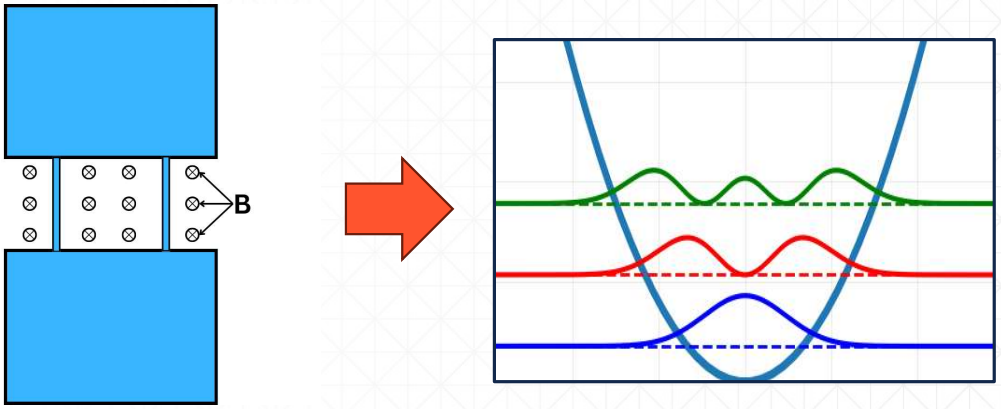
"Computers need bits, quantum computers need quantum bits (qubits)"

Paper #4: *Sun et al. Supercond. Sci. Technol.*

***U.S. Patent Filed* #64/072,143**

Q: ***Can qubits be made from nanowires?***

A: ***Yes! And they're 1000x smaller and more robust***



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2. Breaking nanowire device symmetries creates a diode

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   Paper #3: Zhao, Z., Sun, C. et al. arxiv 2606.14051

3. Nanowires form a new family of small, robust qubits

   Paper #4: Sun et al. Supercond. Sci. Technol.

   U.S. Patent Filed #64/072,143

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