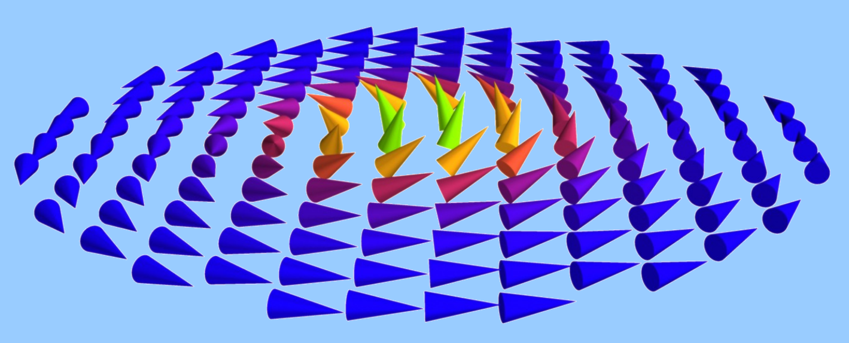

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Current driven nucleation of domain walls in cylindrical nanowires

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Idea

Pushing a domain wall through pinning centers using fields or currents

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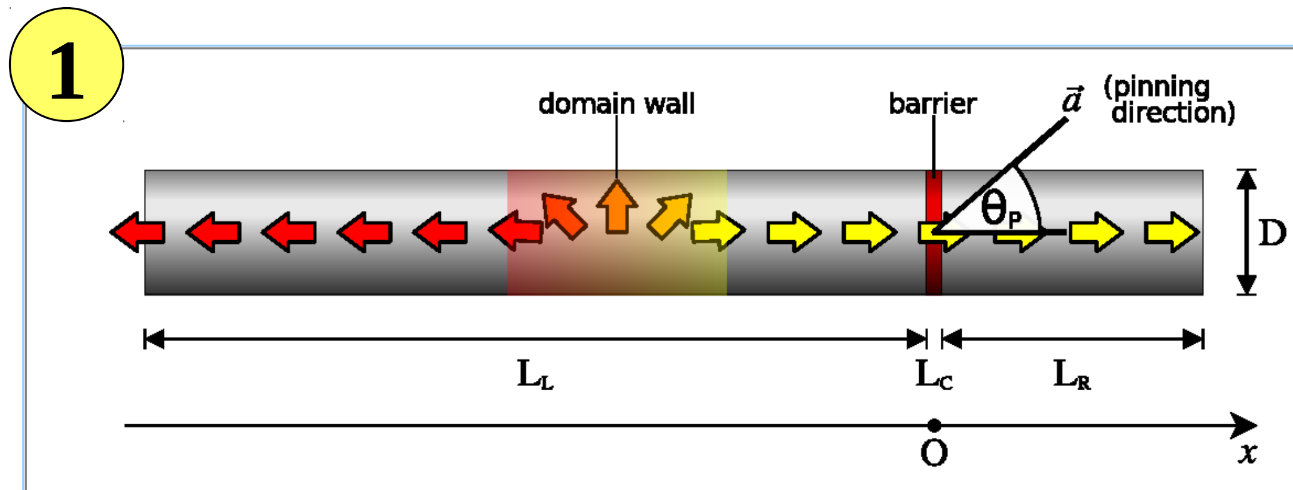


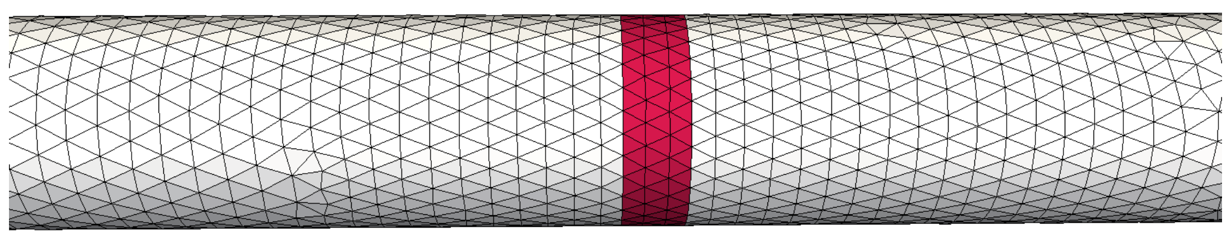
We study the **motion of a domain wall through a barrier** (pinning center) in a cylindrical nanowire [2].

We use micromagnetic simulations [1] and push the domain wall through the barrier by **using a magnetic field or an electric current** (spin transfer torque).

