

# Cryogenic instruments for microscopy and nano-precise sample positioning



Technology leader in nanoscale applications.



# AGENDA

- 1 Attocube – an introduction
- 2 Cryogenic nanopositioning
- 3 Closed-cycle cryostats
- 4 Cryogenic microscopy solutions



# AGENDA

- 1 Attocube – an introduction**



## The NanoFactory

>>> modern working & production facilities



- Nanoprecision made in Germany
- 9.100 m<sup>2</sup> ground space, 1.200 m<sup>2</sup> production space
- Flexible manufacturing and supply chain



Munich | Berkeley  
3 regional US sales representatives  
16 worldwide distributors

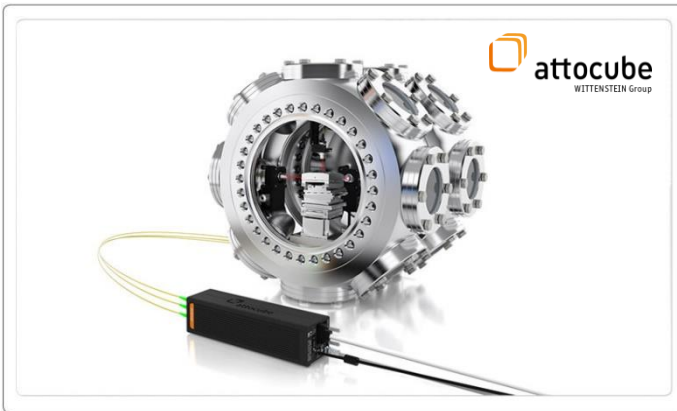


# Strategic Business Sectors

3 business sectors optimally serve customers in attocube's key markets

## MOTION & SENSING

precision engineering components



From engineers, for engineers.

focus on ambient and HV  
engineering customers

components and modules for  
precision engineering customers

## CRYOGENIC INSTRUMENTS

cool tools for cold science



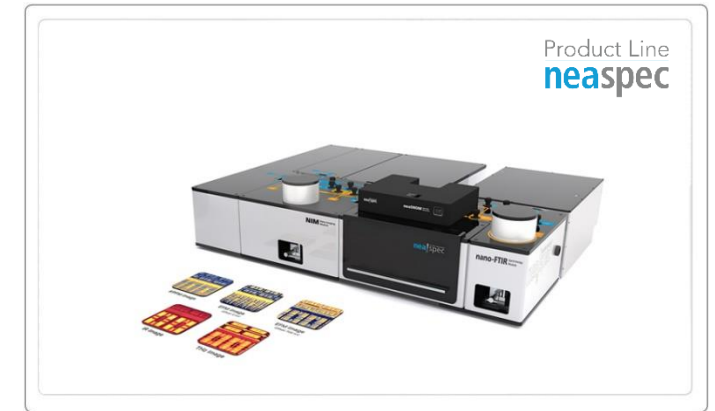
From physicists, for physicists.

focus on flexible  
research customers

components, modules and research platforms for  
condensed matter physics at cryogenic temperatures

## NANOSCALE ANALYTICS

advanced imaging & spectroscopy



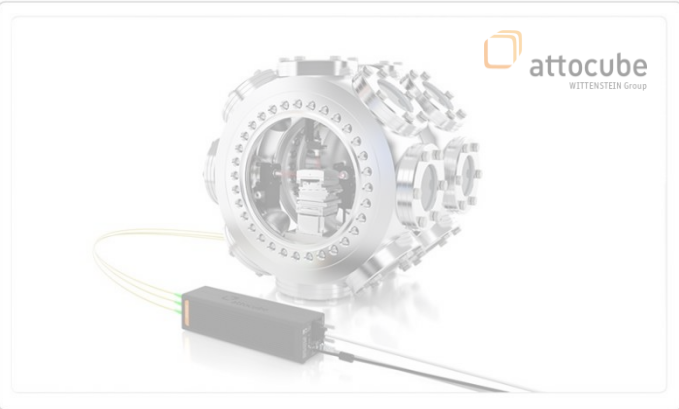
From experts, for experts.

focus on ready to use solutions  
for dedicated applications

turn key solutions for nanoscale  
analytics in surface science & inspection

## MOTION & SENSING

precision engineering components



## CRYOGENIC INSTRUMENTS

cool tools for cold science



## NANOSCALE ANALYTICS

advanced imaging & spectroscopy







# AGENDA

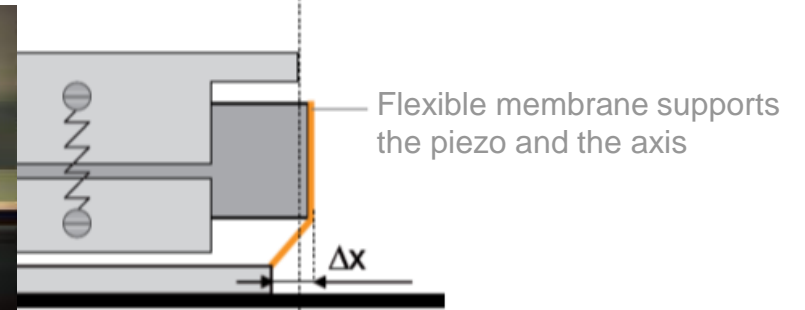
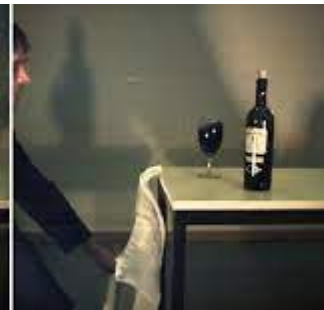
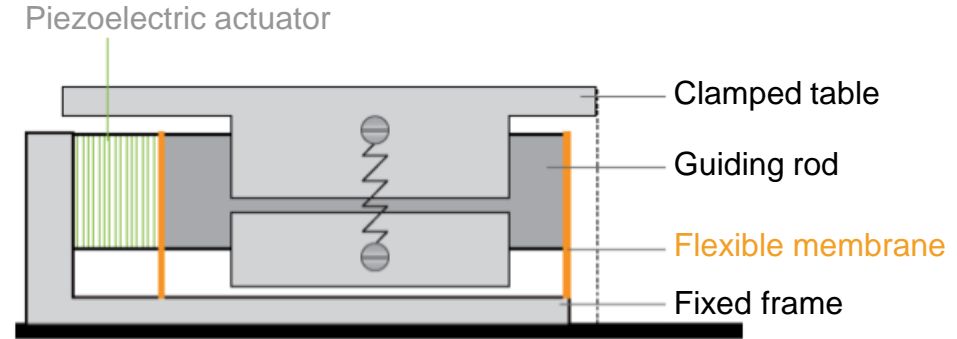
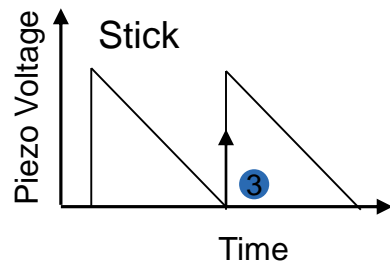
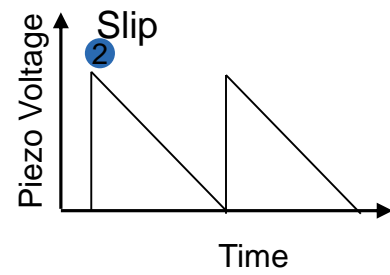
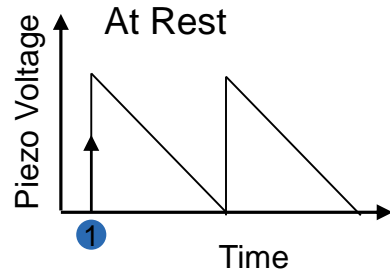
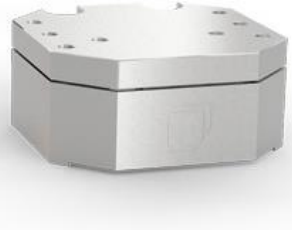
- 1 Attocube – an introduction
- 2 **Cryogenic nanopositioning**



