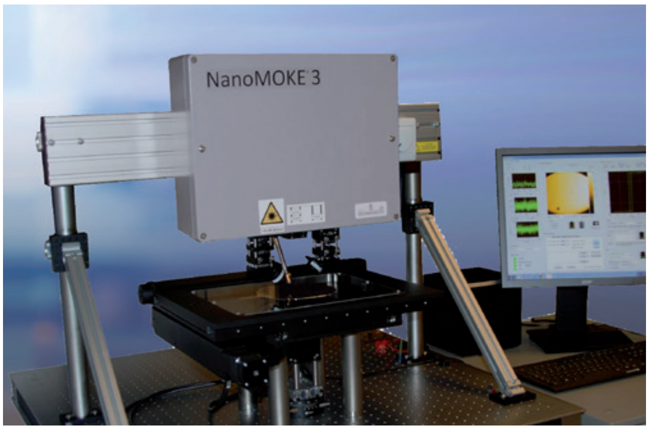
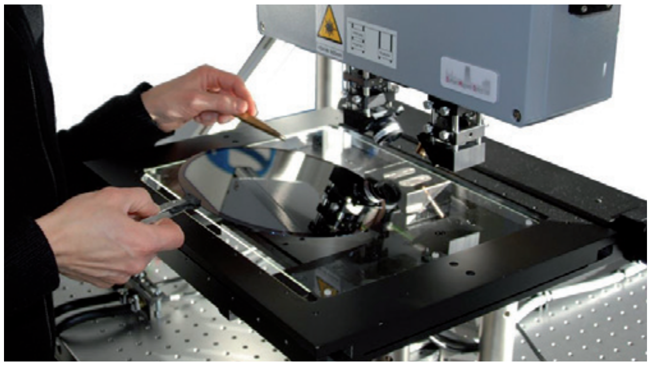
NanoMOKE3 Wafer Mapper Specifications



The NanoMOKE®3 Wafer Mapper



Loading a 200 mm wafer into the NanoMOKE3 Wafer Mapper

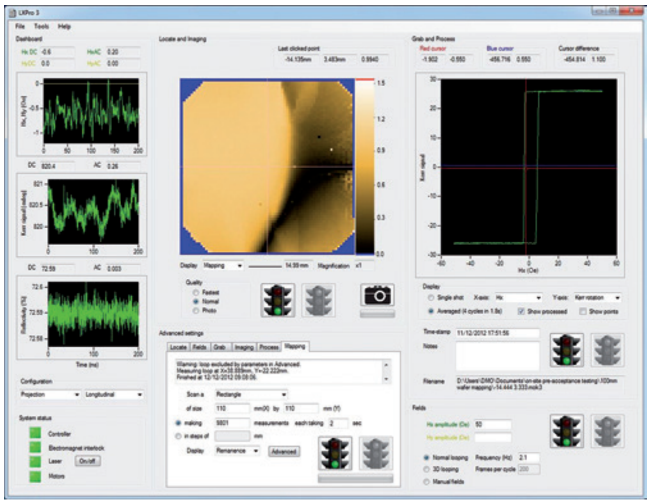
The NanoMOKE®3 Wafer Mapper is an ultrahigh sensitivity Kerr effect magnetometer specially configured for measuring magnetic hysteresis loops and domain images across the entire surface of large area samples. It is ideally suited for wafer-scale development and manufacture of MRAM, magnetic sensors and advanced materials.

The NanoMOKE®3 Wafer Mapper is built around Durham Magneto Optics Ltd's well-established NanoMOKE®3 optical head. The optical head contains a temperature- and current-stabilised 660 nm laser, galvanometric deflector mirrors, polarisation analysis optics and a high-sensitivity, high-resolution digital camera with high intensity 660 nm incoherent imaging light source. Together, these components allow state-of-the-art hysteresis loop measurement and excellent quality domain imaging.

The Wafer Mapper uses a horizontally mounted motorised wafer stage which can move 200 mm in x and 196 mm in y. A projected field electromagnet mounted beneath the wafer applies fields of up to 0.3 T in any in-plane direction (for in-plane magnetised samples) or in the z-direction (for out-of-plane magnetised samples). Because the electromagnet sits beneath the sample, there are no limits on sample size or movement imposed by the pole pieces of the electromagnet. All optics and mechanics sit on a vibration isolating optical table, allowing the system to be used in normal laboratory environments. A 19" control rack sits next to the table and contains a PC, the NanoMOKE®3 optical head controller and the electromagnet power supply.

