Enabling Optics on the Nanoscale

NanoWizard® NANOOPTICS

Comprehensive solutions for **AFM and Raman** spectroscopy, Tip-Enhanced Raman Spectroscopy **(TERS)**, Aperture **SNOM** and Scattering-type SNOM **(sSNOM)**, Confocal microscopy, NanoManipulation in optical fields

Unique integration with optical microscopy by **tip and sample scanning** design, **DirectOverlay**™ mode, **980 nm** deflection detection system and special filter set

Designed for optimum imaging in air or liquid with excellent stability especially for **BioTERS** applications

Expanded flexibility with the **widest range of modes and accessories** with the Vortis™ Advanced controller with 2 channel gated photon counting

JPK Instruments

we have joined Bruker

BRUKER

JPK — EXPERIENCE IN NANOOPTICS

Within the last decade, optical phenomena on the nanoscale have become an exciting area of current research. To study light on the nanoscale, especially its interaction with matter, researchers look for methods with nanometer spatial resolution. Here, a combination of Light Microscopy-derived techniques and Scanning Probe Microscopy is a powerful solution. This so-called Near-field Optical Microscopy delivers optical information from sample surfaces with sub-wavelength resolution.

The first system comprising a JPK NanoWizard® AFM coupled with a Raman spectrometer in 2003 saw the start of a new chapter of SPM and optics. Since then, JPK has installed a large number of systems worldwide.

Based on strong relationships with the NanoOptics community collaborating with home-builders and users worldwide has enabled JPK to develop powerful and flexible systems. Upgradeability guarantees a safe investment for users, and an international team of experienced scientists takes care of service and support.

JPK strongly believes in combining techniques: in particular AFM with optics. This opens up a field of new applications including TERS/SERS, tip-enhanced fluorescence, nanomanipulation with light, chemical surface analysis and compound detection, metamaterials, developments of optically active components such as dyes, markers, light sources and switches. The list grows daily. A large number of user publications show the success of this technology approach. Now JPK introduces the latest platform for AFM and optics – the NanoWizard® NanoOptics system.

THE DEVELOPMENT MILESTONES IN THE NANOOPTICS FIELD

1999 JPK was founded

2003 — **First integration with a HORIBA Jobin Yvon Raman spectrometer** at the group of Prof. Deckert, Jena University, Germany

2005 — **Launch of TAO™ module**: for tip-enhanced NanoOptics

2005 — **First single molecule fluorescence and FRET setup** at the group of Prof. Nienhaus, Ulm University, Germany

2007 — **Launch of BioMAT™ Workstation**: unique coupling of AFM with upright microscopy

2009 — **First integration with a HORIBA Jobin Yvon iHR 550** at the group of Dr. Shikler, Ben-Gurion University of the Negev, Israel

2010 — **First integration with a Renishaw Raman microscope** at the group of Dr. Dunstan, Swansea University, UK

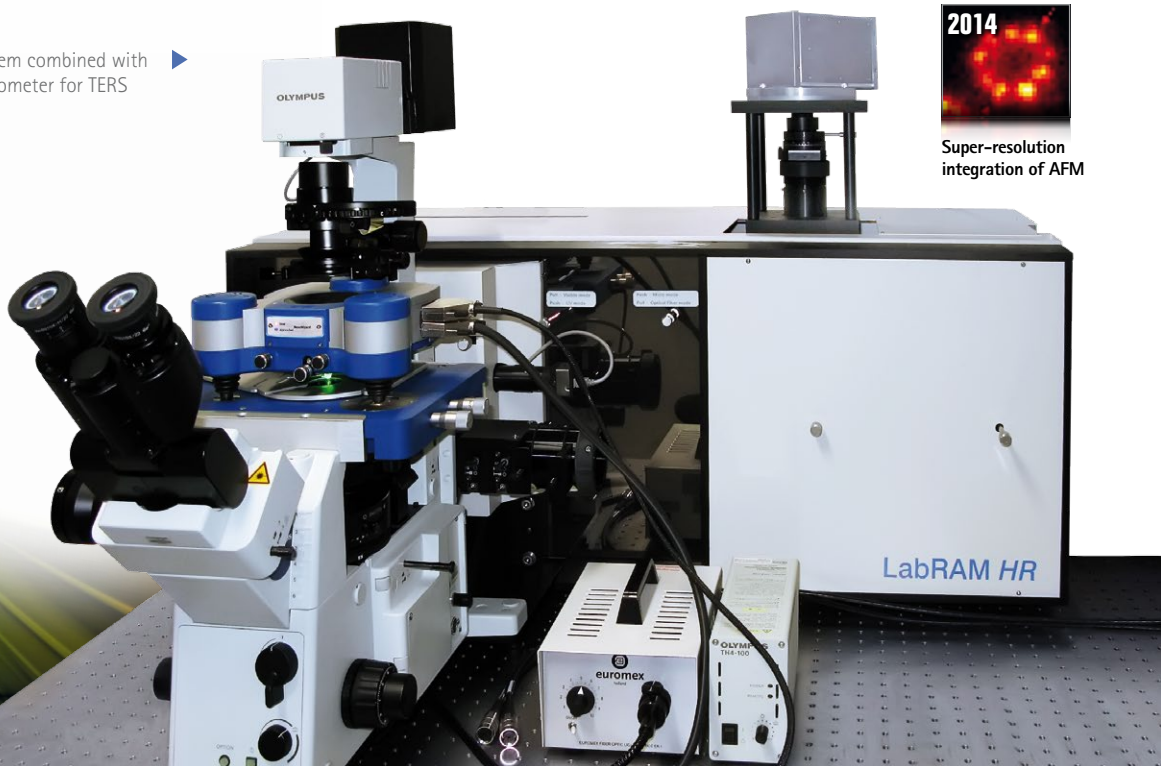
2011 — **NanoWizard® NanoOptics** Comprehensive solution for advanced experiments combining AFM and optical spectroscopy

