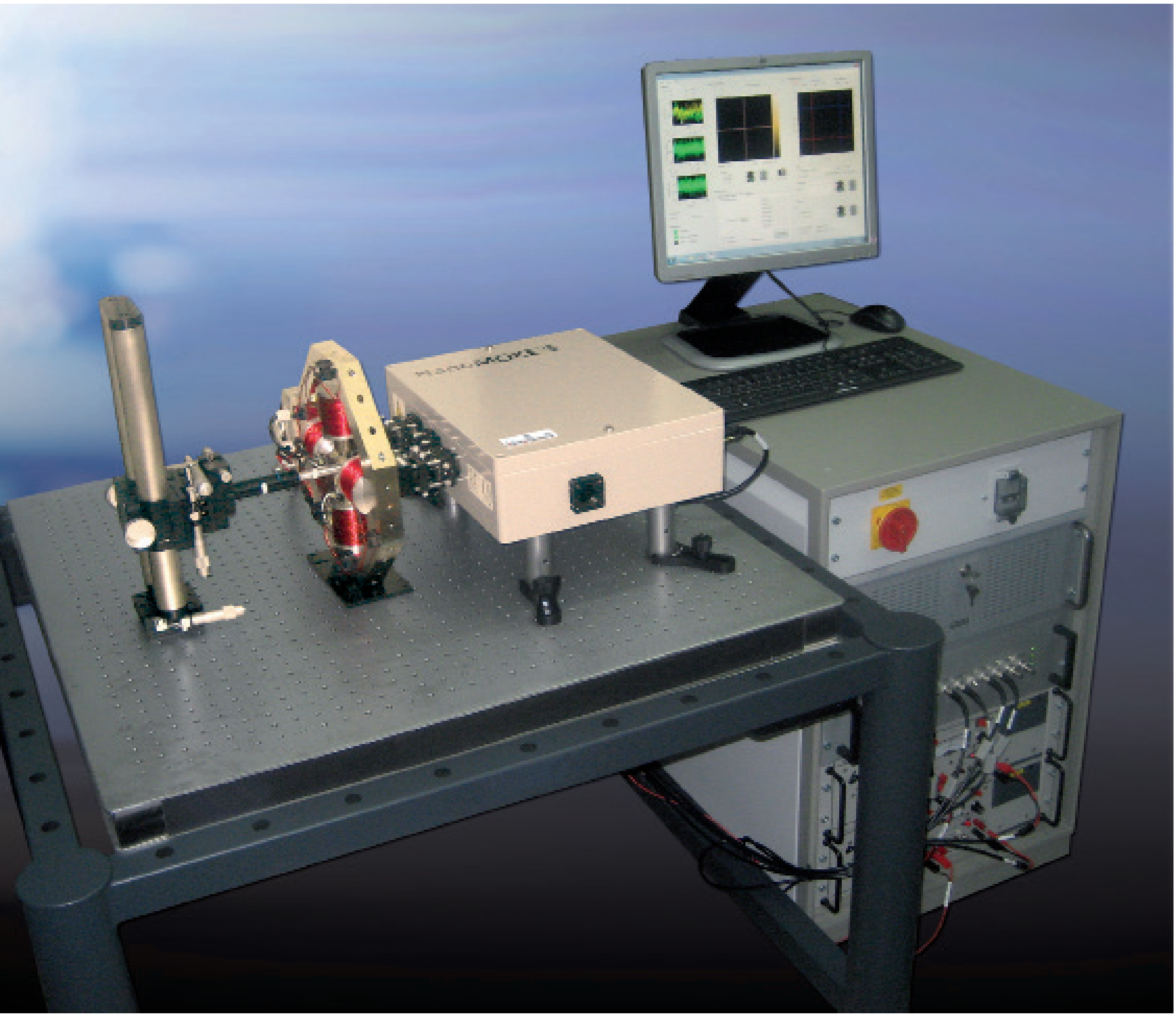
NanoMOKE3 – Specifications

Ultra-high sensitivity Kerr effect magnetometer



NanoMOKE3® is a new generation of ultra-high sensitivity magneto-optical magnetometer and Kerr microscope. Building on the success of NanoMOKE2®, it offers high performance laser magnetometry and near video-rate Kerr microscopy in a single machine. It is sensitive to the longitudinal, transverse and polar magneto-optical Kerr effects and is ideally suited to measuring the magnetic properties of thin magnetic films and magnetic nanostructures. Such measurements are commonly made during research and development into:

- Magnetic nanotechnology
- Magnetic Random Access Memory (MRAM)
- Recording heads
- Patterned magnetic media
- Spintronics/magneto-electronics
- GMR/TMR
- Thin film magnetism
- Magnetic field sensors

Durham Magneto Optics Ltd

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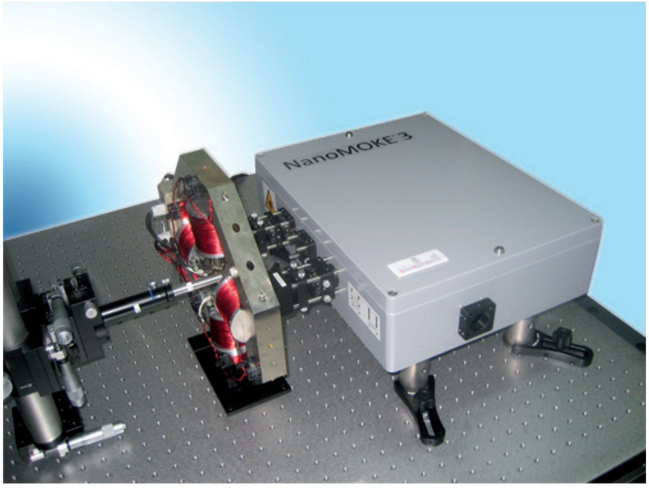
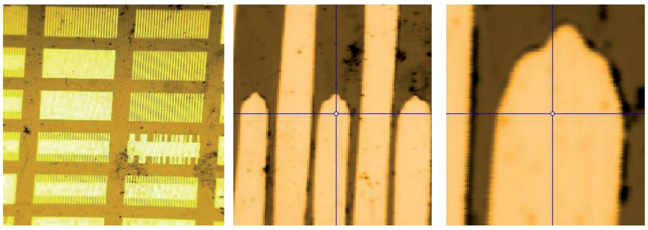
Key features



- **Ultra-high sensitivity and stability combined with very low noise**: reflectivity changes smaller than 0.02% and polarisation changes small than 0.5 mdeg can be detected with a measurement time of just a few seconds.
- **Fully automated integrated optics**: no laser beams or optics to align. Simply place the optics head in front of the sample, adjust the focus, null the detector and start using the software.
- **Highly focused laser spot:** depending on the objective lens selected, the laser spot can be focused to as small as 2μm. This allows hysteresis loops to be measured from small numbers of nanostructures selected out of an array, high hysteresis loop sensitivity to be achieved in single isolated nanostructures or sharp domain images to be captured.
- **Advanced laser rastering mirror system**: built on technology developed for confocal microscopy and optical coherence tomography, NanoMOKE3® includes a pair of high speed precision galvanometric mirrors which move the focused laser beam under computer control. This allows measurements to be made from precisely defined positions on the sample surface and for video-rate imaging by rapid rastering of the laser. This eliminates the traditional divide between Kerr magnetometers and Kerr microscopes: NanoMOKE3® is a true hybrid, offering excellent performance in each role.
- **Excellent imaging quality**: bright, sharp, large field of view and high resolution images can be taken in polar Kerr, longitudinal Kerr and reflectivity contrast modes. Frame rates of up to 4 frames per second allow domain images to be viewed in real time; photographic capture quality allows a publishable quality image to be recorded in 7 seconds.
- **Extendable and interoperable**: auxiliary electronic inputs and outputs allow NanoMOKE3® to be connected electronically to your own experiments. The auxiliary laser input port allows NanoMOKE3® to use an existing laboratory laser instead of the built-in laser. Different objective lens can be selected from a wide range to fit resolution, field of view and working distance according to the experimental needs. Most third-party cryostats, cryogen-free cryocoolers and electromagnets can be successfully interfaced.
- Supplied with **LX Pro 3**, our easy to use and flexible control software. LX Pro 3 allows the laser to be moved so as to locate specific areas, allows complex applied field patterns to be easily generated, records hysteresis loops and allows post-processing of the loops to filter noise, remove artefacts and automatically measure key loop parameters such as coercivity and remanence. It also allows real-time display of images during rastering, capture of photographic quality images and basic image processing such as contrast-brightness correction and profile measurement. LX Pro 3 also includes a macro language which can be used to interface NanoMOKE3® to other software routines that you may wish to write and to automate complex measurements. Public domain image processing software ImageJ is also supplied pre-installed for more advanced image processing tasks.



