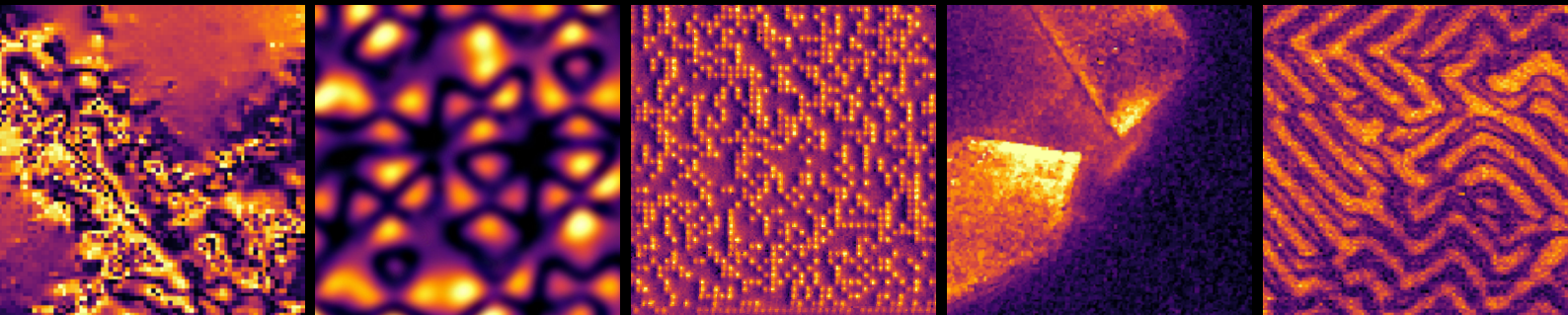




Image Gallery

A selection of measurements performed with ProteusQ



“There is an art to science, and a science in art;
the two are not enemies, but different aspects
of the whole.”

Isaac Asimov

Explore the beauty of the very small with ProteusQ

With the Image Gallery we display a selection of the measurements done by Qnami's Application Scientists in collaboration with researchers from all over the world.

Using ProteusQ, the team was able to quantitatively image a broad range of material systems and magnetic phenomena.

This collection shows how, with our Scanning NV Magnetometer, users can investigate magnetism at the nanoscale, bring unique innovative insight to materials engineering and push the frontiers towards next-generation devices.

Enjoy the journey.

MRAM

Magnetic Nanowires

Nanomagnets

Current Flow in Nanostructures

Multiferroics for Spintronics

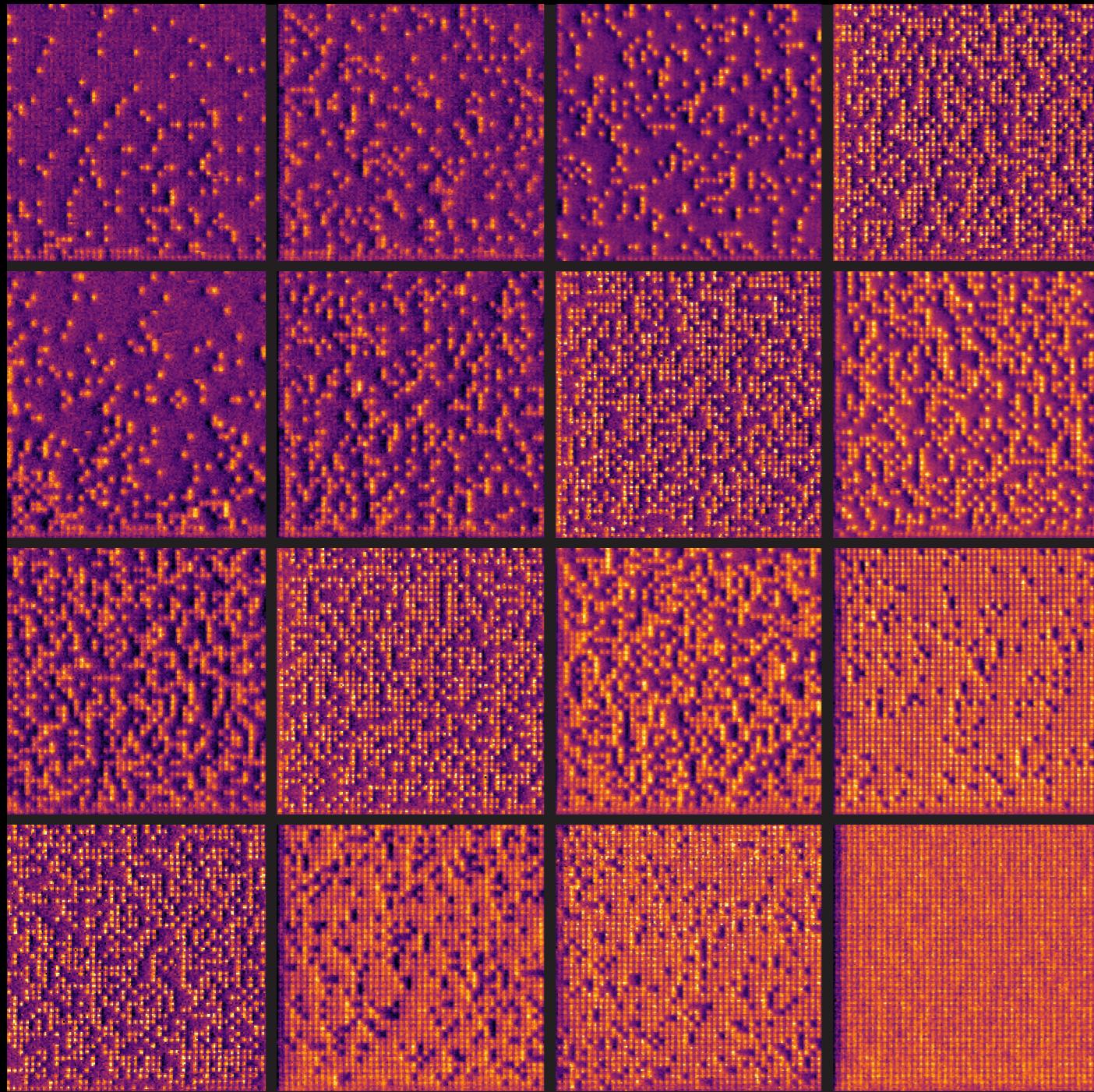
Artificial Spin Ice

Heusler Compounds

Nanopatterned Thin Films

Extreme Topography


And Beyond



MRAM

Push the frontiers towards sustainable and efficient magnetic memories

Thanks to the proven stability of ProteusQ users can perform long-term imaging cycles without worrying about drift while also applying external polar magnetic fields with the fully integrated Magneto PQ.