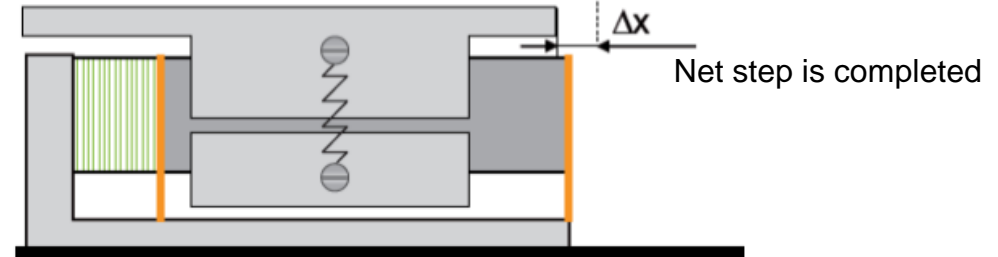
The microscope of Prof. Karrai ~ 25 years ago  
@ Deutsches Museum

# Cryogenic nanopositioning

Selective control of friction – „slip-stick“ - attocube systems nanopositioner working principle



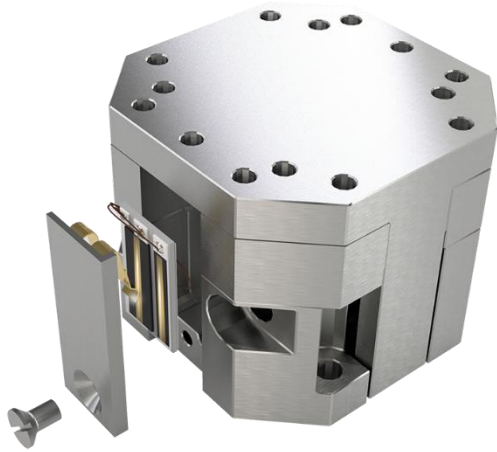
Physik in unserer Zeit, Volume 46, Issue 4 July 2015 Pages 199-201





## *How to know where things are?*

### Resistive feedback



- measurement relative to the positioner itself
- repeatability 1-2 micron

### Interferometric feedback



- measurement relative to the sensor head
- repeatability on the nm-range (no signal interrupt)



## Extreme Environments

- non-magnetic
- available for cryogenic temperatures
- available for high and ultra high vacuum



## Multi Axis Operation

- Combination of various positioners
- Movements with up to six degrees of freedom



## Closed Loop Control

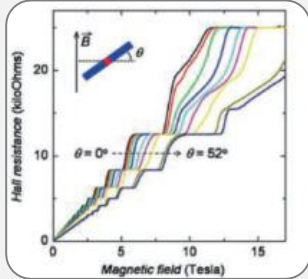
- available with implemented encoders
- exact and repeatable positioning in absolute and relative terms



## Large Travel Ranges

- patented inertial drive technology for use in extreme working environments
- motion over centimetre ranges with small steps
- fine tuning in nm range

## Magneto-Transport Measurements



Angle-dependent Transport Measurements at 40 mK

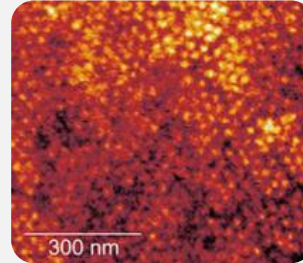


Van der Waals Heterostructure under Rotation at 40 mK

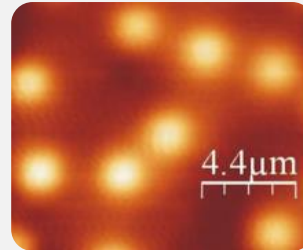


Transition from Slow Abrikosov to Fast Moving Josephson Vortices

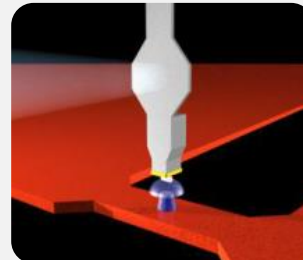
## Scanning Probe microscopy



SPM using attocube Nanopositioners in Magnetic Fields above 30 T

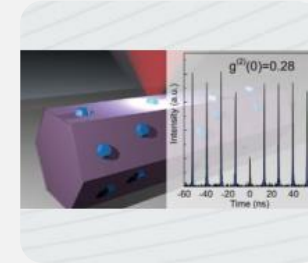


Scanning Hall Probe Microscopy at 300 mK with ANP Positioners

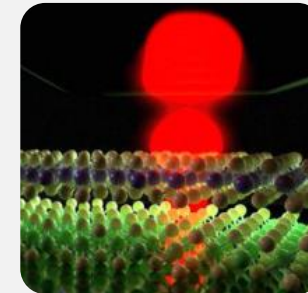


Magnetic Resonance Imaging of Nanoscale Virus at 300 mK

## Optical Measurements



Single Photon Generation with Controlled Polarization from InGaN Quantum Dots



Light-Matter Coupling in TMD Monolayers and Heterostructures



Dissipation in Optomechanical Resonators



# AGENDA

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- 3 **Closed-cycle cryostats**







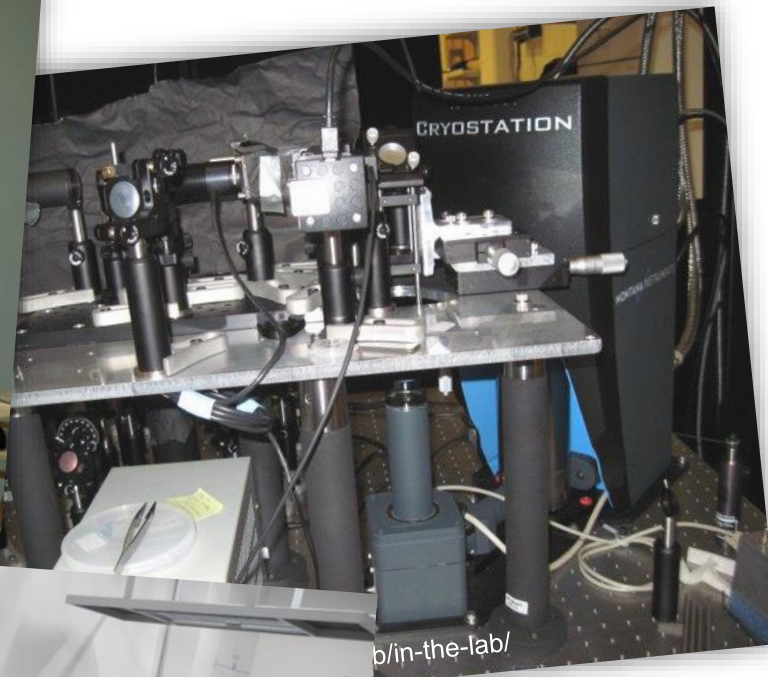
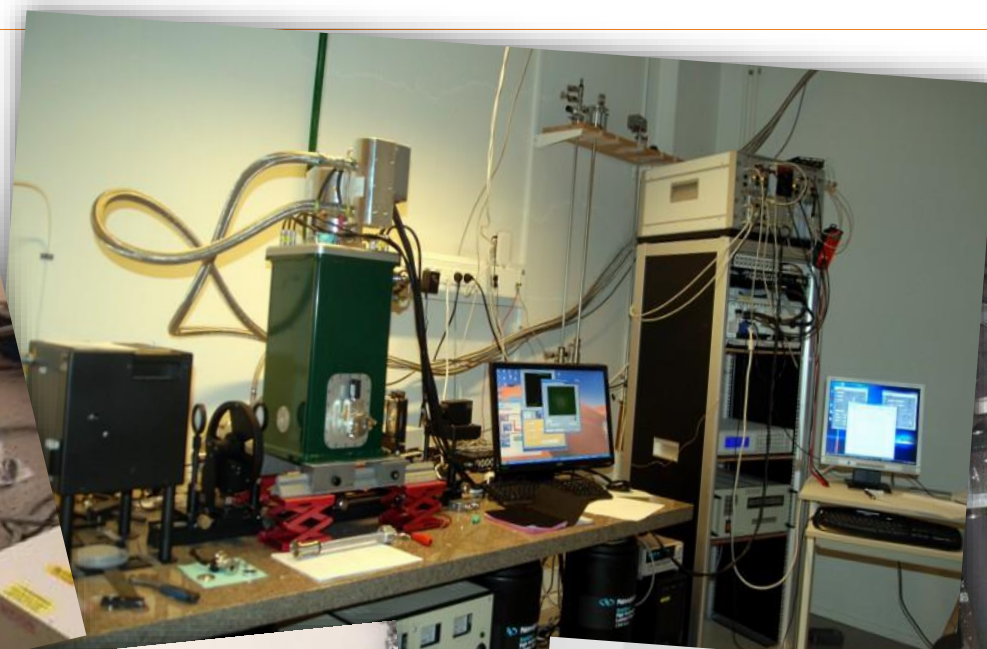
# AGENDA

