RHK Technology
Imaging the Future of Nanoscience

R9*plus*

SPM Control System

EXPLORE WITH CONFIDENCE

How did we make the Revolutionary R9 SPM Controller *even* better?

Only from RHK
The Innovation Leader

schaefer

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R9*plus*

Built for a purpose:

Your research, your success.

When you are pioneering the frontiers of Nanoscience, you can count on RHK's new R9*plus* SPM Controller to lead the way. Its remarkable advancements originate from direct user feedback, RHK's Technical Advisory Board, and our own top scientists. With the *plus* Advantage, no Controller is better equipped or more capable to take on any research challenge you face.

> *When it comes to high resolution SPM measurements with operation at the physical limits, the SPM controller is a crucial component where one should not make any compromise but chose the best available technology. The R9 provides superior stability and noise figures for the output channels controlling the tip movement and approach and superb performance with unmatched digitalization accuracy for the input channels.*

— **Dr. Michael Reichling** | Fachbereich Physik @ ***Universität Osnabrück, Germany***

R9*plus*: Explore with Confidence

With R9*plus*, RHK sets the standard as the Innovation Leader for SPM Control.

Over 1,000 RHK original "Blue Box" Controllers were installed worldwide. Then we revolutionized the field with R9 integrated Controllers. More than 225 R9s are producing published results today. Now, RHK surpasses the market yet again with R9*plus*.

Uniquely integrated in one box, R9*plus* unites near-limitless flexibility and power with thoughtfully designed single-click simplicity and rock-solid stability. R9*plus*'s refined and expanded firmware, software, and even further improved analog circuitry give you highest performance and confident command.

Simply Superior, Growing Around the World

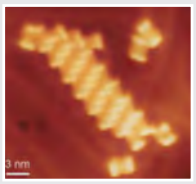
REACHING MORE GLOBAL LOCATIONS

INSTALLING EQUIPMENT IN MAJOR INSTITUES

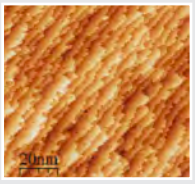
PUBLISHED IN EVEN MORE PUBLICATIONS

Check out the Images of the Month

Brought to us by you, our customers!

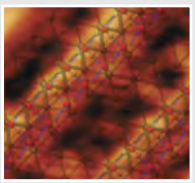


G. Nazin, Uni. of OR: Alkyl-Substituted Thiophene Oligomers on Au(111)

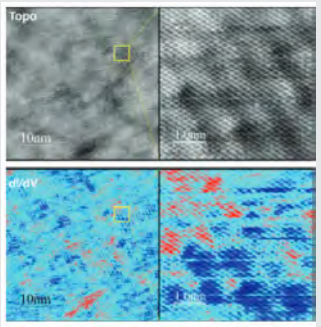


R. Silver, NIST-MD: S Hydrogen-Terminated Si(100) at RT.

X. Deng, NIST-MD: Si(100) epitaxy surfaces at 250 K.



D. Killelea, Loyola Univ.: Double-Stranded Water on Stepped Platinum Surfaces



S. Hollen, Univ. of NH: Graphene on SiC, dI dV mapping.

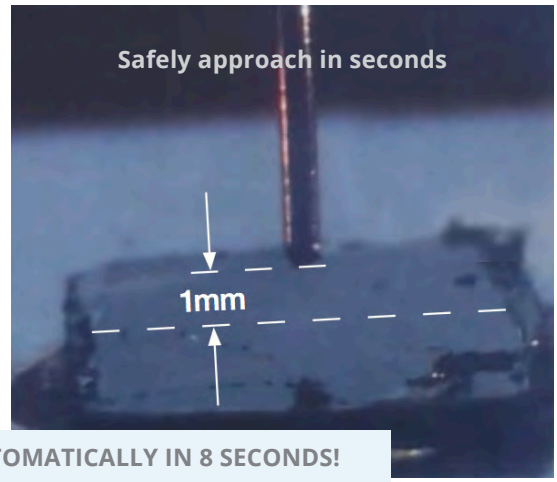
Continued on page 2...

Increase Your Lab's Productivity

R9*plus* fast, fail-safe tip-sample approaches are crucial, especially during experiments when the tip-sample junction cannot be seen, like in deep bore cryostats and high field magnets. This allows the R9*plus* to dramatically increase your productivity by minimizing tip crashes.

> *The transient recorder on the approach procedure is great, I was able to see how much feedback leads to ringing the tip against the sample surface in just a couple minutes, which is exactly what I wanted to know. I'll try to play with some of the other new things I see in the dashboard over the next couple weeks, but this alone should be a tremendous help in protecting some of our more valuable probes.*
>
> — **Brandon McClimon**
> *University of Pennsylvania*

> *... the surprising flexibilities of the R9 IHDL software. This makes the experiment very flexible. All the functions we need can be realized by slightly modifying the IHL file.*
>
> — **Dr. Kai Chang**
> *Prof. Qikun Xue, Department of Physics, Tsinghua University, Beijing China*



AUTOMATICALLY IN 8 SECONDS!

...continued

Check out the Images of the Month

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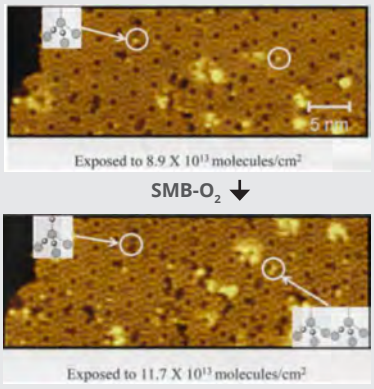
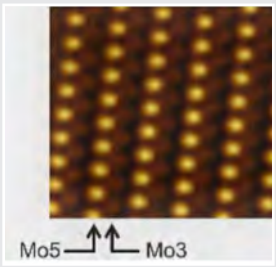
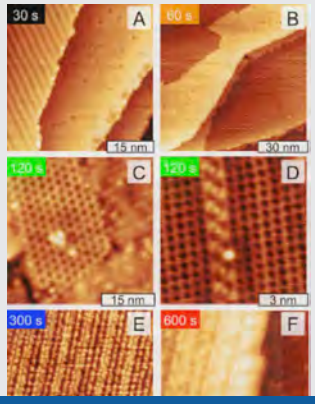


S. J. Sibener, Univ. of Chicago: Oxida on of Si(111)-(7 Å~ 7) Using Kinetic Energy Controlled Supersonic Beams with STM.



M. Boyer, Clark Univ: Li0.9Mo6O17 Superlattice.



Visit ***www.RHK-tech.com*** to see them all.

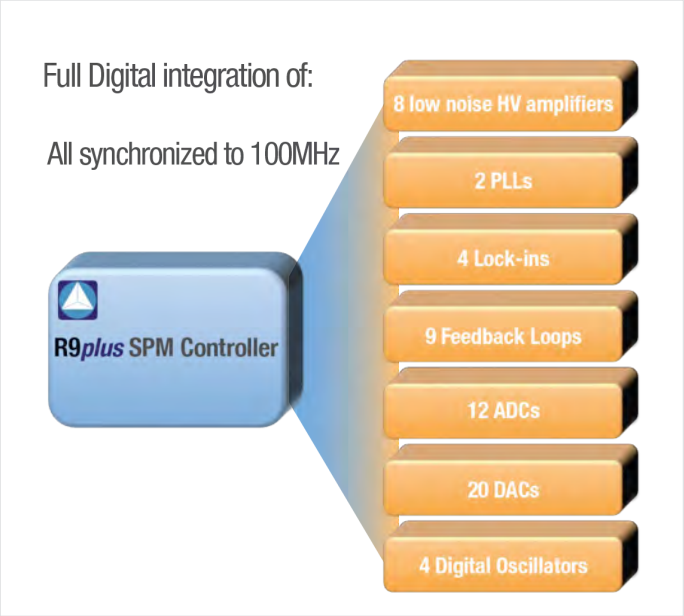
How did we make the revolutionary R9 even better?

2nd generation refined electronics, even quieter and faster with advanced *plus*-capabilities.

