Skyrmion tunneling and merger based OR gate

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Spintronics

It is a field of physics that utilises the orientation of intrinsic spin of electrons, in addition to their charge, for information storage and processing.

Magnetic skyrmions

Skyrmion is a topologically stable vortex like configuration of magnetisation vectors

Why do we care about them?

We can build logic gates based on skyrmions

OR gate

Input		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Landau Lifshitz Gilbert Equation:

$$\partial \mathbf{M}/\partial t = -\gamma\,(\mathbf{M} \times \mathbf{H}_{eff}) + \alpha/M_s\,(\mathbf{M} \times \partial \mathbf{M}/\partial t) + \boldsymbol{\tau}_{CPP}$$

$$\boldsymbol{\tau}_{CPP} = -\beta \in' (\mathbf{M} \times \mathbf{m}P) - \beta/Ms\ [\mathbf{M} \times (\mathbf{m}_P \times \mathbf{M})]$$

$$\beta = \theta_{SH} \hbar J / 2 M_s e t_{Co,track}$$

Establishing the track:

Material parameters:

Material parameters: multilayer Pt/Co strip

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```
// Setting up the free layer

// saturation magnetization
Msat  = 580e3

// exchange stiffness
Aex   = 15e-12
```

Material parameters: multilayer Pt/Co strip

```
// Gilbert damping coefficient
alpha = 0.1

// DMI constant
Dind =3e-3

// magnetocrystalline anisotropy constants
anisu  = vector(0, 0, 1)
Ku1=6e5
Ku2=1.5e5

Temp = 0

m = Uniform(0,0,1)
```

Setting up parameters for skyrmion propulsion:

```
B_ext = vector(0, 0, 0)

lambda       = 1
Pol          = 1
epsilonprime = 0
xi = 0.35

DisableZhangLiTorque=False
DisableSlonczewskiTorque=False

fixedlayer = vector(0, 1, 0)

