

PPMS-SPM

the only scanning probe microscopes for the PPMS® certified and endorsed by  **Quantum Design**

attocube systems' scanning probe microscope family (AFM, MFM, SHPM, CFM) is also available for any 1" (25 mm) bore size cryostat, in particular the Quantum Design PPMS®. Despite their compactness, all microscopes provide a coarse travel range of $3 \times 3 \times 2.5 \text{ mm}^3$ and a scan range of $15 \times 15 \mu\text{m}^2$ at low temperature (4 K).

The outstanding stability of the microscopes allows investigation of nm-sized structures with highest resolution. PPMS users can thus complement their existing equipment with a whole range of versatile tools for state-of-the-art research on the nanometer scale.



attoAFM Ixs

Ultra-Stable, Compact Atomic Force Microscope with interferometric deflection detection for highest stability and sensitivity. Compatible with contact and non-contact AFM mode.



attoMFM Ixs

Ultra-Stable, Compact Atomic Force Microscope with interferometric deflection detection for highest stability and sensitivity. Compatible with dual-pass and constant height MFM mode.



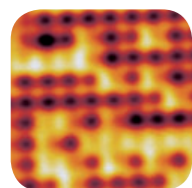
attoCFM I/IIxs & attoRAMANxs

Ultra-Stable, Compact Confocal Microscope based on fiber or free-beam optics for maximum flexibility and stability.



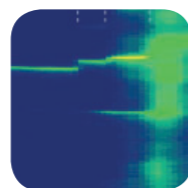
attoSHPMxs

Ultra-Stable, Compact Scanning Hall Probe Microscope with STM tracking 2DEG Hall sensor for maximum field sensitivity.



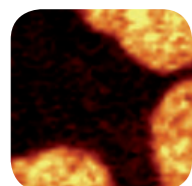
Atomic & Magnetic Force Microscopy

- vortex imaging in superconductors
- magnetic nanoparticles & nanowires
- bit patterned media
- multiferroics



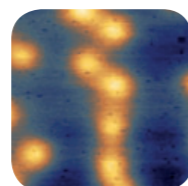
Cryogenic Confocal Microscopy

- photoluminescence and photoconductivity of:
 - quantum dots, nanowires & single molecules
 - 2D-layered materials
 - photonic crystals



Micro-Raman Spectroscopy/Microscopy

- carbon nanotubes
- graphene
- high T_c superconductors
- semiconductor nanowires



Scanning Hall Probe Microscopy

- superconductors
- magnetic nanostructures
- next generation storage media



attoAFM/MFM Ixs

Low temperature magnetic force microscope, cantilever based

The attoAFM Ixs is an ultra-compact atomic force microscope designed particularly for applications at low and ultra low temperature. The instrument works by scanning a sample below a fixed cantilever while measuring its deflection with highest precision using a fiber based optical interferometer. Combined with the ASC500 SPM controller, both contact and non-contact modes are applicable, making the attoAFM Ixs a powerful tool for topographic measurements, force spectroscopy and other imaging modes.

The microscope uses a set of xyz-positioners for coarse positioning of the sample over a range of several mm. Developed particularly for cryogenic applications, the piezo-based scanner provides a scan range of 30 μm x 30 μm at room temperature, and 15 μm x 15 μm at liquid helium temperature. The adjustment of the cantilever is performed outside of the cryostat prior to cooling down the microscope. The exceptional combination of materials allows absolutely stable high resolution imaging of surfaces.



Schematic of the low temperature attoAFM/MFM Ixs in a PPMS cryostat (not included)

PRODUCT KEY FEATURES

- **NEW:** alignment-free cantilever holder
- ultra compact, highly rigid MFM head
- highly sensitive interferometric deflection detection
- adjustment of the cantilever outside the cryostats prior to cooling the microscope

BENEFITS

- **NEW:** tip exchange in less than 2 minutes
- high spatial resolution imaging
- simultaneous ultra high resolution topographic & magnetic force imaging
- compatible with any commercially available MF probe

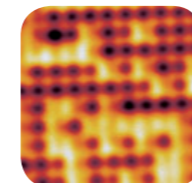
APPLICATION EXAMPLES

- investigation of superconductors
- domain structure studies
- material science

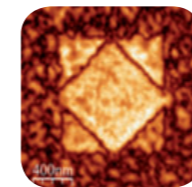
COMPATIBLE COOLING SYSTEMS

- Quantum Design PPMS, see compatibility chart
- any cryostat with bore size $\geq 1"$ (25.4 mm)