 V. Borrás et al. arXiv:2306.15502

Each image of the shown grid is taken after applying a magnetic initialization and switching protocol. The scale of each image is $\sim 10 \mu\text{m} \times 10 \mu\text{m}$
Sample: STT-MRAM chips of 50 nm diameter, with 200 nm pitch, measured on top of a 200 nm thick encapsulation layer

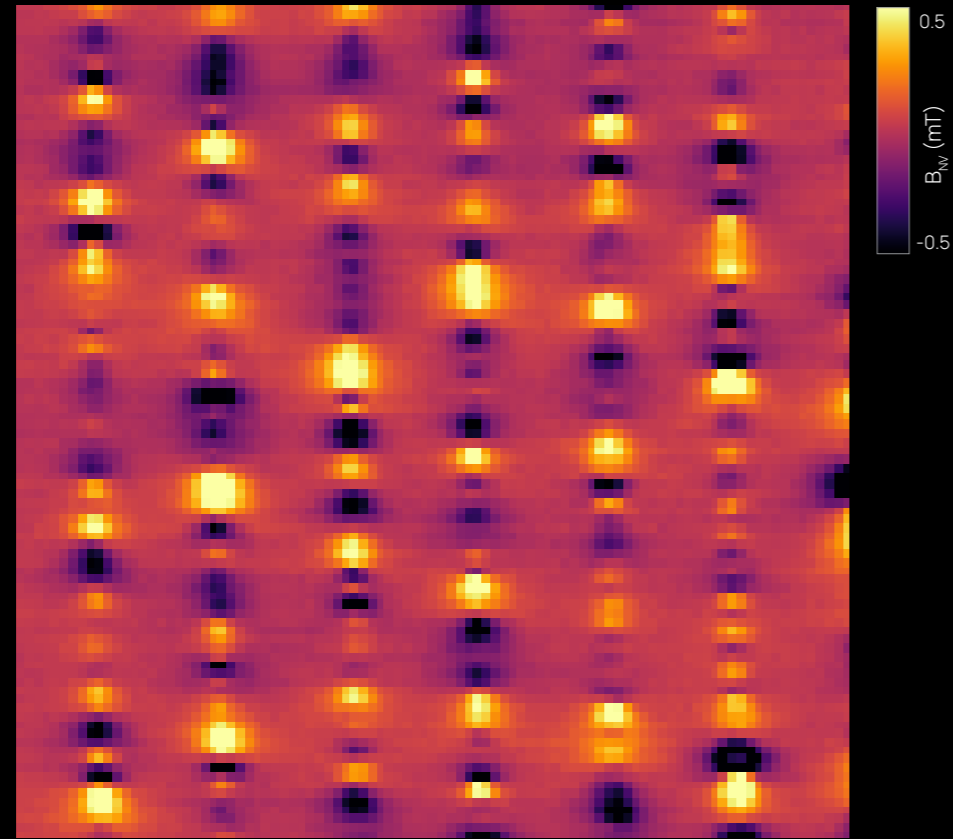
Magnetic Nanowires

Appraise wafer-scale CMOS fabrication for novel race-track memories

The high sensitivity and spatial resolution of ProteusQ allow users to detect weak magnetic inhomogeneities that could deteriorate the quality of the memory wires as potential pinning sites for skyrmions and domain walls.

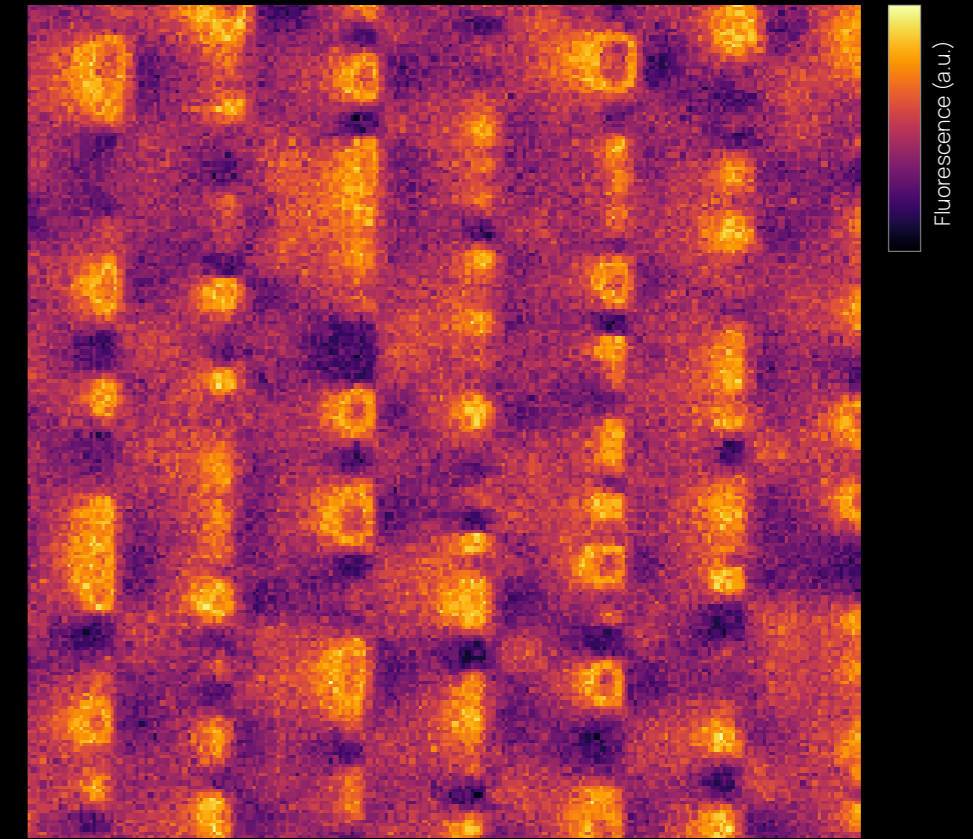


 U. Celano et al, Nano Lett. 2021, 21, 24, 10409–10415



0.4 μm

Full B magnetic map
Sample: CoFeB ultrascaled nanowires (6 nm wide)



0.4 μm


Dual Iso B magnetic map
Sample: CoFeB ultrascaled nanowires (6 nm wide)