Reflectivity images taken using the high speed rastering laser from one of the benchmarking test samples. Image size: left=5 mm; middle=150 μm; right=40 μm.

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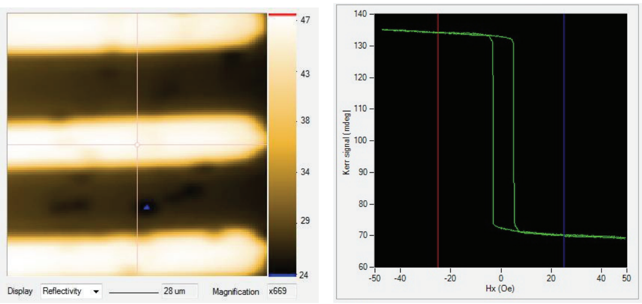
Ultra-high sensitivity Kerr effect magnetometer

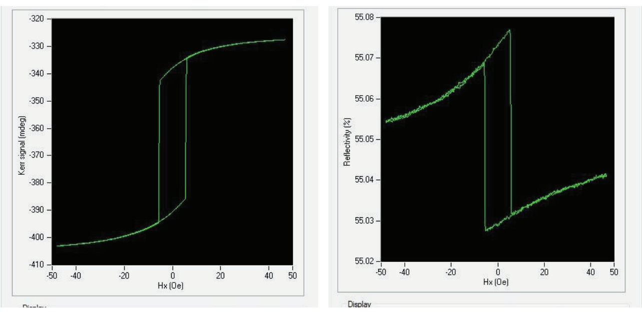
Hardware

The NanoMOKE3® system comes in three parts – the optical head and electromagnet, the electronic control rack and LX Pro 3, the control software. The optical head and electromagnet are mounted on a supplied optical table, which in turn is supported on passive pneumatic isolation legs to reduce mechanical vibration. The electronic control rack is a 19" mounting cabinet and contains all of the power supplies for the electromagnets, the optical head controller unit (which includes analogue input – output electronics) and a PC running LX Pro 3. The PC keyboard, mouse and monitor are conveniently supported for comfortable use. Samples, which must be optically reflective, are usually mounted on standard aluminium microscopy stubs. The stub then fits into the end of a sample stick which is inserted into the sample mount.

