Imprinting superconducting vortex footsteps in a magnetic layer

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LABORATORY OF PHYSICS OF NANOSTRUCTURED MATERIALS

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Flux penetration in superconductors

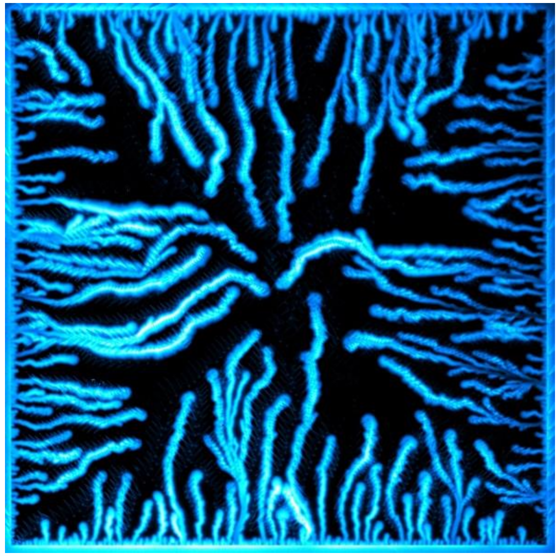
observed by magneto-optical imaging (MOI)

H increased → vortex motion → dissipation in normal core

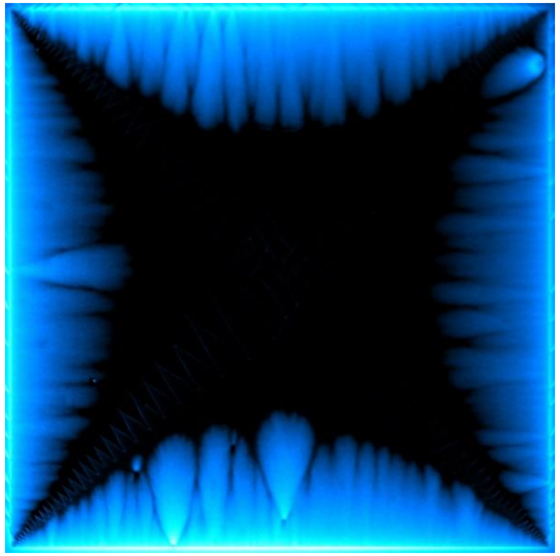
T raises locally

efficient heat removal

Flux avalanches

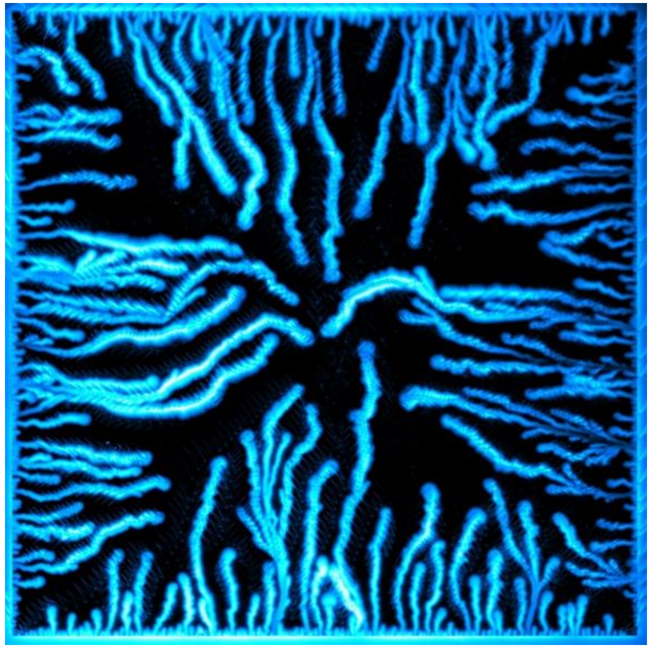


Smooth flux penetration



Why study flux avalanches?

The system undergoes a dramatic transition to a state of lower energy.