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- 3 **Closed-cycle cryostats**



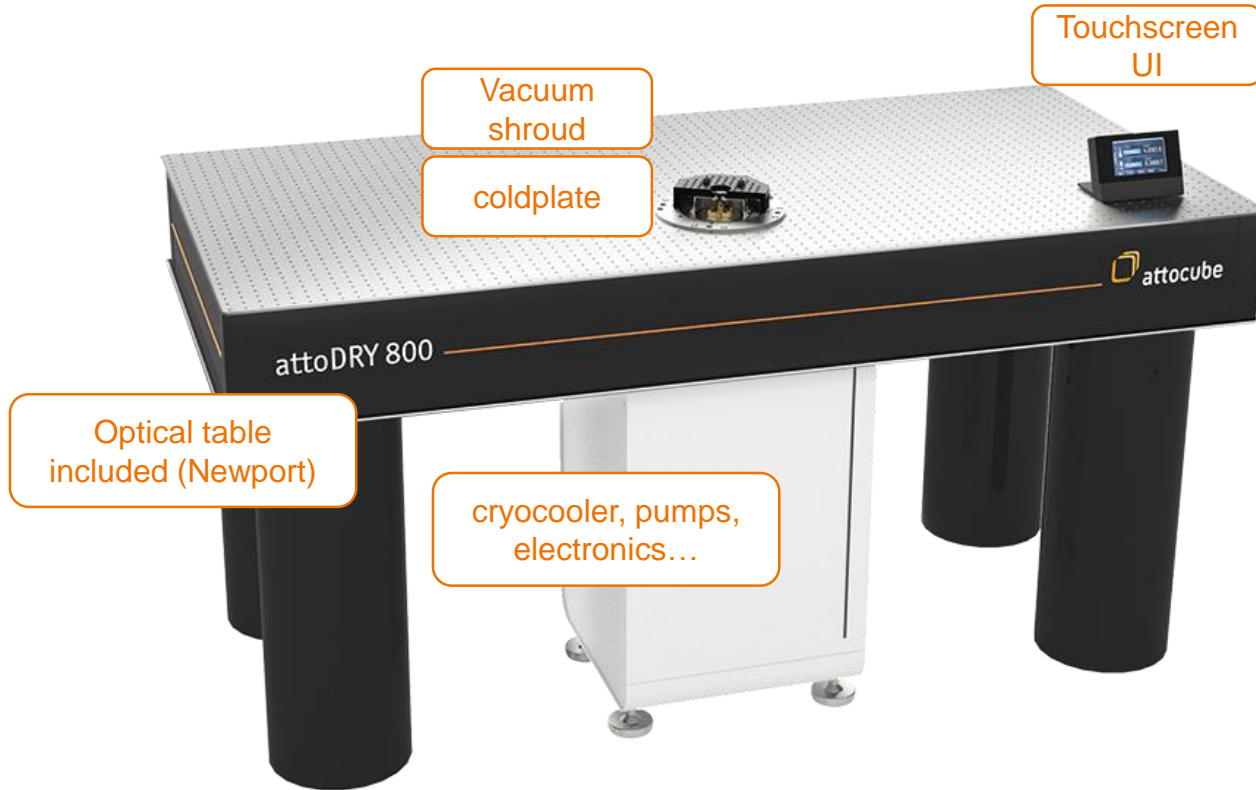
# attoDRY800 – the cryoptical table

The usual optical cryo



# attoDRY800 – the world's first cryo-optical table...

Optical closed-cycle cryostat



Temp. range



Low vibration



Cryogen-free



Fully automated



Touchscreen control



Temp. stability



Fast cooldown

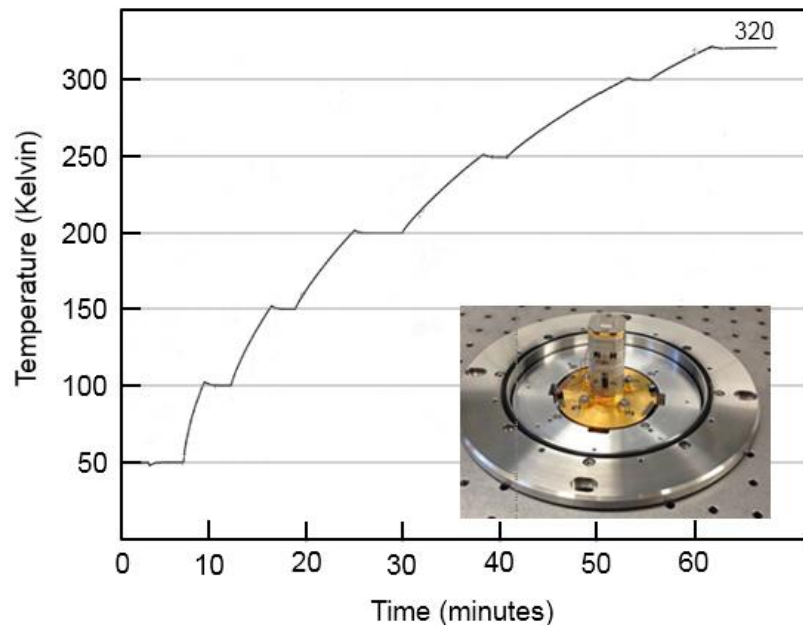


Silent

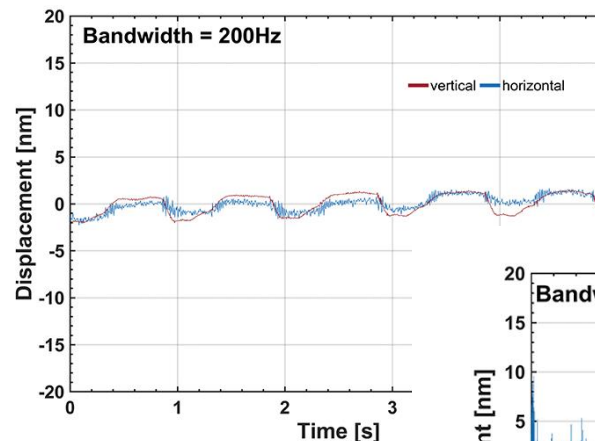


# Temperature sweeps, vibrations measurements

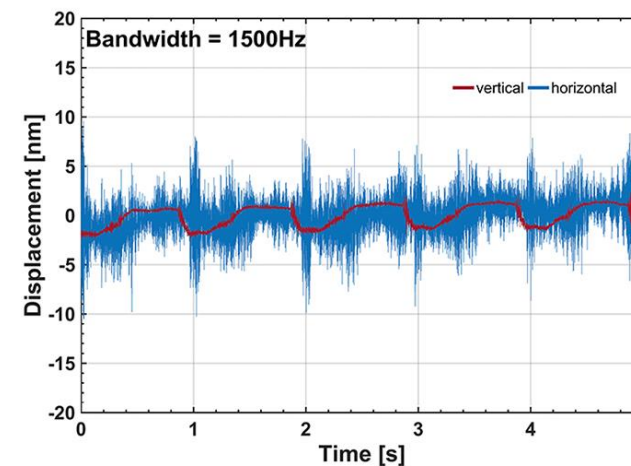
attoDRY800



Base Pressure	<b>&lt;math&gt;5 \times 10^{-6}&lt;/math&gt; mbars</b>
Base Temperature	<b>3.8 Kelvin</b>
Cooling power	<b>170 mW at 5 K</b>
Turnaround time	<b>4h cooling to 5 K, 2h warming up</b>