2012 — **Launch of QI™:** quantitative imaging mode for the most challenging of AFM samples

2013 — **Raman Reflector Kit** for Tip-Enhanced Raman Scattering (upright-TERS) on opaque samples

2014 — **Super-resolution integration of AFM**

NanoWizard® NanoOptics AFM system combined with a HORIBA Jobin Yvon Raman spectrometer for TERS



NanoWizard® NanoOptics — Technology

The NanoWizard® NanoOptics head comes with excellent physical and optical access to the sample from top and bottom as well as from front and side, even when the head and condenser are in place. Additionally, it has an integrated port for fiber SNOM applications.

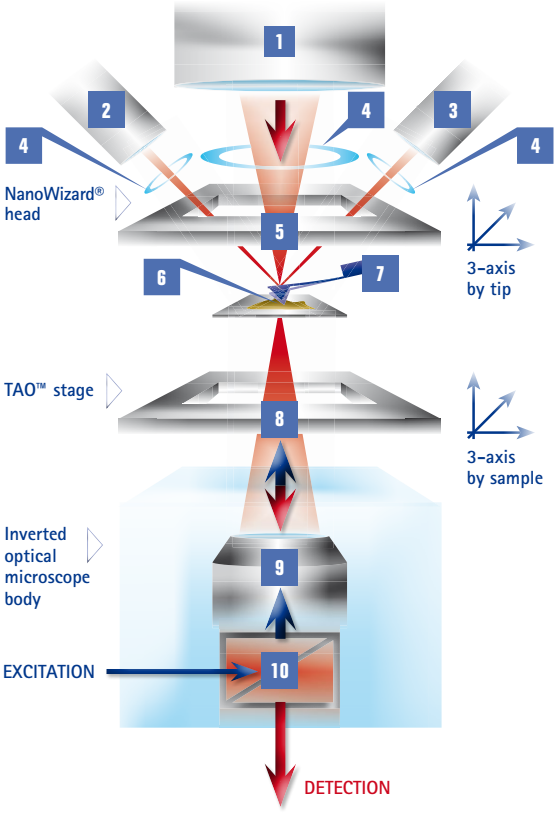
Because stability and reproducibility of the SPM-tip positioning and scanning are vital for applications requiring the collection of single photons over a long time period, the system has been optimized for it. Improved closed-loop control on 5 or 6 axes and highest scanner resonance frequency in z deliver a scanner performance previously not available in a commercial AFM. This ensures highest data quality for imaging and force measurements in air and liquids.

The Vortis™ Advanced SPM controller delivers cutting edge values for noise levels, data acquisition speed, and maximum versatility. Advanced electronics and software for multiple feedback controls, highest bandwidth and access to all signals combined with the ability to work with user-written scripts are all key elements for successful experiments. Synchronization of AFM and spectrometer data is achieved through a user-friendly software interface.

The NanoWizard® is designed for optimal use in liquid and comes with a vapour barrier, encapsulated piezos and a variety of dedicated liquid cells. The system may also be used in air or controlled gas environments. Flexibility in the software and the range of accessories make the system ready for any user-defined experiments. The newly developed fiber-coupled detection unit for sensitive detectors such as APDs and PMTs delivers outstanding results in terms of stray-light suppression.

KEY FEATURES

- Head in 2 versions available
  - **UV transparency version** for top view sample illumination with UV-light
  - **Fiber port version** for fiber SNOM applications
- Highest stability and lowest drift for long term experiments
- Up to 6 axes closed-loop scanning (3 by tip and 3 by sample) with the TAO™ module
- 980 nm laser source for cantilever deflection detection prevents cross talk with other wavelengths
- Special filter sets for blocking and cleaning inside
  - Also versions for 2-photon microscopy available
- Compatible with most commercially available inverted research microscopes (Zeiss Axiovert and Axio Observer lines, Nikon TE and Ti lines, Olympus IX line and Leica DMI/DMi lines
- Seamless integration with inverted microscopes, Raman spectrometers, photon counting systems
- Optional PI PIFOC® module for independent vertical focus positioning
- Coverslip-based sample holders for air, inert gases, liquid and with electrical sample connection
- Flexible Vortis™ Advanced SPM controller with the largest variety of signal channels and Q-control
- Wide range of operation modes and accessories such as Tuning Fork, STM, Conductive AFM, Fiber SNOM, Raman Reflector Kit and fiber coupled detection module