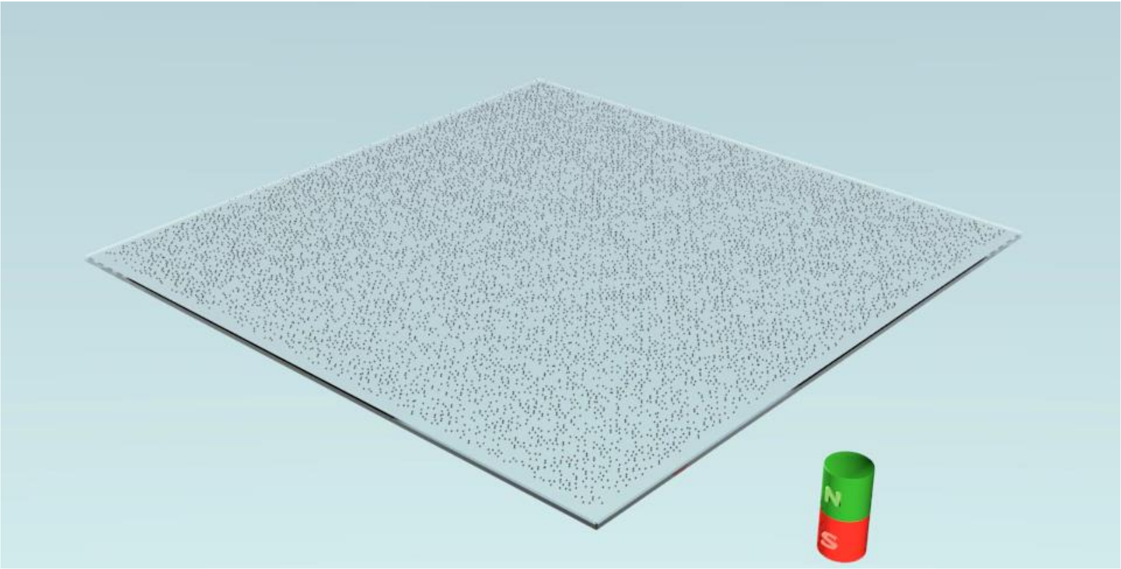
v ~ 10-100 km/s

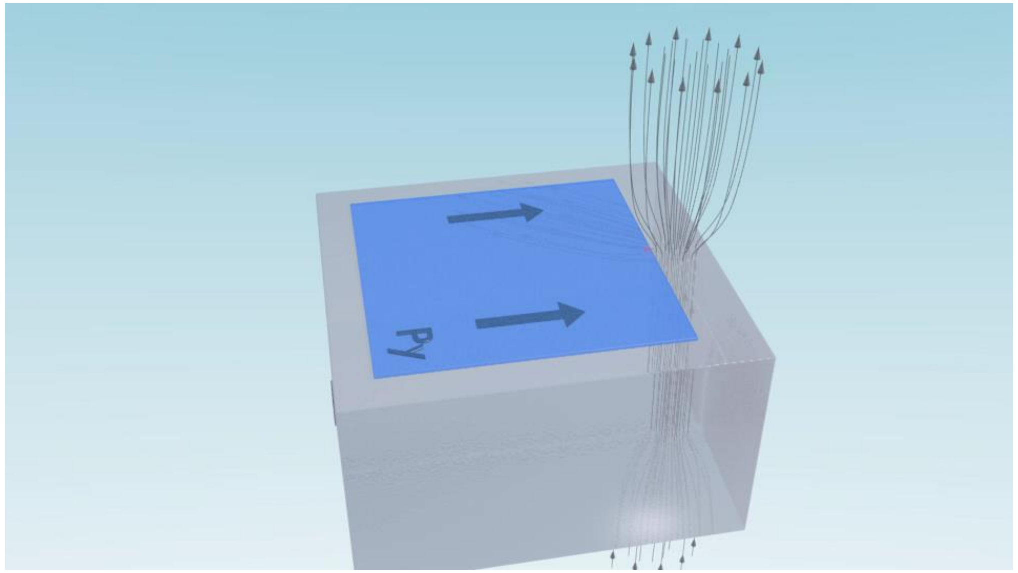
Avalanches are harmful to superconductivity and practical applications.

→ **observe**, **control** and **avoid** flux avalanches.

