

Qnami ProteusQ™

Capture surface magnetic fields at the atomic scale

Product Overview

Key Features

- **Low drift** Scanning NV Magnetometer (SNVM) for room temperature operation
- **Ultimate magnetic resolution** with Qnami Quantilever™ probes
- **Quantum performance** to map a wide range of magnetic signals
- **Single electron spin sensitivity** to capture magnetic signals at a single atomic layer
- **Qualitative and quantitative** analysis modes for robust sample investigation

Designed for ease of use

- **Turnkey instrument** requires no NV expertise to use and record images
- **No optical realignment** required for confocal microscope
- **Safe and quick** probe and sample exchange
- **Intuitive software** interface for automated sample approach and NV readout
- **Programmable** LabQ control and measurement software

Upgradeable with selected options

- DC magnetometry signal and speed boost modes
- AC magnetometry and pulsed measurement modes
- Advanced Scanning Probe Microscopy (SPM) functionality
- External magnet

Patented

The only Scanning NV magnetometer produced under license to patent family WO2014051886A1 from Harvard University

Applications

Magnetometry

- Magnetic nanostructures and spintronics applications
- Domain wall analysis, exotic magnetic textures
- Ferromagnets, antiferromagnets, multiferroics
- 2D materials

Thermometry

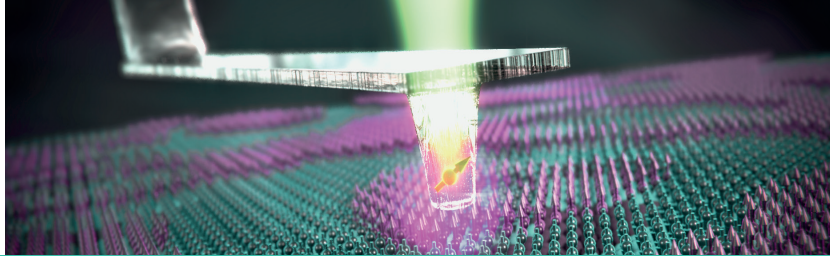
- Surface temperature imaging
- Locate thermal defects
- Identification of nanoscale thermogenic sources

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Specifications



NV Magnetometry

○ Magnetic sensitivity

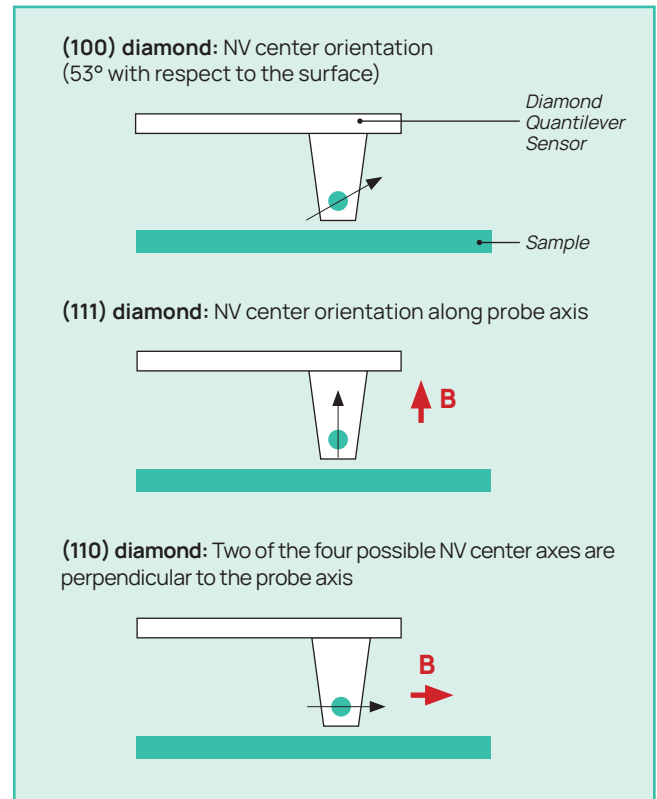
Better than $2\mu\text{T}/\sqrt{\text{Hz}}$ in continuous wave operation mode (CW-ODMR: Continuous Wave – Optically Detected Magnetic Resonance spectroscopy)

○ Magnetic spatial resolution

Entirely defined by the NV center distance to the sample surface (insertion depth plus scanning height)

○ Optimized nanoscale magnetic sensors

- Patented Qnami Quantilever™ Sensor Technology
- Optimized for high optical throughput and unprecedented resolution
- Natively compatible with Qnami ProteusQ™
- A starter pack of 10 Qnami Quantilever™ MX probes is included
- Available with three insertion depths to meet application-specific requirements: 10nm, 18nm, or 28nm
- Available in three orientations for optimal application choice (graphical representation on the right)



SPM Platform

○ Sample Size

Max. $40 \times 50 \text{mm}^2$, 15mm thickness

○ Coarse sample positioning stage

- $5 \times 5 \times 15 \text{mm}^3$ motorized approach system for XYZ sample positioning, with positioning resolution $< 1\mu\text{m}$
- 18mm z-range for safe probe and sample exchange

○ Precise nanoscale sample scanner

- $100 \times 100 \times 15 \mu\text{m}^3$ XYZ piezo closed-loop sample scanner
- XY non-linearity of 0.05%
- Z non-linearity of 0.05%

