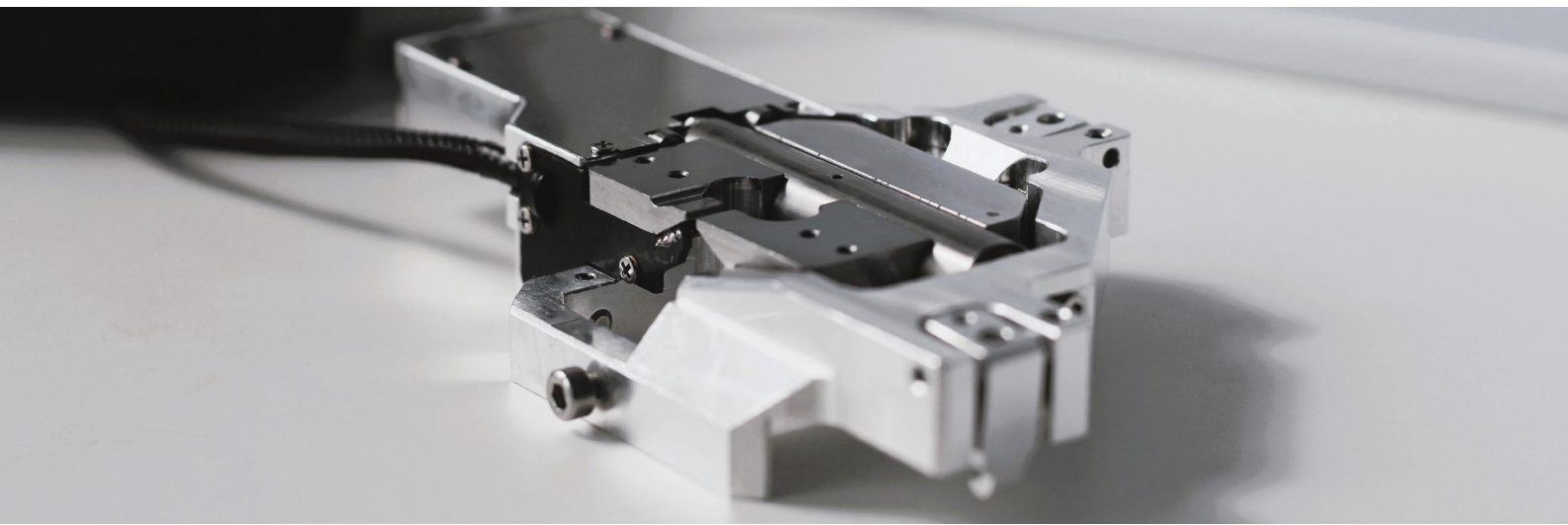# Magneto PQ

Scanning NV Magnetometry in a tunable bipolar magnetic field

May 2023

Extended characterization capabilities in bias magnetic fields

Magneto PQ is a bipolar magnet designed to provide precise and reliable external magnetic fields in a controlled and repeatable fashion. Combined with ProteusQ, it enables the user to probe magnetic nano-structures under external magnetic fields with the unprecedented precision of Scanning NV Magnetometry. Together, the two allow for easy design validation of novel magnetic devices.
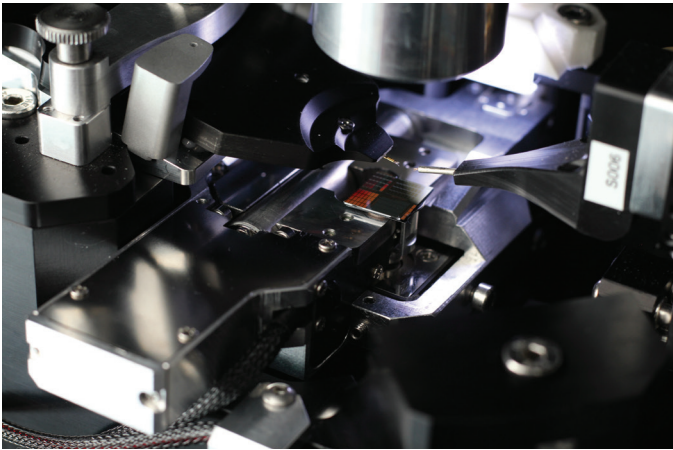
○ **POLARITY**
apply positive and negative field to perform full hysteresis loops and provide valuable insight into the magnetic properties of a wide range of materials