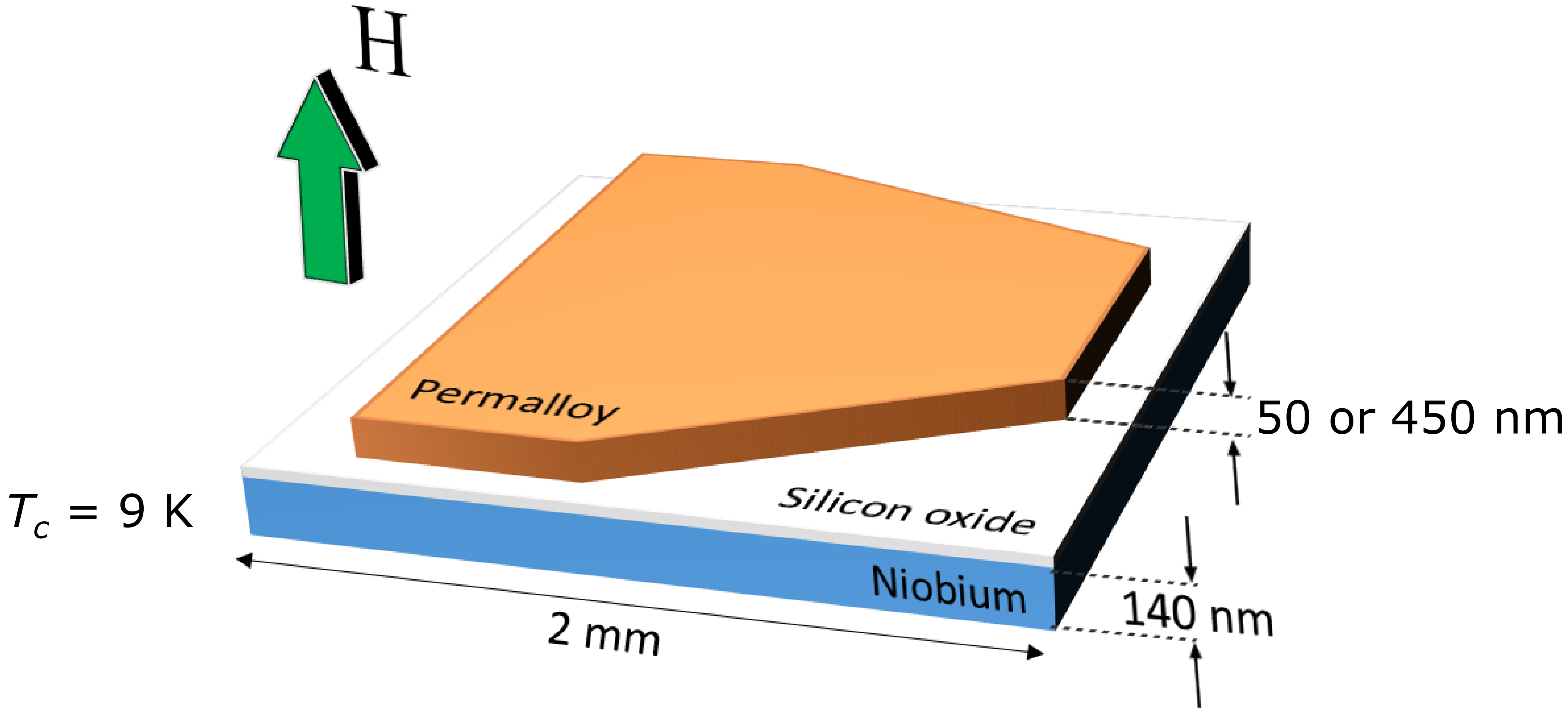
Imprinting magnetic fields

Idea: use a magnetic layer to record the vortex trajectories.