> *I am very happy with R9, 'it just worked.' I got atoms right away, even in ambient conditions.*
>
> — **Dr. Joe Smerdon**
> ***University of Central Lancashire, UK***

- Native 64-Bit Application for greater stability, higher speed operation, and unlimited data arrays for advanced spectroscopy measurements.
- New FPGA architecture for greatly enhanced configuration flexibility.
- More data channels - now over 60 channels available for advanced measurements.
- Data streaming rate 5x faster. High Speed Scanning 5x faster.
- New Analog Circuitry with 4x lower noise.
- Improved Lock-In Amplifiers - now increased demodulation bandwidths up to 100 kHz.
- Up to 6x Lock-In Amplifiers, 2x PLLs.
- Lock-In Amplifiers and PLLs configurable to operate independently or in series.
- New KPFM with a click: multi -frequency measurements *plus* added feedback loop for measuring Contact Potential.
- Up to 9 Feedback Loop controllers for multiple probes, KPFM, interferometers, etc.
- Multiple Feedback Loops can be connected in parallel or series.
- New Probe Drive Interface: programmable output voltage range allows optimal probe drive for resonators with Qs from 1 to 1,000,000.
- New, Improved Signal Control Module replaces IVP-R9. Programmable output voltage range provides lower noise for high resolution spectroscopy without limiting total voltage output range.
- Dual-Probe Scan Control with dual scan area windows: Enables 1 controller to operate 2 separate SPMs.
- Inventor SDK/IHDL: customize routines; exchange data via LabVIEW VIs, MATLAB, Python, etc.
- Zoom FFT for thermal resonance peak detection.
- PerfectSpec™: Fully customize spectroscopic measurement techniques. Optimize performance for any parameter, e.g., ultimate low noise or high data throughput.
- Real-time spectroscopy data slicing can slice through arrays of spectroscopy curves to generate current maps during acquisition.
- Non-integer powers of 2 for spec grid: acquire spectroscopic grids of any density, such as 100 x 50 points.
- Digital filter bandwidths increased to 0.01 Hz to 100 kHz. Bandwidths can be set to any arbitrary value.
- Non-square scans for scanning rectangular images in addition to square images.
- Assignable Monitor DACs: DACs 1 - 4 can be linked to output data from any of the 60 internal signals to interface to external equipment.
- Independently assignable Low Voltage Scan DACs, now no longer tied to HV scan DACs.

Guided by user feedback, advances even beyond R9 success



NEW *plus* OPTIMIZED ARCHITECTURE

To surpass R9's revolutionary performance, we combined second-generation refined electronics, new features, flexibility, and easy daily operation. *plus* architecture also includes improved, 4x quieter analog electronics, expanded firmware/software, and new 4x lower noise HV outputs.

R9*plus*, THE PERFECT UNION

RHK does the apparent Impossible...yet again. Unlike competing models offering only either-or trade-offs, R9*plus* unites and delivers all the most needed, desirable capabilities. These are at the heart of the *plus* Advantage.

- High Speed + High Precision + Perfect Synchroniztion.
- Low noise + High Dynamic Range.
- New, even deeper capabilities + single-click simplicity.
- One-box Integration + greatest expandability and configurability.
- Superb for advanced users + quickly mastered by beginners.

UNEQUALED SYSTEM PERFORMANCE

All *plus* internal hardware modules are fully digitally integrated and software configurable, eliminating all interconnecting cables. Expanded capabilities are quickly available without hardware changes – patented fully synced lock-ins, single or dual PLLs, and KPFM. True 64-bit software collects and processes larger data sets. R9*plus* accelerates Scan Speed up to 5x faster, and offers up to 9 Feedback Loop controls.

RHK's patented IHDL provides easy, drag-and-drop setup of components that connect and validate automatically. 10ns transient measurement captures fleeting events, and TBDA (Time Based Data Acquisition) captures and records all parameter changes in real-time for later review. R9*plus* noise floor is diminished to only a few nV/√Hz, yet the analog bandwidth is almost 20 MHz.

plus Wide Dynamic Range generates and measures signals continuously from µV to volts, and generates and demodulates frequencies from mHz to 20MHz.

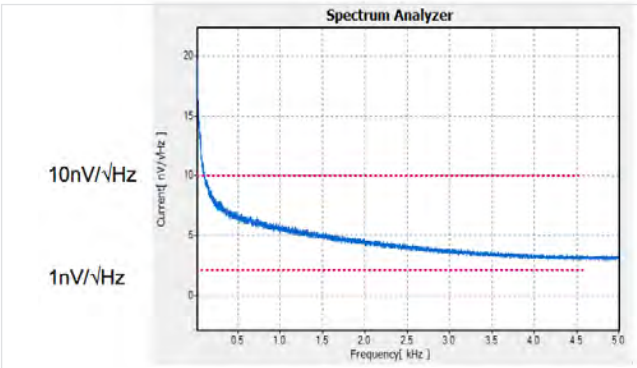
> *My experience with RHK has been very positive. Working directly with an RHK engineer, I was able to customize an STM system for the types of experiments that I want to conduct... Everyone at RHK has been extremely responsive to questions I have had...about software functions, the ability to customize measurements, electronics, hardware, and inquiries for new system components and upgrades. I have and will continue to highly recommend RHK to other researchers looking to construct a high-quality STM system and who would like to work with a company which is very responsive to their questions and needs.*
>
> — **Dr. Mike Boyer** | *Clark University*

Guided by user feedback, advances even beyond R9 success

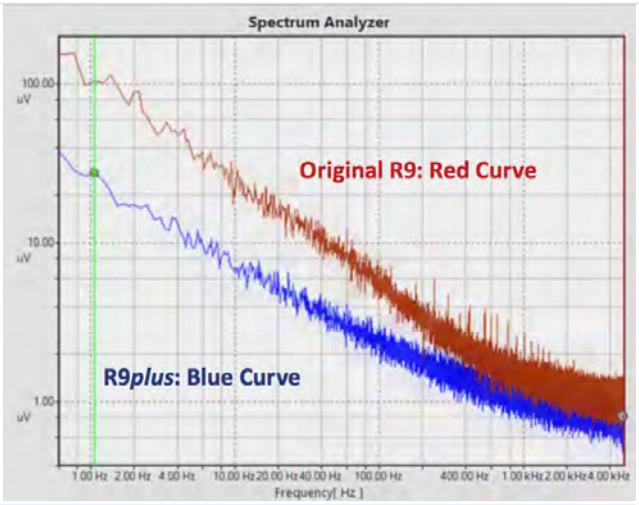
plus: EVEN HIGHER SIGNAL QUALITY

Signal purity and stable electronics are crucial for precision SPM measurements. R9*plus*' second-generation electronics push the noise level to the theoretical minimum. Matched and optimized state-of-the-art electronics yield an input noise of <10 nV/√Hz. A full 64 bit frequency resolution of 5.4pHz is realized on all internal PLL/lock-ins.

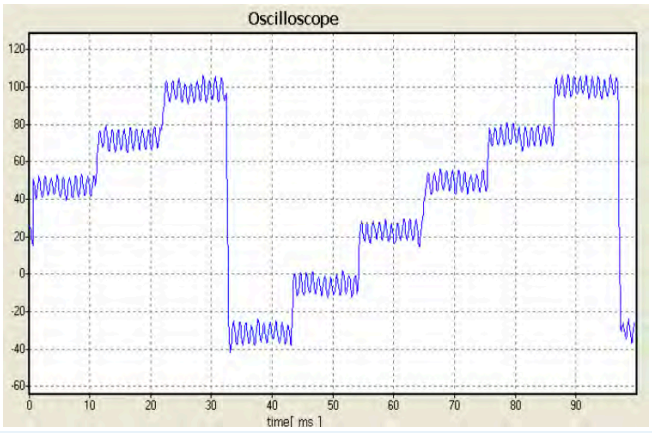
Signal accuracy is optimized via high-speed single-ended and differential impedance-matched analog inputs and outputs. Linear power supplies provide low noise density and interference-free high frequency operation. There is no need to limit bandwidth to hide high frequency power supply noise.



R9*plus:* EVEN LOWER HIGH VOLTAGE OUTPUT NOISE



R9*plus:* EVEN LOWER HIGH VOLTAGE OUTPUT NOISE



BIAS VOLTAGE SHOWING 5 µVp SINE WAVE ON 25 µV STEPS

UltraDACs™

RHK's UltraADCs™ provide massive oversampling at 100 MHz, yielding resolution exceeding 24 bits. Coupled with R9*plus*' sophisticated computer-modeled output filters enable DC output changes below 0.1µV and AC modulations of less than 10µV.

All R9*plus* outputs use UltraDAC ™ technology to allow modulation of all outputs, such as bias voltage and all piezo elements, while synchronously detecting any input signals with the integrated lock-ins and PLLs. Patented Phase Synchronization assures maximum precision by providing exact synchronization of all excitation and detector references, and eliminates loss of phase accuracy inherent in multi-unit configurations.

> *The specs of the R9 were too good to pass up and I have not been disappointed. I am using the pulse counter, PLL and lock-ins for an eventual experiment that will combine confocal and AFM for extremely high res MFM measurements. The R9 has moved a step beyond their competitors.*
>
> — **Dr. Chris Mellor**
> *University of Notingham, UK*

Explore with confidence

MULTI-SPEED DATA PATH: SEE WHAT YOU'VE BEEN MISSING

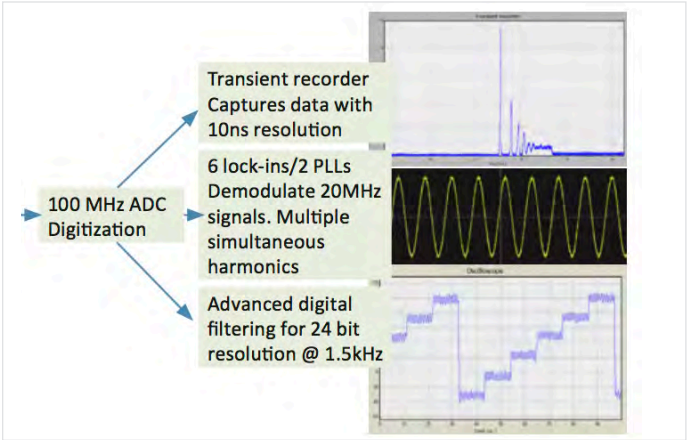
Only R9*plus* reveals what you have been missing. Its Multi-Speed Data Path delivers a revolutionary way to have both high speed and high precision measurements with perfect synchronization.