Lowest vibrations  
on the market



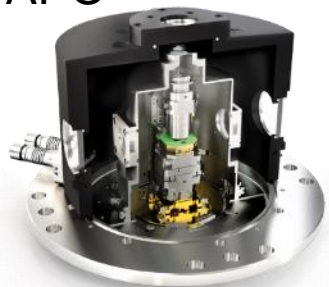
- p2p vibrations @ 200 Hz (1500Hz)**
- Vertical: 3 nm (4 nm)
  - Horizontal: 2 nm (17 nm)



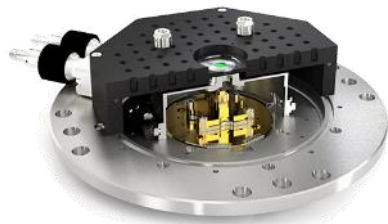
# attoDRY800: Endless possibilities for optical configurations...

Choose your vacuum shroud!

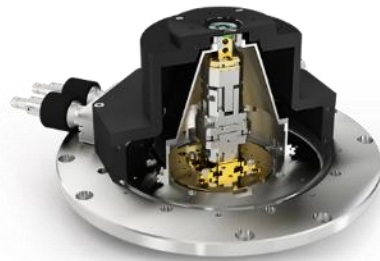
LT-APO



Basic



RT-SWD



RT-SWD/LCCG

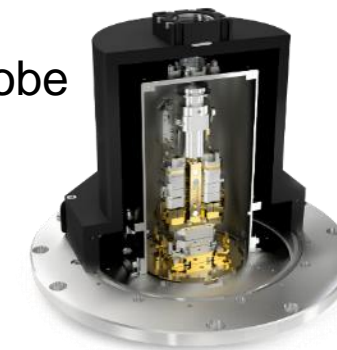


HV objective

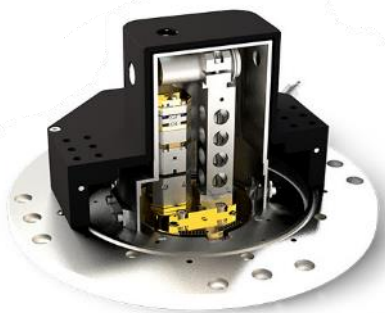
RT-fiber  
transmission



Photonic Probe  
Station



RT-LT transmission

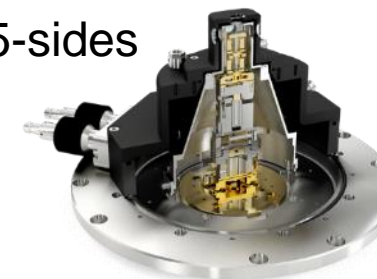


LT-APO transmission



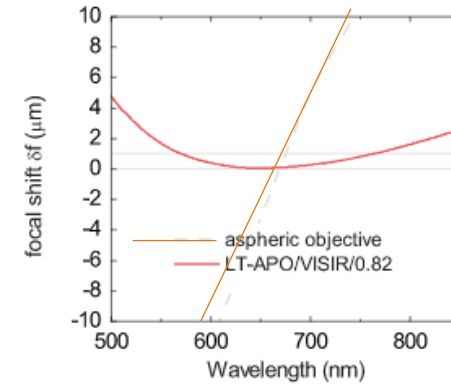
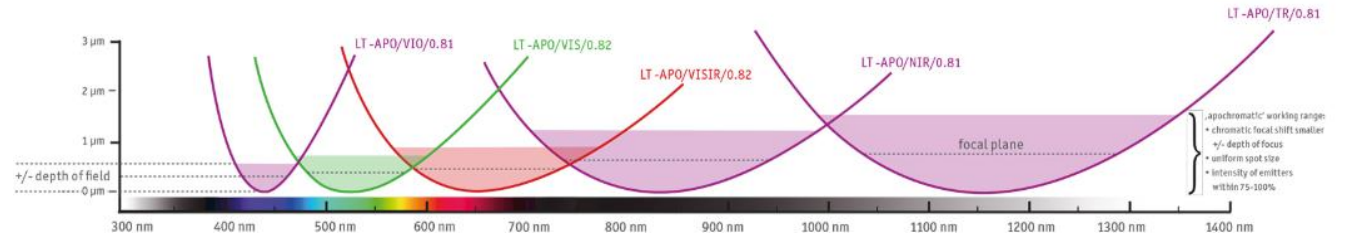
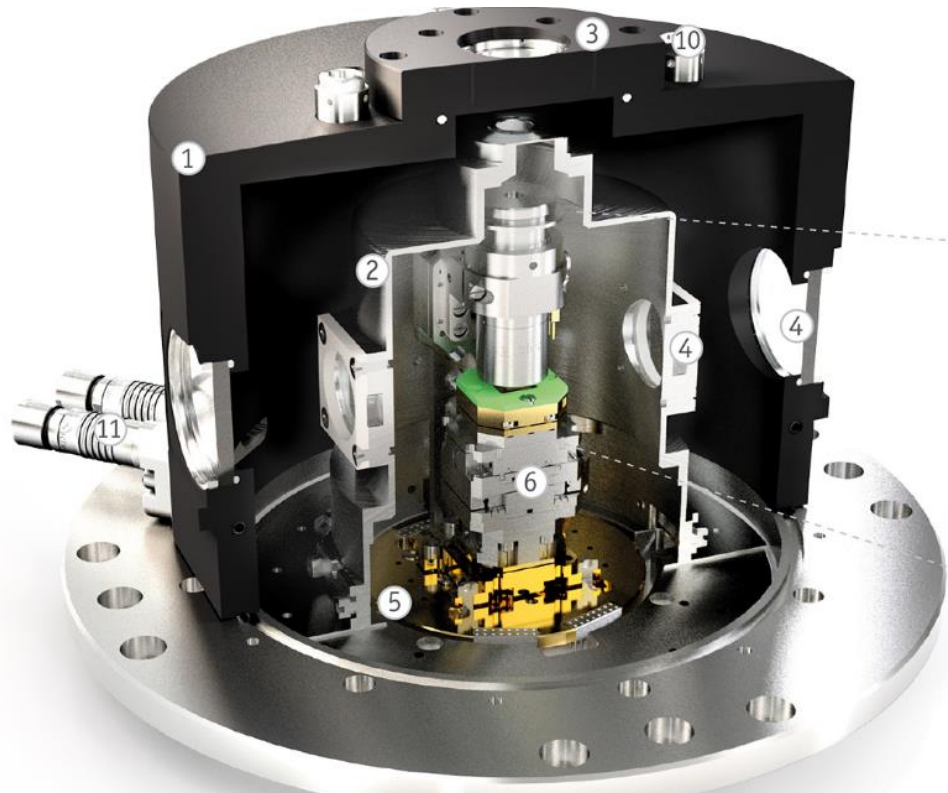
RT Transmission