Sample design

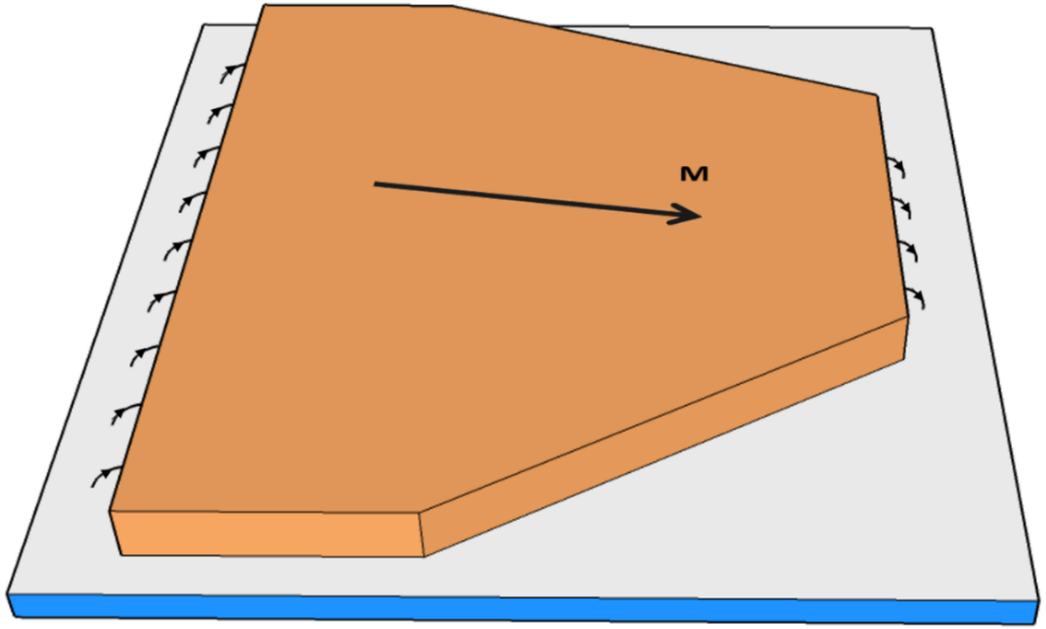


Avalanches reach the Py at full speed and at different angles.

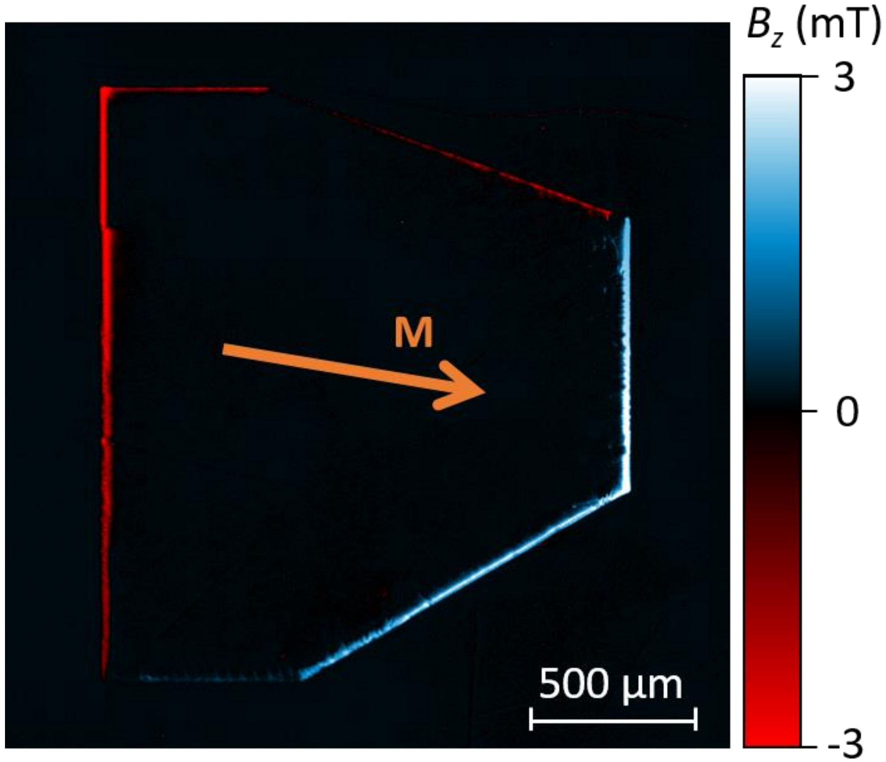
J. Brisbois *et al.*, *Sci. Rep.* **6**, 27159 (2016).