Application examples



Magnetic Domain Imaging



Piezo-Response Force Microscopy



Vortex Imaging

Microscope Setup	
AFM type	cantilever based, interferometric deflection detection
sensor head	alignment-free cantilever holder (see page 36) tip exchange in less than 2 minutes
Titanium housing diameter	23.9 mm (designed for 1" bore size such as PPMS)
sample environment	He exchange gas (others on request)
Operation Modes	
feedback	amplitude modulation (AM), phase modulation (PM), frequency modulation (FM)
imaging modes	contact-mode, non-contact mode
Standard techniques (incl.)	AFM, MFM
Ready for	KPFM, PRFM, conductive-tip AFM (may require additional hardware)
Sample Positioning	
positioners and scanners	coarse positioners ANPxyz101 with piezo scanner ANSxyz100
coarse range (open loop)	3 x 3 x 2.5 mm ³
step size	0.05 .. 3 μm @ 300 K, 10 .. 500 nm @ 4 K
fine scan range (open loop)	30 x 30 x 4.2 μm ³ @ 300 K, 15 x 15 x 2 μm ³ @ 4 K
Suitable Cooling Systems	
bore size requirement	designed for a 1" (25.4 mm) cryostat/magnet bore
compatible cryostats	see PPMS compatibility chart
Suitable Operating Conditions	
temperature range	1.5 .. 300 K (dependent on cryostat) mK compatible setup available on request
magnetic field range	0 .. 14T (dependent on magnet) (16T compatible version available on request)
operating pressure range	1E-6 mbar .. 1 bar (designed for exchange gas atmosphere)
AFM tip compatibility	
alignment-free cantilever holder (default)	compatible with PointProbe® Plus XY-Alignment Series by Nanosensors
conventional cantilever holder (optional)	compatible with standard commercial cantilevers
Resolution*	
measured RMS z-noise (contact mode @ 4 K, 5 ms pixel integration time)	< 0.05 nm (expected) < 0.15 nm (guaranteed for PPMS without reliquefier (RL) option / RL off; EverCoolI/II off)
z deflection noise density	< 3 pm/√Hz (dependent on laser system)
z bit resolution full range mode	7.6 pm
Scan Controller and Software	
ASC500 SPM Controller	for detailed specifications please see attoCONTROL section

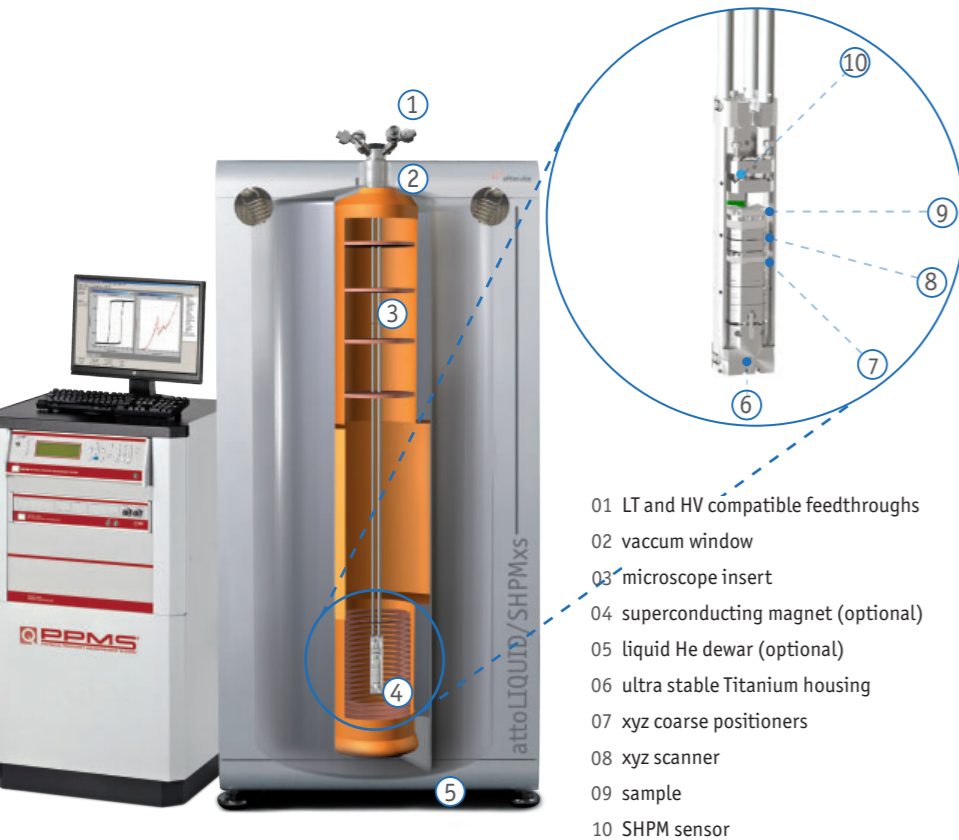
* Resolution may vary depending on applied tip, sample, and cryostat