②

The barrier is modeled as a thin region of the nanowire with a magnetic anisotropy of strength K_1 directed at an angle θ_P from the nanowire axis.

The nanowire is made of permalloy. As the radius is smaller than 50 nm (it is 10 nm in this study) domain walls in the wire are **transverse domain walls** (rather than vortex domain walls).



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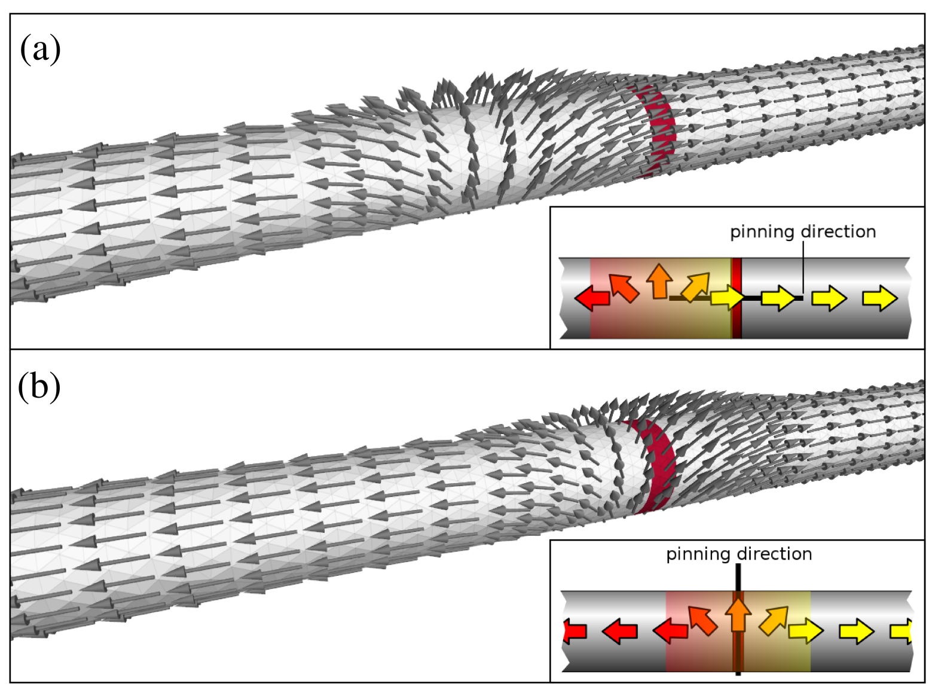
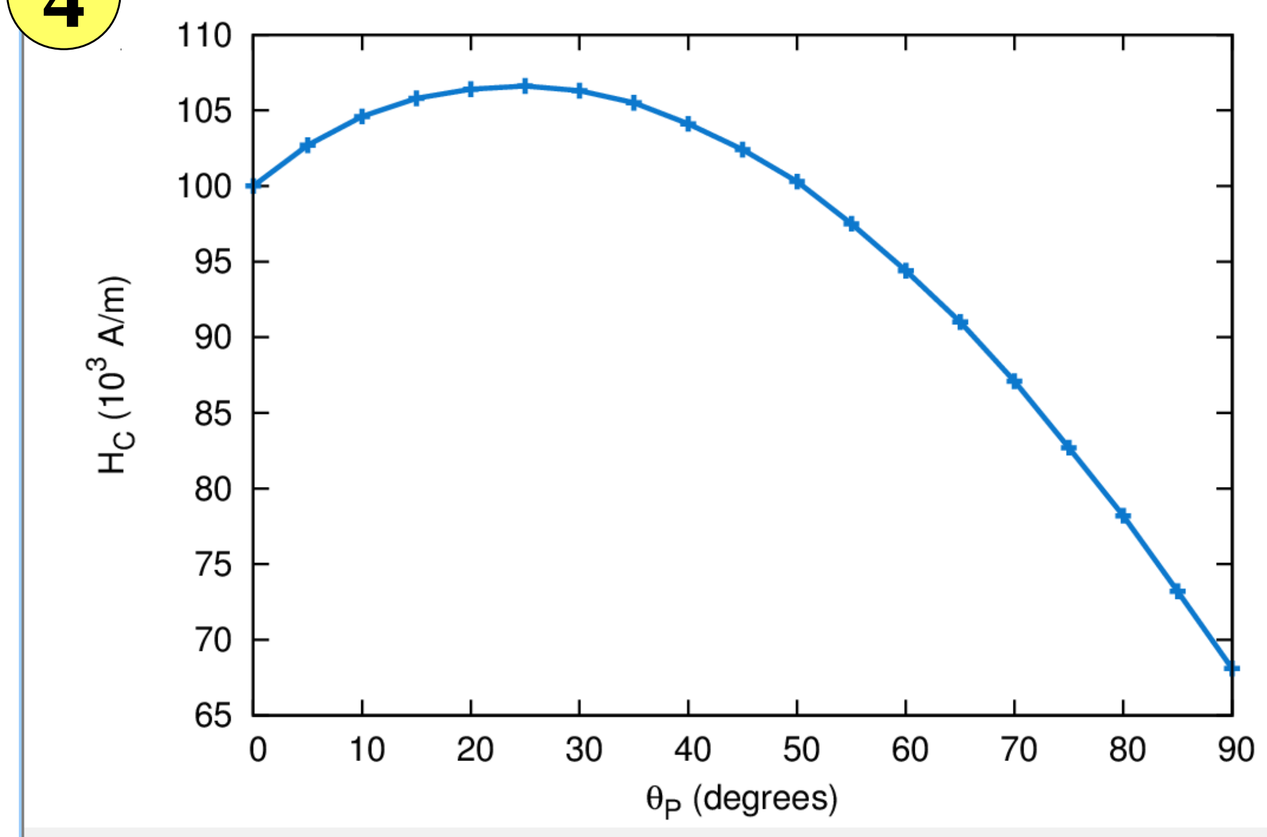