Magnetic field of the Py layer

The direction of magnetization is easily controlled…



In-plane saturation field ~ 2 mT



… and easily reversed!

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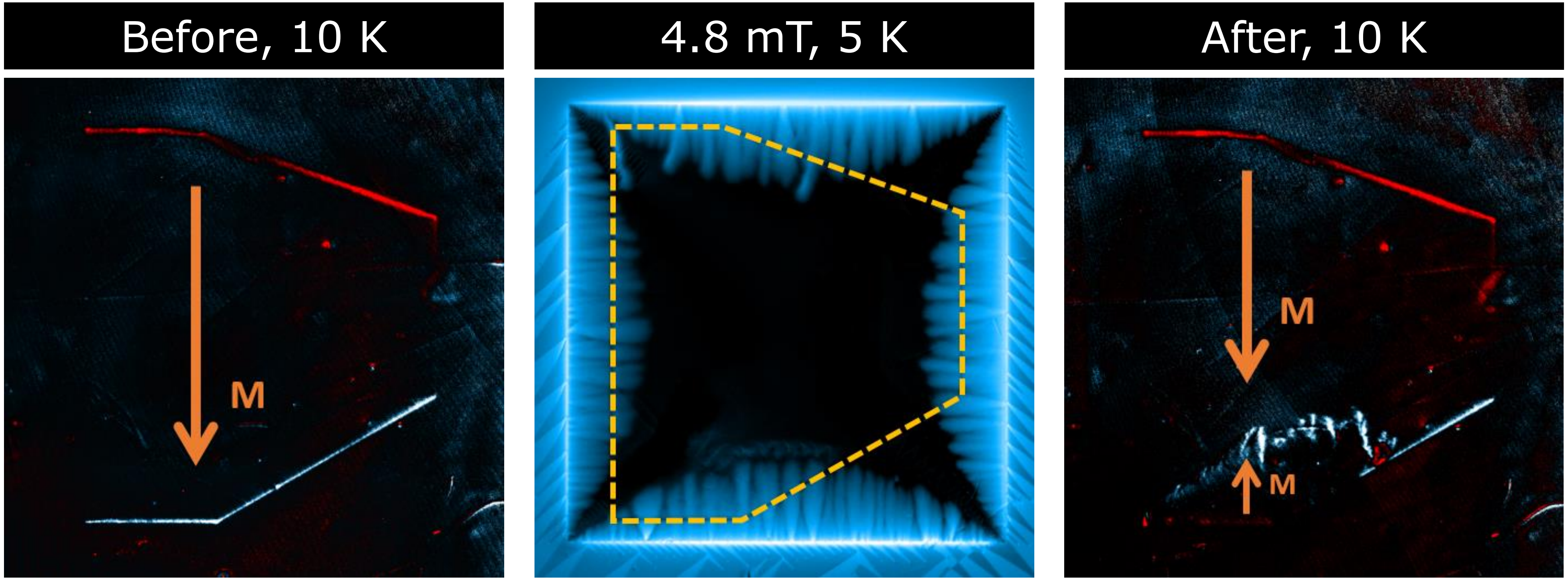
Vortex footprints in the Py layer

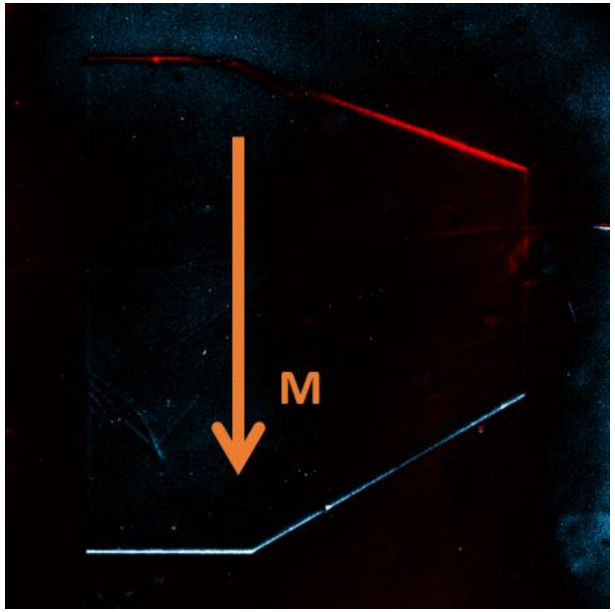


The reversal of the in-plane magnetization leaves a head-to-head domain wall with out-of-plane field.