attoSHPMxs

Low temperature scanning Hall probe microscope

The attoSHPMxs is a compact scanning Hall probe microscope, designed particularly for operation at low temperature and high magnetic fields. At the heart of the attoSHPMxs, a molecular beam epitaxy (MBE) grown GaAs/AlGaAs Hall sensor measures magnetic fields with unrivalled sensitivity. Local measurements of the magnetization of a sample are obtained by scanning the sample underneath the Hall sensor and simultaneously recording the Hall voltage, directly yielding the local magnetic field.

While other local probes may outperform the Hall sensor with respect to its lateral resolution, its ability to non-invasively obtain quantitative values for the local magnetic field makes the Hall sensor a unique tool for the study of superconductors and magnetic materials.



- 01 LT and HV compatible feedthroughs
- 02 vacuum window
- 03 microscope insert
- 04 superconducting magnet (optional)
- 05 liquid He dewar (optional)
- 06 ultra stable Titanium housing
- 07 xyz coarse positioners
- 08 xyz scanner
- 09 sample
- 10 SHPM sensor

Schematic of the low temperature attoSHPMxs
in a PPMS cryostat (not included)

PRODUCT KEY FEATURES

- STM distance tracking for conductive samples
- high spatial resolution:
250 nm & 400 nm sensors available
- noise-equivalent magnetic field:
15 nT/√Hz @ 4 K (40 μA Hall current)
- typ. attainable field detection limit:
15 μT (bandwidth 10 Hz @ 277 Hz)

BENEFITS

- gain quantitative & non-invasive magnetic information
- ultra-high field sensitivity combined with sub-micron resolution
- fits standard cryogenic and magnet sample spaces

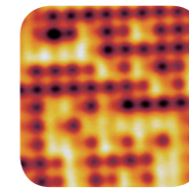
APPLICATION EXAMPLES

- investigation of superconductors
- domain structure studies
- material science

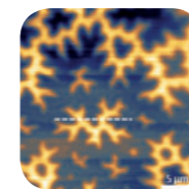
COMPATIBLE COOLING SYSTEMS

- Quantum Design PPMS, see compatibility chart
- any cryostat with bore size $\geq 1"$ (25.4 mm)