Software

The NanoMOKE®3 Wafer Mapper uses the same software application as the standard NanoMOKE®3 system: LX Pro3. This application allows hysteresis loops to be measured, topographic and domain images to be captured and loop measurements to be automated across the surface of the wafer. Once loops have been measured from different points across the wafer, LX Pro3 automatically analyses the loops for coercivity, field offset, remanence, amplitude and reflectivity and plots a map of the sample surface. The hysteresis loop underlying any pixel in the map is automatically loaded by clicking that pixel. An intelligent filter checks each loop against reflectivity and Kerr amplitude thresholds in order to remove any measurements made off the edge of the sample or on damaged areas.



Mapping remanence ratio across a 100 mm permalloy wafer

A special software feature allows pseudo domain images to be constructed by plotting the Kerr signal at a given field point number from each loop simultaneously. As one steps through consecutive field points magnetic switching across the entire wafer is seen.

Quantum Design
EUROPE

Quantum Design GmbH
Breitwieserweg 9
D-64319 Pfungstadt

Please contact: David Appel
+49 6157 80710-449, appel@qd-europe.com
Find your local contact at www.qd-europe.com

Durham Magneto Optics Ltd

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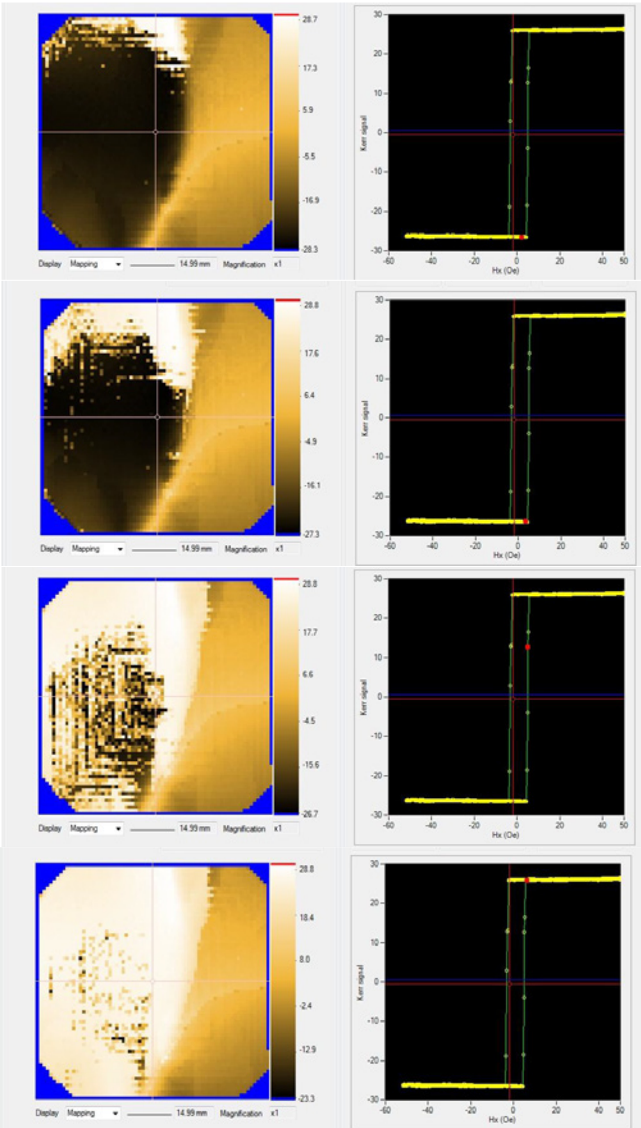
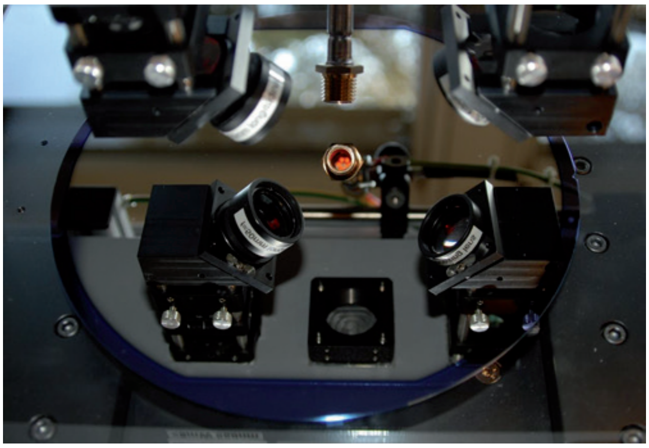
Observing magnetic switching across a 100 mm permalloy wafer. The hysteresis loops on the right are measured in the centre of the wafer. The point highlighted in red is the field point chosen for the wafer-scale image on the left. One sees that magnetic switching starts at the top of the wafer and sweeps down the left hand half as one steps between successive field points.