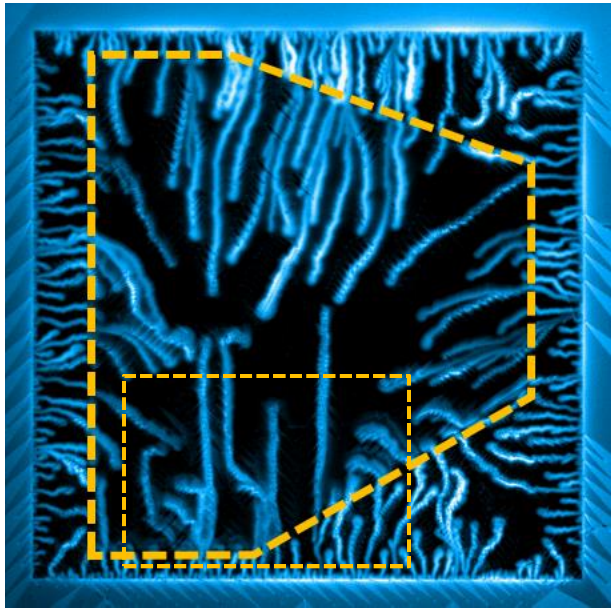
J. Brisbois *et al.*, *Sci. Rep.* **6**, 27159 (2016). L. Uspenskaya *et al.*, *JAP* **113**, 163907 (2013).