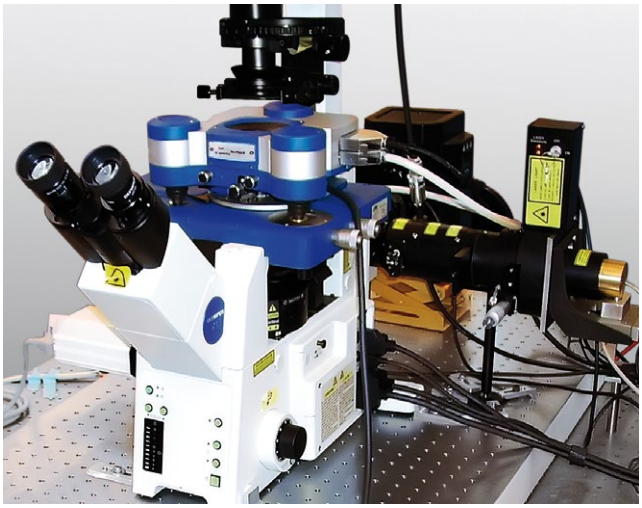


1 Condenser lens from microscope
2 Detector for cantilever deflection
3 Laser for beam deflection
4 Filters
5 Tip scanner
6 Sample
7 Cantilever
8 Sample scanner
9 High-NA objective lens
10 Fluorescence splitter

EXPERIMENTS IN THE OPTICAL NEAR-FIELD

The instrument is ready for a broad range of applications from nanoscale optical imaging by aperture and scattering-type SNOM to experiments involving interactions of light with the sample such as absorption, excitation, non-linear effects and quenching.

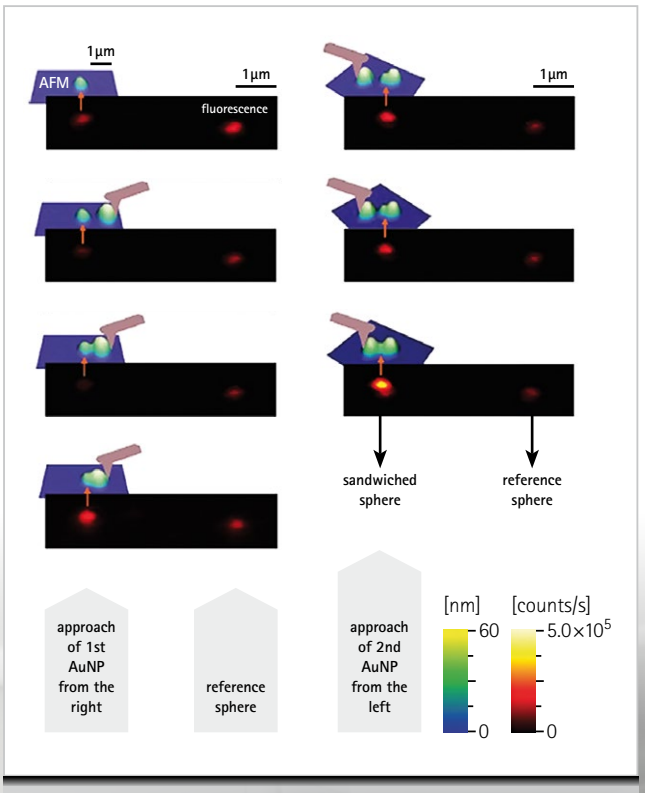
By using a standard inverted optical microscope with condenser optics, the NanoWizard® is easy to set up and run with full optical imaging capabilities in a matter of minutes. The user is able to choose high-NA immersion objective lenses and a wide range of detectors and cameras to meet their experimental requirements.



▲ NanoWizard® AFM with TAO™ module on a single photon detection setup

OPTICAL NEAR-FIELD EXPERIMENTS

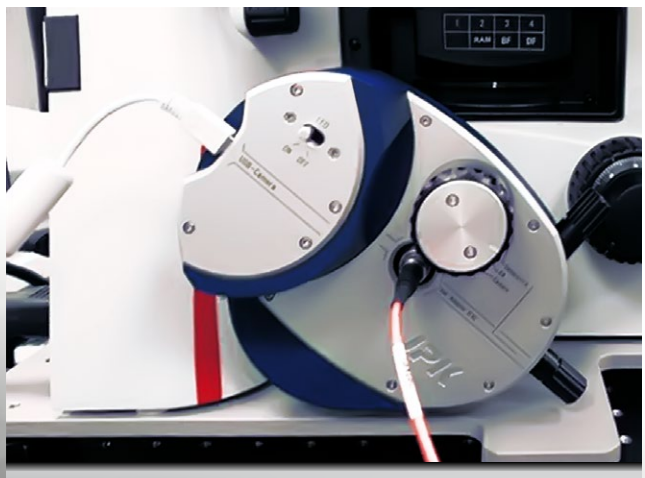
- **Aperture fiber SNOM experiments**
  An integrated fiber SNOM port in the NanoWizard® NanoOptics head and the Tuning Fork module allows hassle-free integration of techniques.
- **Scattering-type SNOM (sSNOM) experiments**
  The new system is perfect for tip-enhanced applications such as fluorescence with nano-antennas made of nanofabricated or chemically modified tips. As an alternative to cantilever based optical probes, STM tips can be used with the new Scanning Tunnelling Microscopy (STM) module.
- **Nanomanipulation in optical fields**
  The new system is ideal for studying optical surface properties of dyes and markers, quantum dots/rods or metamaterials such as quenching or plasmon generation in combination with topography, nanomechanical, electrical and magnetic properties. Thanks to the symmetric design of stage and head as well as the latest closed-loop scanner technology in a 5- or 6-axis configuration, long-term stability and reproducibility reach the highest possible level.