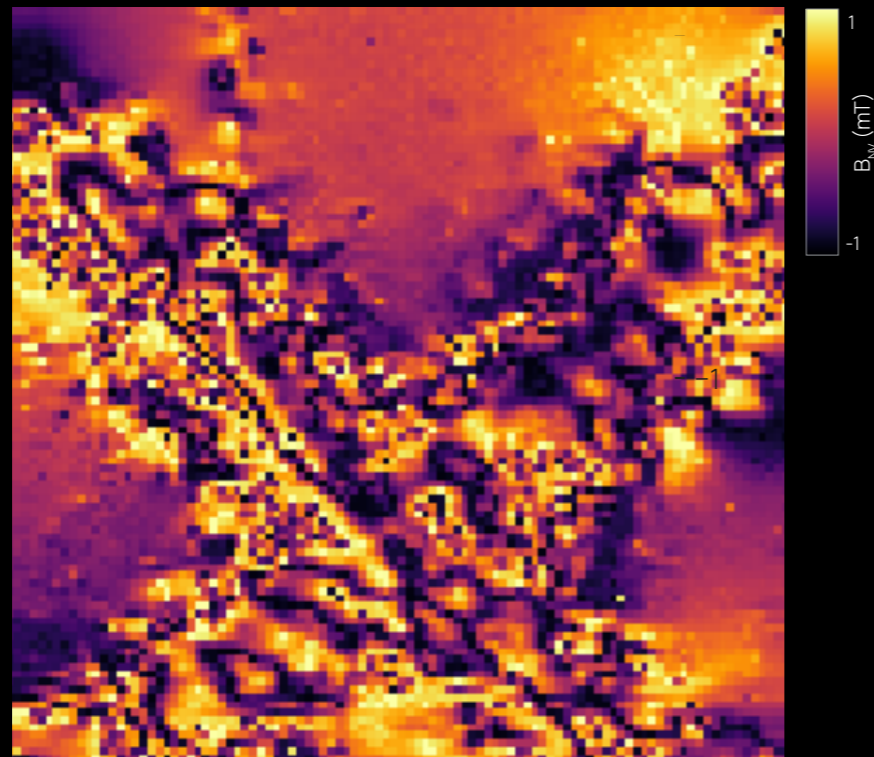
Nano- magnets

Improve device fabrication by assessing artefacts

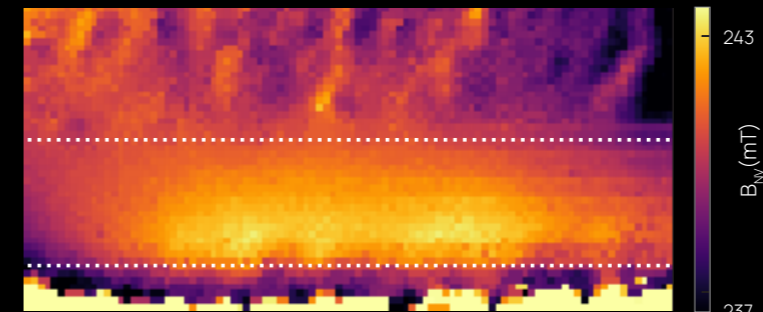
Among state-of-the-art Scanning Probe Magnetometry technologies, Scanning NV Magnetometry is the one showing the spatial resolution and sensitivity to image magnetic fields at length scales relevant to spin qubit devices.

ProteusQ's accuracy is consistent for a wide range of measured stray magnetic fields: from weak magnetic fields coming from small halo particles to high magnetic fields coming from the entire Cobalt structure.

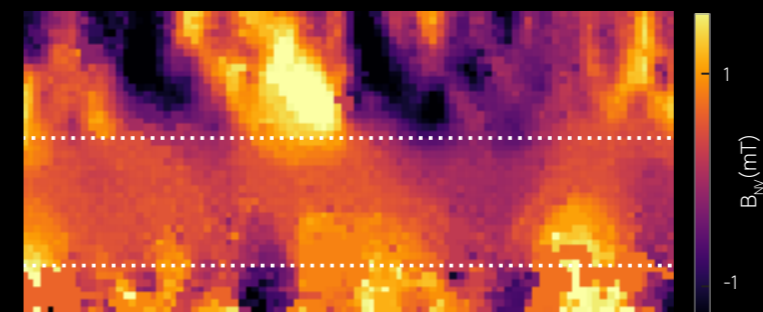
 L. Zaper et al, arXiv:2306.06650



0.6 μm Full B magnetic map at an intersection of two nanomagnets
Sample: FEBID patterned Co nanomagnets



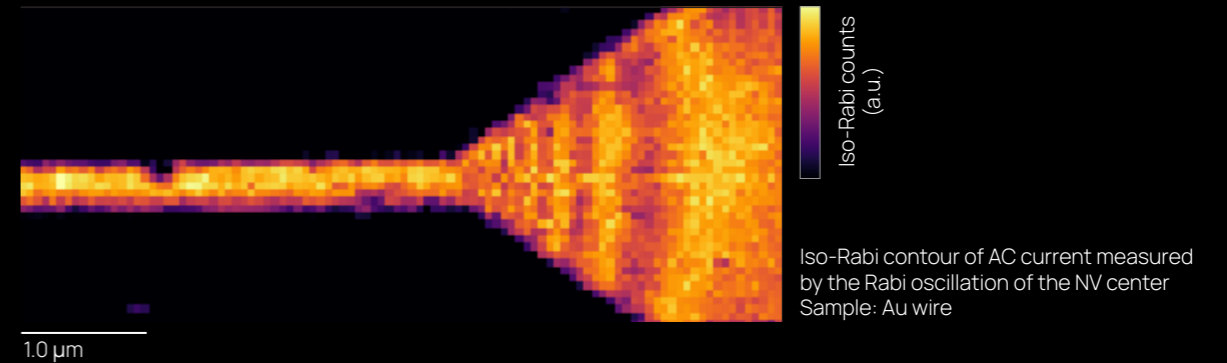
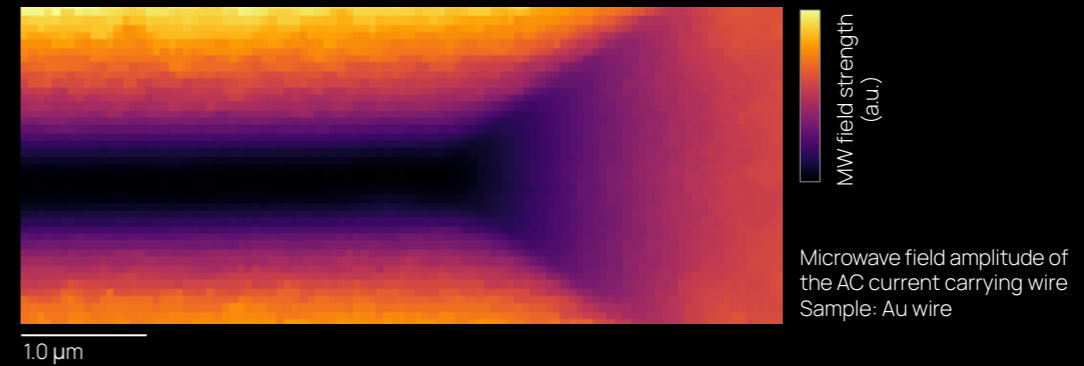
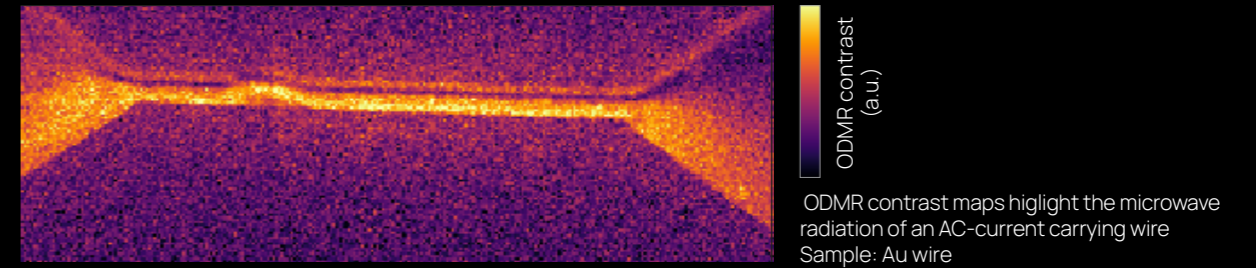
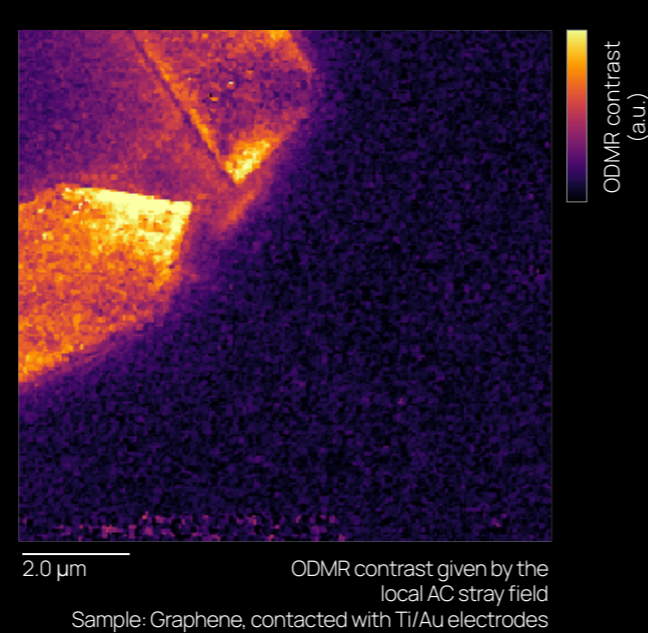
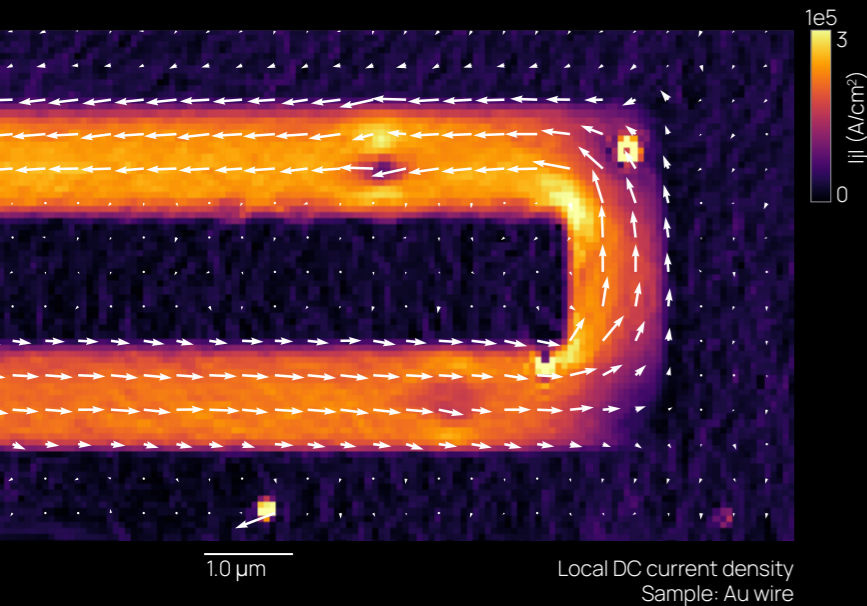
0.5 μm Full B magnetic map measured under the effect of a high in plane bias magnetic field (240 mT)
Sample: FEBID patterned Co nanomagnets



