Majorana Corner Modes in Triangular Superconductor Islands

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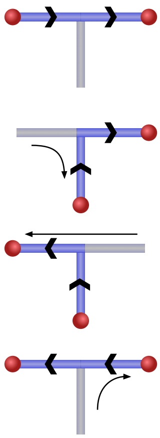
Motivation

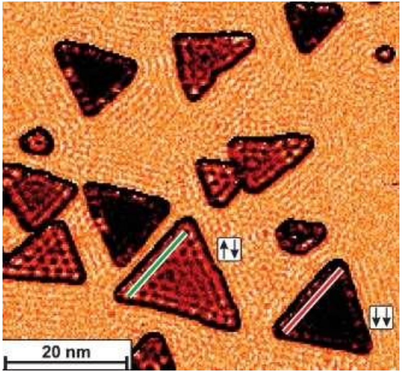
- P-wave superconductors contain half-quantum vortices.
  - Majorana fermions located at core of a vortex.
  - Braiding vortices exhibits Non-Abelian statistics.
- 1D p-wave superconductors host Majorana fermions on end points.
  - Possibly measured in real systems:
    Mourik, *Science* **336**, 1003 (2012)
    Nadj-Perge, *Science* **346**, 602 (2014)
- Quasi-1D T-junction
  - Braiding of Majorana fermions is defined for 2D.
  - In practice challenging to make, but still feasible and seriously pursued.



Alicea, *Nature Phys.* **7**, 412 (2011)

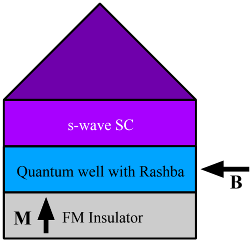
Motivation

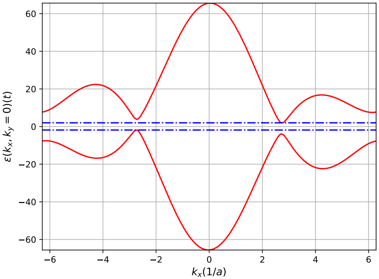
- Consider triangular islands, topologically similar to T-junctions.
- Islands of three-fold rotational symmetry occur naturally in epitaxial growth on close-packed metal surfaces.
- Good platform for transition from 2D to 1D topological superconductor.

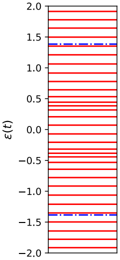


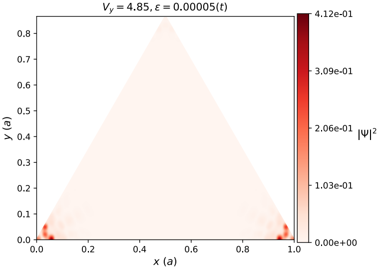
Triangular Co islands on Cu(111).
Pietzsch et al., *PRL* **96**, 237203 (2006)

Previous Work

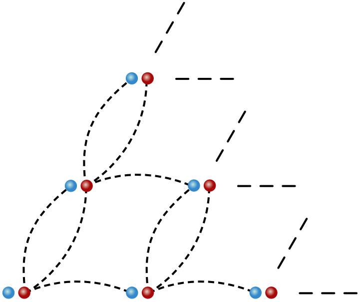








Kitaev Limit with Vector Potential on a Triangular Island



$$\mathcal{H} = \sum_{<j,l>} \left[-te^{i\phi_{l,j}} c_l^\dagger c_j + \Delta e^{i\theta_{l,j}} c_l^\dagger c_j^\dagger + h.c. \right] - \sum_j \mu c_j^\dagger c_j$$

$$\phi_{l,j} = -\frac{e}{\hbar} \int_{\mathbf{r}_j}^{\mathbf{r}_l} \mathbf{A} \cdot d\mathbf{l}$$

$$\mathbf{A} = -\frac{2\pi}{3\sqrt{3}a} \hat{\mathbf{y}}$$

Majorana Number of 1D Chain with Vector Potential

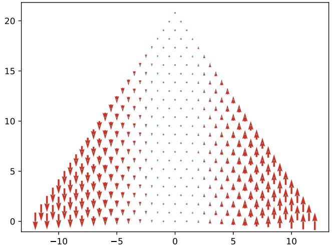
μ ./figures/Majorana-number.pdf

ϕ

$\phi =$ ./figures/kitaev-chain-mu_pi.pdf

Triangular Chain

$$\mathbf{A}(x) = Bx\hat{\mathbf{y}}$$



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Hollow Triangle

../../../research-code/mf-quantum-logic-gate-scripts/data/figures/linear-

../../../research-code/mf-quantum-logi

Summary

- Introduction of vector potential allows for additional tunability of topology.
- Triangular islands with a gapped interior can be a promising platform for hosting and manipulating MZMs.
- Next steps
  - Search for safe MZMs in hollow triangles outside the Kitaev limit.
  - Develop a robust braiding scheme.

Majorana fermion notation and coupling isolations

The complex fermion operator can be written as a superposition of two Majorana fermions $c_j = \frac{1}{2}(a_j + ib_j)$. Due to the nature of Majorana fermions, $a_j^\dagger = a_j$, the creation operator is $c_j^\dagger = \frac{1}{2}(a_j - ib_j)$.

$$H = -\frac{i\mu}{2}\sum_j a_j b_j - \frac{i}{2}\sum_{\langle jl\rangle}[(t\sin\phi_{jl} - \Delta\sin\theta_{jl})a_l a_j + (t\sin\phi_{jl} + \Delta\sin\theta_{jl})b_l b_j$$
$$+(t\cos\phi_{jl} - \Delta\cos\theta_{jl})a_l b_j - (t\cos\phi_{jl} + \Delta\cos\theta_{jl})b_l a_j].$$

$$(t\sin\phi_{jl} - \Delta\sin\theta_{jl})a_l a_j, \quad (1)$$
$$(t\sin\phi_{jl} + \Delta\sin\theta_{jl})b_l b_j, \quad (2)$$
$$(t\cos\phi_{jl} + \Delta\cos\theta_{jl})a_l b_j, \quad (3)$$
$$(t\cos\phi_{jl} - \Delta\cos\theta_{jl})b_l a_j \quad (4)$$