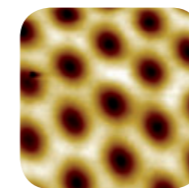
Application examples



Magnetic Domain
Imaging



Scanning Hall Probe
Microscopy



Vortex Imaging

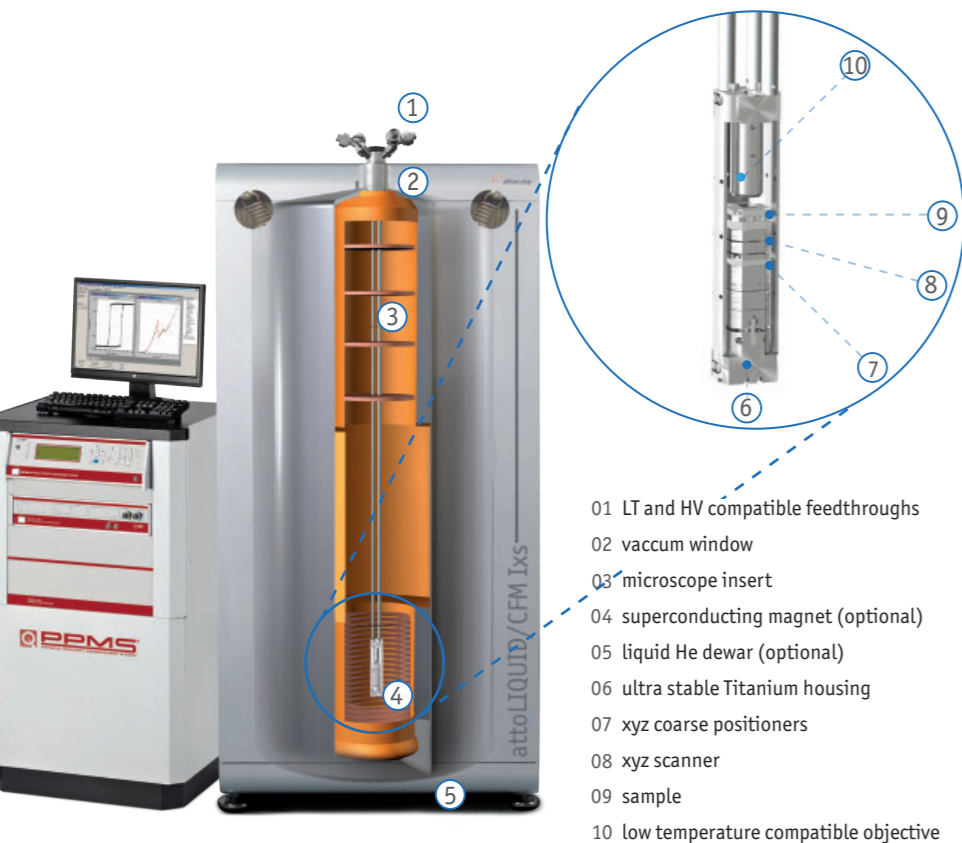
Microscope Setup	
SHPM sensor unit	Hall cross sensor (MBE grown GaAs/AlGaAs heterostructure)
Titanium housing diameter	23.9 mm (designed for 1" bore size such as PPMS)
Operation modes	
feedback (during autoapproach)	STM distance tracking
imaging modes	constant height
Sample Positioning	
coarse range (open loop)	3 x 3 x 2.5 mm ³
step size	0.05 .. 3 μm @ 300 K, 10 .. 500 nm @ 4 K
fine scan range (open loop)	30 x 30 x 4 μm ³ @ 300 K, 15 x 15 x 2 μm ³ @ 4 K
Suitable Cooling Systems	
bore size requirement	designed for a 1" (25.4 mm) cryostat/magnet bore
compatible cryostats	see PPMS compatibility chart
Suitable Operating Conditions	
temperature range	1.5 .. 300 K (dependent on cryostat) mK compatible setup available on request
magnetic field range	0 .. 14 T (dependent on magnet) (16 T compatible version available on request)
operating pressure range	1E-6 mbar .. 1 bar (designed for exchange gas atmosphere)
Probes	
probe design	MBE grown GaAs/AlGaAs heterostructure
active area	400 nm (high resolution); 250 μm (ultra high resolution)
field sensitivity	1500 V/AT
noise-equivalent magnetic field (theoretical)	15 nT/√Hz @ 4 K and 40 μA Hall current; 80 nT/√Hz @ 77 K and 40 μA Hall current
typical attainable field detection limit (measured)	15 μT typ. (bandwidth 10 Hz @ frequency 277 Hz)
Resolution	
control electronics	16 bit over selected scan range (virtually unlimited bit resolution)
lateral (xy) bit resolution @ 300 K	0.46 nm at 30 μm scan range
z bit resolution @ 300 K	0.065 nm at 4.3 μm scan range
lateral (xy) bit resolution @ 4 K	0.18 nm at 12 μm scan range
z bit resolution @ 4 K	0.030 nm at 2 μm scan range
Scan Controller and Software	
ASC500 SPM Controller	for detailed specifications please see attoCONTROL section

attoCFM Ixs

Low temperature confocal microscope, free-beam optics

The attoCFM Ixs has been developed to offer a maximum amount of flexibility for a convenient adaption to a large number of different quantum optics applications. This is realized by an external optics head, positioned outside the cryostat. Furthermore, the free-beam optical design allows for completely independent adjustment of the excitation and collection port. Therefore, applications such as Raman spectroscopy

become accessible by appropriately filtering of the excitation and detection signals. The easy handling opens up new possibilities in quantitative surface characterization in the sub-micron range.