0.5 μm Full B magnetic map. Without the effect of an in-plane bias magnetic field, the sample decays again in magnetic domains
Sample: FEBID patterned Co nanomagnets

Current Flow in Nanostructures

Optimize transport devices for DC and RF currents



ProteusQ together with the Vario PQ sample holder allows measurements while applying varied external parameters such as current or voltage.

The ProteusQ's stability, together with the integrated pulsed measurements, and the enhanced signal-to-noise ratio of the Quantilever MX+ enable high-sensitivity noise spectroscopy mapping measurements to go beyond the state-of-the-art current flow characterization and accelerate the optimization of the device design.

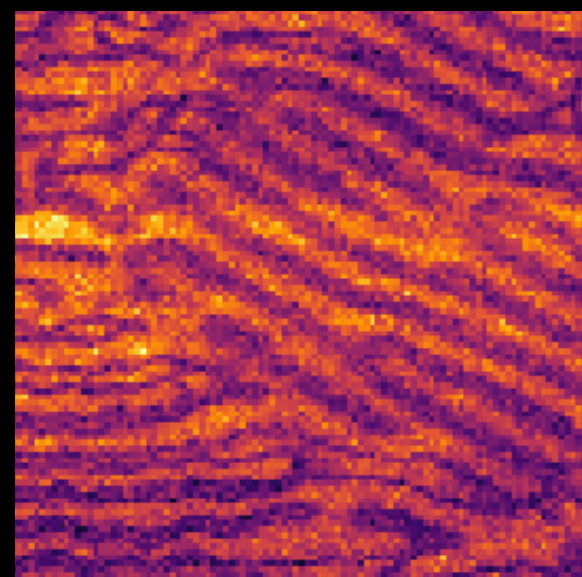
Multiferroics for Spintronics

Bring material engineering to the next level

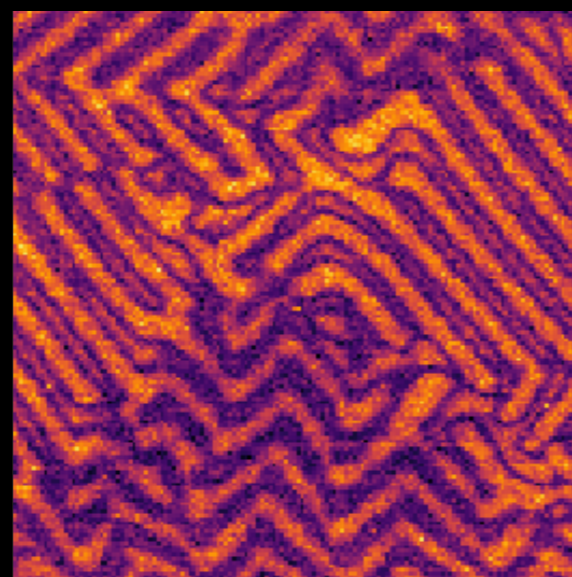
Fast sample turn-around and a wide range of optimized measurement modes allows the user to rapidly match the best mode to each sample, increasing measurement efficiency and drastically reducing the time to results.



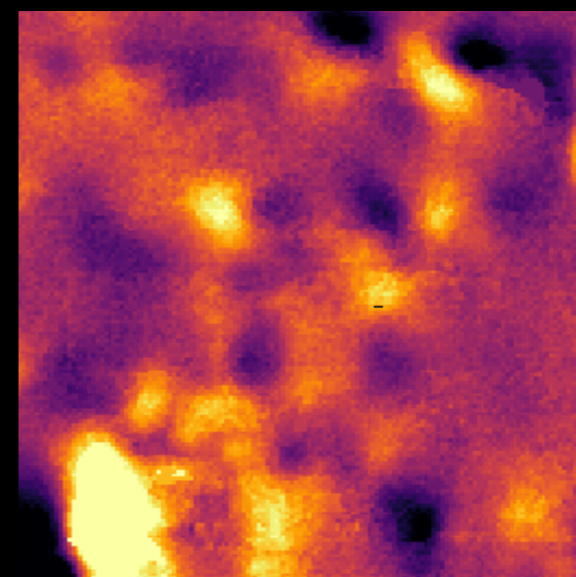
 H. Zhong et Al. Phys.Rev. Applied 17, 044051



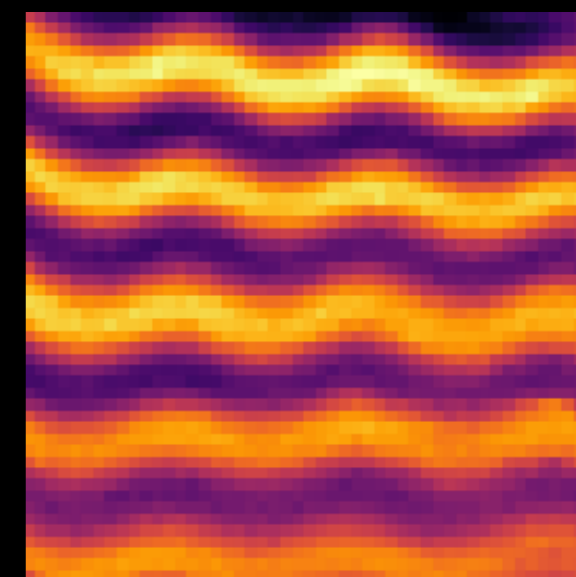
0.4 μm
Dual Iso-B magnetic map
Sample: $\text{BiFeO}_3/\text{DyScO}_3$