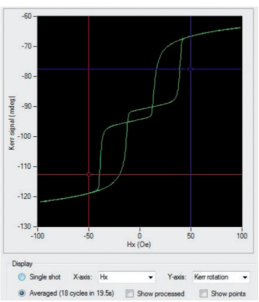
Results gallery



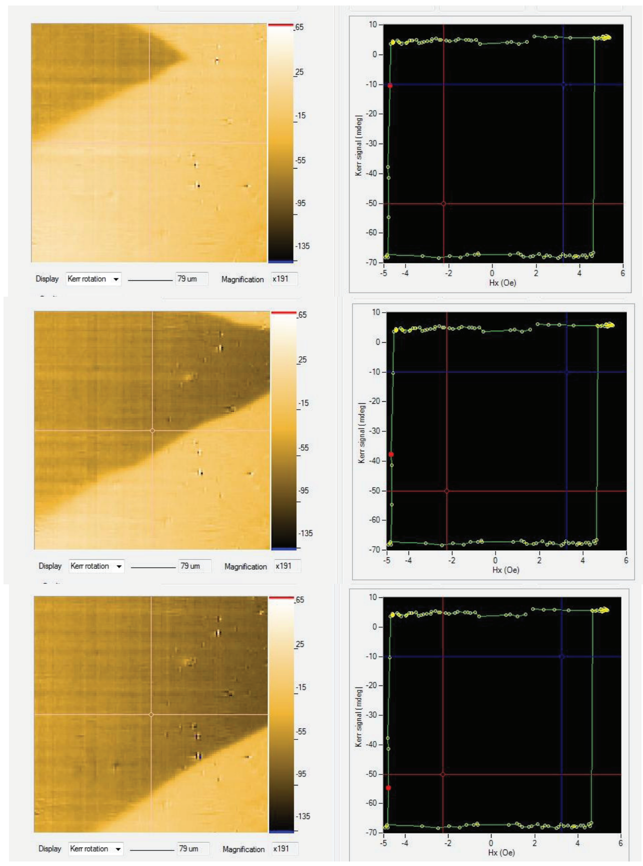
A single-shot hysteresis loop (right) recorded from a 30 µm wide Permalloy microwire (imaged left) using the longitudinal Kerr effect.



Vector magnetometry using simultaneously measured Longitudinal (left) and Transverse (right) Kerr effects.



Hysteresis loop from bilayer CoFeB (3 nm) synthetic ferrimagnet



Combined domain imaging-hysteresis loop measurement

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Technical specifications

Laser

Class 3R red (660 nm, <5 mW) solid state laser diode with noise cancellation system. Intensity noise <0.02% 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 is 400 – 700 nm.

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. Large distance movements of laser beam on sample surface achieved by manual verniers (x, y, z and theta).

Imaging

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). 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 available lens include

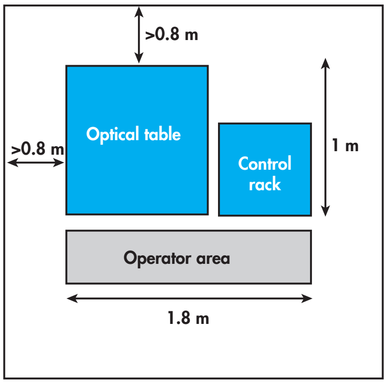
- 50 mm focal length standard polar Kerr lens. Compatible with quadrupole electromagnet, optional dipolar electromagnet, room temperature measurements and optional cryostat. Supplied with base system.
- 32 mm focal length standard longitudinal Kerr lens. Supplied with base system. Suitable for use at room temperature. Compatible with quadrupole electromagnet. Supplied with base system.
- High resolution right angle polar Kerr lens. Suitable for use at room temperature. Compatible with quadrupole electromagnet and optional dipolar electromagnet. Supplied with base system.
- 160 mm focal length longitudinal lens with relay mirror. Compatible with dipolar electromagnet. Suitable for use at room temperature and with optional cryostat. Supplied with optional dipolar electromagnet.

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

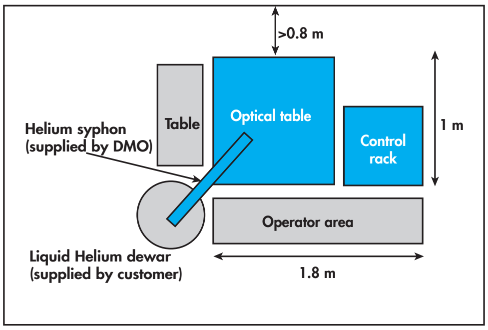
Equipment footprint

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.