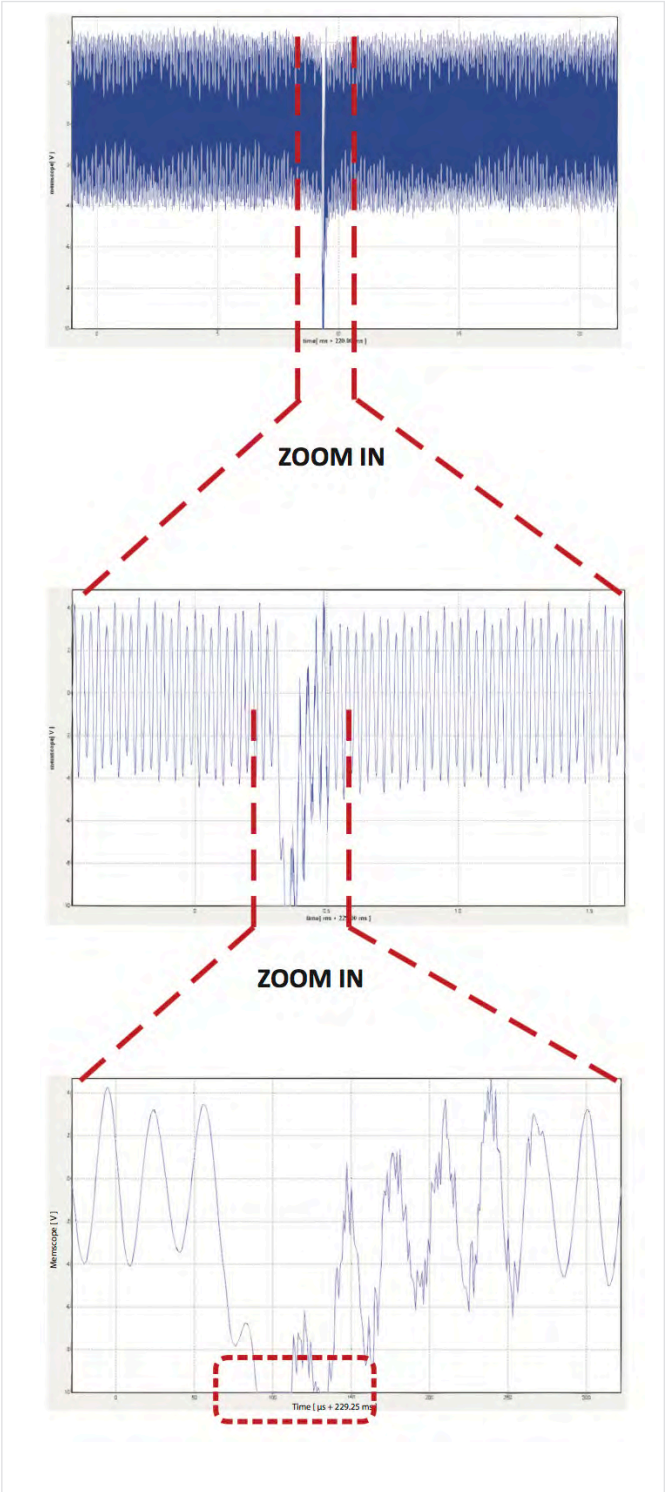
As the data are digitized at 100 MHz, they flow into 3 separate parallel paths. One path flows into our transient recorder's ring buffer. R9*plus* is always filling this buffer; contents can be grabbed at any time.

The full 100 MHz data stream also flows to the PLLs and lock-in amplifiers, allowing signals and higher harmonics up to 20 MHz to be demodulated. The final data path flows into our digital filters which over-sample the signal down to a 200 kHz rate while increasing its resolution up to 24 bits.

TRANSIENT RECORDER: ZOOM IN FOR INSIGHT WITH R9*plus*

As these graphs from the R9*plus* Transient Recorder show, data are captured a few milliseconds before and after the trigger. Now you can Crash-Proof your tip-sample approaches, even for challenging experiments like the shear-force tuning fork example (RIGHT). Even Transients as short as 5µs can be captured with R9*plus*. Contrast this with the limitations of controllers where input data are heavily filtered before digitalization and high frequency information is permanently lost.





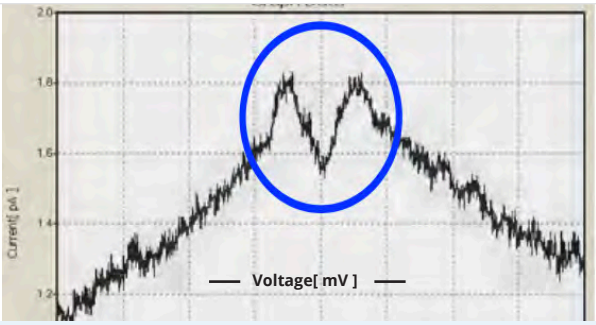
Individual tuning fork oscillations displayed as probe approaches surface. Zooming in shows an otherwise imperceptible double impact of probe tip on sample surface, exciting the 2nd Eigen mode for precisely 6 oscillation cycles. Only R9*plus* reveals what you have been missing, giving you insights needed for research success.

Explore with confidence

SUPERIOR SPECTROSCOPY WITH PERFECTSPEC™

The combination of exceptional electronics and stability allow ramping any combination of signals while measuring any number of channels. With the sensitivity and precision provided by oversampling and the ability to ramp and measure any number of signals, the complete range of voltage spectroscopies (I/V, dI/dV, etc.) and Z-spectroscopies (FvZ, dC/dZ, etc.) are fully implemented. Now you have outstanding flexibility to acquire single point measurement, or during scanning acquire a grid or line of spectra while avoiding drift, creep and hysteresis.

In addition, the transient data recorder captures high speed, me-based spectroscopic data up to 100x faster than with typical controllers. One-Box integration of all components for advanced spectroscopic measurements delivers unprecedented capabilities and experimental flexibility.

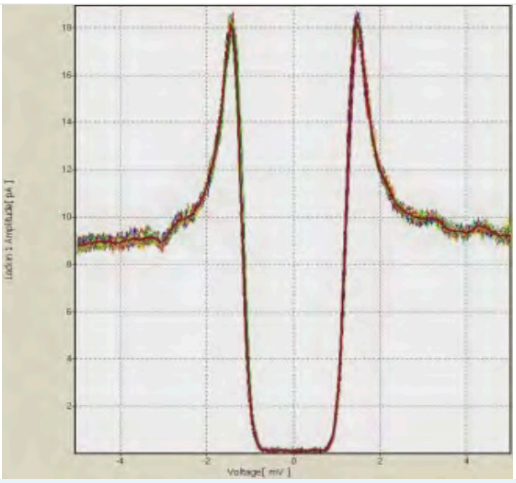


20 monolayer Pb/1 monolayer PTCDA molecule/20 monolayer Au/ Si substrate. Smaller gap is due to proximity effect of superconductivity. Image courtesy of Dr. Ken Shih, University of Texas Austin.

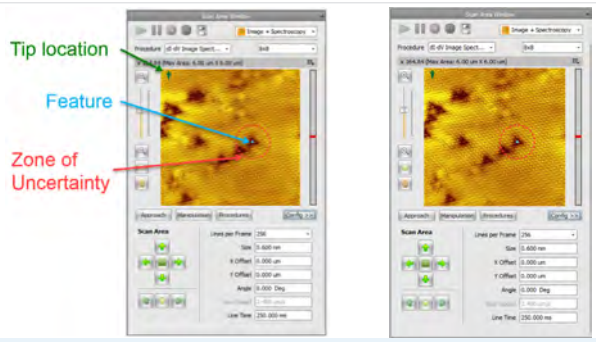
SPECTROSCOPY ARRAYS

- Evenly spaced grid: 4x4 points to unlimited arrays (native 64-Bit App.)
- Grid mode over selected region.
- Line mode: user-defined number of points along a line.
- Interactively selected points.
- Point(s) chosen during a scan.
- Non-integer powers of 2 for grids of any density, e.g., 100 x 50 points.

> *The R9 controller is working great for us. The internal lock-in has stability and resolution which is comparable to the industry standard SRS 830 and for us that is a big plus of R9. Another plus of R9 is the convenience of use.*
>
> — **Dr. Pratap Raychaudhuri**
> *Tata Institute of Fundamental Research, Mumbai India*



Raw spectroscopy data taken on Pb single crystal. Graph shows 50 dI/dV curves acquired at 350 mK. Dark line shows average of individual curves. Image courtesy of Dr. Pratap Raychaudhuri, Tata Institute of Fundamental Research.