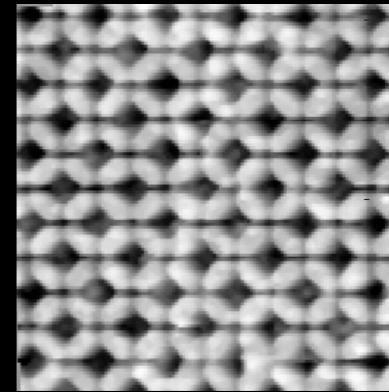
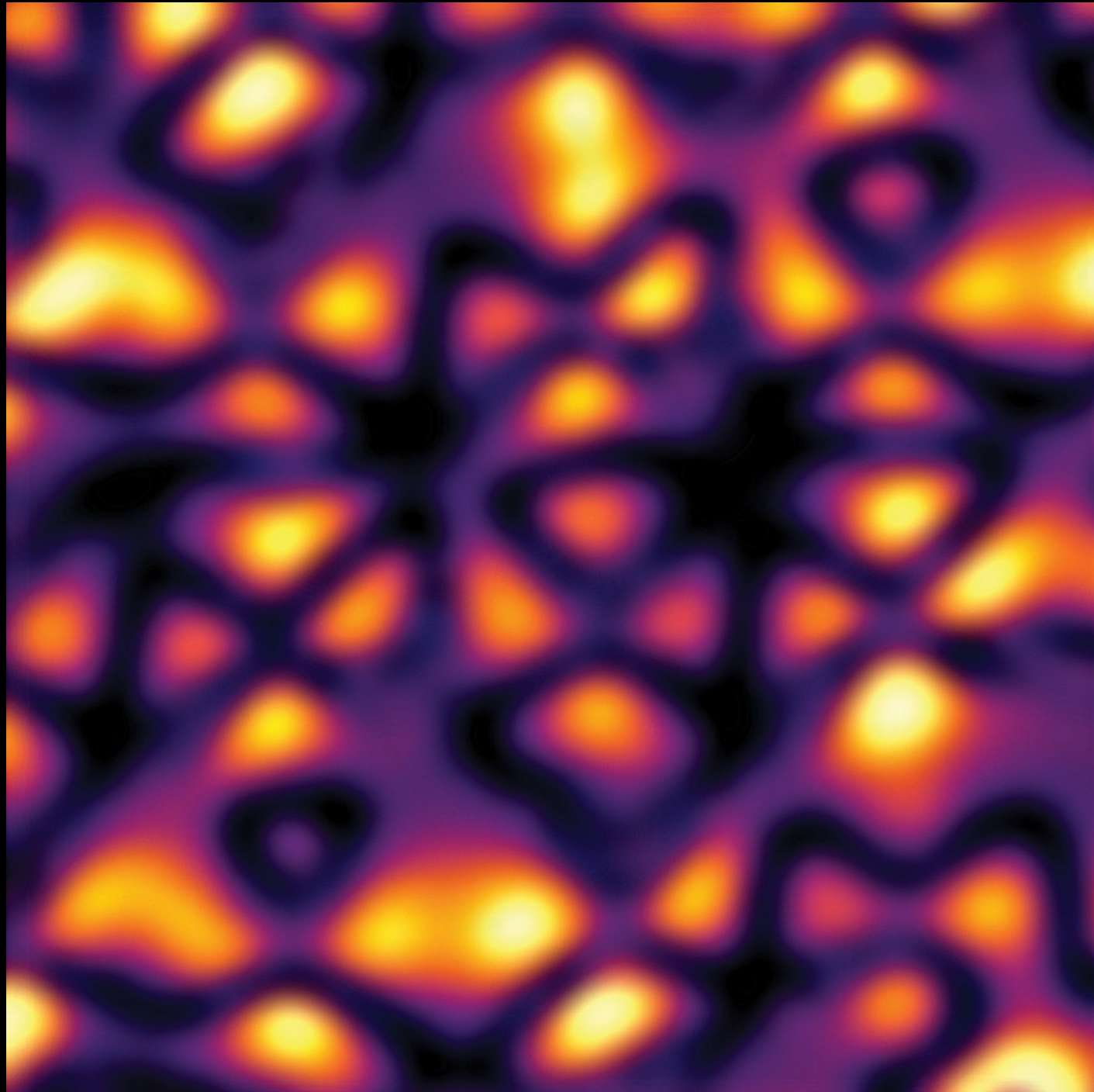
0.2 μm
Single Iso-B map
Sample: $\text{BiFeO}_3/\text{DyScO}_3$



0.3 μm
Ultrasensitive pulsed magnetic map
Sample: $\text{BiFeO}_3/\text{SrRuO}_3/\text{DyScO}_2$



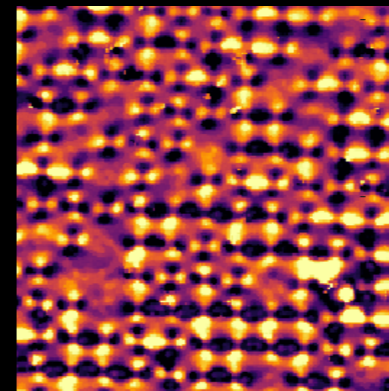
0.1 μm
Full B magnetic map
Sample: $\text{BiFeO}_3/\text{SmScO}$



Height (nm)
20
-20

Topography map
Sample: Co nanomagnets

2.0 μm



B_{av} (mT)
1.5
-1.5

Full B magnetic map
Sample: Co nanomagnets

2.0 μm

Full-B magnetic map
Sample: nanomagnets

Unlike with other probe microscopies such as MFM, ProteusQ allows the user to characterize and fine-tune the properties of artificial spin ice structures without perturbing them.