◀ Enhancement of fluorescence with gold nanoparticles. The three-axis scan stage of the AFM head is used to align the AFM tip with the optical axis. The fluorescence and AFM images are recorded by raster-scanning the sample.

From: A. Bek, R. Jansen, M. Ringler, S. Mayilo, T. A. Klar, J. Feldmann. Fluorescence enhancement in hot spots of AFM-designed gold nanoparticle sandwiches. Nano Lett. 2008, 8, 485-490.

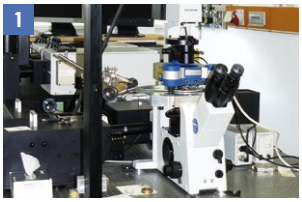
▼ Fiber-coupled detection unit mounted on a Leica microscope side port

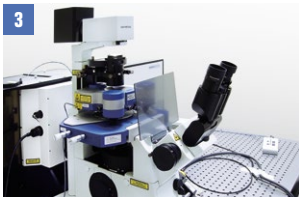


RAMAN AND TIP-ENHANCED RAMAN SPECTROSCOPY (TERS) FOR SOFT MATTER

The instrument is tailor-made to combine Raman spectroscopy with AFM. This allows straightforward integration of the AFM into a Raman system without compromising the performance or experimental capabilities of either technique.

The combination of Raman spectroscopy with AFM empowers the correlation of the information of both techniques simultaneously. Conventional Raman spectroscopy together with AFM enables chemical information in conjunction with the surface properties delivered by the AFM. In order to perform analysis with the highest spatial resolution in the nanometer-range, TERS uses the Raman-enhancing benefits of the surface plasmons of the AFM tip. The metal coated AFM/STM tip is used as a field enhancer while scanning the sample. This results in Raman signals with the spatial resolution in the order of the tip diameter simultaneously with the surface information provided by the AFM.
Due to the highest stability and the design for liquid applications the instruments is perfect for BioTERS applications.





1 Setup with Acton Advanced SP2750
2 Setup with Renishaw inVia
3 Setup with Jobin Yvon LabRAM HR

KEY COMPONENTS AND BASIC PARAMETERS FOR RAMAN/TERS/BIOTERS EXPERIMENTS

Tip and sample scanner combination

- NanoWizard® head (3 scan axes) and TAO™ sample scanner module (2 or 3 scan axes) on top of an inverted microscope integrated into a Raman spectrometer

Suppression of optical cross talk between AFM and Raman excitation/signal

- 980 nm laser source in the AFM
- Blocking and cleaning filters in the AFM head

AFM stability over long time

- High performance closed-loop scanners and symmetric design of AFM head and stage
- Coverslip based fluid cells with temperature control and fluid exchange for highest stability in combination with oil or water immersion objectives

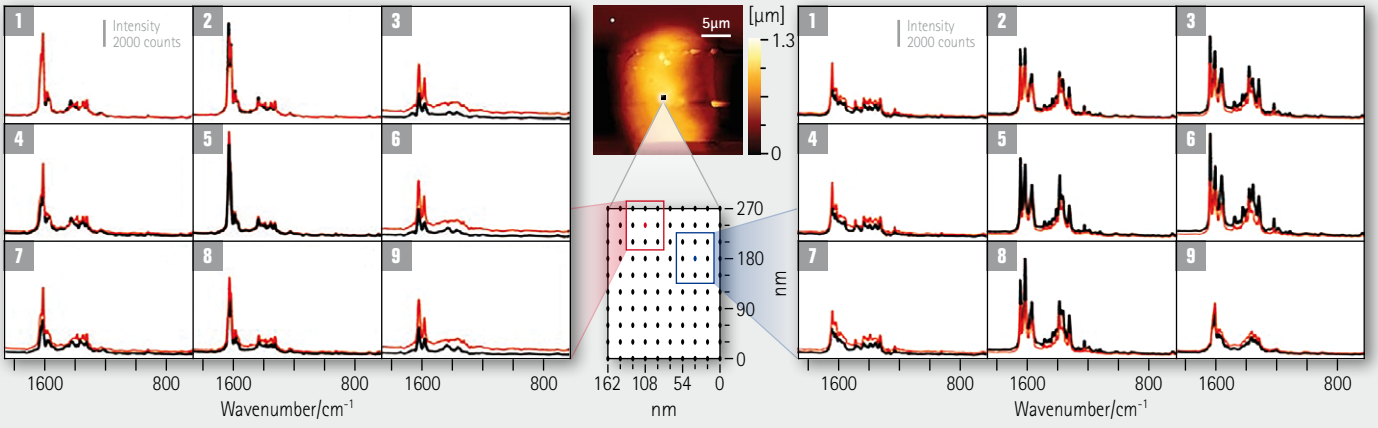
System integration

- Synchronization between AFM tip and sample position, and Raman signal recording in the JPK software
- JPKs proven algorithm to find the perfect tip position in the focus of the high-NA objective lens