- 01 LT and HV compatible feedthroughs
- 02 vacuum window
- 03 microscope insert
- 04 superconducting magnet (optional)
- 05 liquid He dewar (optional)
- 06 ultra stable Titanium housing
- 07 xyz coarse positioners
- 08 xyz scanner
- 09 sample
- 10 low temperature compatible objective

PRODUCT KEY FEATURES

- optical setup offering highest flexibility
- modular beam splitter head outside of cryostat
- wavelength and polarization filtering of the excitation and collection signal possible
- large coarse positioning range at low temperatures
- interferometric optional encoders for closed loop scanning (optional)
- low temperature objectives with NA up to 0.82
- sample monitoring via CCD camera (field of view: 75 μm)

BENEFITS

- fits standard cryogenic and magnet sample spaces
- very broad variety of applications, ranging from classical CFM measurements to Raman spectroscopy
- excellent stability in high magnetic fields
- highest measurement sensitivity
- access to a large area on the sample surface

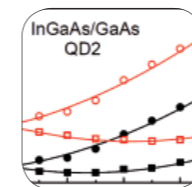
APPLICATION EXAMPLES

- solid state physics and quantum dot optics
- fluorescence observation
- biological and medical research on tissue samples in cytological and neurological applications

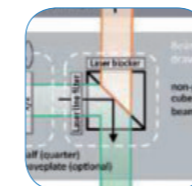
COMPATIBLE COOLING SYSTEMS

- Quantum Design PPMS, see compatibility chart
- any cryostat with bore size $\geq 1"$ (25.4 mm)

Application examples



Confocal Imaging



Resonant Fluorescence



Kerr-Effect Measurements

Microscope Setup	
Confocal microscope head	free-beam based external optics head coupled to low temperature objective
Titanium housing diameter	23.9 mm (designed for 1" bore size such as PPMS)
Confocal Unit	
configuration	compact and modular design, up to three optical channels standard configuration: 1 excitation channel, 1 detection channel
key benefits	quick and reliable alignment of each channel, steering mirror for the combined beams exceptional long-term stability
quick-exchange of optical components	beamsplitters, filter mounts for up to 4 filters/ polarizers (1" diameter), optional piezo-electric rotator with filter mount
LT-compatible objective	achromat, NA = 0.82, WD = 0.4, confocal resolution ~ 550 nm (@ 635 nm in reflection)
inspection unit	sample imaging with large field of view: ~ 75 μm (attoDRY), ~ 56 μm (attoLIQUID)
Illumination	
extinction wavelength range	632 nm, others on request
port specification	FC/APC-connector for single mode fibers
Detection	
detection mode	e.g. reflection, luminescence, fluorescence, Raman (optional)...
detection wavelength	detector upon user's choice, typically Si detector (coupling of the light to other detectors possible, e.g. spectrometer, APD, ...)
port specification	FC/APC-connector for single mode fibers (other connector types on request)
pinhole size	dependent on fibers, typically 3..9 μm mode field diameter
options	low temperature compatible detector below the sample for transmission measurements (intensity), polarizer and retarder, filters
Sample Positioning	
coarse range (open loop)	3 x 3 x 2.5 mm ³
step size	0.05 .. 3 μm @ 300 K, 10 .. 500 nm @ 4 K
fine scan range (optional, open loop)	30 x 30 μm^2 @ 300 K, 15 x 15 μm^2 @ 4 K
Suitable Cooling Systems	
bore size requirement	designed for a 1" (25.4 mm) cryostat/magnet bore
compatible cryostats	see PPMS compatibility chart
Suitable Operating Conditions	
temperature range	1.5 .. 300 K (dependent on cryostat) mK compatible setup available on request
magnetic field range	0 .. 14T (dependent on magnet)
operating pressure range	1E-6 mbar .. 1 bar (designed for exchange gas atmosphere)
Scan Controller and Software	
ASC400 CFM Controller	for detailed specifications please see attoCONTROL section

Schematic of the low temperature attoCFM Ixs

in a PPMS cryostat (not included)