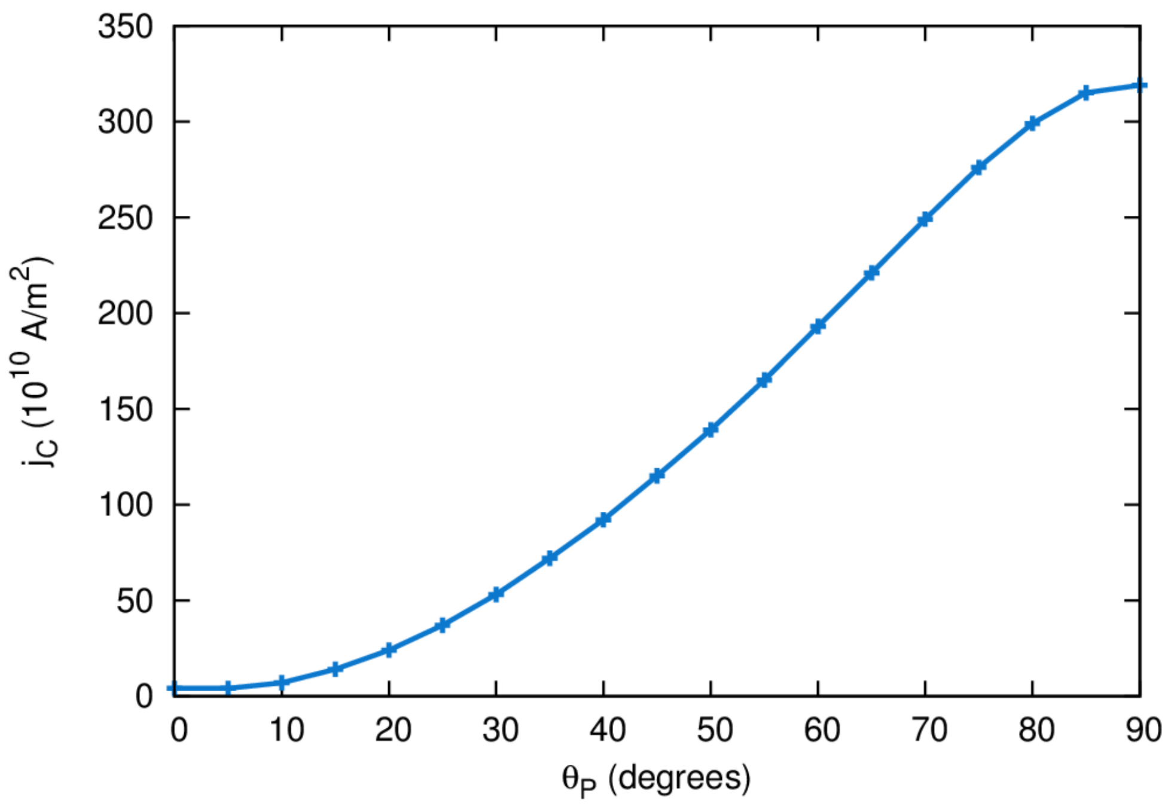
If a weak field or current are applied to push the domain wall toward the barrier, the domain wall either (a) sits in front of it (symmetric barrier, θ_P = 0°) or (b) falls inside it (asymmetric barrier, θ_P = 90°) [2].