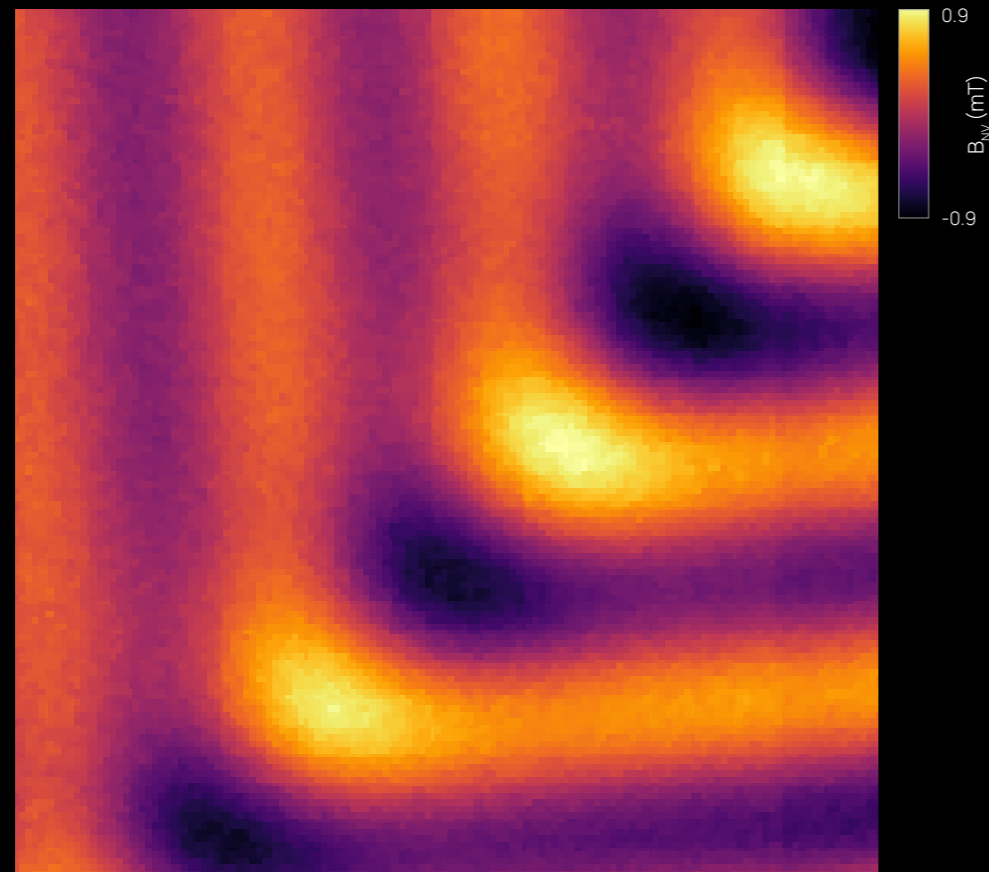
Thanks to unique Quantilever MX design, high-quality topographic images can be performed to assess both structural and magnetic properties of the sample.

Heusler Compounds

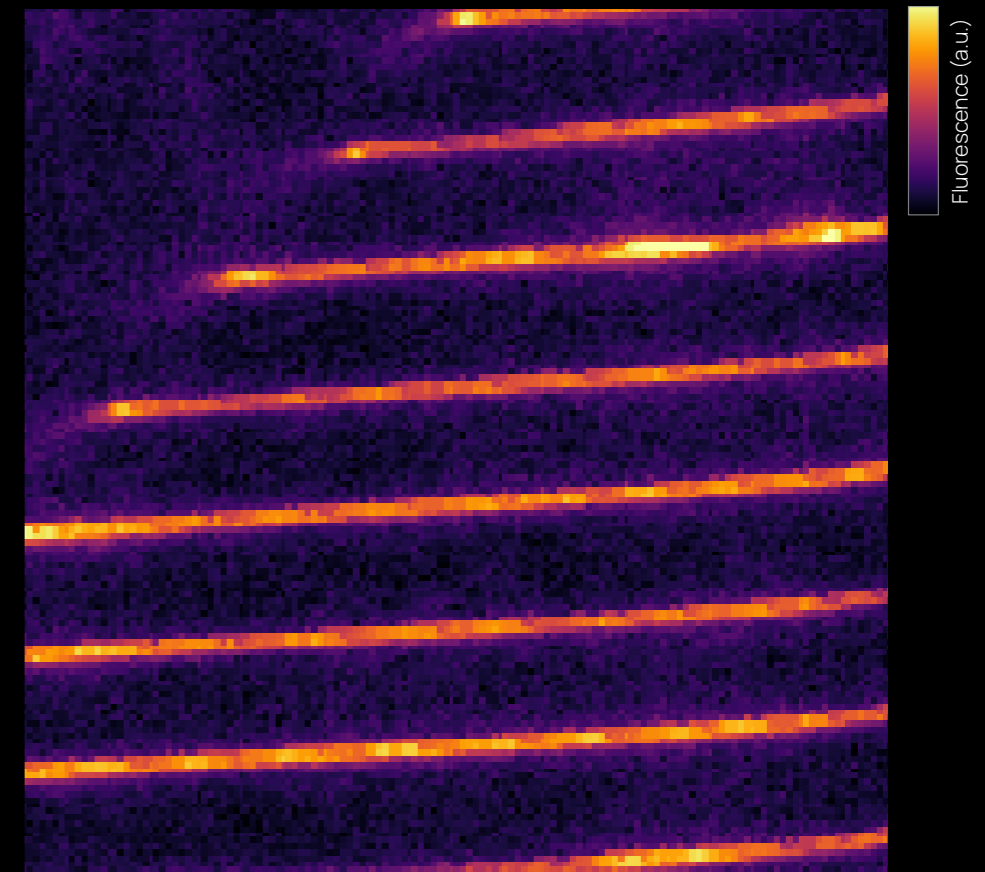
Unlock the potential for future spintronics devices

The stripe phase in ferromagnetic thin films is a hallmark for skyrmions. The stray magnetic field in such samples leads to quenching of the NV center when landed, an effect that can be exploited for high-resolution imaging. At a larger tip-to-sample distance, the quenching effect becomes weaker, permitting a quantitative measurement of the magnetic field.

By combining the quenching and the lifted two-pass modes available with ProteusQ, users can both localize the chiral band domains and quantify their magnetic field.



Full B magnetic map with lifted mode
Sample: Heusler compound with chiral band domains

