SPECTRUM

News from Quantum Design Europe

Edition 42 | July 2024

The ideal tool on measuring the quantum Hall effect

The study of quantum transport in nanomaterials, such as bilayer graphene, has become a large and exciting field due to the unique properties that can be observed. Examples are (unexpected) transitions like superconductivity, magnetic ordering, charge density waves, and other correlated phenomena. By changing experimental variables like temperature, field-effect gates, or magnetic fields, the properties and behaviors of the sample can be tuned. These nanomaterial samples can be analyzed and characterized by electrical transport techniques, such as the classical Hall effect (HE) and the quantum Hall effect (QHE).

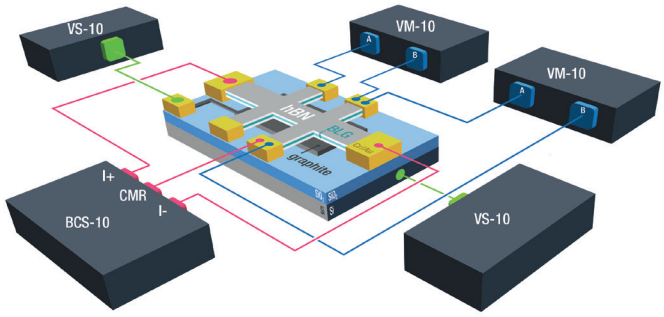

Fig. 1: M81 circuit diagram for a multi-gate reverb bar device

Within the family of two-dimensional electron gas (2DEG) systems, nanomaterials allow for the observation of the QHE. The QHE gives an insight into the energy states, degeneracies and the band structure of the sample. Materials that belong ot the 2DEG family are graphene or boundary layers between semiconductors like GaAs/AlGaAs structures.

When measuring Hall resistance (Hall voltage divided by current), Hall 2DEG materials exhibit plateaus of about 25.8 kΩ and corresponding integer fractions. This value is known as Von-Klitzing constant R_K and can be attributed to h/e^2. This is the result of the quantization of electron energy level.

The experiment requires the presence of a magnetic field, low temperatures and sensitive yet flexible measurement electronics. This ar-

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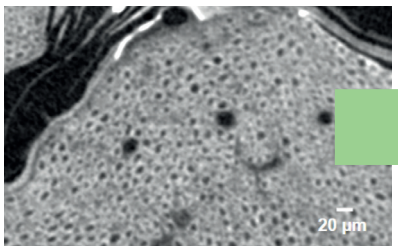
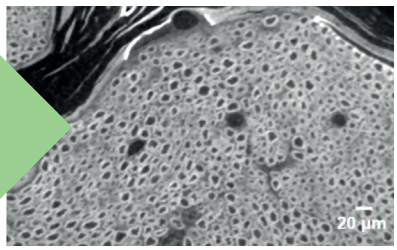
Eclipse XRM – the new standard in X-ray tomography

Eclipse XRM from Sigray is the first non-lens-based XRM that reaches 300 nm spatial resolutions. In addition, it provides a very good material contrast for both biological and soft/light materials (e.g. polymers) and samples from the semiconductor industry and geological research. It is one of the most versatile XRM systems on the market.



Previous leading 3D XRM/MicroCT
3D X-ray microscopy with 0.5 µm spatial resolution of sciatic nerve cells



The leading resolution of EclipseXRM
New functions with a spatial resolution of 0.3 µm, almost a 2-fold improvement in resolution

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Content

Quantum Design EUROPE

The ideal tool on measuring the quantum Hall effect

» ticle features the setup of such an experiment.

Fig. 1 shows a schematic layout. The sample is bilayer graphene (BLG) which is encapsulated with boron nitride (hbn). The probe has a Hall bar structure type 1-2-2-1. On the bottom (see "graphite") there is an additional contact for gate voltage.