Brand X: acquires separately imaged topography and spectroscopy, creating uncertainty about location. R9*plus* PerfectSpec: acquires spectroscopy simultaneously with topography. You always know where your data were taken.

Explore with confidence

EXCEPTIONAL STS MAPS

PerfectSpec™ uniquely provides both high quality topographic images and optimized spectroscopic data simultaneously. R9*plus* adjusts bias modulation, feedback and other imaging parameters separately for the topographic and spectroscopic portions of measurements.

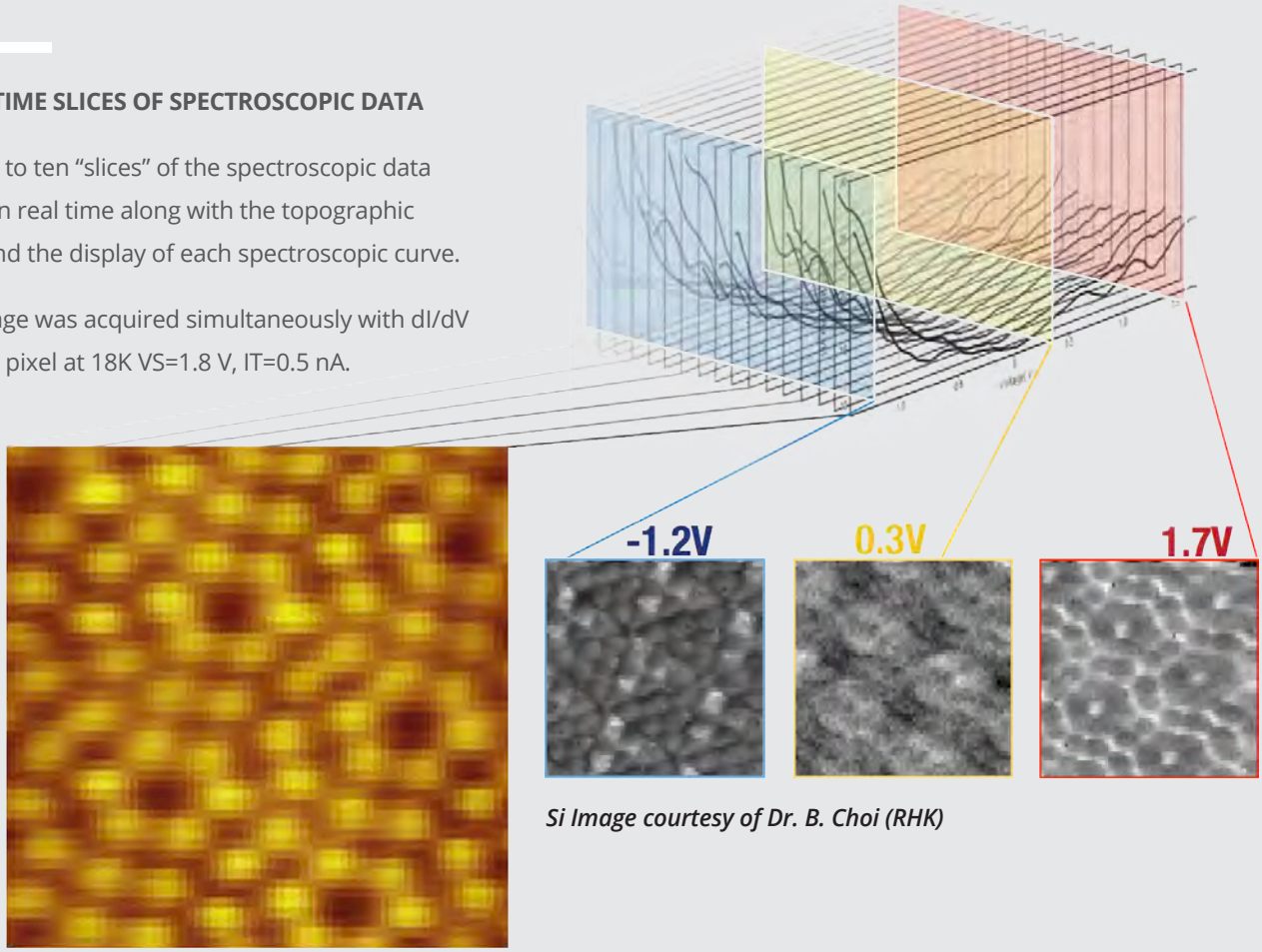
In addition, the spectroscopic curve at each pixel can be displayed and analyzed individually. Using offline analysis, key regions of interest can be selected. Spectroscopic data can be averaged to compare feature properties to substrate properties. *plus* power is elegantly harnessed through our software user interface, giving novices and experts the level of control they need.

> *The R9 is a very powerful digital SPM controller. Very easy to use. When acquiring spectroscopy, a lot of flexibilities with a very precise adjustment of tunneling junctions.*
>
> — **Dr. Jindong Ren & Prof. Haiming Guo**
> *Institute of Physics, CAS, Beijing, China*

UP TO 10 REAL-TIME SLICES OF SPECTROSCOPIC DATA

R9*plus* allows up to ten "slices" of the spectroscopic data to be displayed in real time along with the topographic measurement and the display of each spectroscopic curve.

Topographic image was acquired simultaneously with dI/dV spectra on every pixel at 18K VS=1.8 V, IT=0.5 nA.



Si Image courtesy of Dr. B. Choi (RHK)

Enjoy the *plus* at every level of your experience & research

Quickly mastered by beginners, yet superb for advanced users, R9*plus* offers ease of use for beginners without limiting capability and flexibility for experts. At any level of user experience and any step of simple or demanding experiment procedures, R9*plus* is at your side with fully integrated internal electronics, intuitive GUI, readily customizable IHDL routines, highest data integrity, helpful diagnostic tools, lowest noise, and highest speed.

USER & EXPERIMENT LEVEL	R9*plus* ADVANTAGES
New SPM users Basic STM-AFM measurements and imaging	▸ Single-Click Procedure & Experiment Templates included for SPM basics ▸ Total hardware, firmware, and software integration – no confusing cable connections and boxes ▸ dataSAFE records all history behind the scenes, even if you forget ▸ ProbeGuard automates failsafe tip approach so you can scan productively, instead of replacing damaged tips. ▸ Integrate 2-way data exchanges with LabVIEW VIs, MATLAB, Python, and more ▸ Advanced Drift Correction
Intermediate/ Experienced users Longer multi-step procedures, data collection, and virtual instruments	▸ Diagnostic Tools: Transient Recorder, 4 Channel Oscilloscope, Zoom FFT, Spectrum Analyzer, Data Logger. ▸ Integrated internal lock-in amplifiers for spectroscopic measurement and feedback control. ▸ Single-click KPFM templates provide multi-frequency measurements *plus* added feedback loop to measure contact potential difference. ▸ Highest Data Integrity: ultra-low noise electronics, highest resolution ADC and DACs. ▸ Insert DataWatchers into procedures to ensure parameters stay within safe values, or to trigger new processes. Responses as fast as 5µs.
Advanced power users Complex, sophisticated, highly customized procedures & experiments	▸ Fully traceable results are captured with Time-Based Data Acquisition ▸ 2 PLLs, linked or independent, for multi-frequency measurements and nano-optical modes. ▸ Second Scan Generator and additional Z axis feedback loop to simultaneously control 2 scan heads. ▸ Inventor SDK to customize IHDL procedure and experiment routines. ▸ Add new functions with a simple download. No hardware upgrade needed, thanks to its future-proof digital upgradeability.

ADVANTAGE

Multiple Internal, Integrated Lock-Ins

MULTIPLE HARMONICS

A non-linear interaction mechanism between tip and sample will create a number of harmonics at multiples of the can lever excitation frequency. Having multiple Lock-In amplifiers allows detecting these harmonics in real-time while scanning. This means the non-linear interaction mechanism can be studied. This is useful in plain NC-AFM as well as in apertureless NSOM, where the nonlinearity of the optical interaction can be studied. In this mode the Lock-In amplifiers will run at exactly integer multiples of the interaction frequency.

SIDEBANDS

For UHV NC-AFM, combined with FM Kelvin Probe Microscopy it is useful to detect the amplitude of the sideband that is created by mixing between the cantilever frequency and the Bias modulation frequency. This way the bandwidth of the NC-AFM PLL can be better decoupled from the Kelvin measurement. This allows for faster imaging with less noise.