Flexibility

- Large variety of AFM/SPM operation modes
- Vortis™ Advanced controller with highest speed and lowest noise with a large number of signal channels accessible with the Signal Access front panel
- Easy-to-use and fully featured JPK software for advanced experiments for beginners and experts
- **Raman Reflector Kit** for TERS on opaque samples

▼ TERS mapping on fixed single human colon cancer cells (HT29 in liquid); Raman data analysis by hyperspectral unmixing algorithm N-FINDR. From: M. Richter, M. Hedegaard, T. Deckert-Gaudig, P. Lampen, V. Deckert: "Laterally resolved and direct spectroscopic evidence of nanometer-sized lipid and protein domains on a single cell", Small 7(2): 209 (2011)



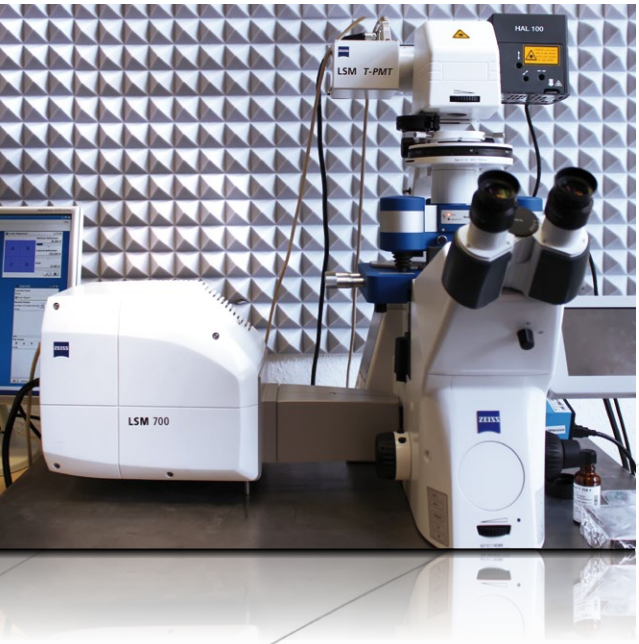
ADVANCED FLUORESCENCE TECHNIQUES AND TIME CORRELATED SINGLE PHOTON COUNTING (TCSPC)

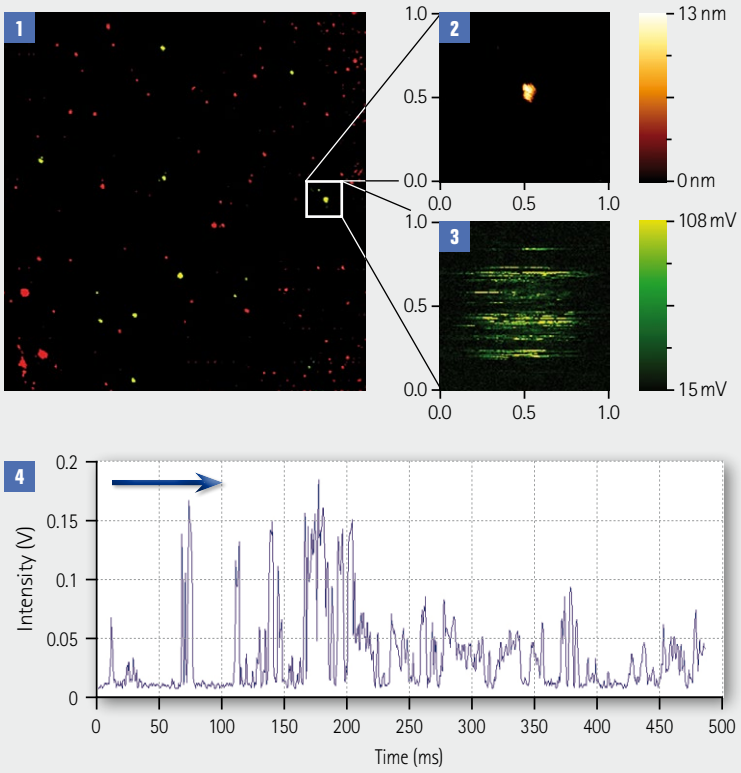
Advanced fluorescence techniques and Time Correlated Single Photon Counting (TCSPC) Complementary techniques to AFM, such as epi-fluorescence, confocal laser scanning microscopy, TIRF, FRET, FCS, FLIM, FRAP, STORM, PALM, STED, spinning disc, etc., give insight about the behavior or location of particular features.

It is now possible to routinely combine AFM imaging and force measurements with these optical methods on the same sample spot simultaneously.