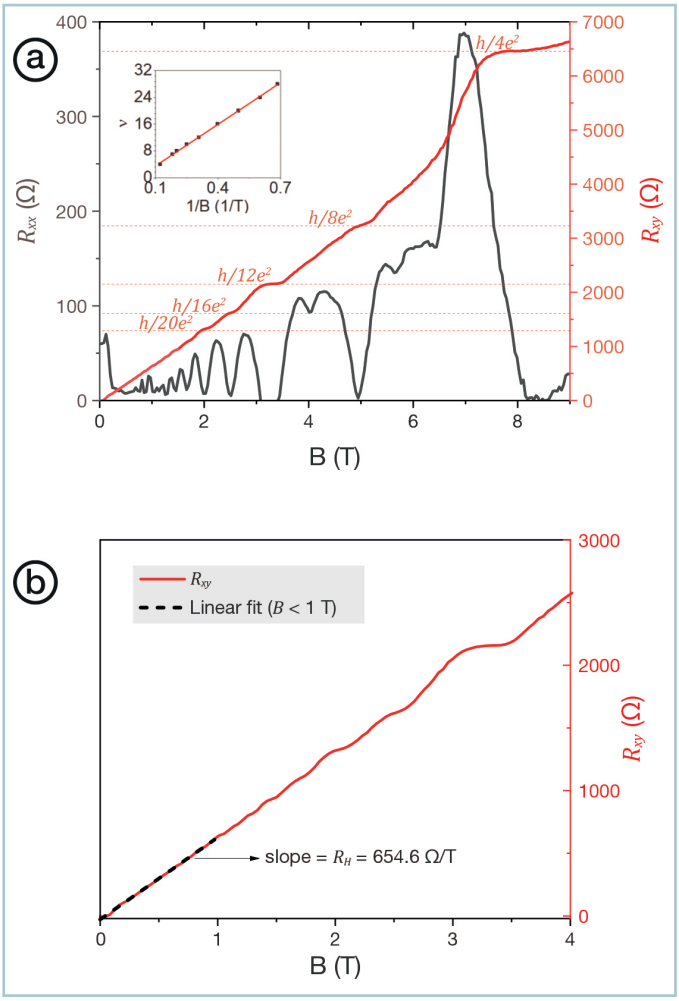

Fig. 2: (a) σxx and σxy as a function of carrier density after gate to carrier density conversion, highlighting steps of 4e2/h for B = 2 T; (b) σxy versus carrier density density for 2 T and 6 T, highlighting steps of e2/h for B = 6 T.

Measurement electronics include two voltage sources (VS-10), one current source (BCS-10) and two voltmeters (VM-10). The balanced current source provides an AC current of 50 nA at 17 Hz. The two voltmeters VM-10 measure the longitudinal Vxx and the transversal component Vxy of the Hall voltage. The two VS-10 voltage sources provide gate voltage for tuning carrier density and contact resistance. The measured voltages enable the calculation of the corresponding longitudinal and transversal Hall resistances Rxx und Rxy.

Fig. 2 shows R_{xx} und R_{xy} as functions of the magnetic field. It also shows typical quantum oscillations and quantization plateaus.

About the experiment M81-SSM modules were used for the electrical setup. The M81 offers high flexibility when it comes to source and measuring modules. A total of 6 modules can be combined on an M81 main board. The above application requires low noise and high sensitivity both of which are also ensured by the M81 setup.

The DryMag from Lake Shore was used as crystat. DryMag features a base temperature of 1.5 K and a superconducting 9 T magnet.

This article is based on an application note from Lake Shore. The app note describes the setup in more details and depicts further contextual information like the influence of gate voltage, Landau fans, meausrement of Hall parameters, and more.

You can get a full copy of the app note "Quantum Hall Effect Measurements in Nanomaterials" off the Lake Shore website or through us.

We look forward to your comments!

Please contact us
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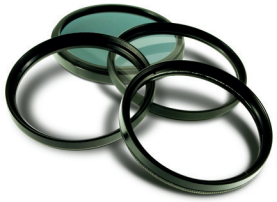
Web portal for inquiries for Andover bandpass filters

Andover offers a wide range of standard bandpass filters. To make it easier for you to select the right filter, we have set up a web portal. Here, you can see all filters in a clear layout. To automatically narrow the selection of filters shown, users can choose the specifications they are looking for. In the detailed view, you can see all specifications at a glance, together with the individual filter curves. Thus, you can find the right filter with just a few clicks. Our automatic inquiry system will immediately forward your selection to the corresponding staff. We will then contact you and give you a quote.



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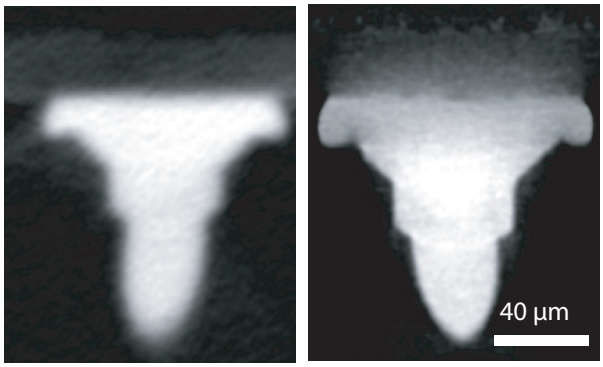
Eclipse XRM – the new standard in X-ray tomography

» Eclipse XRM can be fitted with up to two x-ray tubes and various detector systems (flat panel, lens-based detectors and others).