RT free-beam  
5-sides



# LT-APO option (cold objective)

attoDRY800 vacuum shroud options



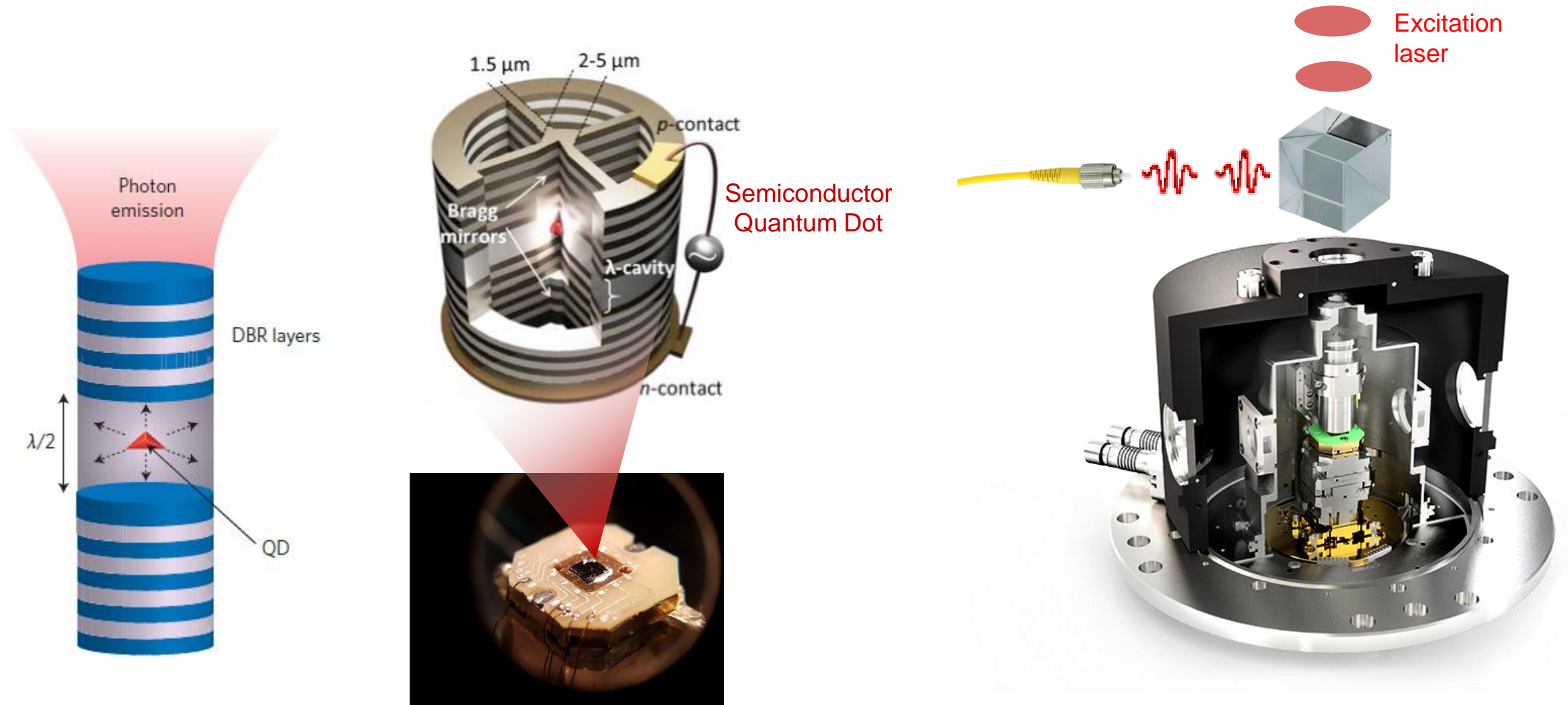
- ANPxy311 stages for sample positioning (6x6mm travel)
- Cold apochromatic objective LT-APO with high NA (>0.8)
- minimal sample drift, broadband high collection efficiency
- sample holder with 12 electrical contacts; temp. sensor & heater included
- feedthrough ring with blind flanges included, DC/SMA/fiber feedthroughs optional

- Multi-color excitation and detection
- Different configurations available



# Application example: QDs as single photon sources

In partnership with Quandela – [www.quandela.com](http://www.quandela.com)





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# attoDRY2100

automated top-loading cryostat with variable temperature & superconducting magnet



cryogen-free & **low vibration** cryostat platform

→ no liquid helium required & enables SPM

Different options for superconducting magnet:

→ 9T, 12T, 9/3T, 1/1/1 T, 5/2/2T

automated temperature and magnetic field control

→ fast parameter change via touchscreen

variable temperature (1.65 .. 300 K) @ full field

→ transport measurements & LT-SPM



Temp. range



Low vibration



Cryogen-free



Fully automated



Touchscreen  
control



Temp. stability



Fast cooldown

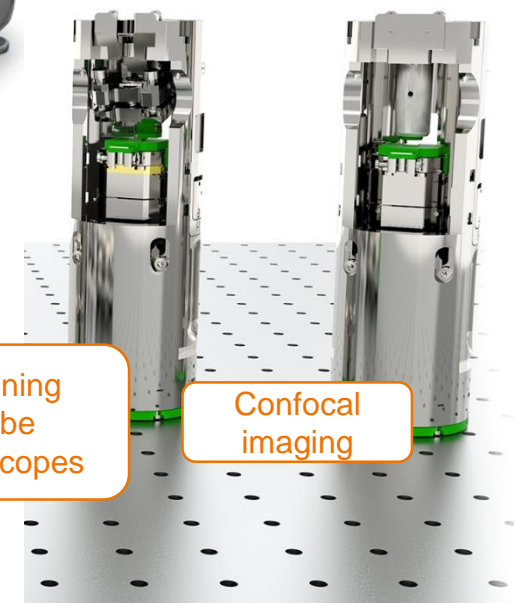


Silent



# AGENDA

- 1 Attocube – an introduction
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- 3 Closed-cycle cryostats
- 4 **Cryogenic microscopy solutions**



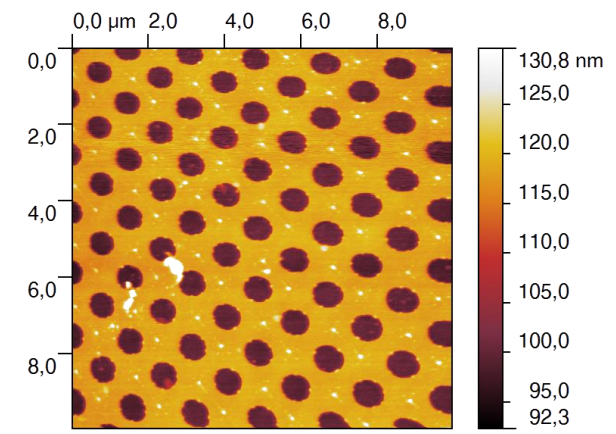
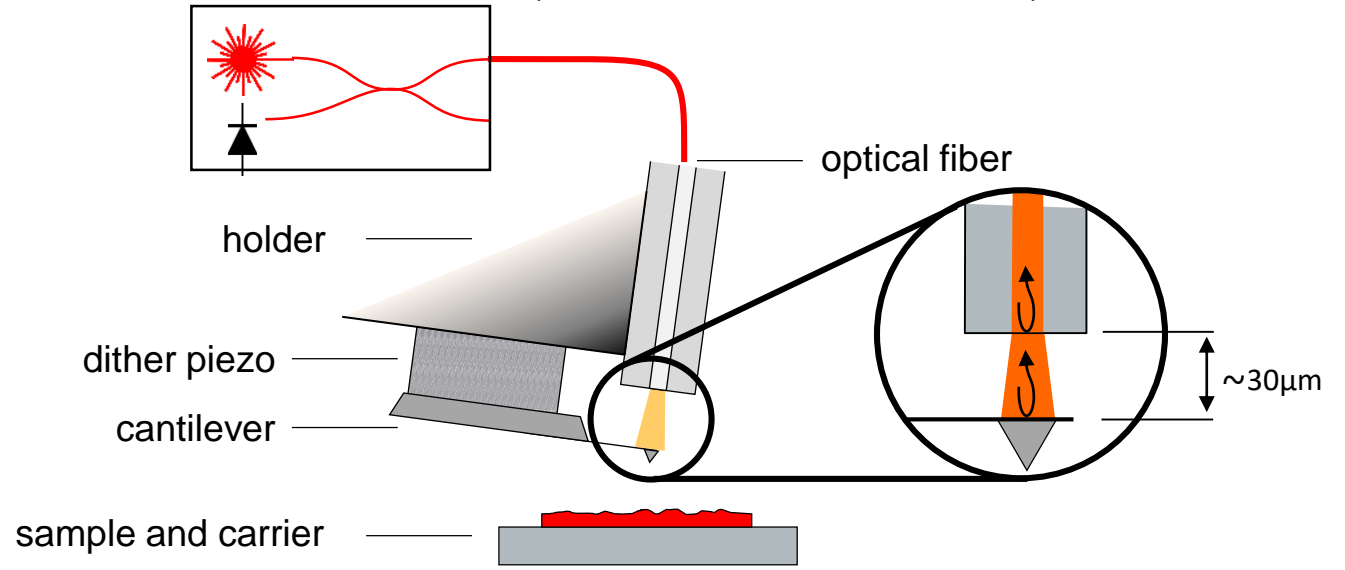
Scanning  
probe  
microscopes