④



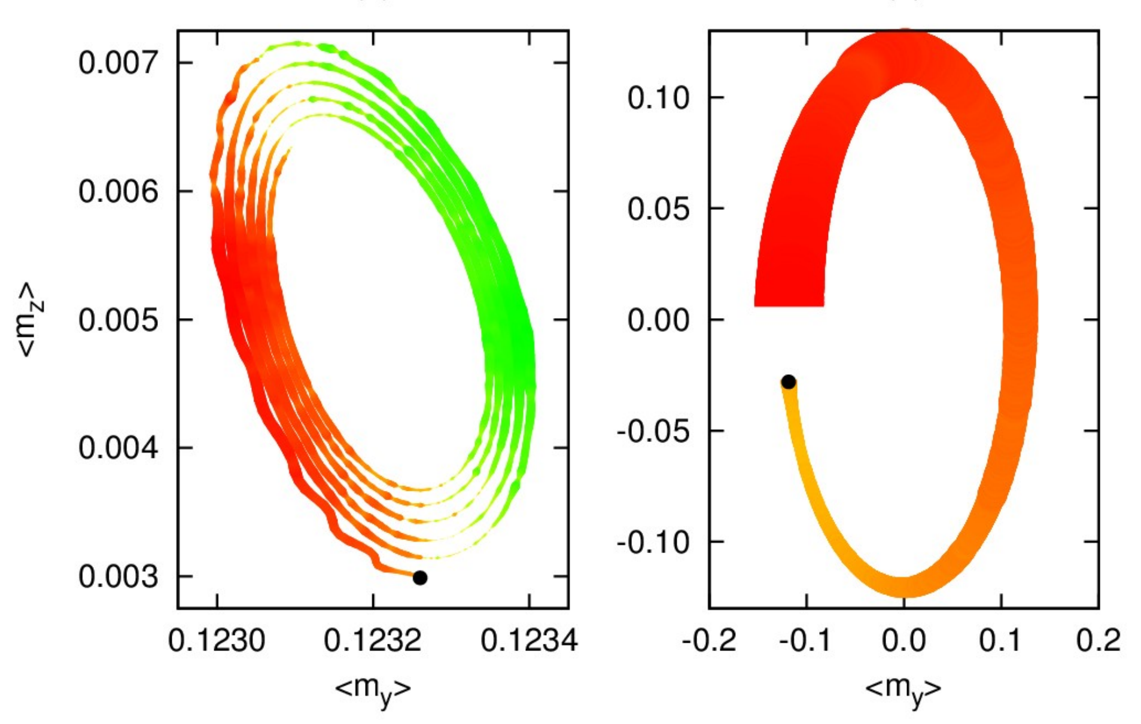
The plot shows the **critical magnetic field**, H_C, required to push the domain wall through the barrier for different angles, θ_P, of pinning in the barrier [2].

⑤



The plot shows the **critical current density**, j_C, required to push the domain wall through the barrier for different angles, θ_P.
j_c increases of a factor 130 when θ_P varies between 0° and 90° degrees.
Why is the current driven motion so strongly affected by the pinning direction?