Outstanding image quality: Sigray EclipseXRM offers true 300 nm resolution and clearly superior contrast for a wide range of samples, from large intact circuit boards (see above) to geological and biological samples.

This internal structure makes it ideal for integrating a wide range of in-situ stages. It can achieve a spatial resolution of <500 nm even at a working distance of 50 mm.

Phase contrast mode, offset tomography and the ability to perform spiral scans round off the overall package. Intuitive software equipped with the latest machine learning options is available for evaluating the measurement data.

Contact us for initial test measurements.

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FusionScope – groundbreaking method for cantilever tips in new paper on Magnetic Force Microscopy (MFM)

The FELMI-ZFE Institute for Electron Microscopy and Nanoanalysis in Graz has published an innovative paper on Magnitic Force Microscopy (MFM) and the new method to make magnetic cantilever tips by focused electron beam induced deposition (FEBID).

MFM represents a valuable extension of atomic force microscopy (AFM), whereby cantilevers with functional coatings are currently primarily used for the investigation of magnetic surface features. Despite their proven usefulness, the additional films inevitably lead to an increase in the tip radii, which reduces the lateral resolution. To overcome these limitations, the FELMI-ZFE researchers present a novel approach involving additive direct writing of 3D magnetic nanostructures by focused electron beam induced deposition (FEBID) using a HCo3Fe(CO)12 precursor.

It starts with the identification of an optimal 3D design for functional magnetic structures in order to subsequently optimize the most important process parameters acceleration voltage and beam current and also evaluates the post-growth process. This enables the manufacturing of high-crystalline nano-tips with minimal surface contamination and tip radii of less than 15 nm.

In a next step, these cantilever tips are compared with commercial products. The results show not only outstanding performance in MFM measurements but also virtually loss-free behavior even after almost 8 hours of continuous operation. Remarkably, no drop in performance is observed even after more than 12 months of storage under ambient conditions, which underlines the sustained high performance of the developed nano-tips.

To test these novel cantilevers, they used the unique functions of the FusionScope, such as the practical profile view. This enables both precise positioning of the AFM and observation of the interaction of the tip with the sample surface. The

study demonstrates the expertise and success of the researchers and confirms the central role of the FusionScope in the further development of scientific research at the nanoscale.

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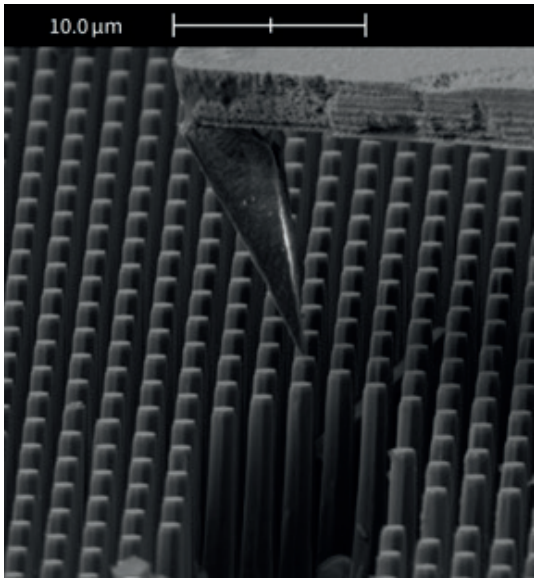
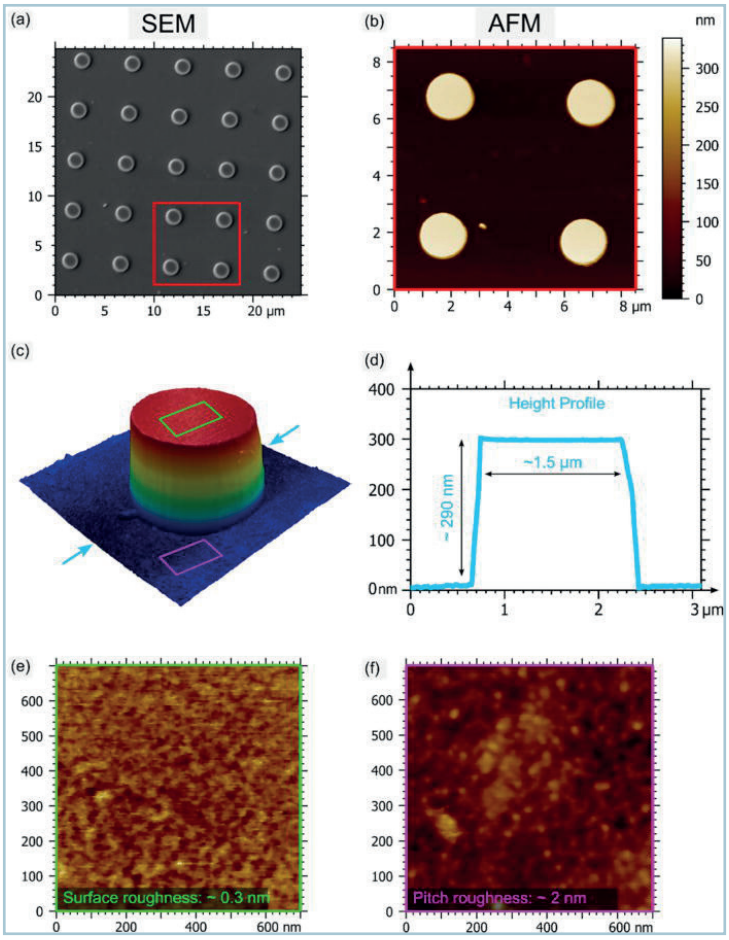
Deep-reactive ion etching of silicon nanowires – a groundbreaking method to fabricate nanostructures