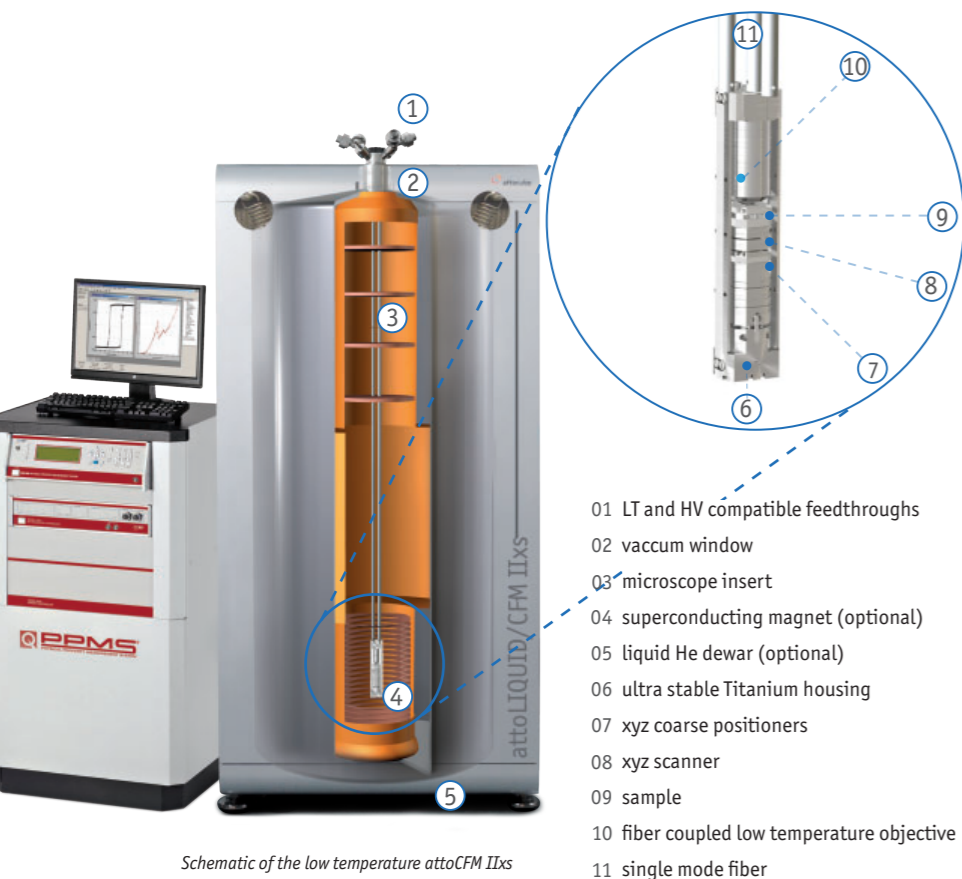
attoCFM IIxs

Low temperature confocal microscope, highly stable and compact

The attoCFM IIxs is a compact confocal microscope based on one single-mode fiber. The one-of-a-kind combination of materials allows absolutely stable measurements at low temperature over weeks on a single quantum object, even when refilling the bath cryostat with liquid helium. Furthermore, combining the attoCFM IIxs with cryogen-free cooling solutions is easily possible, opening up new possibilities in cryogenic long-term investigations while considerably reducing operational costs.

Objectives with a working distance of up to 3 mm or with a numerical aperture of up to 0.68 are available, see page 184.

Principle - A laser beam is coupled into one arm of a single mode optical fiber coupler. The fiber end of the second arm is placed in a ceramic ferrule to guarantee an accurate position of the fiber in the objective axis. This single mode fiber illuminates the sample and plays the role of the blocking pinhole aperture when collecting the scattered light from the sample.