⑥

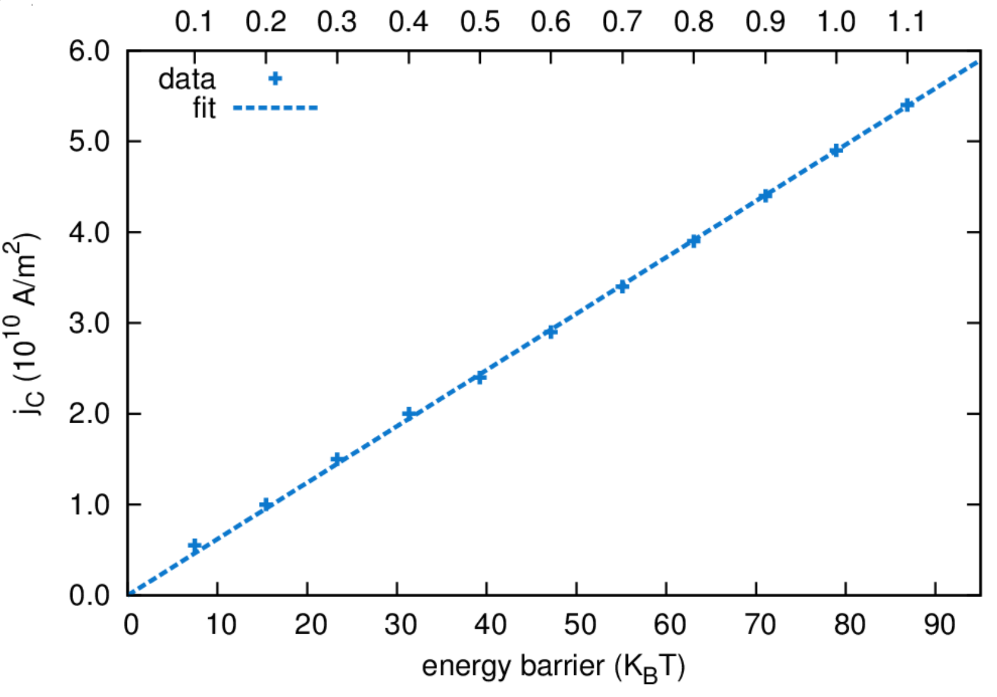


The important factor is whether the spin transfer torque can **accumulate** its effect. The magnitude of the spin transfer torque term in the LLG equation is comparable to the magnitude of the damping term. If the latter can oppose to the former, we can gradually pump energy into the system [2].

And…

Higher currents can be used to overcome higher energy barriers, but...

⑦

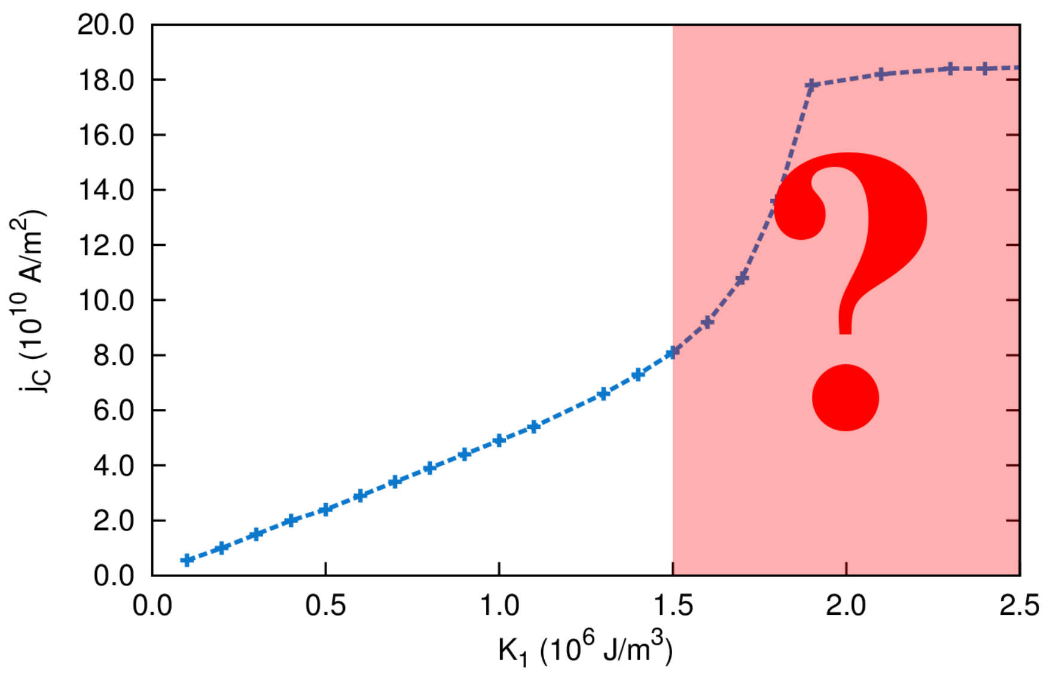


The critical current density j_C required to overcome an energy barrier, ΔE, is **linearly proportional** to ΔE.
From our analytical model [2],