The fabrication of nanostructures has made great progress in the last years, particularly in the semiconductor industry and nanotechnology. The recent publication of a consortium of European metrology institutes presents a groundbreaking method to fabricate nanostructures that has the potential to revolutionize the development of nanoelectronics and nanosensors.

The paper, which was published in the Journal of Applied Physics, describes an innovative approach for the fabrication of silicon nanowires by deep- reactive ion etching (DRIE). The technique allows the specific structuring of silicon substrates and the accurate manufacturing of nanowires. By precise control of the ion etching, nanowires with tunable height, width and form can be fabricated, which allows a variety of applications in nanoelectronics, sensor technology and photonics.



One important aspect of this method is the scalability and reproducibility. By using DRIE, nanowires can be manufactured in large quantities, which makes them ideal for the mass production of nanostructures. Furthermore, the precise control of the process parameters allows high reproducibility of the fabricated nanostructures, which is crucial for the development of reliable nanoelectrical devices.



Our sophisticated correlative microscope FusionScope was used to examine silicon nanowires with scanning electron microscopy and measure the surface roughness with atomic force microscopy at the same time.

This technology allows a great variety of applications. Silicon nanowires are used in the semiconductor industry for the manufacturing of nanotransistors, nanosensors and nanoscale components. They can also be used in biotechnology for the development of high-throughput biosensors and in photonics in the manufacturing of nanolasers.

All in all, the publication "Deep Reactive Ion Etching of Silicon Nanowire" is a valuable contribution to the manufacturing of nanostructures. It opens up new ways to fabricate nanoelectronics and nanosensors. With its precise control and scalability, this method has the potential to shift the boundaries of nanotechnology and facilitate new applications in various fields.

Jiushuai Xu et al.; Appl. Phys. Rev. 11 (2): 021411 https://doi.org/10.1063/5.0166284

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FusionScope gives brand-new insights into 3D nanostructures

The paper "Spectral Tuning of Plasmonic Activity in 3D Nanostructures via High-Precision Nano Printing" of the FELMI-ZFE institute treats the unique optical characteristics of plasmonic nanoparticles which are more and more used in commercial products like photovoltaics or biological and chemical sensors.

To tune their plasmonic properties according to the desired application, it is crucial to control the geometry in every detail. In the past, this has not been reliably demonstrated for complex 3D nanoarchitectures yet.

This paper presents how Focused Electron Beam Induced Deposition (FEBID), a highly flexible additive 3D direct-write technology with spatial nano-scale precision, is used for the controlled and tunable fabrication of plasmonically active 3D nanostructures that exhibit highly concentrated, well defined and predictable local resonances.

As model systems, Au-nanowires and 3D nano-tips of various geometries are prepared by FEBID and characterized by scanning transmission electron microscopy-based electron energy loss spectroscopy (STEM-EELS). The results are complemented with corresponding simulations, which depict very good accordance with experimental findings.

FusionScope allows the precise identification, approximation and characterization of STEM-EELS analyzed Au-nanostructures. Even though these nanostructures have a size of only a few nanometers and are applied on a 5 nm thin TEM grid, this particularly challenging setting can easily be mastered by the FusionScope. This way, on-demand spectral tuning of the plasmonic response becomes accessible via upfront modeling and design of suitable 3D nanostructures, to achieve customized plasmonic responses, therefore paving the way for yet unrealized plasmonic applications in 3D space.