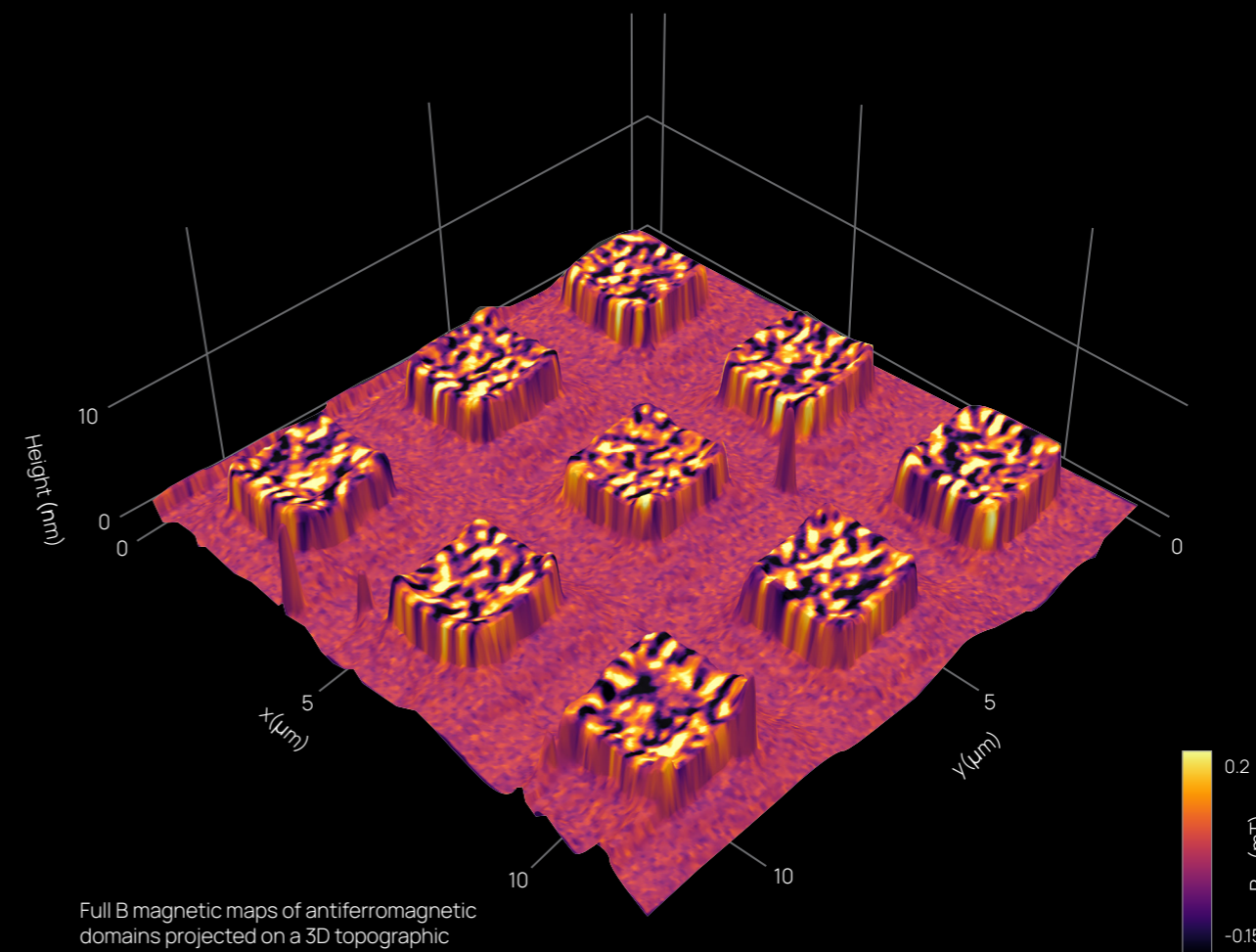
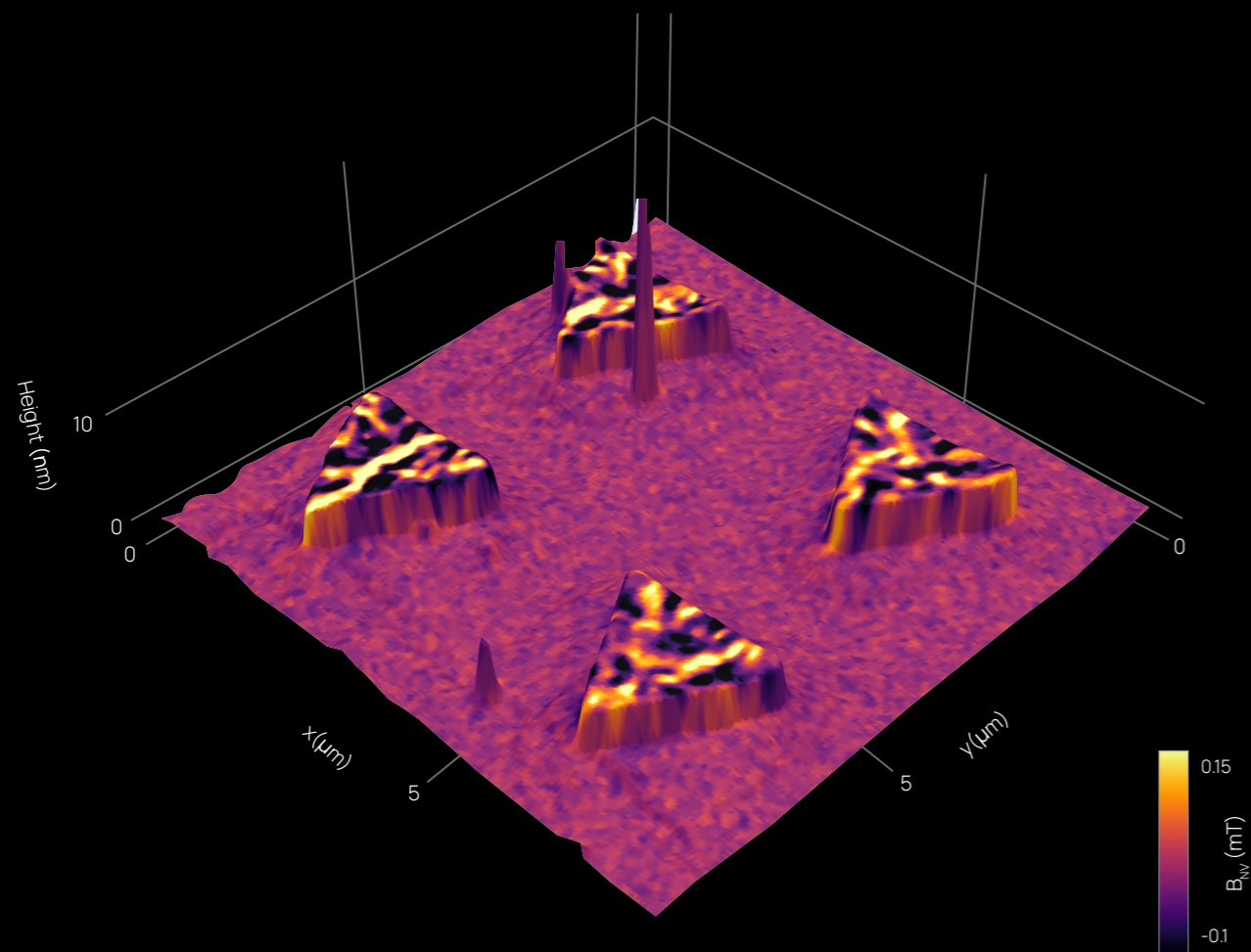


Quenching mode map (<50 nm spatial resolution)
Sample: Heusler compound with chiral band domains

Nanopatterned Thin Films

Understand the interplay of structure and magnetic order of nanoscale magnetic bits

The full data set available by using the ProteusQ software, LabQ, allows the user to obtain both magnetic and topographical information on their samples. This unlocks the understanding of the interconnection between small magnetic textures and geometrical boundary conditions.