$$I_C = (e\gamma\alpha/3\mu_0\mu_B)\,\Delta E.$$

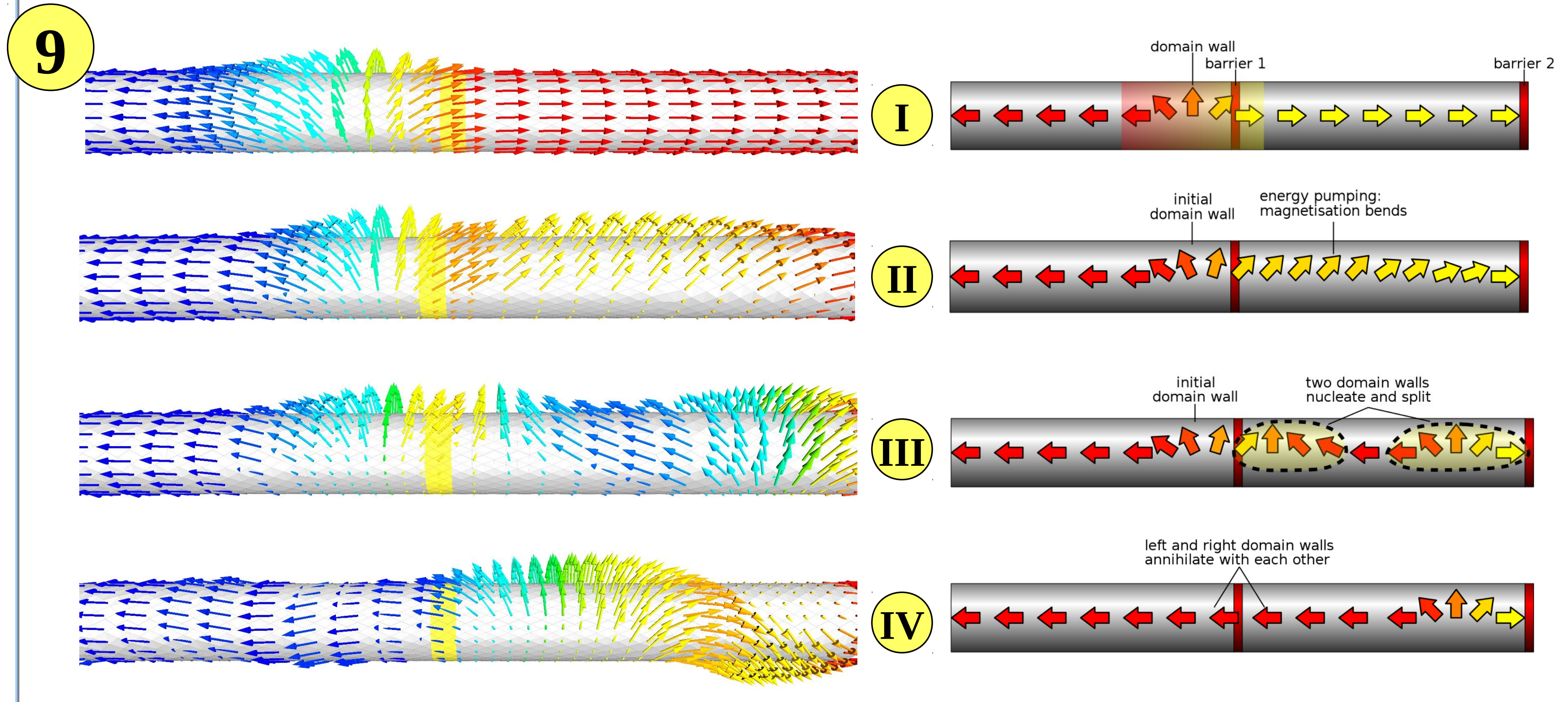
The total current, I_C, required to overcome a barrier ΔE depends only on the damping, α, and the gyromagnetic ratio, γ.

⑧



The critical current density becomes non-linear for strong energy barriers, ΔE. This suggests a **different mechanism** for the motion of the domain wall through the barrier.
The case K_1 = 2.1·10⁶ J/m³ is studied below.

⑨



Case K_1 = 2.1·10⁶ J/m³: the domain wall does not go through the barrier directly. Instead, it annihilates with one of the two domain walls that – for this regime of currents – form on the right of the barrier.

I. The domain wall is pushed against the barrier.
II. Before it passes throughout the barrier, something else happens: the magnetization bends out of the nanowire axis (j = 1.82·10¹¹ A/m²).
III. Once enough energy has been accumulated, a couple of domain walls forms: one moves toward barrier 1, the other toward barrier 2.
IV. The domain walls on the sides of barrier 1 annihilate with each other.

CONCLUSIONS: Current-driven nucleation of domain walls in cylindrical nanowires offers an **alternative way** for a transverse domain wall to go through a barrier. On the one hand, this mechanism must be controlled in the design of novel domain wall memories. On the other, it offers a way to nucleate domain walls using electric currents.

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