Schematic of the low temperature attoCFM IIxs in a PPMS cryostat (not included)

PRODUCT KEY FEATURES

- miniaturized microscope head
- interferometric or capacitive encoders for closed loop scanning
- designed for highest stability
- optimized for minimal light loss
- large coarse positioning range at low temperatures
- ultra compact version for 1 inch (25.4 mm) setups available

BENEFITS

- fits standard cryogenic and magnet sample spaces
- minimized drifts enable long-term measurements
- excellent stability in high magnetic fields
- highest measurement sensitivity
- access to a large area on the sample surface

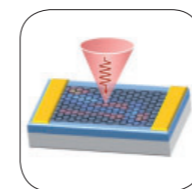
APPLICATION EXAMPLES

- solid state physics and quantum dot optics
- fluorescence observation
- highly stable long term experiments on single quantum dots
- biological and medical research on tissue samples in cytological and neurological applications
- fast 3D-imaging

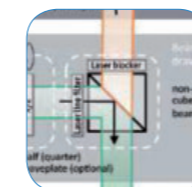
COMPATIBLE COOLING SYSTEMS

- Quantum Design PPMS, see compatibility chart
- any cryostat with bore size $\geq 1"$ (25.4 mm)

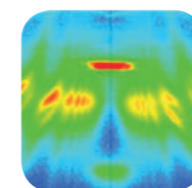
Application examples



Photocurrent



Resonant Fluorescence



Quantum Dot Spectroscopy

Microscope Setup	
confocal microscope unit	fiber optics based for maximum stability
pinhole configuration	one single-mode fiber for excitation and detection (blocking pinhole)
Titanium housing diameter	23.9 mm (designed for 1" bore size such as PPMS)
Illumination	
extinction wavelength range	limited to wavelength range of single mode fiber
light source	fiber coupled laser, typically 635 nm
light power on the sample	1 pW .. 500 μ W
port specification	FC/ APC-connector for single mode fibers
Detection	
detection mode	e.g. reflection, luminescence, fluorescence, ...
detection wavelength	detector upon user's choice, typically Si detector (coupling of the light to other detectors possible, e.g. spectrometer, APD, ...)
port specification	FC/APC-connector for single mode fibers (other connector types on request)
options	low temperature compatible detector below the sample for transmission measurements (intensity), polarizer and retarder, filters
Optical Parameters	
pinhole size	dependent on fibers, typically 3 .. 9 μ m mode field diameter
spot size	diffraction limited
compatible objective	LT-IWDO, LT-LWDO (for details, see page 184)
Sample Positioning	
coarse range (open loop)	3 x 3 x 2.5 mm ³
step size	0.05 .. 3 μ m @ 300 K, 10 .. 500 nm @ 4 K
step scan range	within coarse range; e.g.: 200 x 200 μ m ²
sample monitoring	sample/focus monitoring via CCD camera
fine scan range (optional, open loop)	30 x 30 μ m ² @ 300 K, 15 x 15 μ m ² @ 4 K
Suitable Cooling Systems	
bore size requirement	designed for a 1" (25.4 mm) cryostat/magnet bore
compatible cryostats	see PPMS compatibility chart
Suitable Operating Conditions	
temperature range	1.5 .. 300 K (dependent on cryostat) mK compatible setup available on request
magnetic field range	0 .. 14 T (dependent on magnet) (16 T compatible version available on request)
operating pressure range	1E-6 mbar .. 1 bar (designed for exchange gas atmosphere)
Scan Controller and Software	
ASC400 SPM Controller	for detailed specifications please see attoCONTROL section

attoRAMANxs

Low temperature micro-Raman spectroscopy

The cryogenic Raman instrument combines a high resolution, low temperature confocal microscope with ultra sensitive Raman optics. This innovative product enables state of the art confocal Raman measurements at cryogenic environments combined with magnetic fields of up to 14 T. The attoRAMANxs is a ready-to-use system and is delivered with a Raman laser source (532 nm / 633 nm wavelength as excitation source available), ultra-high throughput spectrometer including a peltier-cooled, back-illuminated CCD, and a state-of-the-art Raman controller/software package. The attoRAMANxs uses a set of xyz-positioners for coarse positioning of the sample over a range of several

mm, and is also available with an interferometric encoder for closed loop operation. Developed particularly for cryogenic applications, the piezo-based scanner provides a large scan range of $30\ \mu\text{m} \times 30\ \mu\text{m}$ at room temperature, and $15\ \mu\text{m} \times 15\ \mu\text{m}$ at liquid helium temperature. The Raman image is obtained by scanning the sample with respect to the laser focus and measuring the spectral distribution of the Raman signal for each point.