Cryogenic low temperature system requirements

- Liquid helium dewar
- Small table to support temperature controller and gas flow controller
- Helium gas return line (if helium gas is to be captured)
- Cryogenic handling personal protection equipment



Standards

All equipment is CE marked and conforms to EN61326.

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Electromagnet

The standard electromagnet is of quadrupole design, allowing fields to be applied in any direction within the plane of the sample. Separate power supplies allow the X- and Y- direction fields to be controlled separately and simultaneously. Arbitrary field waveforms can be generated under computer control. Up to 1.2 kG (0.12 T) in each of X- and Y-directions can be generated by the electromagnet. An electronic feedback loop continuously compares the actual field in the electromagnet with that requested by the software and automatically adjusts the power supply.
The recommended sample size is 0.5 – 2.5 cm. The electromagnet gap size is 30 mm.

An add-on option allows a dipolar electromagnet to be temporarily inserted in place of the standard quadrupole. The dipolar electromagnet can apply fields of up to 0.46 T in the plane of the sample (for longitudinal Kerr effect measurements) or up to 0.2 T perpendicular to the plane of the sample (for polar Kerr effect measurements). Maximum field strength is obtained for loop sweep rates of less than 0.2 Hz.

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.

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.

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.

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 <0.1 G (0.01 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 liquid helium cryogenic sample stage which allows measurements to be made in the temperature range 4.2 K – 500 K. Requires the dipolar electromagnet and cannot be used with the quadrupole electromagnet.

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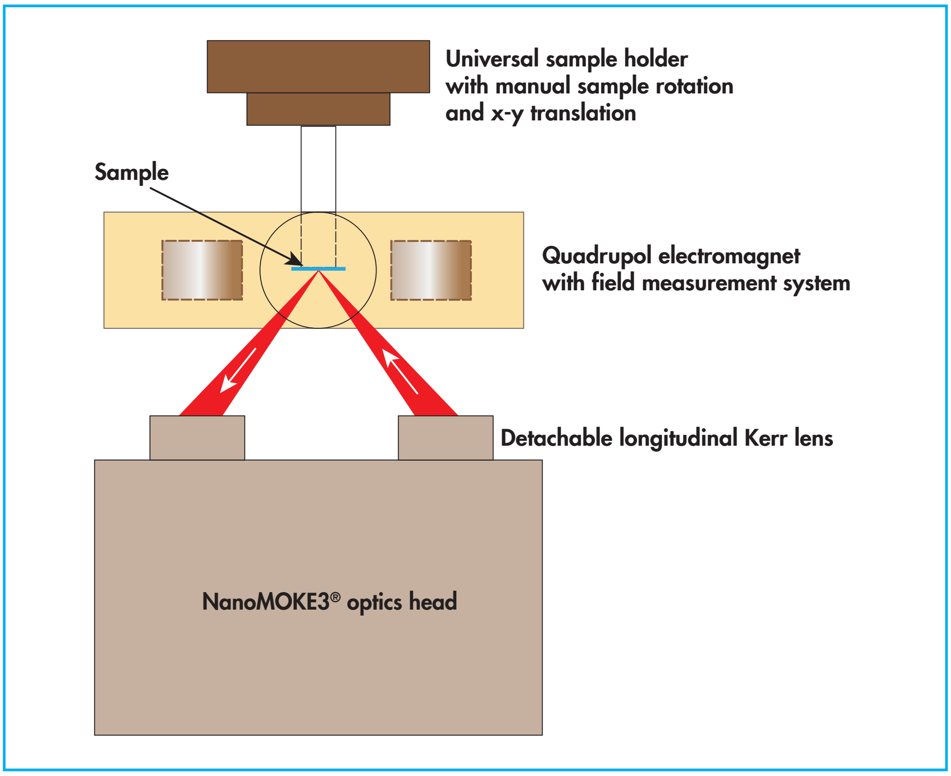
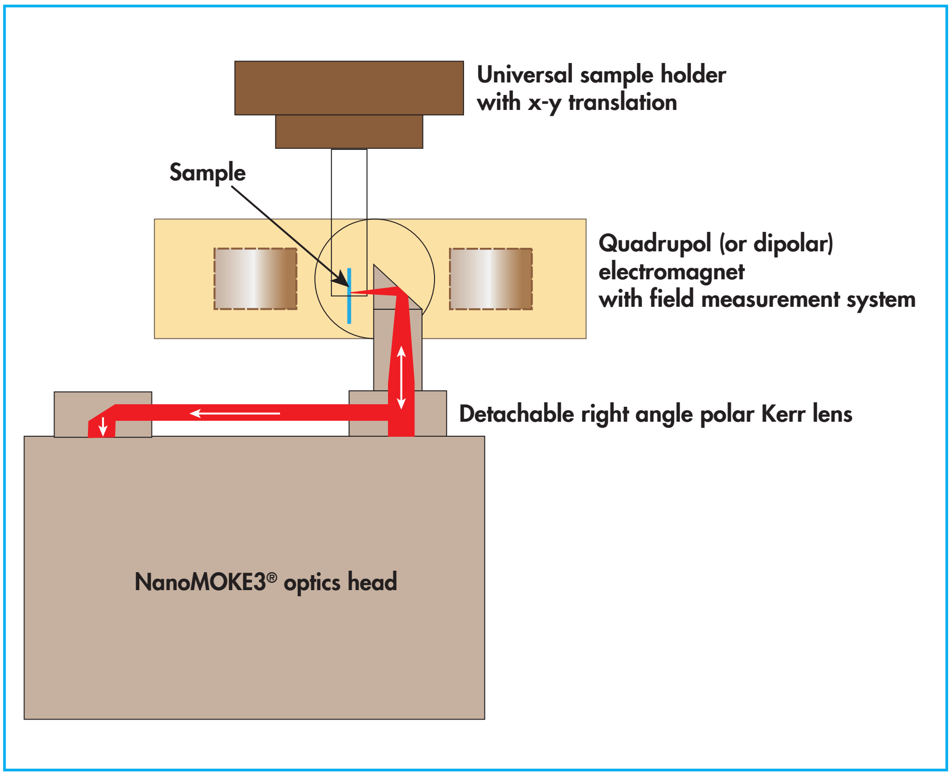
Typical system configurations