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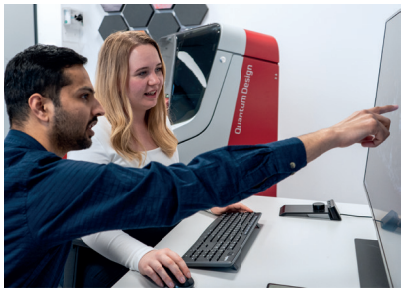
Discover the world of correlative microscopy in our new FusionScope demo lab

We are happy to receive you at our new demo lab here in Pfungstadt. Experience yourself the advantages of FusionScope, our correlative atomic force and scanning electron microscope.

Learn firsthand how FusionScope combines highest precision, versatility and correlative microscopy in just one scientific instrument.

Our experts will be by your side to lead you through the process and help you get the best results out of your samples.



Do you have challenging samples where you want to characterize roughness, mechanical or electrical properties at nanometer precision? Fix an appointment today and discover the world of correlative microscopy.

We look forward to demonstrating how the FusionScope can measure your samples!

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The difference between pulse-tube and Gifford-McMahon cryo-coolers

Two types of cryo-coolers are possible, if a cryostat is to be operated without liquid helium: Pulse tube (PT) and Gifford-McMahon (GM) coolers. There are 3 differences between these two types which refer to the price, intended orientation and the maintenance interval.

- At the same cooling power, GM cryo-coolers are generally cheaper than PT cryo-coolers.
- PT cryocoolers only work properly if they are operated purely vertically with the second stage facing downwards. In contrast, GM cryo-coolers can be operated in every orientation; though the cooling power is a bit lower when the cooling head is not operated vertically, but the base temperature normally stays the same.
- Most GM cryo-coolers need to be maintained every 10000 operating hours, compared to 20000 operating hours with PT coolers.

However, there is an important difference which has to do with the vibrating level. Both GM and PT cryo-coolers are mechanical coolers that generate vibrations at both the room temperature mounting flange of the cold head (which is the interface to a vacuum housing or chamber) and at the second stage (where the sample to be cooled is normally mounted). A PT system typically has lower vibrations (less than 20 µm) than a GM system. Therefore, the PT system is the first choice when the sample needs to be mounted as stable as possible.

However, there is an exception to almost every rule. These are the cryostats with very low vibrations in the range of 5-10 nm from Montana Instruments and Quantum Design.

Montana offers the CryoAdvance50. The cryostat with peak-to-peak vibrations of 5nm uses a GM cold head. This is used because the stronger but linear vibrations in the z-direction of the GM radiator can be better isolated in the existing design than the more omnidirectional vibrations of the PT radiator. The OptiCool from Quantum Design is equipped with a powerful PT cryo-cooler, as it not only has to generate liquid helium for temperature control up to 1.7 K, but also cools the superconducting 7 T magnet. This allows a temperature stabilization to 10nm.

www./qd-europe.com/optische-kryostate/

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Small particles, great friendship – 25 years of partnership with CPS Instruments

On the occasion of the official opening of our new building, our long-term partners Marc Steinmetz and Merijn Staps of CPS Instruments stopped by. As a gift, they not only brought a selection of tasty craft beers from an Amsterdam brewery, but also an award for the longtime, trustful partnership between our two companies. How time flies!

Since the year 2000, Stefan Wittmer has brought more than 100 CPS disc centrifuges into the field, Alexander Schrenk has maintained a large part of them and has repaired the few that needed mending. Only a few, because the CPS instruments are just as stable as our friendship!

We are very happy about the award and look forward to the next 25 years of joint particle analysis!

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New thin film stress measurement system FLX 2000-A

Toho Technology has extended their portfolio by another film stress measurement system. It utilizes patented "Dual Wavelength" technology to measure the deflection of a wafer including deposited thin films and the Stoney equation to determine the resulting wafer/film stress.

	FLX 2000-A	FLX 2320-S	FLX 2320-R	FLX 3300-T
Wafer sizes	25 - 200mm	25 - 200mm	25 - 200mm	200&300 mm
Temperature measurements to 500°C	No	Yes	No	Yes
Rotational stage	Yes (manual)	No	Yes (automatic)	No
Patented Dual-Laser technology	Yes	Yes	Yes	Yes

The table shows the differences between the two Flexus models

Toho's new system FLX 2000-A boasts the same features as the FLX-2320-S and -R minus the temperature control and automated sample stage. The system is easy to use, extremely robust, and very fast, thanks to the optical measurement. The manual quick-touch rotational platform allows easy 3D mapping. The system is ideal for use in Academic settings or low volume fabs. As with the other systems, WinFLX Software is used for analysis.