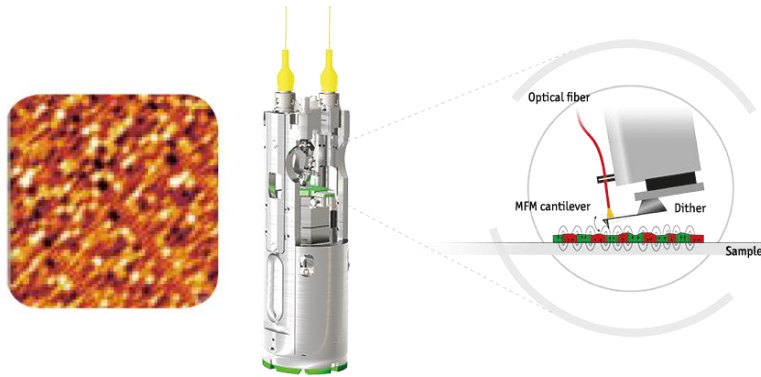
Confocal  
imaging



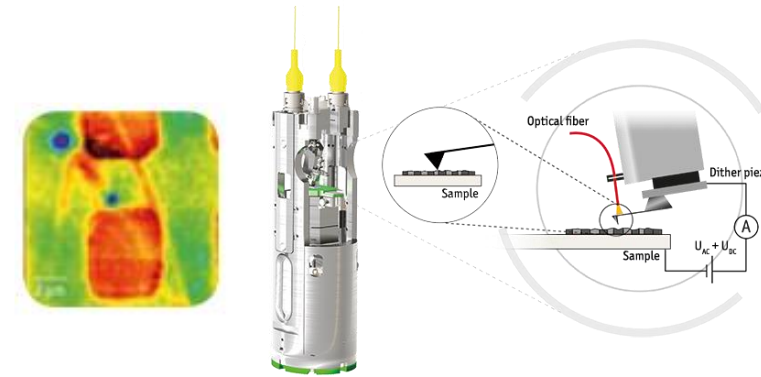


Laser detector module (1310nm with DFB laser diode)

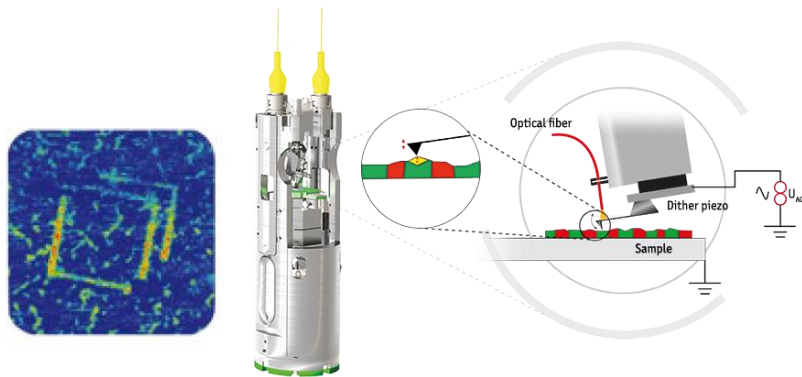




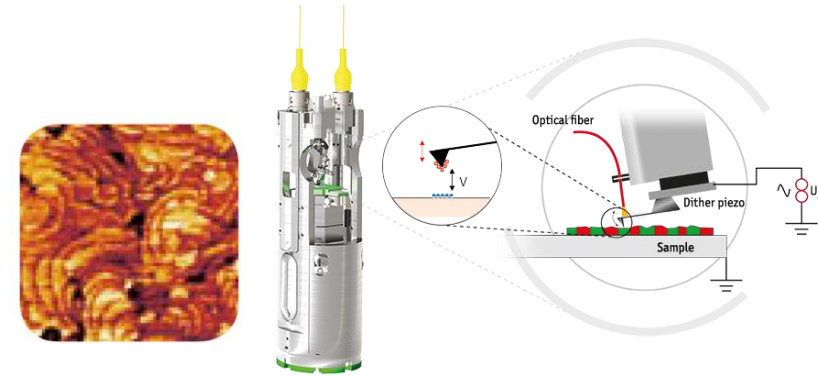
**Magnetic Force Microscopy (MFM)**  
optional AFM mode upgrade



**Conducting-tip Atomic Force Microscopy (ct-AFM)**  
optional AFM mode upgrade



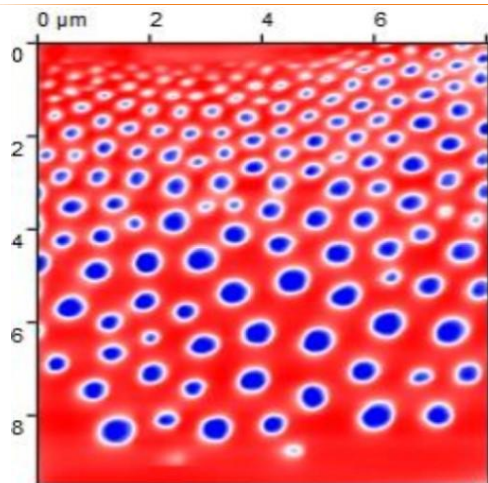
**Piezoresponse Force Microscopy (PFM)**  
optional AFM mode upgrade



**Kelvin Probe Force Microscopy (KPFM)**  
optional AFM mode upgrade

# Application examples: attoMFM

Imaging of magnetic structures



Size-dependence of Antiskyrmions in  $\text{Mn}_{1.4}\text{PtSn}$

Further reading:

[T. Ma et al., Adv. Mater. 32, 2002043 \(2020\)](#)

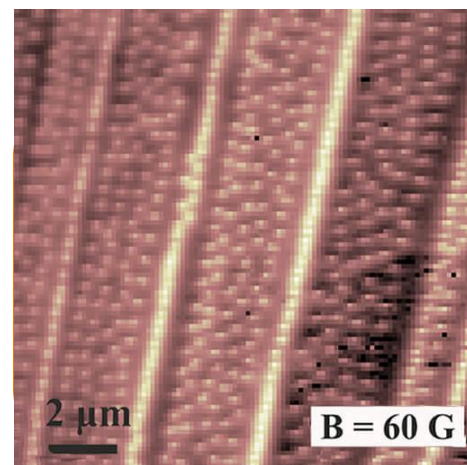
[A.K. Sharma et al., Adv. Mater. 33, 2101323 \(2021\)](#)