○ **AUTOMATED OPERATION**
run complex measurements protocols and acquire high confidence data hassle-free
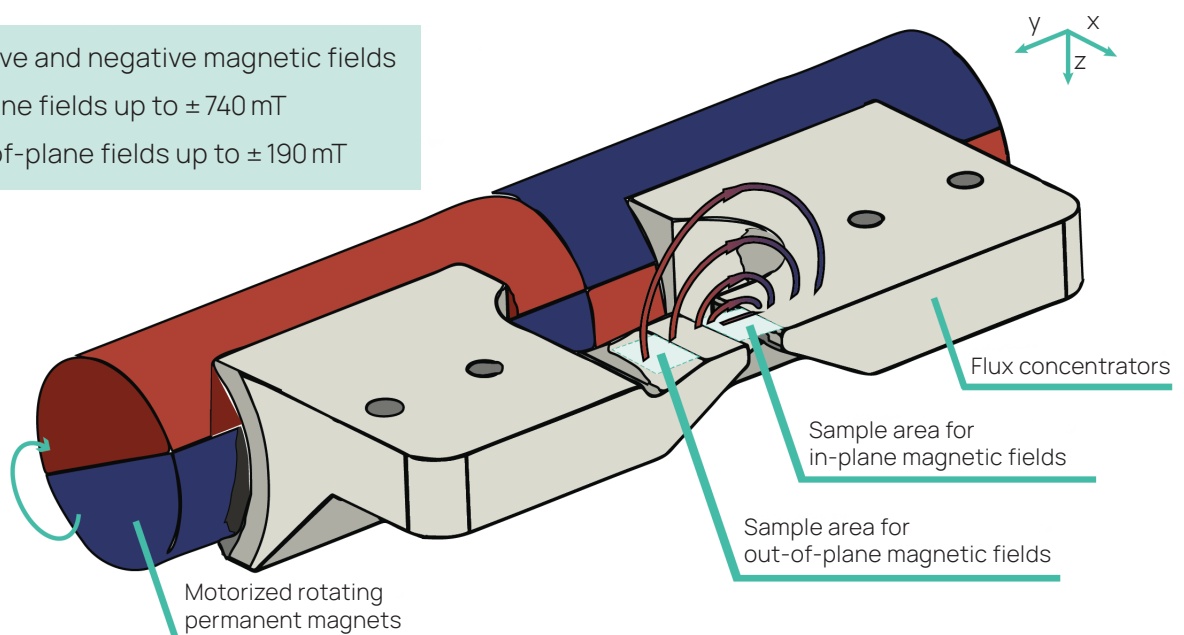
○ **STRONG FIELDS**
condition magnetic textures and topological structures in a wide range of materials at room temperature

Strong polar magnetic fields without sacrificing imaging resolution

The fully integrated and compact design of Magneto PQ is based on motorized permanent magnets and flux concentrators that generate strong positive and negative magnetic fields in the region of interest. The design allows users to easily switch between in-plane (IP) and out-of-plane (OOP) magnetic fields to probe any sample according to their needs.

In Magneto PQ, permanent magnets avoid the need for water cooling (which induces experimental complexity). The mounting frame keeps the magnet mechanically decoupled from the sample and the NV probe to further avoid mechanical vibrations. This results in greater flexibility and less vibration to ensure accuracy in the measurements and maintain AFM contact while tuning the magnetic fields.

- Positive and negative magnetic fields
- In-plane fields up to ± 740 mT
- Out-of-plane fields up to ± 190 mT

Flux concentrators

Sample area for in-plane magnetic fields

Sample area for out-of-plane magnetic fields
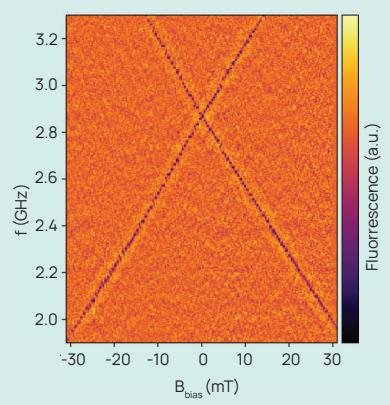
Motorized rotating permanent magnets

Complex measurement protocols made simple

The operation of Magneto PQ is fully integrated in the ProteusQ software and guarantees reliable and consistent results. With the ability to enter any given position of the sample and get the required field strength from the magnet in that position, Magneto PQ saves time and effort in adjusting the magnet and ensures precise measurements.

ProteusQ's unrivalled thermal stability and closed-loop piezo positioners allow full access to the sample and tip area during experiments, while enabling unattended measurements of magnetic imaging cycles over several hours.