ADVANTAGE

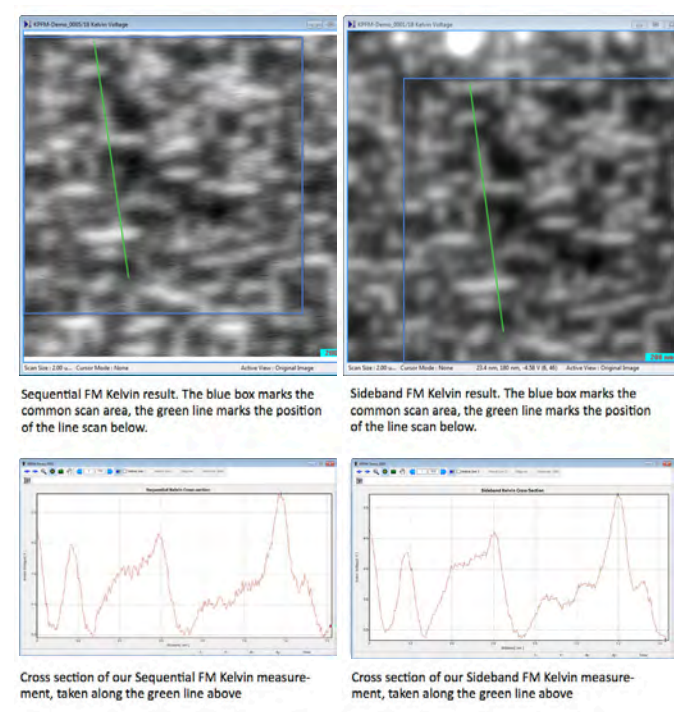
Dual PLLs

Two Phase Locked Loops (PLLs) allow to drive and to measure two independent oscillation modes simultaneously. This can be used for multi-lever arrangements as well as for dual-probe NC-AFM.

ADVANTAGE

plus Simplifies, Optimizes KPFM

- One-Click KPFM switches between different KPFM modes, without reconfiguring external cables.
- In place of a typical multi-box solution, R9*plus* is a fully integrated one-box solution with fully synced PLLs, lock-ins, and built-in interferometer feedback detection.
- Integrated internal Lock-Ins simultaneously measure 2*ƒBias and 3*ƒBias for dC/dZ and dC/dV signals.
- LockGuard provides fast 5µs response to protect the AFM probe if the PLL becomes unlocked.
- Measures up to 60 channels of data simultaneously, with high flexibility and very low intrinsic noise.



Sequential FM Kelvin result. The blue box marks the common scan area, the green line marks the position of the line scan below.

Sideband FM Kelvin result. The blue box marks the common scan area, the green line marks the position of the line scan below.

Cross section of our Sequential FM Kelvin measurement, taken along the green line above

Cross section of our Sideband FM Kelvin measurement, taken along the green line above

KPFM Images courtesy of Dr. Peter Milde, TU Dresden; and Dr Steffen Porthun, RHK

ADVANTAGE

plus KPFM Module in operation

ENABLES

FM Sideband Kelvin, FM Sequential Kelvin, AM Kelvin, Resonance enhanced AM Kelvin, and Dielectric spectroscopy (Frequency-dependent electrostatic measurements).

INTEGRATES AND INTERNALIZES

Kelvin Lock-in, Phase rotation sweep, Kelvin PI controller, and Bias Drive oscillation.

ADVANTAGES

— NC-AFM PLL and Kelvin Lock-In run on the same FPGA chip on the same low-jitter clock, providing superior detection performance.

— Bias Drive and Lock-In reference can be swept phase-synchronously.

— *plus* KPFM set up is simple and compact.

— No external is hardware necessary. Everything you need is inside R9*plus*.

Capture a river of rich information

HOW ARE DATA COMMONLY RECORDED?

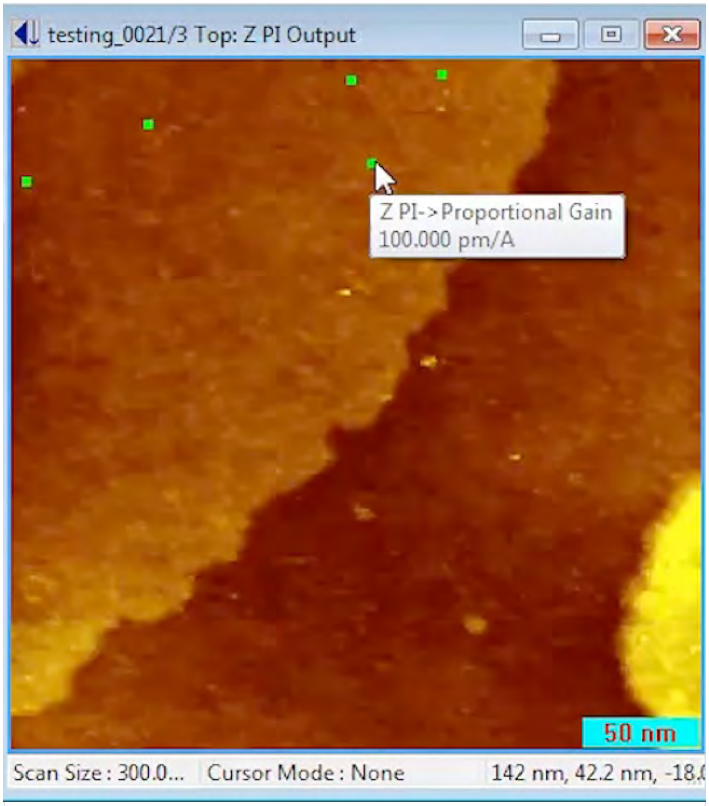
Since the early days of SPM, users have represented images as pixilated data. However it is important to remember that the real world is not made of pixels. The real world is analog, and subtle probe/surface interactions can be lost in the conversion from the analog to digital worlds. Another common problem is that the imaging parameters such as scan speed, bias voltage, and feedback parameters are typically only recorded at one point in the image. Parameter changes during an image, this information is not captured.

DIG DEEPER INTO YOUR DATA

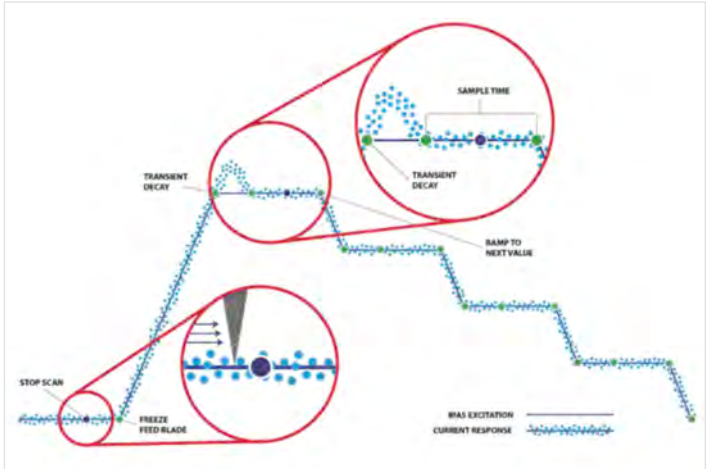
R9*plus* treats a measurement as a continuous interaction between the probe and sample, and provides an accurate representation of this interaction at every point in the image. Every change to an operating parameter, such as the bias voltage, scan speed, or feedback parameters, etc. is recorded to sub-pixel precision and stored with the data file. These changes are displayed on your images as shown on the image at the right. The R9*plus* also records data continuously during the experiment and at a much higher density than pixels, enabling you to dive more deeply into your data to retrieve information that is lost due to averaging on other systems. This unique TBDA capability provides a path allowing the advanced researcher to investigate interactions previously inaccessible.

OPTIMIZE YOUR OPERATING PARAMETERS

TBDA accurately records and displays the setting of every parameter at every pixel in the image, which allows the best parameter set to be selected. For spectroscopic data, the collection of data at points not normally acquired allows ramp speeds and dwell times to be set to provide optimal signal to noise at minimum acquisition times, saving precious research time and resources.



TBDA automatically stores all parameter changes in the data file and displays them on the image at sub-pixel precision



SPECTROSCOPY APPLICATION (TBDA)

Graphically configure and customize

R9*plus* GUI

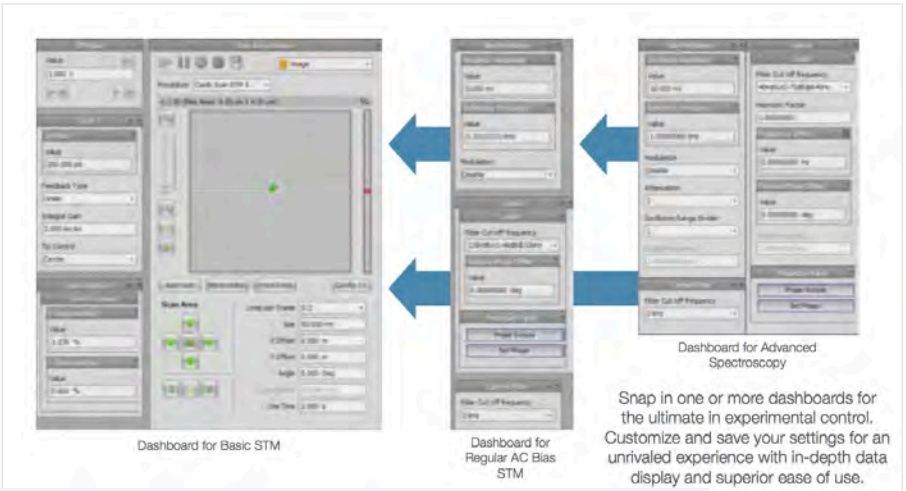
Not all SPM users are Control experts. And even experts appreciate streamlined operation. R9*plus* offers ease of use for beginners without limiting *plus* capability and flexibility for experts. Any level of user can snap in Dashboards, from Basic STM to Advanced Spectroscopy, for experimental control. Customize and save your settings for in-depth data display and superior ease of use.