Variable temperature measurements

Temperature-dependent measurements (room temperature and above) can be made using the gas heater option of the NanoMOKE®3 Wafer Mapper. When fitted, this option places a gas heater pipe close to the surface of the wafer causing hot argon or nitrogen gas to flow onto the wafer at the point where the laser spot is focused allowing measurements between room temperature and 400 °C to be made.



Making elevated temperature measurements under hot gas flow. The picture shows the gas heater pipe with its red-hot filament visible in its reflection in a 200 mm wafer.

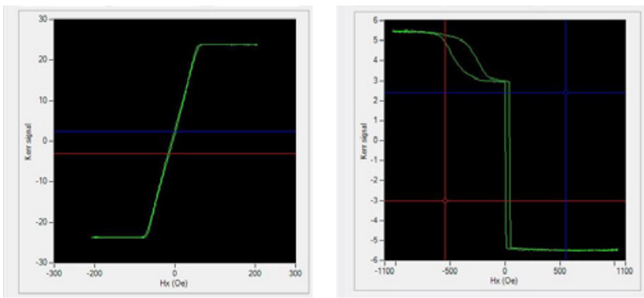
Magnetic field

By default the NanoMOKE®3 Wafer Mapper has a maximum applied field strength of 0.3 T. This is usually sufficient to allow full hysteresis loops to be measured from exchange-biased systems and to saturate along the hard axis of most spintronic materials. A pulsed field option is available to increase this maximum applied field strength to 0.8 T (in-plane and out-of-plane).

Magneto-optics

Detachable lens on the front of the NanoMOKE®3 optical head allows the optical configuration to be changed between longitudinal/transverse Kerr effect (45° beam incidence) and polar Kerr effect (0° beam incidence).

The NanoMOKE®3 optical head is sensitive to longitudinal Kerr effect, polar Kerr effect and transverse Kerr effect and can detect Kerr rotation and Kerr ellipticity. Typical noise levels are <0.5mdeg rms for Kerr rotation and ellipticity and <0.005% rms for transverse Kerr effect (200 ms loop acquisition time).



Measuring free layer hard axis anisotropy (left) and the full hysteresis loop of an exchange-biased spin valve (right). Samples courtesy of Ricardo Sousa, Spintec, Grenoble.

Quantum Design EUROPE

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D-64319 Pfungstadt

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✆ +49 6157 80710-449, appel@qd-europe.com
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Technical specifications

Laser

Class 3R red (660nm, <5 mW) solid state laser diode with noise cancellation system. Intensity noise <0.005% rms. Polarisation noise <0.5 mdeg rms. Multiple averages of a hysteresis loop can be taken and combined to further reduce noise. The auxiliary laser input port allows external lasers supplied by the user to be used in place of the internal laser. Permitted wavelength range for external laser: 400 – 700nm.

Magnetometry

Laser can be fixed on any point on the sample surface and hysteresis loops measured at that point. Position of laser on sample surface is selected by double-clicking a frozen video image in the software.

Imaging

Two imaging modes:
(i) Laser can be rastered under computer control to acquire real time images. Frame rates: 4 frames per second (highest speed); 1.8 frames per second (normal); 1 frame per 7 seconds (photograph).
(ii) High sensitivity CCD camera with red incoherent light source.
Image can be formed from Kerr signal or reflectivity. Background subtraction available to remove non-magnetic structural features from image.

Lens

Objective lens for magnetometry and imaging externally mounted and detachable. Currently supplied lens:

- 50 mm focal length standard polar Kerr lens.
- 32 mm focal length standard longitudinal Kerr lens.

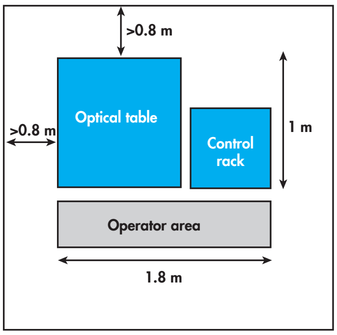
Power and system requirements

220 – 240 V, 8 A AC, 50 Hz single phase or 110 V AC, 16 A, 60 Hz single phase (specify at time of ordering). No excessive vibration

Equipment footprint - room layout

Optical table and legs:
1 m x 1 m
Electronic control rack:
0.7 m x 0.7 m.