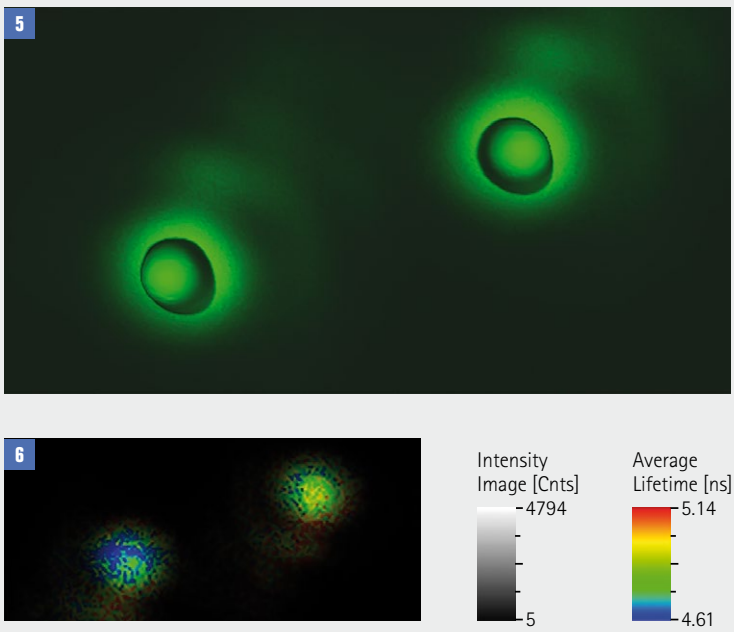
▼ NanoWizard® AFM combined with a Picoquant MicroTime 200 FLIM system

▼ NanoWizard® AFM combined with a Zeiss LSM 700 confocal laser scanning system





1 AFM height image (10 × 10 µm²) of light emitting (green) and non light emitting (red) CdSe quantum dots
2 AFM topography – cluster of 3 quantum dots
3 Fluorescence – blinking prevents accurate size/shape estimation
4 Time series of fluorescence at the center of the optical spot

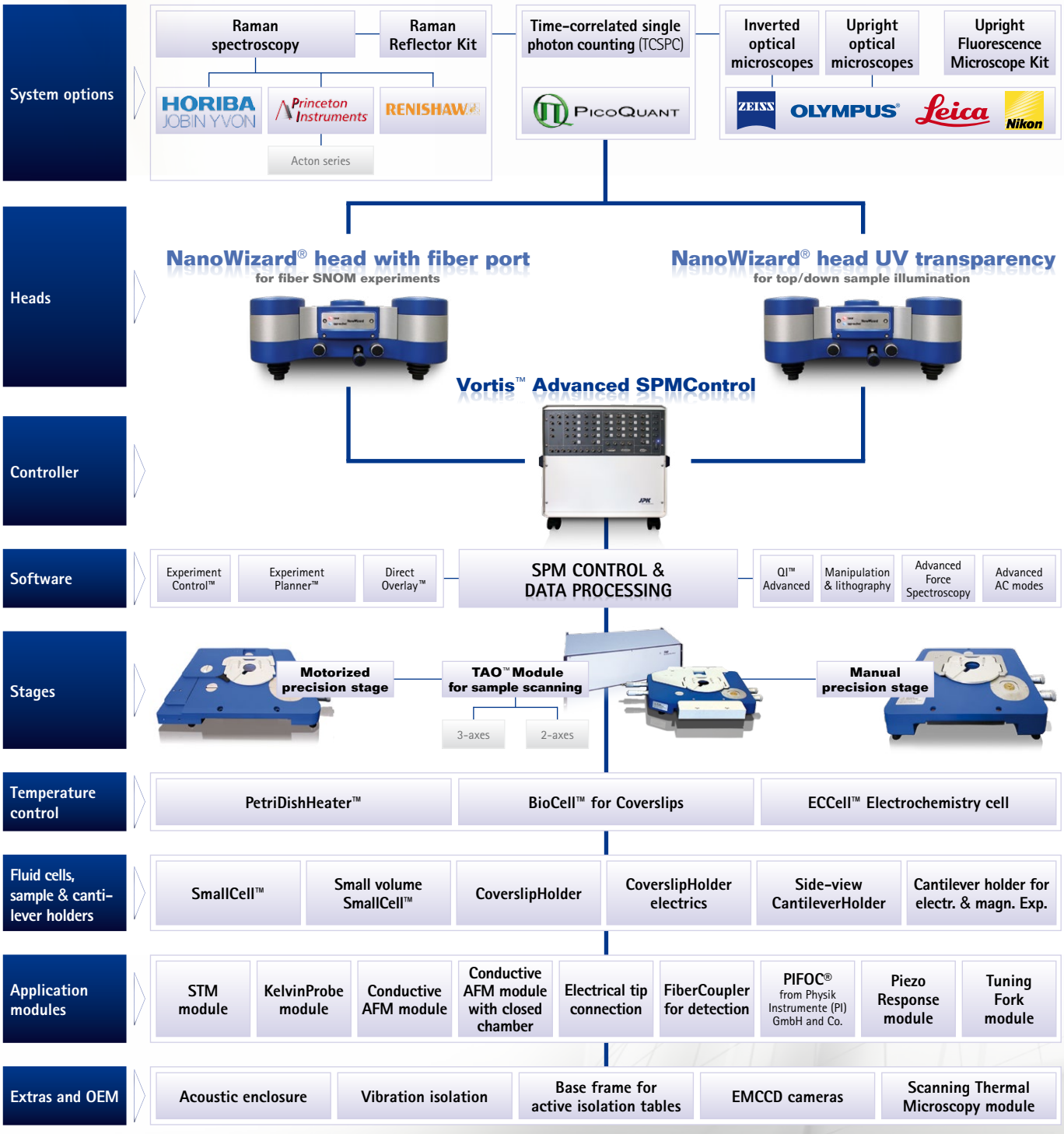


Simultaneous AFM and FLIM measurements on nanoparticles. Scan size 800 nm². Picture 5 shows 3D height information with fluorescence signal overlaid in green. Picture 6 shows the lifetime signal.