[A. Chakraborty et al., Adv. Mater. 34, 2108637 \(2022\)](#)

Skyrmions induced by strain gradient in  $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$

Further reading:

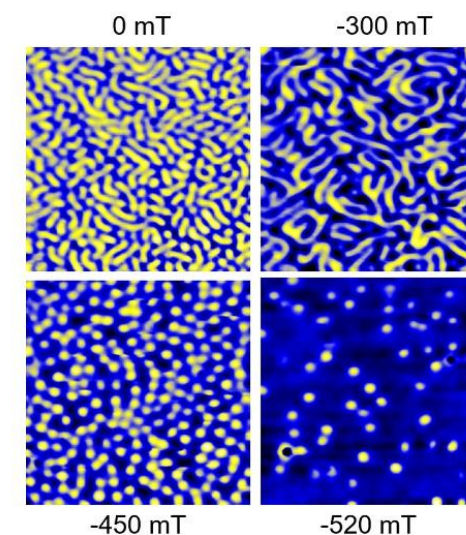
[Y. Zhang et al., PRL 127, 117204 \(2021\)](#)



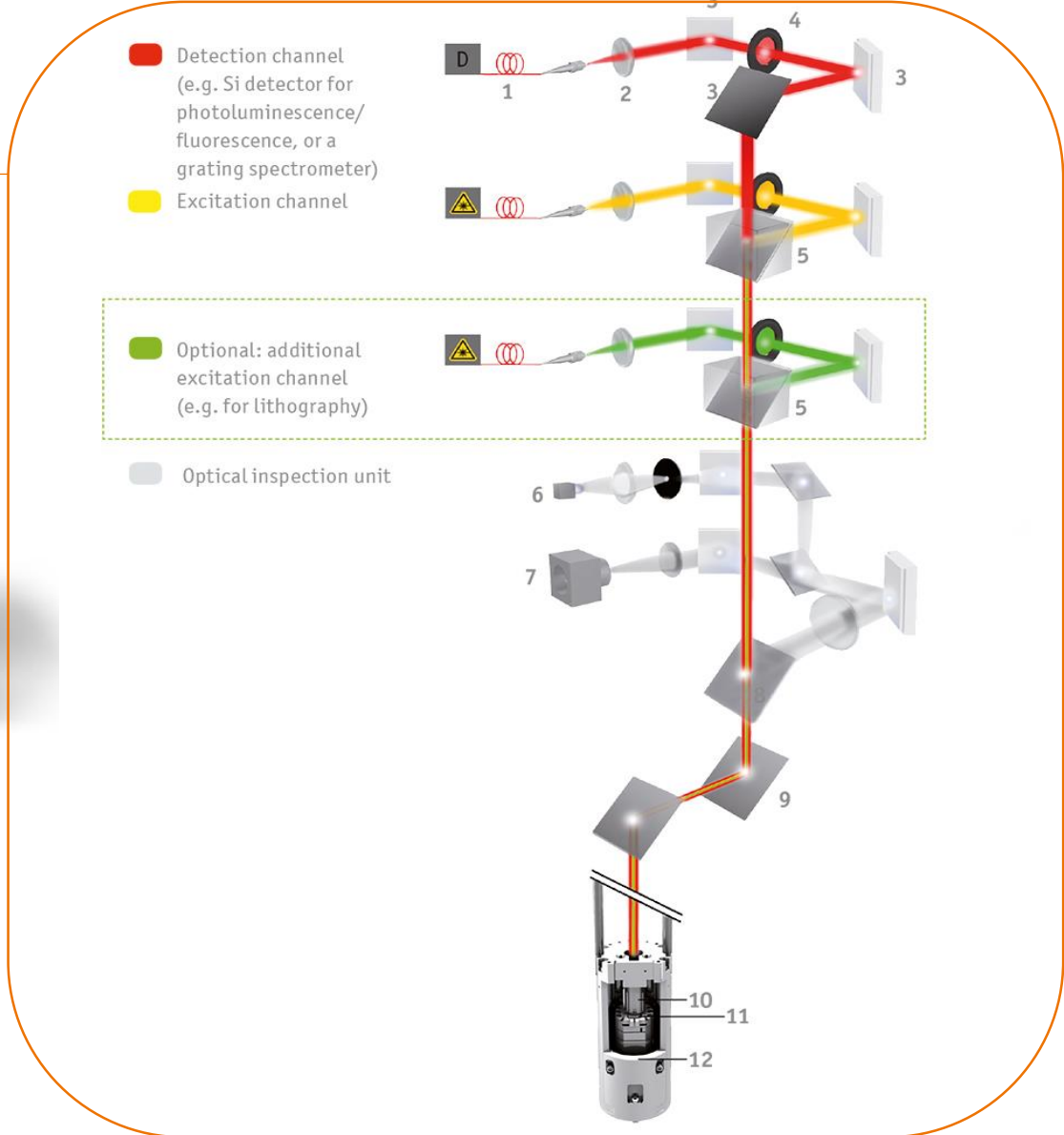
Vortex barriers in high-Tc superconductor Iron-pnictide

Further reading:

[A. Yagil et al., Phys. Rev. B 94, 064510 \(2016\)](#)



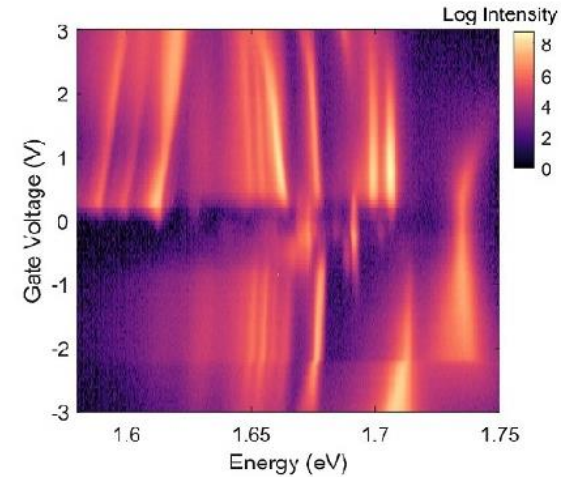
CLOSED LOOP





# Application examples: attoCFM I

Confocal imaging at cryogenic temperatures



Photoluminescence of Excitons in TMD  $WSe_2$

Further reading:

[P. Rivera et al., Nature Commun. 12, 871 \(2021\)](#)

Photoluminescence of magnetically doped colloidal CdSe/CdS quantum dots

Further reading:

[S. Lorenz et al., Nano Lett. 20, 1896 \(2020\)](#)

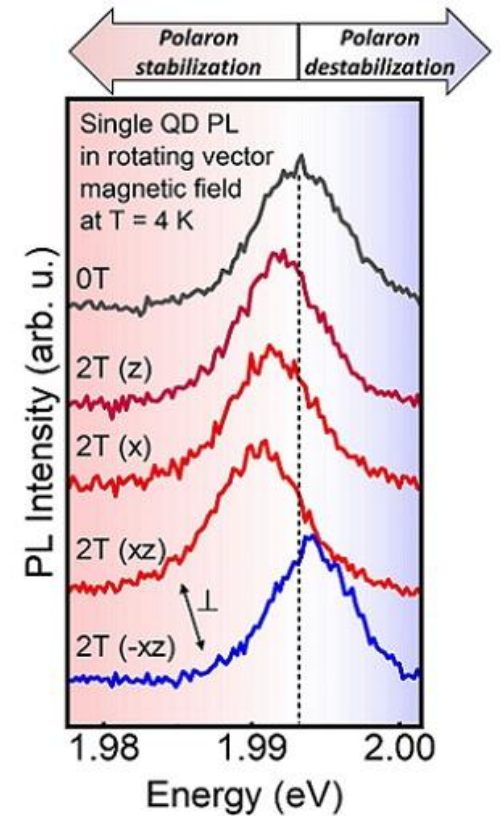
Polarized single photon emission from elliptical micro pillars