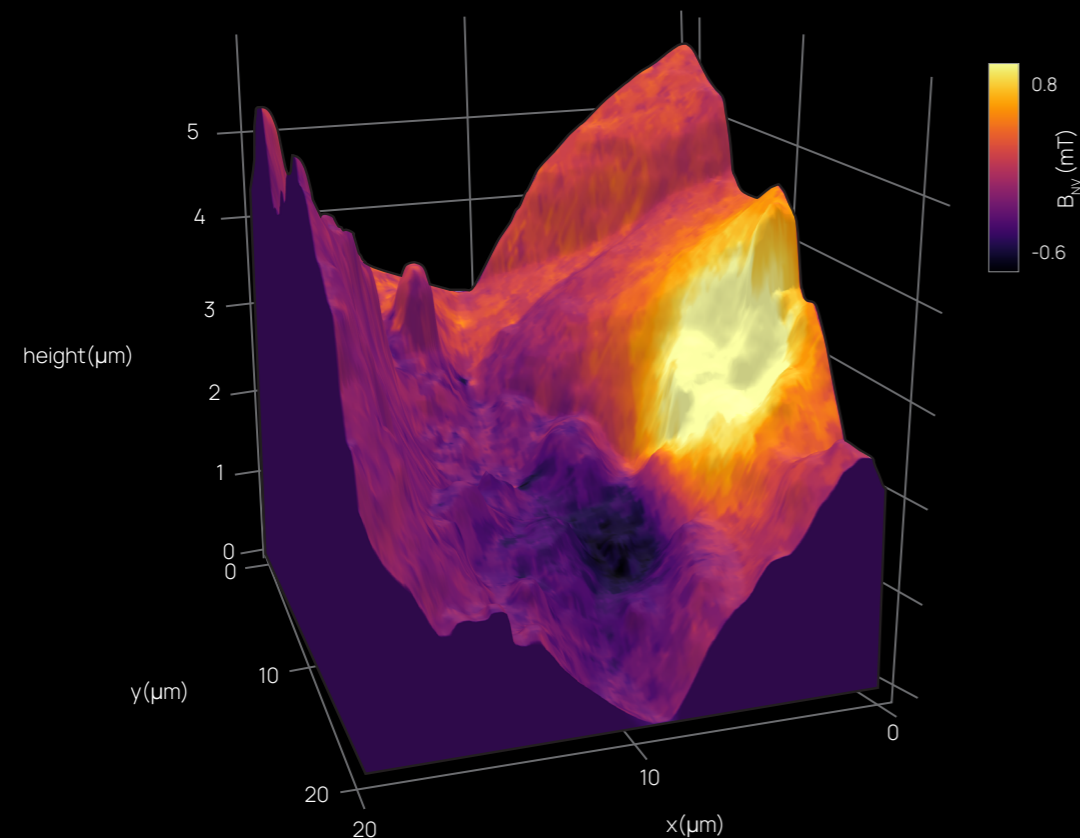
Full B magnetic maps of antiferromagnetic domains projected on a 3D topographic image of differently shaped nanostructures
Sample: $\text{La}_{0.67}\text{Sr}_{0.33}\text{FeO}_3$

Extreme Topography

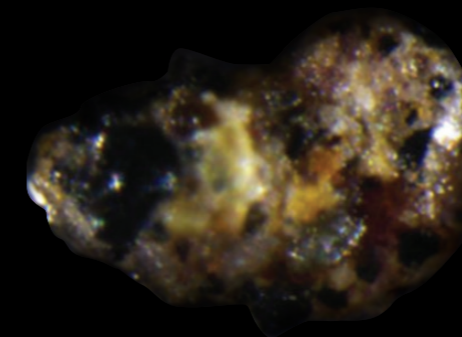
Inspect nanomagnetism on highly topographic structures



The scanning probe (left) and the microwave antenna (right) approaching the sample (in the lower part of the image) to start the measurement. Image taken with the ProteusQ side view camera.



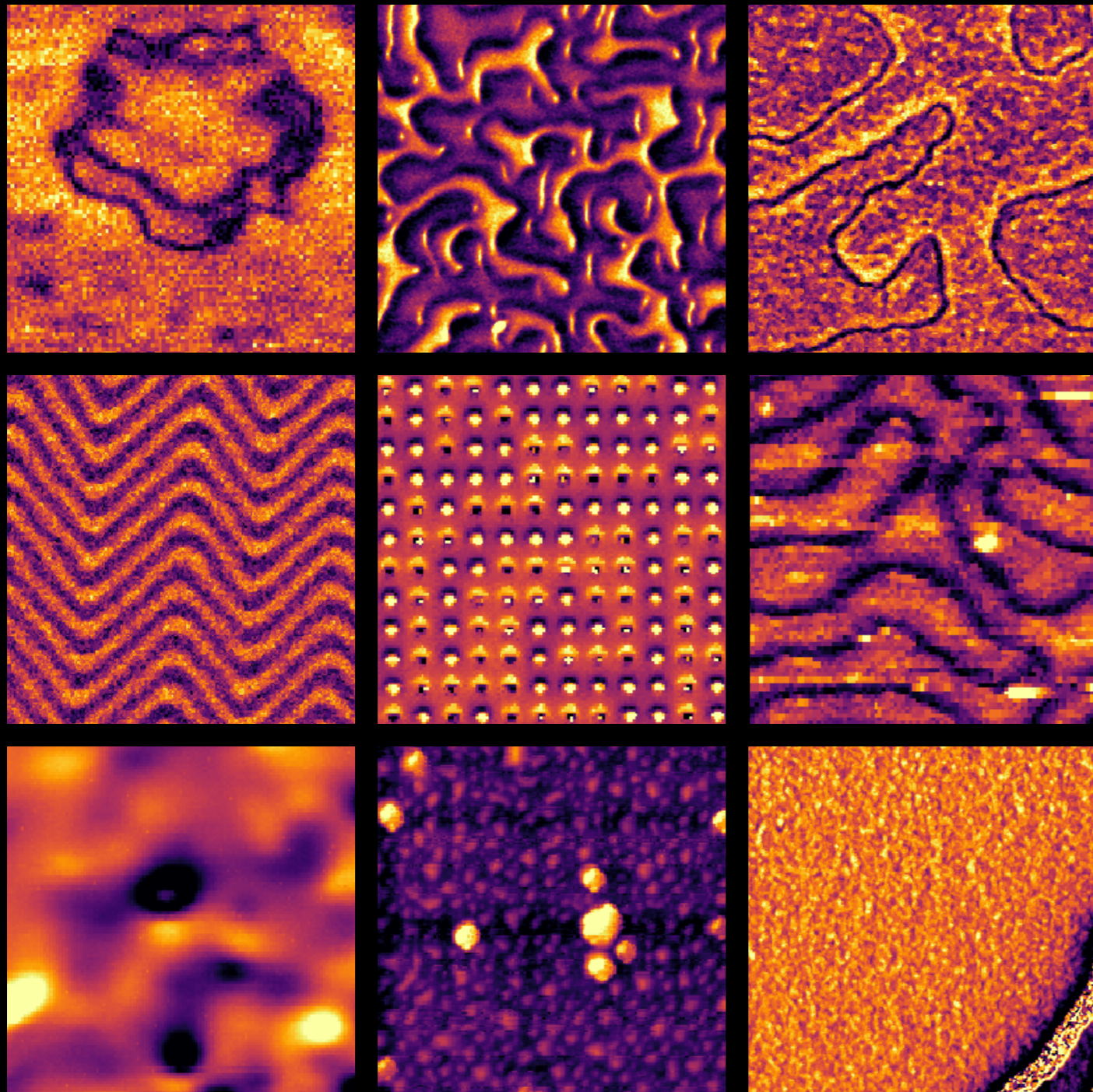
Full B magnetic map projected on a 3D topographic image of the sample



Sample: a mineral shell of Foraminifera

The large, precise dynamic range of the ProteusQ closed-loop positioning together with the optimal AFM performance of the Quantilever MX, allows accurate tracking and magnetic probing at the nanoscale even of a few microns rough samples.

This curious monocellular creature usually creates a shell out of chalk, digesting the rocks in its usual habitat. However, when ferrous rock is available it will use this, resulting in magnetic particles on its shell.



And Beyond

Make sense of the very small

ProteusQ empowered researchers to make sense of a variety of material systems and magnetic phenomena, ranging from memory devices to nanoparticles, from artificial spin ice systems to mineral shells. The team already looks forward to the next ones to come.

Do you have a sample you would like to analyze with ProteusQ? Would you like to assess its magnetic properties at the nanoscale, unveil its complex magnetic textures, and gain a deeper understanding of it? Let's talk.

Scan the QR code to check with our team if your sample is eligible for a free proof-of-concept measurements. Your image may be featured in the next edition of our Image Gallery.



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