Schematic of the low temperature attoRAMANxs in a PPMS cryostat (not included)

- 01 LT and HV compatible feedthroughs
- 02 vacuum window
- 03 microscope insert
- 04 superconducting magnet (optional)
- 05 liquid He dewar (optional)
- 06 ultra stable Titanium housing
- 07 xyz coarse positioners
- 08 xyz scanner
- 09 sample
- 10 single mode fiber for interferometric deflection
- 11 low temperature compatible objective

PRODUCT KEY FEATURES

- optical setup offering highest flexibility
- modular beam splitter head outside of cryostat
- wavelength and polarization filtering of the excitation and collection signal possible
- large coarse positioning range at low temperatures
- low temperature objectives with NA up to 0.82
- sample monitoring via CCD camera (field of view: $50\ \mu\text{m}$)

BENEFITS

- fits 1" clear bore cryostats and magnets
- highest flexibility and sensitivity combined
- with minimal light loss
- highly stable long term measurements ultra
- sensitive room temperature Raman optics
- state-of-the-art Raman controller/software package

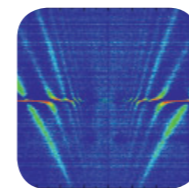
APPLICATION EXAMPLES

- nanotechnology and nano-structured surface inspection
- stress measurements
- waveguides
- imaging of surface plasmon waves
- surface structure and properties
- defect analysis and phase separations
- nanotube properties characterization
- graphene characterization and layer analysis
- diamond films and inclusions

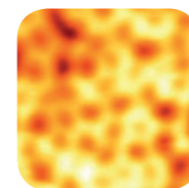
COMPATIBLE COOLING SYSTEMS

- Quantum Design PPMS, see compatibility chart
- any cryostat with bore size $\geq 1"$ (25.4 mm)

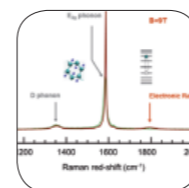
Application examples



Raman Imaging



Phase Transitions



2D layered Materials

Microscope Configuration	
configuration	compact and modular design, up to three optical channels standard configuration: 1 excitation channel, 1 detection channel
quick-exchange of optical components	beamsplitters, filter mounts for up to 4 filters/ polarizers (1" diameter), optional piezoelectric rotator with filter mount
LT-compatible objective	NA= 0.82, WD= 0.4 mm, confocal resolution ~ 550 nm (@ 635 nm in reflection)
inspection unit	sample imaging with large field of view: ~75 μm (attoDRY), ~56 μm (attoLIQUID)
Illumination	
extinction wavelength range	532 nm, on request
light source	dedicated Raman laser, single mode fiber coupled
light power on the sample	typically 1 pW .. 10 mW
optical filter	laser line filter
Raman Signal Detection	
spectrometer	ultra-high transmission spectrometer, f=300 mm
total optical transmission	greater 60% at 532 nm
filters	dichroic mirror & edge filter for signal detection as close as 90 cm^{-1} to the laser
gratings	typ. 600/mm and 1800/mm grating
pixel resolution	1 cm^{-1} at 1800/mm grating
CCD camera	back-illuminated CCD, peltier-cooled to -60 °C at 20 °C room temperature, 1024x127 pixels, 90% quantum efficiency at 532 nm, 100 kHz readout converter
Imaging Modes	
Raman	2D Raman images time and single point Raman spectra
confocal	2D confocal images in reflection and transmission mode
Sample Positioning	
coarse range (open loop)	3 x 3 x 2.5 mm^3
step size	0.05 .. 3 μm @ 300 K, 10 .. 500 nm @ 4 K
step scan range	within coarse range; e.g.: 200 x 200 μm^2
sample monitoring	sample/ focus monitoring via CCD camera
fine scan range (open loop)	30 x 30 μm^2 @ 300 K, 15 x 15 μm^2 @ 4 K
Suitable Cooling Systems	
bore size requirement	designed for a 1" (25.4 mm) cryostat/magnet bore
compatible cryostats	see PPMS compatibility chart
Suitable Operating Conditions	
temperature range	1.5 .. 300 K (dependent on cryostat) mK compatible setup available on request
magnetic field range	0 .. 14 T (dependent on magnet)
operating pressure range	1E-6 mbar .. 1 bar (designed for exchange gas atmosphere)
Scan Controller and Software	
	Dedicated FPGA-based RAMAN controller providing coarse positioning and scanning signals for sample positioning and scanning in x, y, and z direction. Control Software for extensive Raman signal data acquisition and post processing.