OPTIONS AND ACCESSORIES

The NanoWizard® NanoOptics AFM can be used in a large number of configurations. The schematics shown here focuses on the combination with optical methods where the sample is prepared on glass substrates, typically coverslips, which are used for high-NA optics applications.

The AFM system can be used for many more applications. It is also possible to interface and run different heads such as the ForceRobot® 300 and the CellHesion® 200 or to use the TopViewOptics™. For special configurations and experimental requirements, please ask us.



For more detailed information about all options see the brochures and product notes or visit www.jpk.com.

SPECIFICATIONS FOR THE NANOWIZARD® NANOOPTICS AFM

System specifications
- Atomic lattice resolution on inverted microscope (< 0.030 nm RMS z noise level)
- Ultra-low noise level of cantilever deflection detection system < 2 pm RMS free (0.1 Hz - 1 kHz) and high detector bandwidth of 8 MHz for high speed signal capture
- Tip-scanning, stand-alone system, with a rigid low-noise design and drift-minimized mechanics – the best choice for simultaneous AFM and laser scanning experiments
- 980 nm IR deflection detection light source with low coherence for interference-free measurements
- The only liquid-safe AFM with integrated vapor barrier, special encapsulated piezo drives and tip-moving design
- Transmission illumination with standard condensers for precise brightfield, DIC and phase contrast
- Scanner unit
  - Best closed-loop AFM on the market for reproducible tip positioning and long time position stability
  - 100 × 100 × 15 µm³ scan range
  - Position noise level < 0.15 nm RMS in xy (in closed-loop) and 0.06 nm RMS sensor noise level in z (3 kHz bw)

Vortis™ Advanced SPMControl electronics
- State-of-the-art digital controller with lowest noise levels and highest number on signal channels
- High speed 16 bit AD conversion with 60 MHz for the photodector-signals
- 24 bit ultra precise ADC with 2.5 MHz
- High speed Lock-in amplifier technology for precise amplitude and phase detection
- High speed data capture with optional burst mode
- Modular hybrid analog/digital design with latest PPC technology (PowerPC @ 660 MHz)
- Gigabit Ethernet interface for fast data link
- Number of data points that can be captured continuously: restricted only by HDD
- Thermal noise acquisition up to 3.25 MHz
- Optional Signal Access Module (SAM) with analog and digital connectors for maximum experimental freedom
- 2 channel gated photon counting

SPMControl software
- True multi-user platform (perfect for imaging facilities)
- User-programmable software
- Fully automated sensitivity and spring constant calibration using thermal noise or Sader method
- Patented DirectOverlay™ for combined optical and AFM information
- Outline™ mode for precise selection of a new scan area in the optical image
- Improved ForceWatch™ mode for force spectroscopy and imaging for cantilever-drift free measurements
- Comprehensive force measurement with TipSaver™
- Advanced spectroscopy modes such as various force clamp modes or ramp designs, e.g. for temperature ramps, pulling speed or force feedback
- Powerful Data Processing (DP) functions with full functionality for data export, fitting, filtering, edge detection, 3D rendering, FFT, cross section, etc.
- Powerful batch processing of images and force curves including WLC, FJC, step-fitting, JKR, DMT model and other analyses

Stages and sample holders
- Stages are available for all major inverted optical microscope manufacturers such as Zeiss, Nikon, Olympus and Leica
- HybridStage™: Combined piezo and motorized stage for automated mapping or scanning of large areas up to 200 µm²
- TAO™ module stage for sample scanning applications
  - For confocal imaging, scattering-type SNOM, Raman, TERS experiments
  - Liquid-safe, robust and drift-minimized design for highest stability
  - 100 × 100 µm² version or
  - 100 × 100 × 10 µm³ scan range
  - Closed-loop by capacitive sensors with the same specs as the head scanner
  - Independent positioning of tip and sample with respect to the optical axis by using TAO™ stage
- Motorized precision stage with 20 × 20 mm² travel range with joystick or software control
- Manual precision stage with 20 × 20 mm² travel range
- Holders for Petri dishes, coverslips, microscope slides or metal SPM discs are available
- Special holders and liquid cells possible
- Ø 140 × 18 mm³ free sample volume

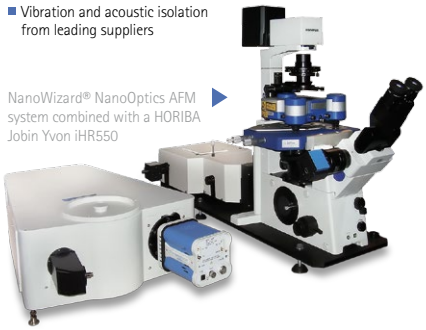
Optical configurations
- Fits on inverted microscopes from
  - Zeiss (Axio Observer, Axio Vert 200, Axio Vert A1)
  - Olympus (IX line)
  - Nikon (TE 2000, Ti line) and
  - Leica (DMI/DMi line)

