Multiple stable Bloch points in confined helimagnetic nanostructures

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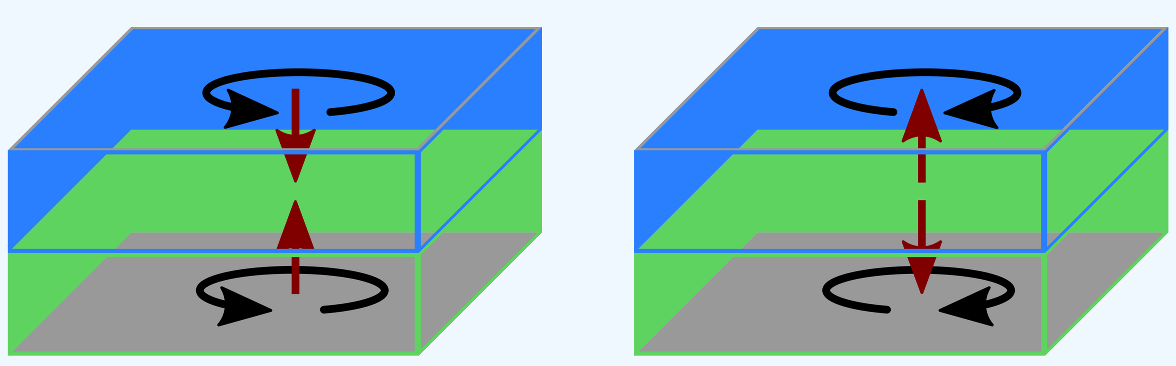
Introduction

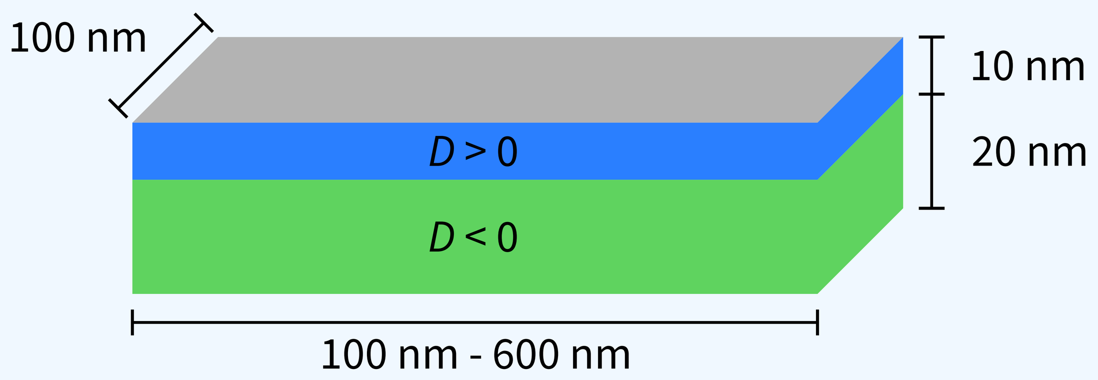
- Stacking two vortices with the same chirality and opposite core orientation results in a discontinuous magnetisation in the middle - a Bloch point - that is energetically expensive and can be expelled by reversing the orientation of one layer while fixing chirality.
- Chirality and orientation cannot change independently when adding Dzyaloshinskii-Moriya interaction.
- In a nano-disk consisting of two helimagnetic layers with different chirality a stable Bloch point can exist at the interface between the layers [1].
- Two different stable configurations can exist, with the magnetisation either pointing inwards (head-to-head, HH, a) or outwards (tail-to-tail, TT, b).
- We demonstrate that a nano-strip consisting of two layers with different chirality can host multiple Bloch points in different configurations.

a head-to-head (HH) **b** tail-to-tail (TT)



Methods

- System geometry:



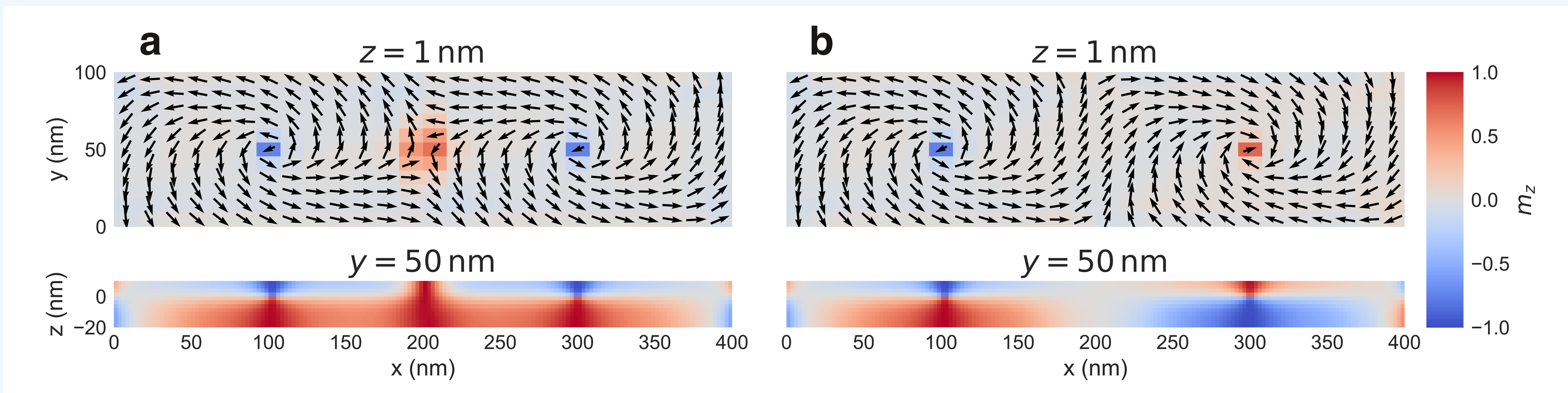
- Material parameters based on FeGe:
  - $A = 8.85\,\mathrm{pJ/m}$
  - $M_s = 384\,\mathrm{kA/m}$
  - $D = 1.58\,\mathrm{mJ/m^2}$
- Hamiltonian:

$$w = A(\nabla \boldsymbol{m})^2 + D\boldsymbol{m} \cdot (\nabla \times \boldsymbol{m}) + w_d$$

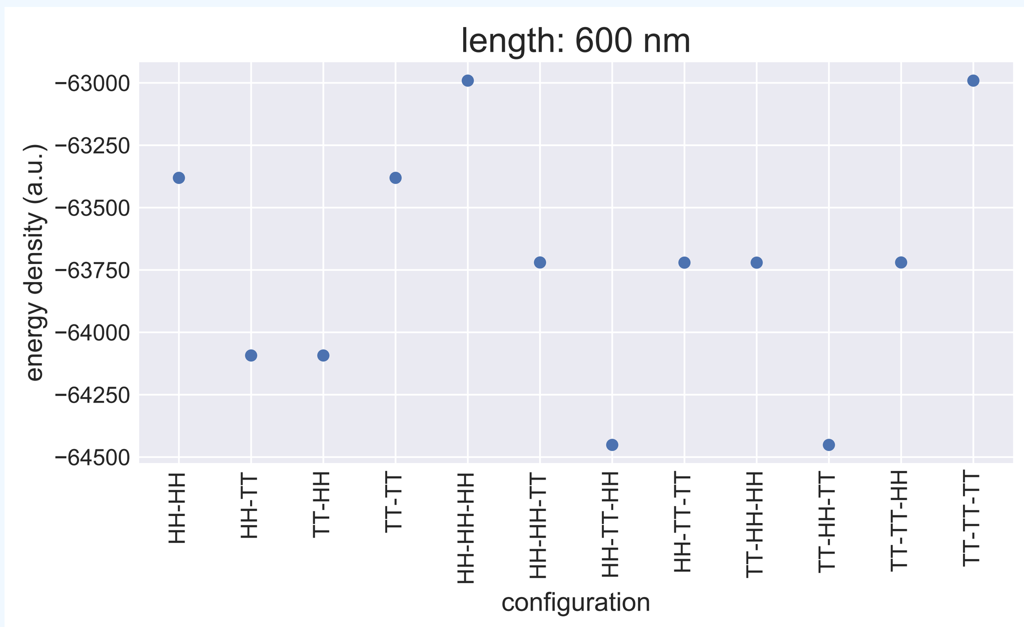
- We perform finite-difference micromagnetic simulations using Ubermag [2, 3].
- We initialise the system using piecewise uniform out-of-plane magnetisation.