ICONIC HARDWARE DESCRIPTION LANGUAGE (IHDL™)

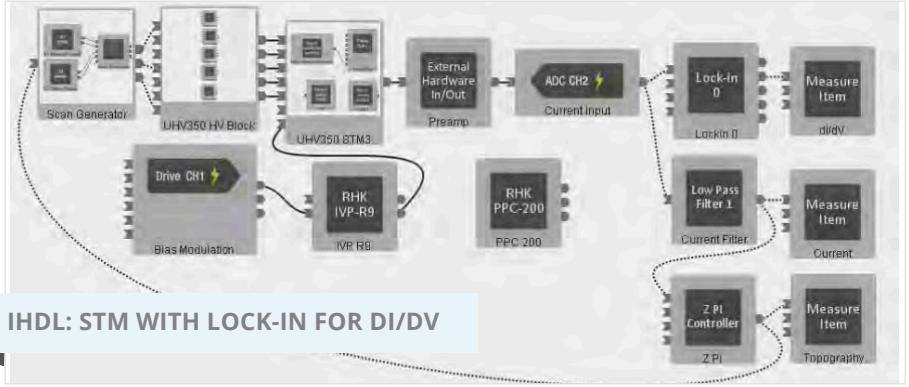
RHK's patented IHDL provides easy, Graphical Drag-and-Drop setup of components that connect and validate automatically. IHDL provides simple-to-advanced user-customized control and configuration of Control Firmware/Hardware, SPM Settings, and Experiment Procedures.

- **Firmware/Hardware Configurator** provides fast, customized set-up of any complexity. Simply select and graphically connect icons for ADCs, DACs, lock- ins, PLLs, etc. Devices automatically configure and connect when a template is implemented.
- **Microscope Configurator** provides ultimate flexibility and an optimized interface to any SPM. You can set output limits on high voltage amplifiers as a function of SPM temperature; automatically ground piezo elements during cooling; allow multiple scanners on one SPM, and much more.
- **Experiment Procedure Designer** provides simplicity for beginners and total flexibility for experts. Pre-configured experiment templates provide quick set-up. Personalized templates can easily be shared with your colleagues.

> *We really appreciate the strong flexibility of the R9. Our microscopes require very different driving signals. The R9 can support those requirements easily by simply reorganizing the IHL file. There are so many high voltage output ports. The most important is that all of those outputs are independent. Even for very complicated operation, it is very easy to be realized.*
>
> — **Dr. Haibiao Zhou**
> *University of Science & Technology of China* | Hefei, China



GUI: SNAP-IN DASHBOARDS, FROM BASIC TO ADVANCED



IHDL: STM WITH LOCK-IN FOR DI/DV

R9*plus* leads the way with advanced future-proof control

Today's SPMs are increasingly more powerful and precise. With such instrument advances, your SPM Controller now determines the actual performance and productivity of your overall system. Do not let your existing SPM controller impede your research with electronics or software that constrain your experimental freedom. Its jungle of noisy cables, poor dynamic range, and lost or disregarded data can limit your progress.

With R9*plus* access to over 60 signals, ultra-high speed acquisition and output, up to 2 PLLs, up to 6 integrated internal Lock-In Amplifiers, and IHDL customized experiment design, you can explore with confidence on any SPM.

> *No other STM controller we looked at provided the degree of flexibility the R9 offers, especially concerning user control of the high-voltage amplifiers - i.e. the relatively unique setup of our self-made STMs requires the Z-scan high voltage amplifier to be able to generate user-defined arbitrary wave forms, which at the point of purchase no other company wanted to guarantee. The R9 works flawlessly in this regard, so I'm convinced we made the right choice to buy the R9. Great experience with the tech support of our SPM1000 also heavily influenced our decision to buy RHK again.*
>
> — **Simon Diesch/Prof. Dr. Elke Scheer**
> **Uni. Konstanz, Germany**

PREFER LABVIEW OR MATLAB?

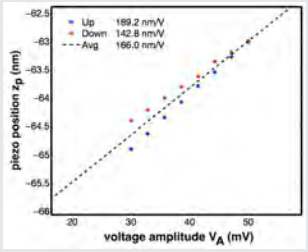
R9*plus* supports LabVIEW data acquisition and display VIs, as well as MATLAB, Python, and many other 3rd party external software programs. R9*plus* enables you to automate complex procedures quickly and easily, and exchange data with external software.

LABVIEW / MATLAB AND THE POWER OF R9*plus*

Example Applications from our users

"LabVIEW remote control can enable numerous interesting functions through R9 such as synchronization with external instruments, automatic scan data acquisition and scanning probe based lithography."

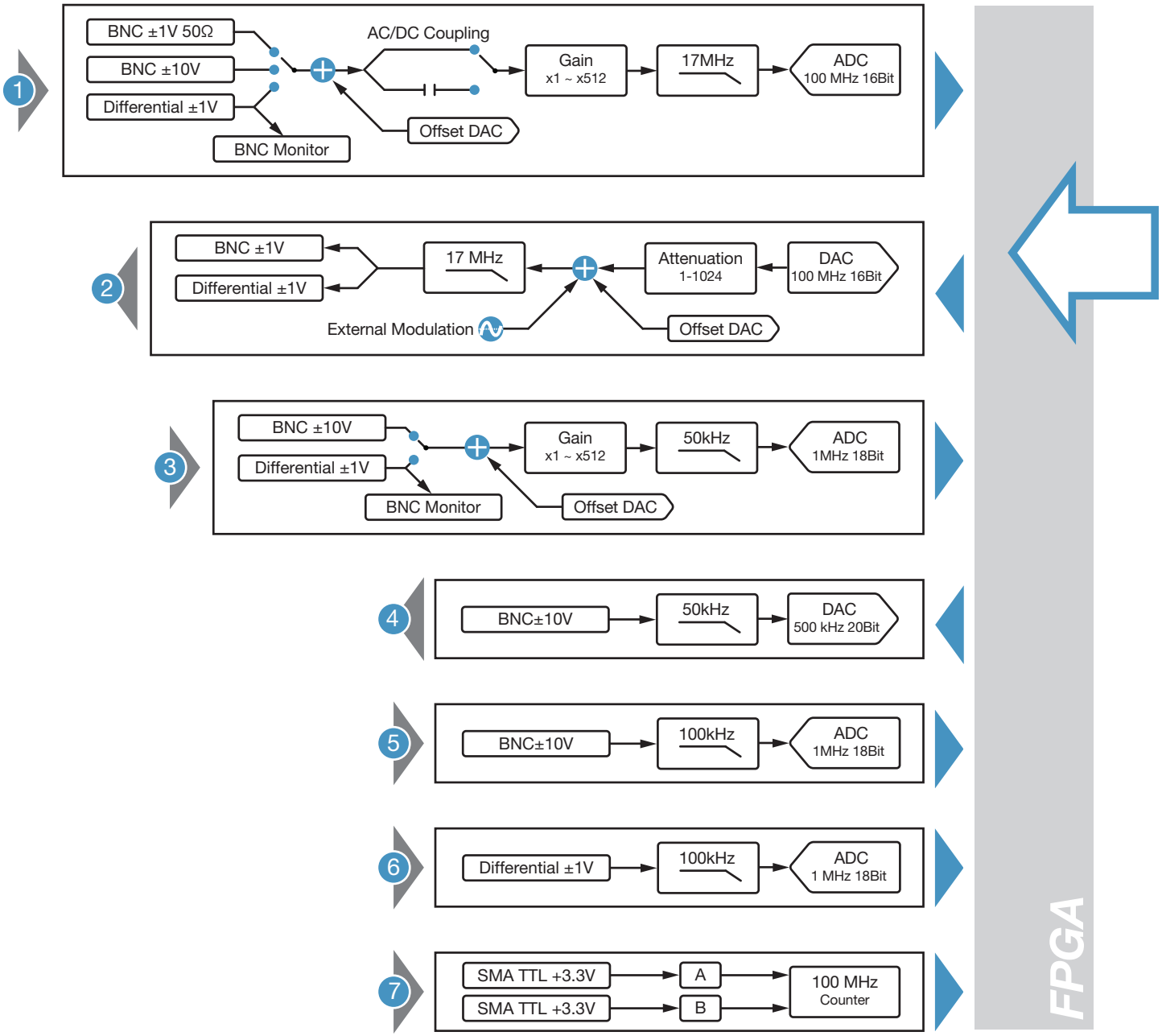
— **Dr. Cheng Cen** | West Virginia University, US



"A fully automated procedure to achieve highly reproducible calibration factors was implemented as simple to use MATLAB script for remote control of the R9. As the R9 offers a large variety of commands to control nearly all functions remotely, we need only 25 lines of MATLAB script for the routine automatically performing all steps for the amplitude calibration."