Room temperature longitudinal Kerr with standard quadrupole electromagnet



Room temperature polar Kerr

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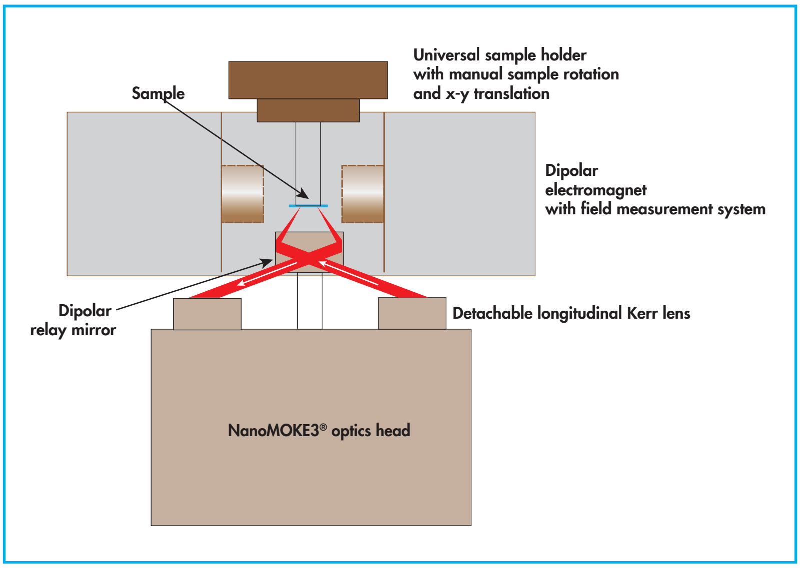
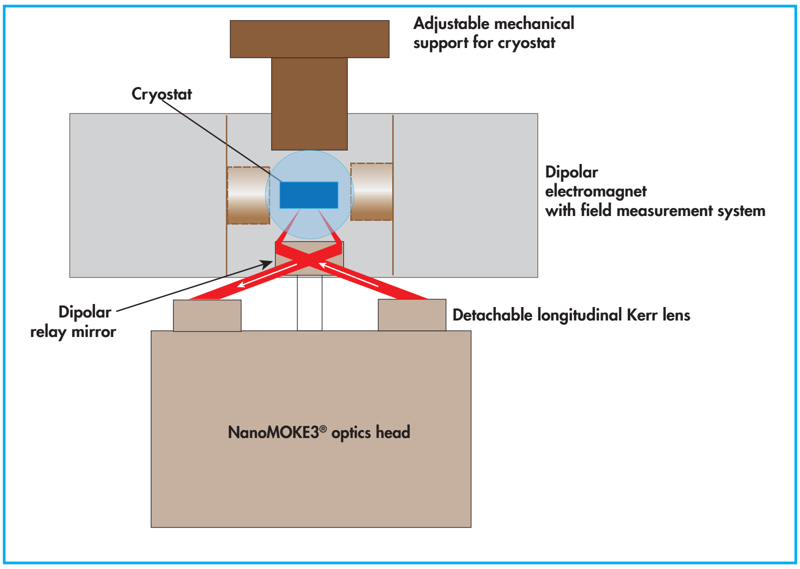
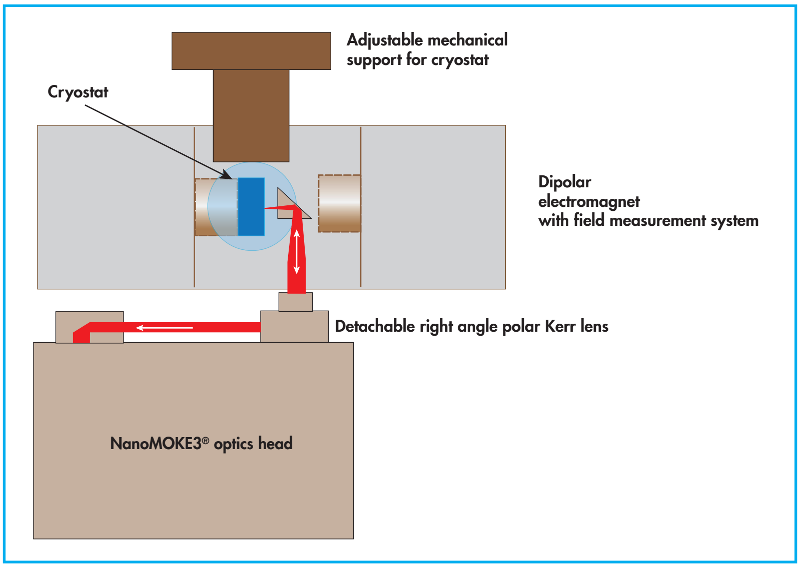


Room temperature longitudinal Kerr with optional high field dipolar electromagnet

Low temperature longitudinal Kerr





Low temperature polar Kerr

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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
	Passive air support optical table with manual pump for increasing pressure
	Universal sample holder for quadrupole and dipolar electromagnet with manual verniers for sample rotation and x-y-z translation
	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
	1.2 kG quadrupole electromagnet including field measurement system
	All cables
	Three benchmarking test samples
	Full installation (half a day) and one day of user training
Optional high field dipolar magnet	Dipolar magnet for use with longitudinal and polar Kerr effect
	Field measurement system
	160 mm focal length longitudinal Kerr lens
	All cables
Optional liquid helium cryostat	Liquid helium cryostat with single low birefringence optical view port
	Helium syphon with needle valve
	Temperature controller
	Gas flow pump
	Turbo pumping station for cryostat evacuation
	Adjustable mechanical support for cryostat
	All cables
	Extra day of user training

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