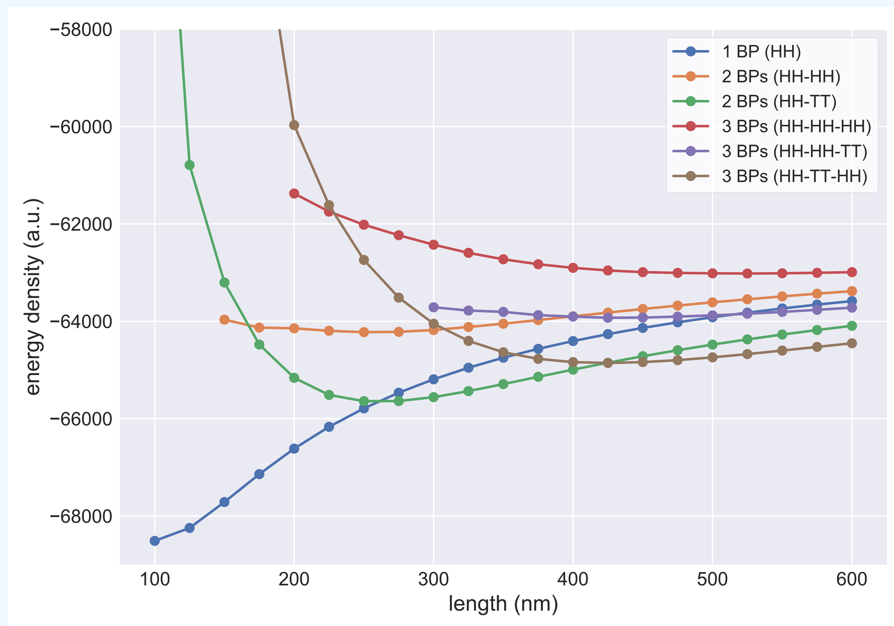
Magnetisation configurations

- We simulate multiple different configurations resulting in up to three Bloch points.
- Each Bloch point has a magnetisation pattern either pointing inwards (head-to-head, HH) or outwards (tail-to-tail, TT).
- Two Bloch points in one strip can either be of the same type (a, HH-HH) or of opposite type (b, HH-TT).



Energy comparison





- We compare energies for all combinations of two and three Bloch points.
- Two neighbouring Bloch points are energetically less favourable when they are of the same type.
- Ordering of Bloch points does not affect energy as long as the number of changes of type is fixed.
- One Bloch point is energetically favourable for small lengths.
- With increasing length the configuration with the lowest energy has an increasing number of Bloch points (of alternating opposite type).

Summary

- We show that a nano-strip consisting of two layers with opposite chirality can host multiple Bloch points.
- All combinations of head-to-head and tail-to-tail Bloch points are stable given that the nano-strip is sufficiently long.
- A pair of two neighbouring Bloch points is lower in energy when the two Bloch points are of opposite type.
- The lowest energy configuration depends on the length, in longer strips certain configurations with multiple Bloch points have lower energy.

References

[1] M. Beg *et al.* *Scientific Reports* **9**, 7959 (2019).
[2] M. Beg *et al.* *AIP Advances* **7**, 56025 (2017).
[3] Ubermag repository: https://github.com/ubermag/

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