This intuitive analysis software displays any combination of stress, time, surface deflection, or reflected light intensity measurements. It calculates the biaxial modulus of elasticity, linear expansion coefficient, and stress uniformity. It allows trend plotting for Statistical Process Control (SPC) and the automatic recalculation of stress.

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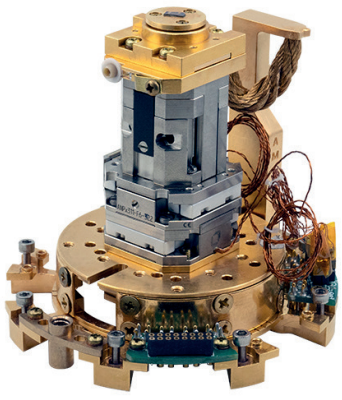
OptiCool – the fastest optical magneto cryostat with high sweep rate at minimum drift

OptiCool features a unique combination of low temperature and vibration with high magnetic field and numerical aperture. The system can be installed directly on an optical stage.

The usual experiments in optical cryostats require precise positioning of the sample in both the x-y plane and the z-axis in order to find areas of interest and to focus a microscope lens on the sample. In most cases, the focus needs to be readjusted when the sample temperature changes. This is due to the thermal expansion of components like sample holder and positioning system and the long compensation times of the positioner after a temperature change. Furthermore, piezo positioners slow down temperature changes significantly due to their low thermal conductivity.



The Rapid Thermal Stage (RTS) solves these issues by controlling the temperature directly on the sample, while the other components are kept on a low temperature. This limits focus shift in a temperature range of 1.8 to 350 K to less than 30 µm. The RTS also allows rapid temperature changes. Heating from base to room temperature takes less than 6 minutes.

The RTS features an integrated thermometer and a heater for precise temperature control and measurement. I can be controlled via OptiCool MultiVu or third party software. Samples can be mounted directly onto the RTS or with help of a disk mount.

- Temperature range: 1.8 K - 350 K
- Sweep time: 2 K to 300K < 6 min
- Drift : < 30 µm (2 K —> 300 K)
- Field strength: 7 T
- Vibrations: 10 nm (peak-to-peak)

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The AI powerboat challenge

Introduction

Self-driving, autonomous boats allow unmanned navigation and operation and are used in maritime intelligent logistics, automated pontoon construction and ocean current research. These boats are key to intelligent navigation, management , maintenance and freight transport and form the technical core of future intelligent water transport networks. The construction of an autonomous self-driving boat requires the coordination of several components of which hull construction is the main focus. Reducing the resistance and maximizing the driving force are crucial objectives.

Materials & Methods

A variety of tests was performed, for example of the limitations of the electric motor, of the boat hulls regarding the drag coefficient, of surface coatings regarding hydrophobic characteristics and on propellers for maximum performance. By using hydrophobic surface coatings and optimizing the choice of propellers, the boat speed was enhanced. The electric motor was improved by exchanging the copper wires with ceramically insulated wiring. This increased performance to 80 W. Programming the boat on the basis of a state machine allowed the autonomous navigation alongside buoy lines.

The spectral components of the buoy were determined by measuring bright, white LED lighting that was transmitted through the buoy with a Hopocolor OHSP-350P spectrometer. Taking into account phase shifts based on different angles of incidence, an optical long pass filter (Quantum Design ET542lp) witha cut-off wavelength of 542 nm was chosen.

Conclusion & Outlook

The team successfully developed a fast boat with automatic navigation. The combination of hull design, choice of propeller, surface coating and improvement of the electric motor resulted in optized boat speed. A program based on a state machine allows the autonomous navigation of the boat. Future improvements could be the implementation of circuit protection mechanisms, optimization of the hull design and further image recognition refinements. All in all, the project is an important step towards intelligent, autonomous boats that can be used in various maritime applications.

https://qd-europe.com/powerboat/

Source: The AI Powerboat Challenge, H. Fang, M. Garger, A. Rusch, und D. Schönenberger, ETH Zürich, 16. Februar 2024

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Save the date

4th International Conference on Atomic Layer Deposition
- 04. - 07. August 2024
- Messukeskus in Helsinki, Finland

BIC – Biointerfaces international conference
- 20. - 23. August 2024
- FHNW School of Life Science in Muttenz, Switzerland