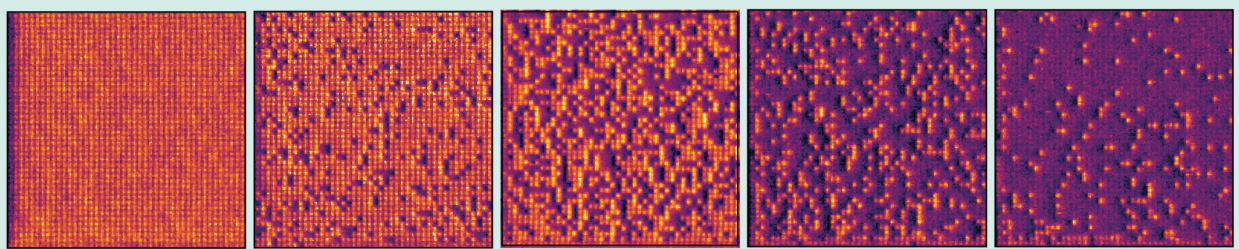## Three simple steps to perform complex measurement protocols

CALIBRATE

SET

```python
for scan in scan_data:
    # Set Magnet field
    set_magnetic_field(scan['b_field_gs'])
    # Create ODMR sequence
    odmr_sequence = create_odmr()
    # Perform XY scan and execute the ODMR
    odmr_data = execute_scan(sequence=odmr_sequence)
    # Calculate the B field per point and plot it
    plot(calc_b_field(odmr_data))
```

MEASURE

○ **CALIBRATE**
A guided routine helps the user to check and optimize the alignment of the NV quantization axis with the magnetic field for best performance.

○ **SET**
Through easy-to-use scripts in Jupyter Notebook and full access to all relevant parameters in the software, tailoring measurement protocols to specific experiments becomes intuitive and comfortable.

○ **MEASURE**
The closed loop scanner and high stability of ProteusQ enables users to perform hours of magnetic imaging cycles without losing the exact mapping area (e.g., 5 imaging cycles of 5 hours each were performed using the full magnet range and resulted in a total drift of 200 nm).

Extending the characterization capabilities of ProteusQ

The Magneto PQ is a compact magnetic field source fully integrated in the ProteusQ microscope. With it, the user can apply strong positive and negative magnetic fields both in-plane (IP) and out-of-plane (OOP) with respect to the sample, to probe the magnetic properties of novel materials and devices.

Key Specifications

Dimensions	118 x 68 x 20 mm	
Sample accessibility	Top and Side high-NA access (100x, NA 0.7)	
Device compatibility	ProteusQ SNVM	
	Beam deflection SPM head (HE002)	
Travel ranges (X, Y, Z)	5 x 5 x 5 mm	
Smallest adjustable field increment	< 0.2 %	
Bi-directional repeatability	< 1% of adjusted field	
Overshoot	< 1 mT	
In-plane B field	Distance above surface	B max
	0 mm	± 740 mT
	0.5 mm	± 570 mT
	1.0 mm	± 410 mT
Out-of-Plane B field	Distance above surface	B max
	0.5 mm	± 190 mT
	1.0 mm	± 130 mT
Field homogeneity	< 0.1% in X	
	< 2% in Y, Z	
Probe compatibility	Quantilever DX	
	Quantilever MX [111], [110] & [100] < ±2 deg	
	Quantilever MX+	
Software integration	Integrated in LabQ	
	Jupyter Notebook integration / scripting mode	
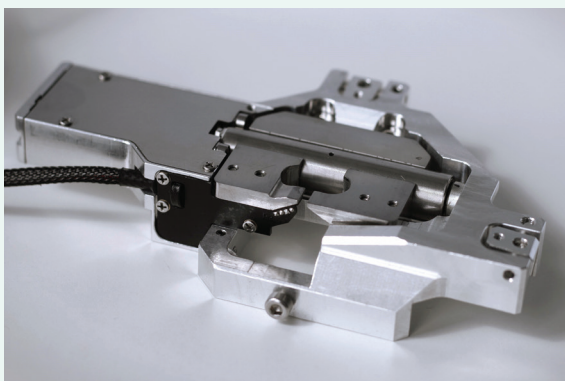
Next level in precision

Qnami ProteusQ™ is a complete quantum microscope. It is the first scanning NV (nitrogen-vacancy) microscope for the analysis of magnetic materials at the atomic scale.

Qnami ProteusQ™ comes with state-of-the-art electronics and software. Its flexible design allows for future adjustments and scaling, expansion, and capability upgrades.

The proprietary Qnami ProteusQ™ quantum technology provides high precision images for you to see directly the most subtle properties of your samples and the effect of microscopic changes in your design or fabrication process.

Qnami ProteusQ™

Magneto PQ is the ultimate magnetic characterization add-on of Qnami ProteusQ. It allows the user to apply external magnetic fields while benefiting from the ultra-high precision of scanning NV magnetometry to probe a wide range of magnetic phenomena and validate the design of novel devices.