Imprinting flux avalanches

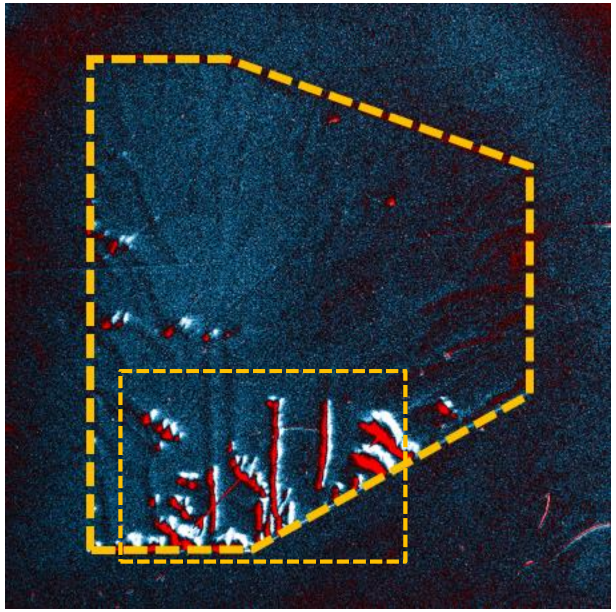
Before, 10 K



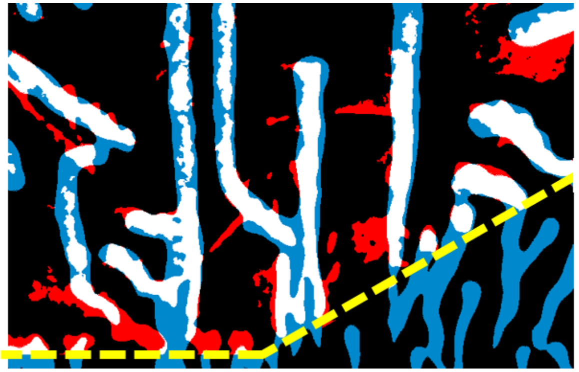
5 mT, 2.5 K



After, 10 K



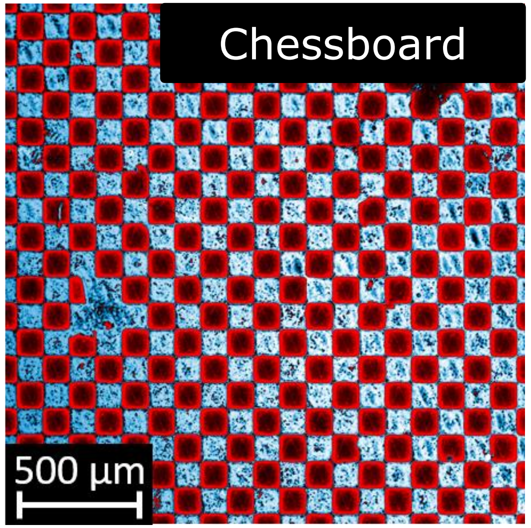
Guiding along the direction of magnetization

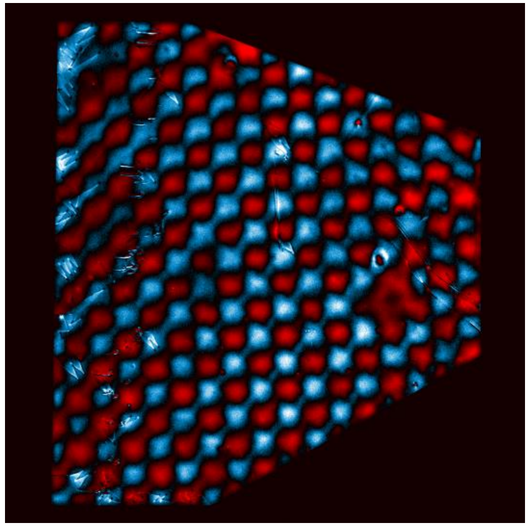


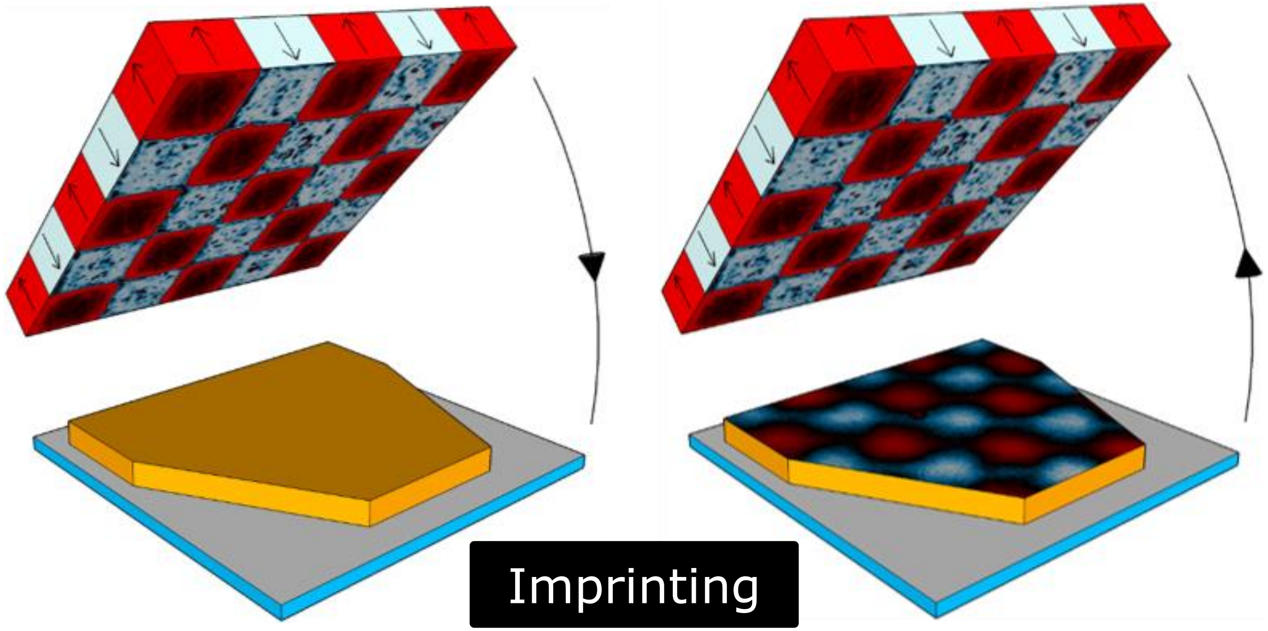
Printings are stable, even up to room temperature!