jz   := 9e10  // current density in A/m2
J = vector(0, 0, -jz)
```

Skyrmion tunneling

Skyrmion tunneling refers to the process where a skyrmion, a stable, localized knot of magnetic moment in a magnetic material, transitions between different energy states or positions within a material.

Skyrmion merger

Skyrmion merger refers to the process where two or more skyrmions - which are topologically protected magnetic textures with particle-like properties - combine to form a single entity.

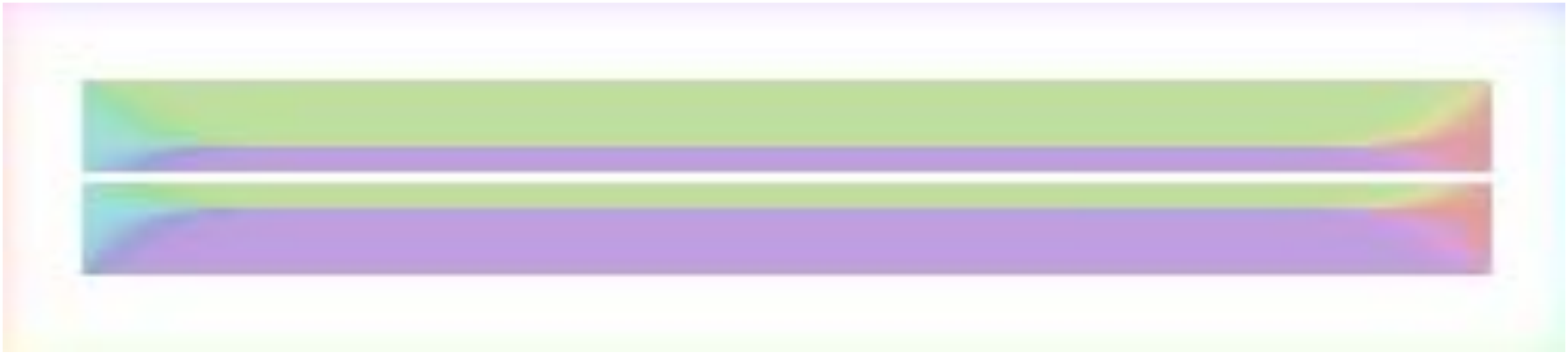
Gate structure:

Input channel

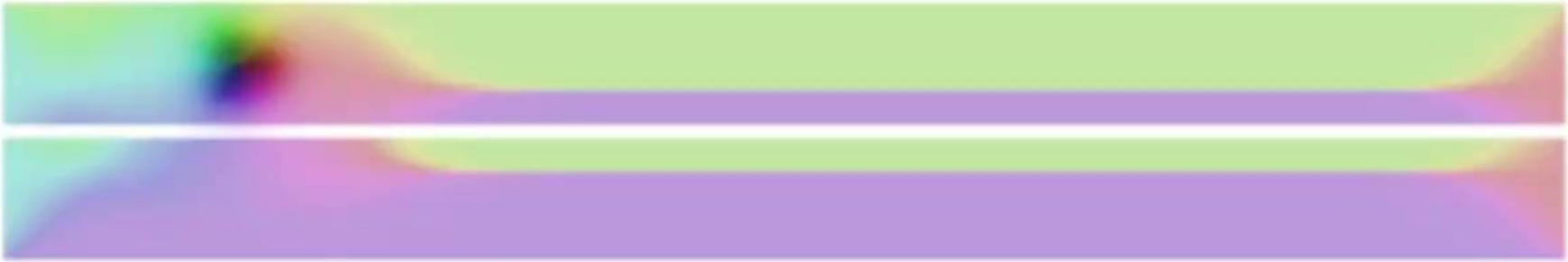
Output channel

Results:

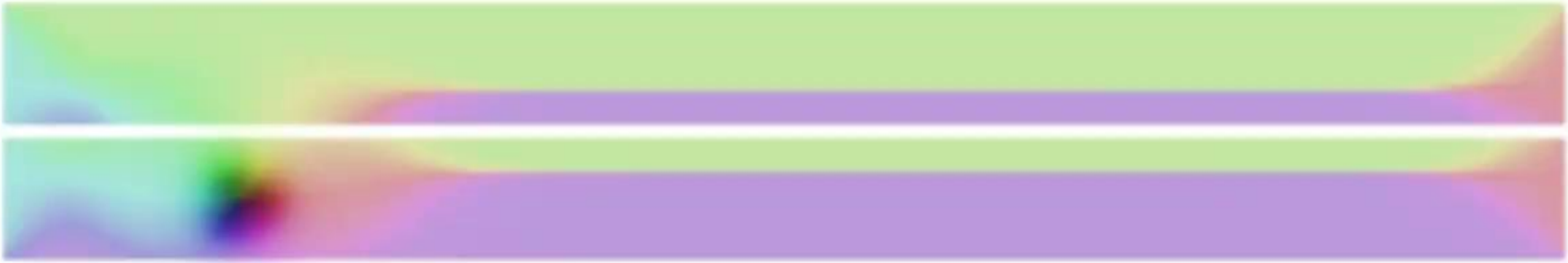
Case A=0,B=0



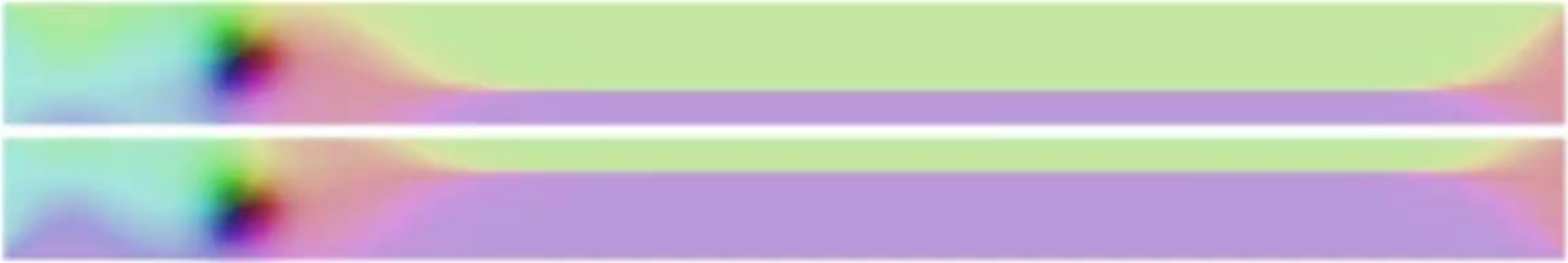
Case A=1,B=0



Case A=0,B=1



Case A=1,B=1



All truth values successfully achieved for OR gate.

Conclusion

By capitalising on the rich physics of skyrmions, we have created a skyrmion tunnelling and merger based OR gate which is structurally simple and satisfies all truth values.

We plan on creating more logic gates in future with this approach.

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Thank you for listening!