EMC – The European Microscopy Congress 2024
- 25. - 30. August 2024
- Copenhagen, Denmark, booth C6D + C6e

CMD31
- 02. - 06. September 2024
- Altice Forum Braga, Portugal

SCS Fall Meeting 2024
- 05. September 2024
- University of Fribourg, Switzerland

GADEST 2024
- 09. - 10. September 2024
- Bad Schandau, Saxony, Germany

IEEE Magnetic Frontiers
- 15. - 19. September 2024
- Darmstadt, Lichtenberghaus

Vision 2024
- 08. - 10. Oktober 2024
- Stuttgart, Halle 10, Stand 10D70

electronica 2024
- 12. - 15. November 2024
- Trade fair center Munich, Germany

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New approach for low-level measurements of nanostructures

Normally, measurements on semiconductor materials, high-temperature semiconductors, new photovoltaic components and organic electronic materials require low-level sources and measurements. Since they are frequently based on nanostructures, even minor heat input can disrupt, damage or even destroy the systems. This is why the measurable signals must be as close as possible to the noise level.

There are two approaches for this type of measurement: DC measurements and AC measurements up to the RF frequency range.

DC measurements result in high-precision, reproducible results which can easily be compared with recognized standards. However, these measurements have their limitations, as they are very sensitive to pink (1/f) noise. The signals of interest are at least as strong as the pink noise, repeated measurements can produce enough statistics to achieve a high level of accuracy.

As the frequency of the measurement increases, the proportion of this noise decreases and only the white background noise remains, which is why AC measurement methods are also very popular. If, on the other hand, the sample is excited at a specific frequency (reference frequency), the measurement obtained is the modulated response of the sample as well as DC signals, such as thermoelectric voltages, which arise from the measurement setup itself and also higher order responses, which are at harmonic frequencies of the reference frequency.

A homodyne or lock-in technique is typically used to extract the modulated signal. For these types of measurements, Lake Shore has developed the M81-SSM.

SSM stands for Synchronous Source Measure. It combines low-level sources and measurements with tightly synchronized DC and AC signals in a half rack device. In addition to DC and AC measurements, lock-in measurements are

also possible from one device. This also simplifies the setup and error sources like unshielded cables or earth loops can be avoided.

More information can be found in Lake Shore's publication "A new approach to improving confidence in low-level measurements of nanostructures".

Read more:
https://bit.ly/3yVxQjK

Please contact us for more information on the M81 and its applications.

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Quantum Design trade shows and conferences – a behind-the-scenes look

We regularly participate in a wide variety of trade shows and conferences. These events are a valuable opportunity for us to present our company and maintain constant communi-

cation with customers, suppliers, and interested parties. Our success at these events would not be possible without the dedicated support of an experienced trade show constructor. Intensive work begins days in advance: setting up, preparing, and planning every aspect of our trade show presence down to the smallest detail.

The trade shows themselves offer us an excellent platform to showcase our latest products and services. At the same time, they allow us to receive direct feedback from our customers and establish new business relationships. Personal interaction and the opportunity to present our innovations live are particularly important to us.

Thanks to careful planning and the support of our trade show constructor, we can ensure that each trade show appearance is a complete success. This keeps us in dialogue with the industry and allows us to continuously grow and evolve.

Please contact us
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Open house at Quantum Design

With great enthusiasm, we opened the doors of our new headquarters in Pfungstadt to all interested visitors on March 06 2024. This open house was a wonderful opportunity for us to present our company and give an insight into what we do.

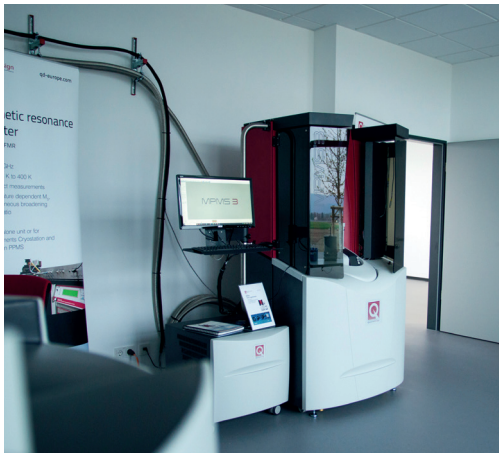
Visitors were able to experience first hand what happens behind our laboratory doors and take a glimpse at the innovative instruments and devices we work with on a daily basis. The smallest of samples and the most impressive machinery was there to exhibit the great variety of our tasks.