J. Brisbois *et al.*, *Sci. Rep.* **6**, 27159 (2016).

Room temperature printings





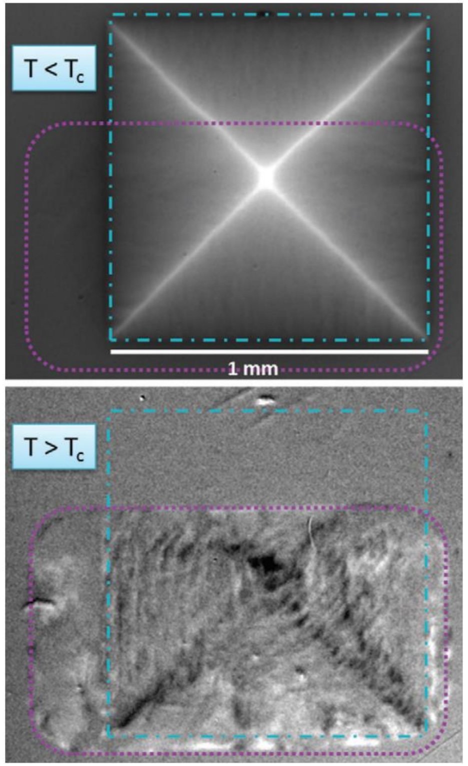


Imprinting works also at room temperature
→ tune the magnetic landscape at will

J. Brisbois *et al.*, *Sci. Rep.* **6**, 27159 (2016).

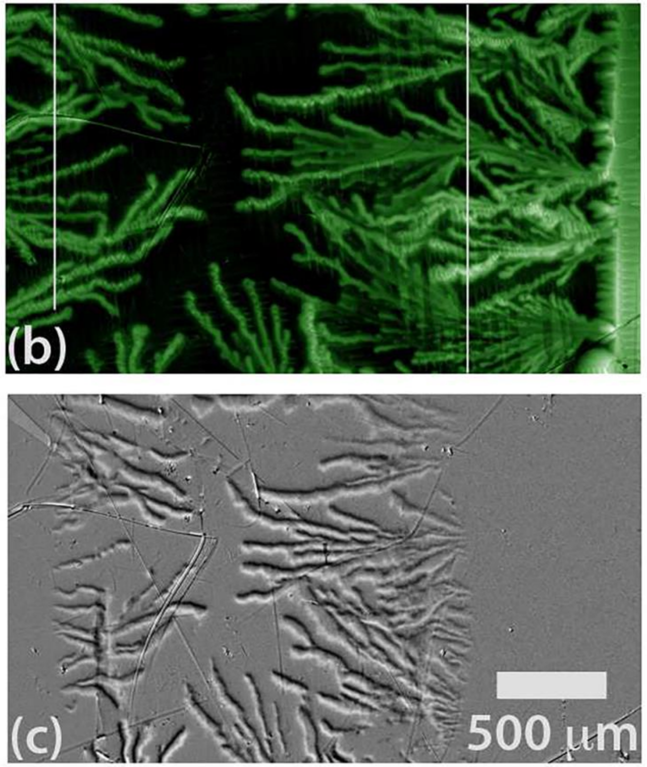
Conclusions

- ✓ Flux is guided by the Py layer.
- ✓ Flux penetration (smooth and avalanches) can be imprinted in a magnetic layer.
- ✓ The printings are stable and can even be observed at room temperature.



Perspectives:

- ✓ Improve the magnetic recording of flux penetration
- ✓ Tune the magnetic landscape at will to guide flux/avalanches



C. Stahl *et al.*, *EPL* **106**, 27002 (2014). R. F. Lopes *et al.*, *J. Appl. Phys.* **121**, 13905 (2017).

Additional information: J. Brisbois *et al.*, *Sci. Rep.* **6**, 27159 (2016).
EPNM website: www.mate.ulg.ac.be

Thank you for your attention!

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