— **Dr. Matthias Temmen, Dr. Jannis Lübbe, Dr. Michael Reichling** | Fachbereich Physik, Uni. Osnabrück, Germany

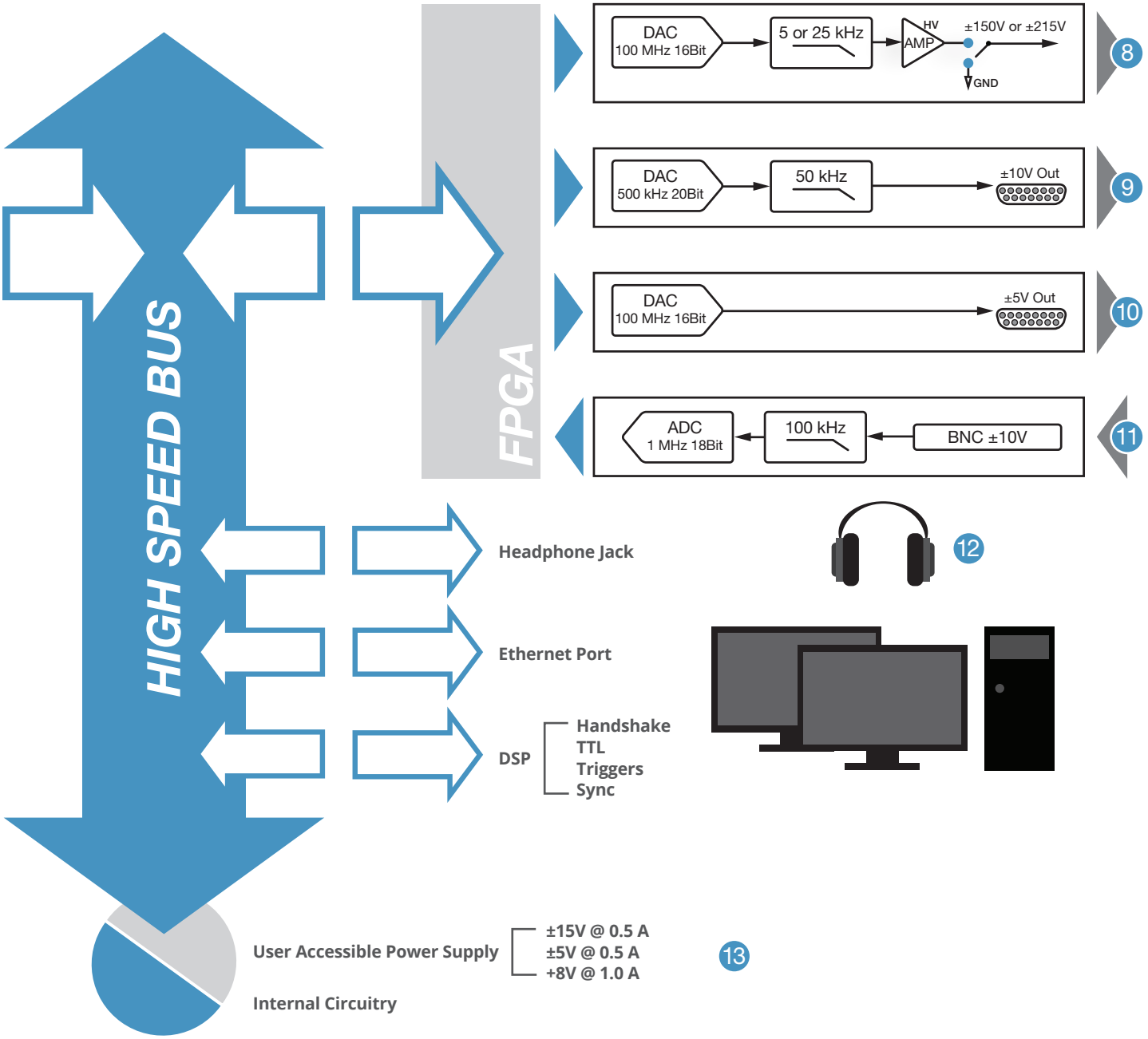
R9*plus*: Hardware Configuration & Attributes



Graphic Key

1. High speed input channels used for feedback or imaging of current, cantilever/tuning fork, etc. Wide bandwidth circuitry enables multiple harmonic capabilities. Massive oversampling provides up to 26 bit resolution. Input multiplexer and coupling are software controlled. Impedence matched, differential input circuitry maximizes high frequency signal integrity.
2. High speed output channels used for bias and cantilever/tuning fork drive. Massive oversampling provides up to 26 bit precision.
3. Input channels used for feedback or imaging of any user signal.
4. User defined outputs can output any internal signal or can be used as secondary feedback outputs.
5. User defined input, ideal for general purpose use such as temperature or pressure data.
6. Used to measure signals from a preamplifier, such as individual PSD sectors.
7. High speed pulse counting inputs. High speed connectors for each input allow reliable pulse counting up to 100 MHz @ 3.3V.

R9*plus*: Hardware Configuration & Attributes *continued*



8 Eight high voltage amplifiers. Each output automatically switched to ground during power up to prevent transient spikes to piezos. [AMP A-E = 5 kHz] [AMP F-H = 25 kHz] Optional: additional 8 high voltage amplifiers, requires second scan generator.

9 Low voltage outputs to drive closed-loop stages. Both low voltage outputs and high voltage outputs are available to drive microscopes with both linearized stages and piezo tubes.

10 High speed outputs optimized to drive SEM column. High speed analog inputs can measure multiple signals from SEM.

11 User defined inputs for position sensors and closed-loop operation. Digitize external modulation and sum into any internal signal.

12 Stereo headphone jack. Can output any two internal signals simultaneously.

13 Fully linear power supplies for ultimate low noise performance. No high frequency noise from switching power supplies. Computer control of laser power and current. +8V is dedicated for Laser I/O supply.

R9*plus* Capabilities & Features

One-Box Integration for AFM/STM	Fully integrated SPM control platform. All connections between modes and measurements are made through software in the digital domain.
Fully integrated SPM control platform. All connections between modes and measurements are made through software in the digital domain.	2 PLLs can be linked or completely independent. Filters can be specified as Time Constant or Filter Cutoff Frequency. Arbitrary (real number, opposed to fixed integer) filter selections are possible, 10mHz to 100kHz. Probe Drive I/F with Buffer Drive electronics. Software Programmable Output ranges: ±0.1V / ±1V / ±10V; AFM signal conditioning electronics.
Digital Lock-In Amplifiers: Up to 6 LIAs or 2 PLLs & 4 LIAs	Filters can be specified as Time Constant or Filter Cutoff Frequency. Arbitrary (real number, opposed to fixed integer) Filter selections are possible, 10mHz to 100kHz.
Feedback Loops	Up to 9.
Kelvin Probe	Measure multi-freq. KPFM. Feedback loop to measure Contact Potential.
Multi-Speed Data Path	Revolutionary way to have both high speed (100MHz @16bit) and high precision (25kHz @ 22bit) measurements with perfect synchronization.
Probe Guard/LockGuard	Fast failsafe tip approach, 5µs response; LockGuard 5µs response; Transient Recorder 10ns response. Auto-continue scan when back in range.
Time-Based Data Acquisition	All data and events are captured on a time basis for later examination.
8x High-Voltage Amplifiers (HVA):	±150V (±215V upon customer request). Voltage can be software limited to any value less than maximum, such as 0-60V.
Additional 8x HVA	Control 2 separate scan systems from 1 IHDL file (e.g., Tube scanner plus Stage scanner). Requires Second Scan Generator.
Second Scan Generator and Feedback Loop	Control 2 separate scan systems from 1 IHDL file (e.g., Tube scanner plus Stage scanner). Enables Low Voltage Scan Outputs to be controlled independently of High Voltage Outputs.
dataSAFE	Record all data in history files even in the event of power outage.
Microscope Diagnostic Tools	Transient Recorder 100MHz acquisition 50MHz FFT; Oscilloscope with 4 channels @50kHz; Data Logger records data over long time periods.
Access all I/O Signals	Configurable control and routing of 60+ I/O signals.
Ultra-low noise oscillator	Phase noise below -174 dBc/Hz for ultimate precision.
First-Stage Preamplifier	RHK or 3rd Party.
CM-PGA Signal Conversion Module with Programmable Gains (Bias- Preamp I/F Module)	Converts differential bias output from R9*plus* into single-ended bias signal at scan head. Converts single-ended preamp signal from preamp into differential output signal to R9*plus*. S/W Programmable Bias Output ranges: ±0.1V / ±1V / ±10V. Includes ±15 V to power preamp.
IHDL/Inventor SDK: Interactive Hardware Development Language	User-customized routines. Supports Labview V.I.s, MATLAB, Python, etc., without added software modules.
PerfectSpec:	Customize spectroscopic measurement techniques. Optimize performance for any parameter, e.g., ultimate low noise or highest data throughput.
DataWatch:	DataWatchers can be inserted in procedures to ensure parameters stay within safe values or to trigger new processes. Responses as fast as 5µs.
SPM Performance Workstation with Dual Flat-Panel Monitors	Dell PC, Windows® 10 or Windows® 7 64-bit Professional. 3-year on-site warranty c/o Dell.
Cable Set for Microscope Connections; Control Accessories; Manuals	Tunneling Gap Simulator for preamp and feedback diagnostics (100 megohm). Straight-through and crossover ethernet cables. BNC-to-BNC cables for back panel connections. User Manual, QuickStart Guide.