Given that, the atmosphere during the day was buzzing with energy and curiosity. Our staff was there to answer questions and share their knowledge. It was inspiring to see how our visitors investigated the processes and technologies which we passionately develop and use.

Apart from the insights into our work, we also had the chance to get in personal touch. Good food and a relaxed ambiance facilitated interesting discussions. New contacts were made and ideas were exchanged.

This day was not only a chance to open our doors to the public, but also a great opportunity to go in exchange with the people around us. We want to say thank you to all who made this such a special day and look forward to future encounters and projects.

The next day we were honored to welcome some of our customers and suppliers at our new facilities. Together with colleagues from our European offices and members of the Quantum Design San Diego, USA management, they also explored our premises and got a comprehensive impression of our new site.



The day started with a hearty welcome followed by short presentation of the many technologies we work with. The presentations were informative and fun and the overall mood was relaxed and enjoyable.

We particularly enjoyed the presentations from our customers who shared their experiences with the de-

vices and technologies they got from us. They talked about the applications in their own businesses, how they profit from these innovations and which goals they have reached thanks to this cooperation.

In the evening, all guests came together for a banquet. Our Managing Director Jürgen Schlütter warmly opened the evening and emphasized the importance of this special meeting. The presentation by Greg DeGeller, Managing Director of Quantum Design USA, was an unforgettable moment. He entertained and inspired in equal measure with charming anecdotes about the company.

The evening was rounded off with delicious food, good conversation and a great band. An impressive laser show was the grand finale as guests mingled in a pleasant atmosphere and celebrated the collaboration between our companies.

The evening was not only a festive banquet, but also a wonderful opportunity to strengthen relationships with our customers, suppliers and employees and celebrate successes together. We are grateful for this special time and look forward to future projects and partnerships.

Please contact us
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Our cryo newsletter - subscribe and keep informed

The QDE cryo newsletter gives information on the latest in crystats, low temperatures and magnetism. In January, we gave an overview of the latest scientific publications with QDE systems.

We also present new products, trade shows and events. If you don't receive our newsletter yet, you can subscribe by simply sending a short mail with the word "Newsletter" to:

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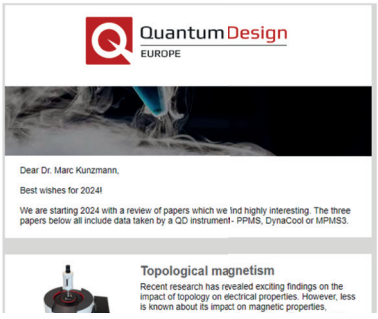

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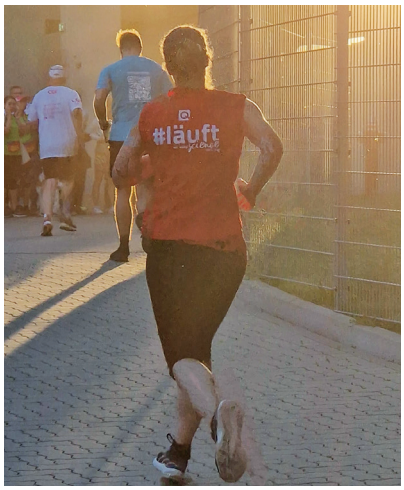
Quantum Design team successful at Merck company run 2024

This year, our team has again successfully finished the Merck company run, which takes place at our local soccer stadium. With a total of 6430 participants from over 290 companies, the run has proven a great success and an impressive sports event.Our colleagues picked from 3 distances: 3.5 km, 5 km or 10 km. Being given this choice, runners of all abilities and preferences found a suitable challenge. Our team was represented on all routes and impressively demonstrated how sporting ambition and team spirit go hand in hand. The atmosphere was electrifying right from the start. High energy and anticipation were in the air as participants gathered at the starting line. Every step along the route was characterized by perseverance and mutual support. Our runners gave their best in bright sunshine and perfect weather conditions.



We can proudly say that each and every one reached their goal! To see how our colleagues successfully lived through the event was really impressive. The joy of having finished was written over everyone's faces.The sporting part of the day turned into the after-run party, which was the perfect end to a great day. The day's success was duly celebrated with good music, hearty food and refreshing drinks.

The Merck company run is not only a local sports highlight, but also plays a big part in our corporate culture. Being a part of it strengthens our team spirit and promotes cooperation across all departments. Many thanks to all participants and supporters who made this day an unforgettable experience. We are proud of our team's performance and are already looking forward to the next Merck company run. Together we have shown that we are not only strong in everyday working life, but also on the running track.

See you next year - We keep science running!

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