Further reading:

[\[1\] Hui Wang et al; Nature Photonics, 13, 770 \(2019\)](#)

[\[2\] Yu-Ming He et al; Nature Physics, 15, 941 \(2019\)](#)

[\[3\] Hui Wang et al; Phys. Rev. Lett. 123, 250503 \(2019\)](#)



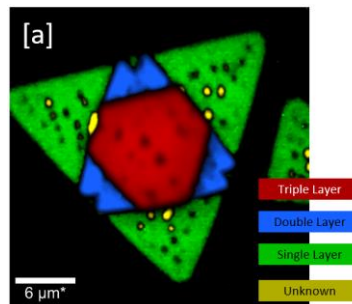
# Application examples: CryoRaman

Confocal Raman imaging at cryogenic temperatures and large magnetic fields

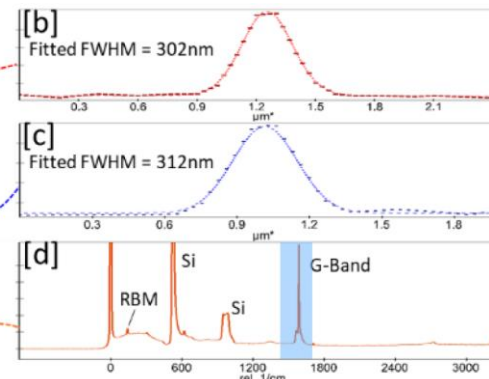
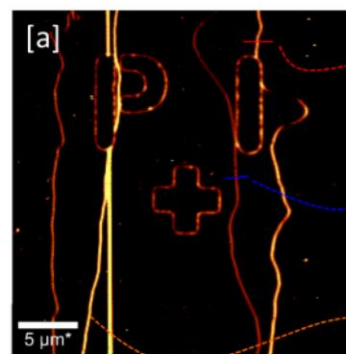
&



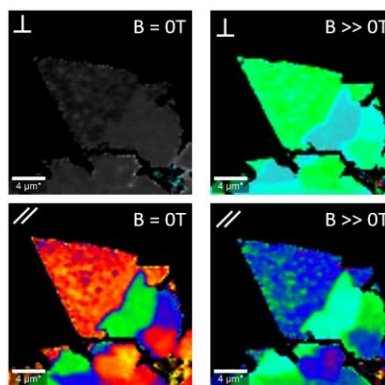
attocube  
WITTENSTEIN Group



Automatic identification of number of MLs in WSe<sub>2</sub>



Spectra of carbon nanotubes:  
Resolution at the diffraction limit



Polarization dependent measurements  
at varying magnetic fields

Further reading:

Dieing, Altman et. Al. cryoRaman  
whitepaper © attocube & WiTec (2021)



# CONCLUSION



We are experts in cryogenic nanopositioning! We offer solutions for all levels of integration: from nanopositioning stages and components for customer setups, to fully integrated microscopy systems.

Technical Note

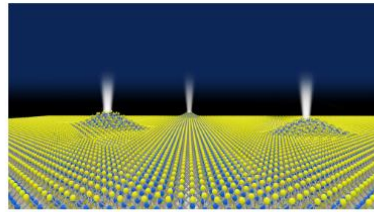
Wide-field cryo-microscopy with the attoDRY800 cryogenic optical table

### Wide-field cryo-microscopy with the attoDRY800 cryogenic optical table

Luca Gragnaniello, Samarth Vadia, Khaled Karraf  
attocube systems AG, Munich, Germany

**(Cooling) Power is nothing without control**  
The study of a physical sample as a function of a range of

The LT-AP0/VISIR objective (NA = 0.82, WD = 0.65 mm [1]) is placed inside the thermally shielded cryogenic space and anchored at the cold plate, just like the sample. Its position with respect to the support is adjustable in a way that ensures that its position is



Presentations on Quantum Optics

Check our whitepapers for more info, and our webinars at [www.attocube.com](http://www.attocube.com)

cryoRaman

Cutting-edge Cryogenic Raman Microscope  
white paper

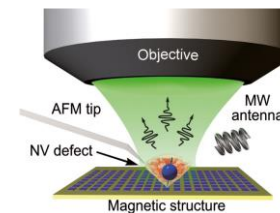


Thomas Diering, Patrick Altmann<sup>1</sup>, Jan Engler<sup>1</sup>, Damon Strom<sup>1</sup>, Mirko Bazzani<sup>2</sup>

<sup>1</sup>WITec GmbH, Ulm, Germany ([info@witec.de](mailto:info@witec.de))  
<sup>2</sup>attocube systems AG, Heer, Germany ([info@attocube.com](mailto:info@attocube.com))

microscope series. This not only delivers a significant leap in spatial resolution (~400nm laterally, <2µm in depth), it also means that cryogenic confocal Raman microscopy can now be augmented with a wide range of upgrades and capabilities that the community has been requesting. For instance, with the

We do much more! Reach out:  
[info@attocube.com](mailto:info@attocube.com) or [philipp.leubner@attocube.com](mailto:philipp.leubner@attocube.com)



**Nanonis Tramea™**  
QUANTUM TRANSPORT MEASUREMENT SYSTEM





# Enabling Scientific Impact

selected customer publications (2013 – 2021)

## 2013

P.J.W. Moll *et al.*, *Nature Materials* 12, 134–138  
O. Gazzano *et al.*, *Nature Communications* 4, 1425  
W. E. Shankset *et al.*, *Nature Communications* 4, 1991  
L. Rondin *et al.*, *Nature Communications* 4, 2279  
R.J. Warburton, *Nature Materials* 12, 483–493  
Y.-M. Heet *et al.*, *Nature Nanotechnology* 8, 213–217  
A. Dréau *et al.*, *Phys. Rev. Lett.* 113, 137601

## 2017

A. Kinikar *et al.*, *Nature Nanotechnology* doi: 10.1038/nnano.2017.24  
B. Wu *et al.*, *Nature Communications* doi: 10.1038/ncomms14480  
G. Wang *et al.*, *Phys. Rev. Lett.* doi: 10.1126/science.abe9163  
M. Manca *et al.*, *Nature Communications* doi: 10.1038/s41467-017-0125-x  
A. Neumann *et al.*, *Nature Nanotechnology* doi: 10.1038/s41467-017-0125-x  
Y. Luo *et al.*, *Nature Communications* doi: 10.1038/s41467-017-0125-x  
I. Gross *et al.*, *Nature* doi: 10.1038/s41467-017-0125-x

## 2019

G. Munoz-Matutano *et al.*, *Nature Communications* doi: 10.1038/s41467-019-0125-x  
Y. J. Chung *et al.*, *Nano Letters* doi: 10.1021/acs.nanolett.9b04637  
P. Schönherr *et al.*, *Nano Letters* doi: 10.1021/acs.nanolett.9b04637  
K. R. Joshi *et al.*, *Physical Review Applied* doi: 10.1103/PhysRevApplied.11.044001  
S. Kolatschek *et al.*, *Journal of Applied Physics* doi: 10.1063/1.5050344  
J. Qian *et al.*, *Optics Express* doi: 10.1364/oe.27.004845  
P. Wang *et al.*, *Review of Scientific Instruments* doi: 10.1063/1.5083994

## 2021

A. J. Sternbach *et al.*, *Science* doi: 10.1126/science.abe9163  
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F. Niroui *et al.*, *Nano Letters* doi: 10.1021/acs.nanolett.0c04043  
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Thank you for your attention!

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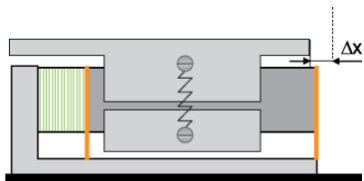
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