  for AFM simultaneously with optical Microscopy
- Fully simultaneous operation with optical phase contrast and DIC using standard condensers
- Combine AFM with advanced commercial confocal microscopes and fluorescence optical techniques such as FCS, FRET, TIRF, FLIM, FRAP, STED, STORM/PALM, SIM and more
- Exact positioning and overlay of optical and AFM data with the unique JPK DirectOverlay™ software module
- Upgradeable for scatter-type SNOM, Raman, TERS measurements
- Superior stability when using immersion lens optics with highest NA in combination with a coverslip based sample holder
- TopViewOptics™ video optics for opaque samples
  - Maximum flexibility even if no fluorescence is needed (the sample stage can be mounted on an optical microscope within a minute)
  - Free access to the sample area for micropipettes or electrical connections
  - TopViewOptics™ with 12 × zoom
- BioMAT™ option (see BioMAT™ brochure)
  - For high-NA upright fluorescence optics combined with AFM on opaque samples
  - Supports upright research microscopes such as Zeiss Axio Imager and Axioscope, Olympus BX51/53 and BX FM as well as LEXT, Leica DM 4000/5000
- Upright Fluorescence Microscope (UFM) Kit
  - Enables the combined use of AFM and optical fluorescence microscopes such as Zeiss Axio Zoom V16, Leica Macroscope Z16 ApoA, Olympus MVX 10 MacroView
- Large variety of cameras supported
  - High-end EM-CCD cameras such as models from Andor (iXon), Hamamatsu and Photometrics (Evolve)
  - sCMOS cameras from Andor (Zyla) or Hamamatsu (Orca)
  - CCD and CMOS cameras from Jenoptik, IDS or µEye

Temperature control options
- Ambient to 300 °C temperature range with 0.1 °C precision with the JPK High Temperature Heating Stage (HTHS™)
- -35 °C to 120 °C temperature range with 0.1 °C precision with the JPK Heating Cooling Module (HCM™)

Fluid cell options
- Inert glass standard cantilever holders for experiments in droplets or custom fluid cells
- JPK´s patented BioCell™ for high-NA immersion lenses and high resolution AFM down to the single molecule level, allows temperature control between 15-60 °C, perfusion and gas flow, made for standard cover slips
- CoverslipHolder offers the same performance as the BioCell™ for ambient temperature experiments
- Temperature controlled electrochemistry cell ECCell™ with transmission illuminations
- PetriDishHeater™ and PetriDishHolder perfect for living cells
- SmallCell™ small volume version for minimized volumes (< 60 µl) and with 3 perfusion ports

Integrated flexibility from a wide range of accessories
(see accessories handbook)
- Different sample holders, cantilever holders and stages for every application
- Large choice of temperature controls (for ambient, liquid and gas), liquid cells even for aggressive solvents
- JPK´s ForceWheel™ handheld accessory for most sensitive experiment control
- Full experimental control by scripting functionality and access to all signals
- CellHesion® module with extra 100 µm closed-loop z-range
- TAO™ module with 100 × 100 µm² or 100 × 100 × 10 µm³ closed-loop sample scanning stage
- Tuning Fork module for alternative tip-sample distance regulation
- Fiber-coupled detection unit with stray-light suppression for Avalanche Photo Diode (APDs) and Photon Multipliers (PMTs)
- Vortis™ Advanced SPMControl station for maximum flexibility
- Comprehensive selection of electrical measurement modes
- Vibration and acoustic isolation from leading suppliers



NanoWizard® NanoOptics AFM system combined with a HORIBA Jobin Yvon iHR550

STANDARD OPERATING MODES

Imaging modes
- Easy-to use QI™ mode for quantitative imaging
- Contact mode with lateral force microscopy (LFM)
- AC modes with phase detection

Force measurements
- Static and dynamic spectroscopy
- Fast Force mapping

OPTIONAL MODES

- Fast scanning option up to 70 Hz line rate
- QI™ Advanced mode for quantitative data
  - Mechanical properties such as adhesion, elasticity, stiffness, deformation
  - Conductivity and charge distribution mapping
  - Contact Point Imaging (CPI) with zero force
  - Molecular recognition imaging for binding site mapping
- HyperDrive™ mode for highest resolution imaging in fluid
- Advanced AC modes such as FM and PM with Q-control
- Higher harmonics imaging
- MicroRheology
- Kelvin Probe Microscopy and SCM
- MFM and EFM (see also QI™ mode)
- Conductive AFM (see also QI™ mode)
- STM
- Electrical spectroscopy modes
- Piezo-Response Microscopy
- Electrochemistry with temperature control and optical microscopy
- NanoLithography and NanoManipulation
- Nanoindentation
- Scanning Thermal AFM
- JPK ExperimentPlanner™ for designing a dedicated measurement workflow
- JPK RampDesigner™ for custom designed force curve segments for clamp and ramp experiments
- ExperimentControl™ feature for remote experiment control
- Environmental control options
- DirectOverlay™ for combined AFM and optical microscopy
- Additional xy or z sample movement stages available with CellHesion®, TAO™ and HybridStage™ module

JPK Instruments — we have joined Bruker — BRUKER

JPK BioAFM Center · Nano Surfaces Division
Bruker Nano GmbH
Colditzstraße 34-36 · 12099 Berlin, Germany
tel.: +49 30 726243 500 · fax.: +49 30 726243 999
www.jpk.com · www.bruker.com

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