○ Low noise, highly stable sample scanner

- 0.1nm RMS in XY dimension in 200Hz bandwidth with capacitance sensors 'on'
- 0.02nm RMS in XY dimension in 100Hz bandwidth with capacitance sensors 'off'
- $< 0.04 \text{nm}$ RMS Z capacitance sensor @ 1000Hz bandwidth
- Long term stability: $< 2 \text{nm}/\text{hour}$ over 24 hours measurement time (at $\pm 0.5^\circ\text{C}$ temperature variation)
- Scanner resonant frequencies 7kHz in XY and 15kHz in Z

Confocal and Widefield Microscopy

○ Objective scanner and optics

- Confocal optical unit with up-straight photon collection
- Main objective 100x Plan Apo infinity corrected, $\text{NA}=0.7$, working distance: 6mm
- $30 \times 30 \times 10 \mu\text{m}^3$ XYZ closed-loop piezo objective scanner for ultra-stable long term spectroscopic laser alignment, resolution 1nm

○ Laser and optics

- Optical diode laser $\lambda=515 \pm 5 \text{nm}$, spectral bandwidth (FWHM) $< 1.5 \text{nm}$
- Tunable output power $0.1\mu\text{W}-20.0 \text{mW}$ at focal point
- Digital modulation with 150MHz, 2.5ns rise/fall time Detection
- Video system including variable LED illumination for widefield microscopy
- Industry USB CMOS widefield camera
- In-coupling of the fluorescence signal into a $50\mu\text{m}$ multimode fiber

Quantum Control Hardware

○ Microwave Control

- Full frequency bandwidth: 0.3-4GHz, operating frequency bandwidth: 2.5-3.5GHz
- Resolution: < 10Hz
- Maximum power: > 30dBm, with 0.1dB power resolution, gain compensated for flat power distribution across the whole frequency bandwidth

○ Single Photon Detection

- Dark counts: < 250Hz
- Dead time: < 35ns, with a count rate of up to 20Mcts/s

○ Connections

- 4 General-purpose Input Output (GPIO) channels with TTL level specifications
- 1 Gigabit Ethernet connection port for high bandwidth data transmission
- Standard FC fiber connector to count the optical signal

○ Microwave Antenna

- Integrated miniaturized microwave near-field antenna
- 4x4x4mm³ xyz manual stage, with < 1μm resolution for precise near-field antenna positioning
- Additional inspection side camera + LED side illumination for easy alignment

○ NV Bias Magnet

NV bias magnet mounted on objective (vertical direction: -2.5 to +2.5mT, manually adjustable)

Quantum Control Software

○ LabQ

- Full set of measurement modules for Scanning NV Magnetometry
- Backbone provided by the Qudi framework
- Open-source and python based
- Modern and intuitive user interface rooted in the Qt framework

○ Features

- Native support for storing data in Gwyddion file format
- Integrated high-level scripting ability via Jupyter Notebooks
- Multilevel access points via generic python API
- One-click automated calibration, measurement and optimization and routines such as
 - fluorescence auto tracking
 - optimal measurement parameter determination
 - smart optimization methods
 - robust fitting algorithms
 - probe parameter determination
 - safe probe approach mechanism

○ NV Imaging Modalities

NV modes for DC Magnetometry (measured simultaneously to sample topography)

- **Magnetic Hilltop Mode:** quenching measurement for qualitative analysis to locate areas with strong magnetic fields
- **Single Magnetic Contour Mode:** single iso-B measurement to localize in the sample a specific magnetic field value
- **Full Magnetic Topography Mode:** determine the full B magnetic landscape of the sample

○ Confocal/SPM imaging modalities

- Closed-loop constant height modes for stray magnetic field measurements
- Tuning Fork based AFM with standard shear-force and normal force modes for sample topography
- Confocal microscopy mode for optical imaging of probe and sample



Optional Upgrades

Measurement

- Hardware Trigger to start experiments
- Continuous live probe monitoring
- External access via GPO ports to the electrically translated fluorescence signal of the APD module
- Operando measurements (measure a sample under operation, e.g. a chip or similar)

DC Magnetometry

- Signal and speed boost with Dual Contour Mode (measure simultaneously two adjacent magnetic contour lines within the sample)
- Speed upgrade(x 100) of the magnetic topography mode

Magnet

- Static magnet
- Vector magnet

AC Magnetometry

- Pulse control and sequence creation in own scripts via python API
- Noise spectroscopy from kHz to GHz domain (measure the amount of noise in a given frequency bandwidth)
- Signal spectroscopy (measure coherent signals in kHz to MHz domains)

Advanced SPM functionality

- Conductive unit for Conductive AFM (current range: 100fA - 10 μ A, voltage range: -10V - +7V)
- Bias voltage extension module (extends range: -50V - +50V)
- STM holder
- Signal Access Module
- Liquid cell
- Sample holders with heating up to 150°C and 300°C

Additional AFM head

AFM imaging modes: contact, semicontact, non-contact AFM, phase imaging, Magnetic Force Microscopy (MFM), Kelvin Probe Force Microscopy (KPFM), Scanning Capacitance Microscopy (SCM), Electric Force Microscopy (EFM), Piezo Response Force Microscopy (PFM), Lateral Force Microscopy (LFM), Force Curve Measurement (Force Distance (F-D) Spectroscopy and Mapping), Nanolithography

System Accreditation

- Patented: Qnami ProteusQ™ is the only Scanning NV Magnetometer produced under exclusive license to Harvard patent family WO2014051886A1
- Certified and compliant for the use in lab environments (CE marked)
- UPS (uninterruptible power supply) to protect the system from external power instabilities in the mains

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