R9*plus* Specifications

Built-in Bias modulation	Directly modulate output bias DAC with sine waves as small as 10 µV. Modulate frequencies up to 10 MHz.
Z-position modulation	Directly modulate output DAC with sine waves as small as 10 pm.
Contact-mode AFM	Position Sensitive Detector (PSD) Module available with 4 channel preamp. Each of 4 quadrants can be simultaneously measured for diagnostic purposes.
Non-Contact AFM	Up to 4 lock-ins and 2 PLLs fully integrated into R9 controller. No separate modules required.
STM control	Single mouse click to switch operating mode. No cable switching needed.
Kelvin Force control	All KPFM functionality fully internal and integrated into R9*plus*. No separate hardware required.
Probe Guard/LockGuard	Fast failsafe tip approach, 5µs response; LockGuard 5µs response; Transient Recorder 10ns response. Auto-continue scan when back in range.
Multi-frequency modulation and detection	Internal oscillators and lock-ins can be synced to provide multi-frequency excitation and multi-harmonic detection. Patented design guarantees exact phase matching even during frequency sweeps.
Power supplies	All-linear supplies eliminate high frequency switching noise.
Analog inputs	2 Ultra-high speed - 100 MS/s - 16 bit.
Input offset	Input signal can be offset up to full scale. Accurately measures small signal riding on large DC off set.
Programmable AC/DC coupling	Input signals can be AC or DC coupled as defined in software configuration.
Programmable gain	Up to 512x at full bandwidth.
Input bandwidth	22 bits at 25 kHz. 24 bits at 1.5 kHz.
	2 High speed - 1 MS/s - 18 bit with programmable gain and input offset. 50 kHz bandwidth.
	9 High speed - 1 MHz - 18 bit, 100 kHz bandwidth.
Analog inputs	2 x 100 MS/s - 16 bit.
Input offset	20 MHz.
Effective resolution	22 bits at 25 kHz. 24 bits at 1.5 kHz.
	8 x 500 kS/s 20 bit, 50 kHz bandwidth, +/- 10V output. Effective resolution 20 bit.
	8 x 100 MS/s - 16 bit, 50 kHz bandwidth, +/- 215V outputs. Effective resolution 22 bit at 25 kHz.
Pulse-counting inputs	2 x 100 MC/s count rate.
Signals	More than 60.
Data transfer rate: Controller/PC	10 - 200 kSamples/s per channel.
High Speed data measurement	Up to 100 MS/s can be captured in burst mode.
High Voltage Amplifier outputs	Fully configurable. Each amplifier software-configurable to drive any piezo output. Each HVA can be modulated using internal Numerically Controlled Oscillator (NCO).
Output limit protection	All HV amplifiers software-limited to any range to prevent damage to piezo elements or other experimental elements. Outputs automatically scaled to designated output range.

R9*plus* SCANNING MODES

Scanning Tunneling Microscopy (STM)
Topography | Current

Modulated STM STS Spectroscopy
I(V) | dI/dV | d2I/dV2 | dI/dZ | Hyperspectral Mapping

Contact AFM
Topography | Lateral Force (LFM) | Conductive (C-AFM) | Spreading Resistance Imaging | Force Modulation (FMM)

Amplitude Modulation AFM
Topography | Phase | Feedback

Magnetic Force Microscopy (MFM) Electrostatic Force Microscopy (EFM)
Two-pass DC/AC | Lift DC/AC | Single-pass, Two-pass | Amplitude Modulation | Frequency Modulation

Kelvin Probe Force Microscopy (KPFM)
Single-pass, Two-pass | Amplitude Modulation | Phase Modulation | Frequency Modulation | dC/dZ imaging | dC/dV imaging

Piezo-response Force Microscopy (PFM)
Voltage | Current | Force

Frequency Modulation AFM
qPlus® | Shear Force (SFM)

Scanning Capacitance Microscopy (SCM)

Scanning Thermal Microscopy (SThM)

Scattering Scanning Near-field Optical Microscopy (sSNOM)

AFM Spectroscopy
Force-distance | Amplitude-distance | Phase-distance | I(V) | Hyperspectral mapping

Nanolithography
Bias or Force controlled patterning | User defined patterning — *Patterns and coordinates saved and loaded from standard file*

R9*plus*

Your Research Your Success

EXPLORE WITH CONFIDENCE

We use the R9 to control an optical electrochemical STM apparatus. It offers a high level of flexibility and an outstanding baseline performance. What makes the R9 work for us is the quality of the support we get from RHK for building a custom apparatus. They were not afraid to try new modes of operations and support new applications. The team at RHK helped us integrate an external potentiostat for our electrochemical STM and an external piezoelectric stage to control the excitation spot of our optics. We upgraded to the R9plus model to have access to this second piezoelectric stage and more versatility in the control of our sample and tip potentials.

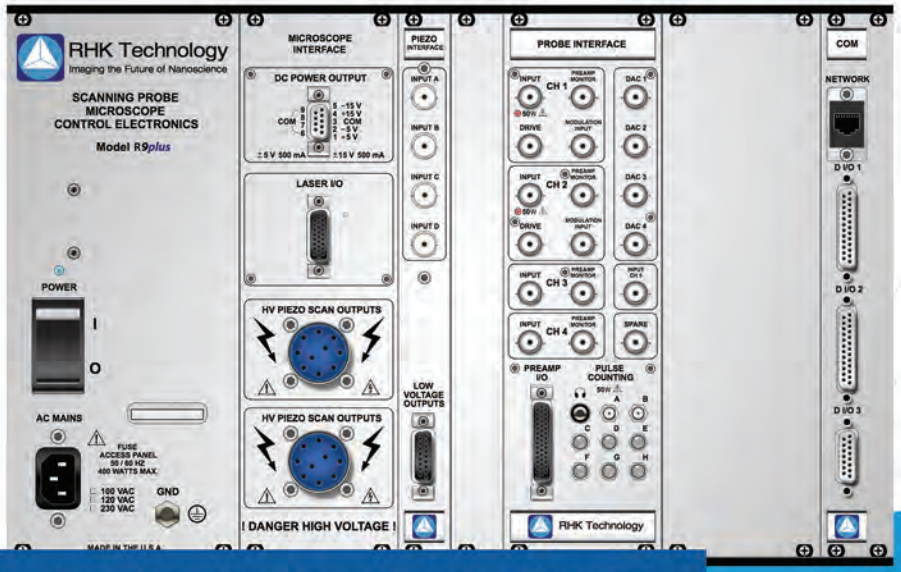
– DR. GUILLAUME GOUBERT
Post-doctoral researcher in the Van Duyne group.

*The R9 is a fully integrated one-box solution with fully synced PLLs, lock-ins, and built in interferometer feedback detection, which replaced our multi-box solution...R9 offers high flexibility. The R9 additional lock-ins could be used to simultaneously measure 2*fBias and 3*fBias for dC/dZ and dC/dV signals. R9 enables one-click switching between the different KPFM modes, no reconfiguring external cables. R9's LockGuard for the PLL provides a fast 5µs response to protect the AFM probe if the PLL becomes unlocked. The R9 allows to measure many channels of data simultaneously. The R9 has very low intrinsic noise.*

– DR. PETER MILDE
Institut für Angewandte Photophysik, TU Dresden

My experience with RHK has been very positive, far beyond typical interactions with an instrumentation company. We use... customized scanning modes. We have been very happy with RHK's support. We call them frequently and we've received a consistent and insightful support and feedback on how to implement and make use of very unusual customized modes... Our Beetle system with R9 is versatile, has powerful capabilities and high precision coupled with excellent service. It has provided results that we have published in the top journals including Science and Nature. They have been a true partner in not just providing great instrumentation but giving excellent service and supporting further experimental innovation.

– DR. ROBERT CARPICK
Univ. of Pennsylvania



Optional second set of 8x High Voltage Ampliflers shown

RHK Technology
Imaging the Future of Nanoscience

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