It is recommended that enough space be left for user access on all sides of the system.



Standards

All equipment is CE marked and conforms to EN61326.

Electromagnet

Projected field electromagnet mounted beneath the sample surface. ±0.3 T in-plane and out-of-plane maximum field strength. The in-plane direction can be manually selected by rotating the electromagnet. Water cooling required. Flow rate monitor
and automatic shut-down of power supply (with software indication) in the event of flow failure provided.

±0.8 T pulsed field available as an option. Full specifications to be announced later.

Auxiliary inputs and outputs

Two auxiliary analogue inputs (±10 V, 16-bit resolution) and two auxiliary analogue outputs (±10 V, 16-bit resolution) are provided. The inputs are logged simultaneously with the hysteresis loop and can be used to measure other parameters from your own experimental set-up, such as temperature, magneto-resistance etc. The outputs can have arbitrary waveforms generated on them with 100 k-samples per second update rate and can be used to stimulate your sample during measurement.

Loop acquisition

The recommended looping frequency is 0.1 – 30 Hz. The allowed range is 0.01 – 70 Hz. Up to 3000 points per loop can be measured with 16-bit resolution. The system automatically adjusts the analogue sampling rate with sweeping frequency to optimise signal to noise ratio.

Vibration isolation

Passive air isolation system to separate optical table from vibration in the floor. Supplied with a manual pump to increase pressure.

Magnetooptical effects

Kerr signal and reflectivity are recorded simultaneously. With any of the polar objective lens attached, the laser beam is incident on the sample with an average angle of zero degrees and polar Kerr rotation/ellipticity can be recorded. With the longitudinal objective lens attached, the laser beam is incident on the sample with an average angle of 45 degrees and longitudinal Kerr rotation/ellipticity and the transverse Kerr effect (via the reflectivity signal) can be recorded. Kerr rotation and ellipticity are reported in actual millidegrees of rotation and reflectivity in actual percent.

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Field measurement

The applied magnetic field is measured by two Hall probes positioned close to the sample. One probe measures the X-component of field and the other measures the Y-component. The single-shot full-bandwidth AC noise on Hall probe measurements is <0.5 G (0.05 mT) rms; this decreases as loop averages are built up. Any offset on the Hall probes can be nulled using one of the supplied test samples.

Field waveform generation

Arbitrary waveforms can be generated on each of the X and Y field channels simultaneously, and synchronised with the Kerr acquisition. Waveforms can be updated at 100 k-samples per second, with a resolution of 16 bits.

Temperature range

An optional gas heater allows the region around the focused laser spot to be heated from room temperature to 400 °C in a flow of hot argon or nitrogen gas.

Benchmarking test samples

Supplied with three test samples.
The first is a 20 nm thick Permalloy film structured into features of ~30 μm width. The second test sample contains a continuous film of perpendicularly magnetised material to demonstrate the polar Kerr effect. The system is guaranteed to be able to perform real-time video-rate polar Kerr imaging of domains from this sample. The third test sample is an unstructured 20 nm thick Permalloy film. The system is guaranteed to be able to measure loops with <1% rms noise (relative to amplitude of loop) with 10 seconds of acquisition time and to be able to perform real-time video-rate Longitudinal Kerr imaging of domains from this sample.

Item	Deliverable
NanoMOKE3® base system	NanoMOKE3® optical head, including built-in 660 nm class 3R laser, video-rate mirror rastering system, longitudinal, transverse and polar Kerr effect detectors.
	19″ control rack containing PC with licensed Windows 7 32-bit operating system, NanoMOKE3® controller with electromagnet power supplies, master power switch, overcurrent circuit breaker
	32 mm focal length standard longitudinal Kerr effect lens
	50 mm focal length standard polar Kerr effect lens (right-angle configuration)
	High resolution polar Kerr effect lens (right-angle configuration)
	Fixed mechanical support for NanoMOKE3® optical head to mount in vertical plane
	0.3 T projected field electromagnet including field measurement system configured for in-plane (any direction) and out-of-plane field directions
	Passive air support optical table with manual pump for increasing pressure
	200 mm wafer motor (mounted in horizontal plane)
	LX Pro 3 software preinstalled
	Distributable copy of LX Lite 3 software which allows data to be processed on other computers
	ImageJ open-source image processing software preinstalled
	All cables
	Three benchmarking test samples
	Full installation (half a day) and one day of user training
Optional gas heater	Gas heater (room temperature - 400 °C)
	Borosilicate heat-proof glass plate on wafer motor
	Heater power control system with gas flow interlock